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David C. Wyld,
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7th International Conference of Control Theory and Computer Modelling (CTCM 2021)

2nd International Conference on Big Data, IOT and Blockchain (BIBC 2021)

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Preface

The International Conference on 7th International Conference on Software Engineering and Applications (SOFEA 2021), October 23 ~ 24, 2021, Sydney, Australia, 7th International Conference of Control Theory and Computer Modelling (CTCM 2021), 2nd International Conference on Big Data, IOT and Blockchain (BIBC 2021), 7th International Conference on Signal Processing and Pattern Recognition (SIPR 2021), 7th International Conference of Networks, Communications, Wireless and Mobile Computing (NCWC 2021), 8th International Conference on Computer Science and Engineering (CSEN 2021) and 2nd International Conference on Education and Integrating Technology (EDTECH 2021) was collocated with 7th International Conference on Software Engineering and Applications (SOFEA 2021). The conferences attracted many local and international delegates, presenting a balanced mixture of intellect from the East and from the West.

The goal of this conference series is to bring together researchers and practitioners from academia and industry to focus on understanding computer science and information technology and to establish new collaborations in these areas. Authors are invited to contribute to the conference by submitting articles that illustrate research results, projects, survey work and industrial experiences describing significant advances in all areas of computer science and information technology.

The SOFEA 2021, CTCM 2021, BIBC 2021, SIPR 2021, NCWC 2021, CSEN 2021, and EDTECH 2021 Committees rigorously invited submissions for many months from researchers, scientists, engineers, students and practitioners related to the relevant themes and tracks of the workshop. This effort guaranteed submissions from an unparalleled number of internationally recognized top-level researchers. All the submissions underwent a strenuous peer review process which comprised expert reviewers. These reviewers were selected from a talented pool of Technical Committee members and external reviewers on the basis of their expertise. The papers were then reviewed based on their contributions, technical content, originality and clarity. The entire process, which includes the submission, review and acceptance processes, was done electronically.

In closing, SOFEA 2021, CTCM 2021, BIBC 2021, SIPR 2021, NCWC 2021, CSEN 2021, and EDTECH 2021 brought together researchers, scientists, engineers, students and practitioners to exchange and share their experiences, new ideas and research results in all aspects of the main workshop themes and tracks, and to discuss the practical challenges encountered and the solutions adopted. The book is organized as a collection of papers from the SOFEA 2021, CTCM 2021, BIBC 2021, SIPR 2021, NCWC 2021, CSEN 2021, and EDTECH 2021.

We would like to thank the General and Program Chairs, organization staff, the members of the Technical Program Committees and external reviewers for their excellent and tireless work. We sincerely wish that all attendees benefited scientifically from the conference and wish them every success in their research. It is the humble wish of the conference organizers that the professional dialogue among the researchers, scientists, engineers, students and educators continues beyond the event and that the friendships and collaborations forged will linger and prosper for many years to come.

David C. Wyld,
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EMERGENCY MANAGEMENT SYSTEM FOR COLLEGE STUDENTS BASED ON BIG DATA PROCESSING TECHNOLOGY

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ABSTRACT

Since 2020, the epidemic of Corona Virus Disease 2019 has swept the world, which has had a great impact on people's life. Especially for college campus life. This paper presents an emergency management system for college students. We use Java Web, big data processing and other technologies to develop, implement and test the system. The system integrates daily management and emergency management, which can meet the basic needs of teachers and students on campus. We hope to provide convenience for students and teachers in learning and management.

KEYWORDS

Web System, Stream Data Processing, Data visualization, Internet Worm.

1. INTRODUCTION

At present, how to respond quickly to emergencies has been paid more and more attention by various countries. How to make the fastest response to natural disasters, emergency traffic accidents, public health emergencies and so on to ensure the safety of personnel and reduce property losses has become a problem that all countries are thinking about. With the development of the Internet, China has entered an era of rapid development of information technology. China's large population base and strong personnel mobility promote economic prosperity and development, but also make the risk spread more quickly.[2] At present, China is in a critical stage of development. The research and application of emergency management system plays a very important role in social development and people's livelihood.

Emergency management system is mainly used in natural disasters, public health, transportation and other fields. There are still many problems in the practical application of the current emergency management system. For the real-time information collection, processing and decision-making efficiency is not high, the emergency information release system is not perfect, there are obvious shortcomings and deficiencies in the information release channels. Facing the national population, the timeliness and dissemination of information is insufficient. In fact, the application scope and population of emergency system are far more than the above. At present, the scale of personnel training in Colleges and universities is expanding, and the number of college students is also increasing. Whether college students can correctly deal with emergencies

affects the campus order and social order. [1] Especially during the novel coronavirus pneumonia, schools need to grasp the geographic location, health status, mobile trajectory and other information of teachers and students in time. But in fact, the efficiency of adopting excel forms and filling out paper forms is low. In the process of information transmission, there will also be problems such as information loss, errors and timeliness reduction. To solve these problems, this paper uses real-time data processing, data visualization and other technologies to obtain geographic location information and health status information. At the same time, it adds daily management functions to the system, which provides convenience for teachers and students.

2. RELATED WORK

2.1. Emergency management system for College Students

Emergency management refers to a set of theory and method system that managers, in order to reduce the harm of emergencies, scientifically analyze the causes, occurrence and development mechanism of emergencies and their negative effects, integrate all aspects of social resources, and effectively deal with, control and deal with them. [5]

College students emergency management system can be divided into eight functional modules. The system not only completes the emergency management, but also adds the daily management of students, which provides great convenience for students and teachers.

User management module: users can login and register, and view and modify personal information on personal page.

Daily check-in module: users fill in the check-in form to complete the information collection, and store the information in the database.

Track positioning module: according to the geographic location information of the login user collected in the database, the system draws the activity track map of the user in recent 14 days. The system obtains the current geographic location information of the user when the user logs in, and displays the current location of the user on the map.

Epidemic distribution module: make the heat map according to the current national epidemic data.

Grade management module: student users can query the grade table of each semester in this module, and the system adopts visual means to display the student grade information on the page in this module. Counselor users can query the transcripts of all students and the visualization of each subject.

Activity management module: in this module, ordinary student users can view the time and place of the activities recently released by the school, and counselor users can also publish activities.

Empty classroom query module: users can select the number of weeks, week and teaching building to query the corresponding empty classroom.

Information display module: in the information display module, users can view the teacher team information, system introduction and development team information.

2.2. Introduction of Stream Data Processing Technology

Stream data is a real-time, continuous, potentially unbounded, uncertain, time-varying (implicit through the arrival time or explicit timestamp) sequence of data items, also known as stream data. Streaming computing is one of the two main processing modes of big data. Streaming computing needs to provide continuous and dynamic services for the data flowing into the system dynamically, and needs real-time computing for the streaming data.

According to the different timeliness of data processing pursued by flow computing, stream data processing can be divided into batch processing model and continuous operator model. The main goal of batch processing model is high throughput, while the main goal of continuous operator model is low latency.

3. REQUIREMENT ANALYSIS

3.1. Functional Requirement

Real time positioning function: after the user logs in, the system automatically obtains the user's current geographic location information and marks it on the map.

Daily check-in function: users submit geographic location information and health status information by filling in the form.

Information visualization function: in the daily grade management, track positioning and epidemic distribution module, the visualization function is used. Different modules need to determine the visualization form according to their specific conditions.

Daily management function: daily management includes activity management, empty classroom query, grade management and other functions to meet the daily needs of students and teachers.

3.2. Performance Requirements

Real time: the system needs to obtain the user's real-time location information, which requires the system to have the characteristics of real-time.

Security: it can protect the system from malicious attacks and protect the user's information privacy from disclosure.

Maintainability: the system needs to be able to maintain and upgrade when the amount of access is too large or other situations occur.

3.3. Feasibility Analysis

This system uses eclipse as the development tool, MySQL database and SSH framework to set the overall system architecture. In the stream data processing function, a big data platform based on flume + Kafka + storm + zookeeper + MySQL is built, which is feasible from the technical point of view.

3.4. Overall Framework Design of the System

The system adopts SSH framework in MVC mode, which is composed of struts, spring and hibernate. Struts can act on the presentation layer to simplify data access in various scopes and realize fast verification. Hibernate acts on the persistence layer to provide efficient mapping relationship between different objects. Spring is mainly used in the business logic layer to complete the program design and development with complex business logic. [3] The overall design of the system is shown in the figure:

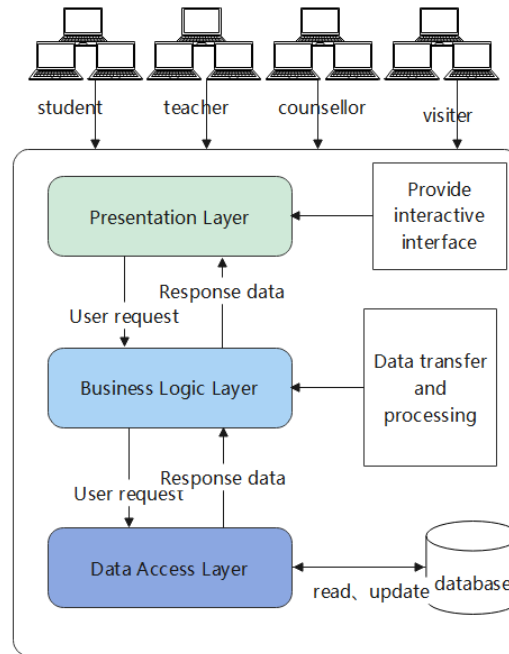


Figure 1. Overall Design of the System

3.5. System Overall Function Design

As shown in the figure, the system consists of seven main modules: user management, empty classroom query, score query and so on. Each module can be divided into several sub blocks.

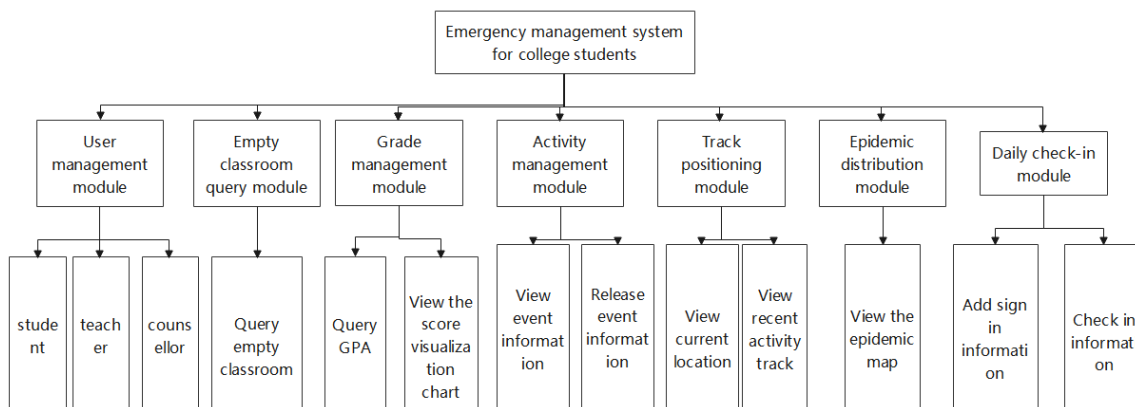


Figure 2. System Overall Function Design

3.6. Detailed Design

3.6.1. Track Positioning Module

The module includes real-time positioning and active track. Real time positioning obtains the user's IP when the user logs in, stores the IP and the corresponding geographic location information in the database, finds the user's geographic location in the database for nearly 14 days in the activity track module, and visualizes the activity track to display on the front page.

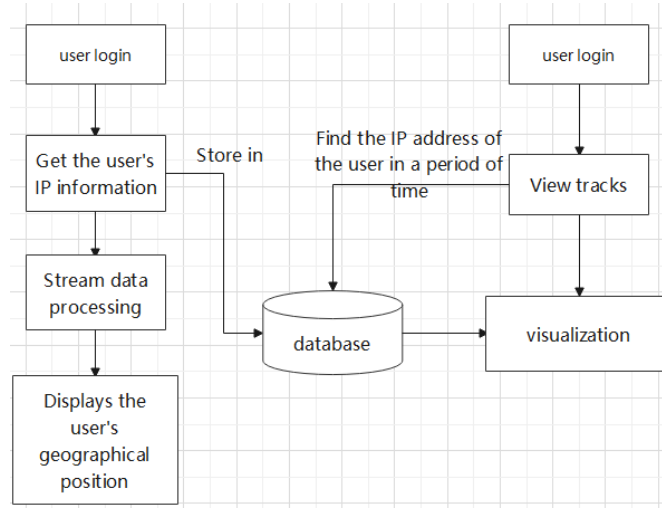


Figure 3. Track Positioning Module

3.6.2. Epidemic Distribution Module

In this module, the epidemic data is crawled through Python crawler technology, and the data is displayed in the form of thermal map visualization after processing.

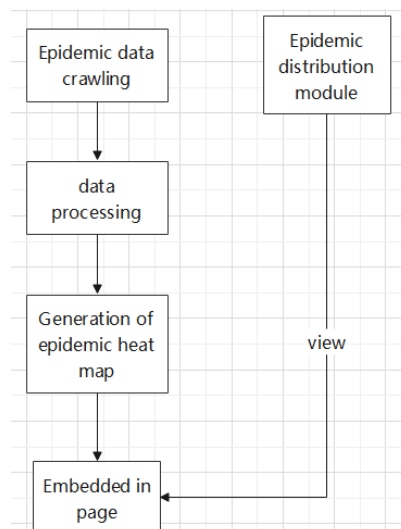


Figure 4. Epidemic Distribution Module

3.6.3. Daily Check-in Module

In this module, the user needs to fill in the basic health information table. The basic information of the table can be queried from the database and returned to the page. After the user completes the health information of the day, click submit to save the information to the database. The collected information of students' status is displayed on the counselor side.

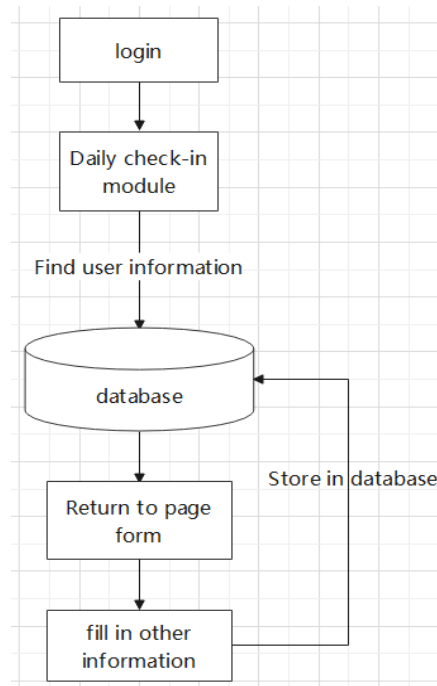


Figure 5. Daily Check-in Module

3.6.4. Grade Management Module

In this module, different users can query the grade data they need. Students can log in to query visual results of their grades, GPA, comparison between grades and grades. Teachers can query the students' grades and their visual results. Counselor users can view the visual results of all students' scores in various subjects and grades.

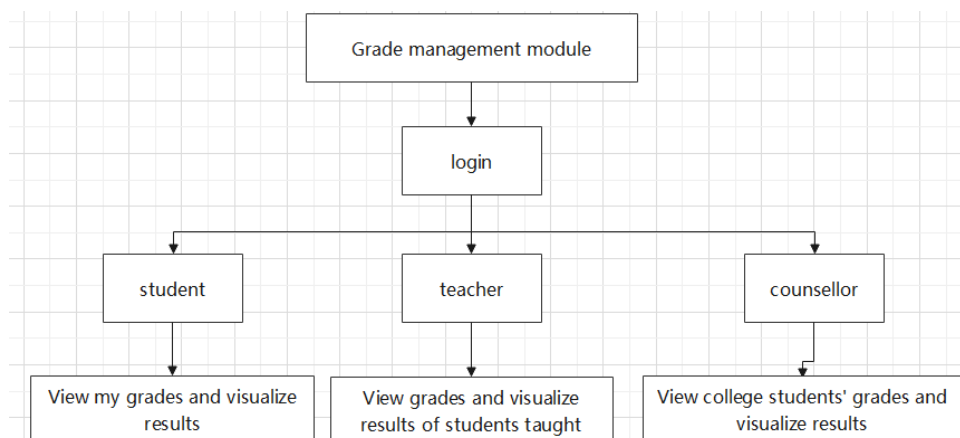


Figure 6. Grade Management Module

3.6.5. Empty Classroom Query Module

In this module, users can query all the empty classrooms of a certain teaching building in a certain period of time.

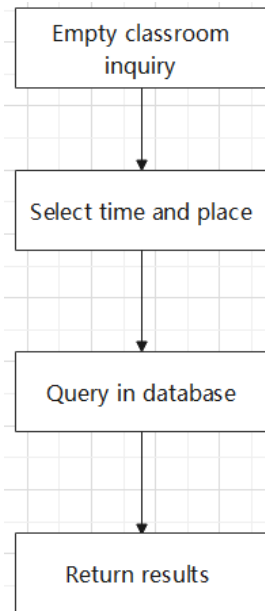


Figure 7. Empty Classroom Query Module

3.6.6. Activity Management Module

In this module, ordinary student users can view the time and place of the activities recently released by the school. Counselor users can view the activity information and release activities on demand.

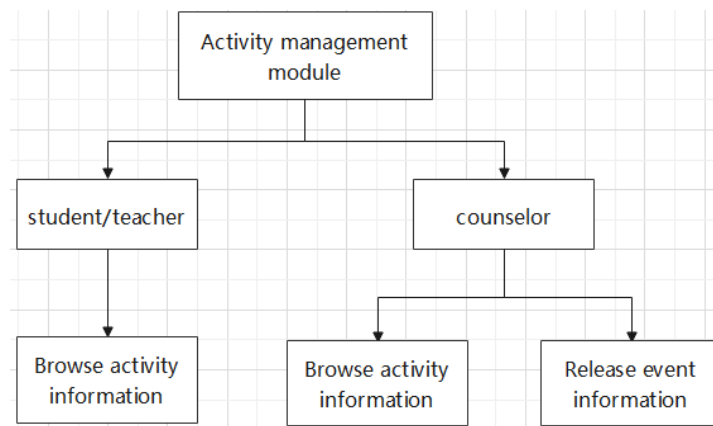


Figure 8. Activity Management Module

3.6.7. Information Display Module

This module includes the display of teacher information, system introduction and development team information.

3.6.8. User Management Module

In the user management module, users can login and register, and view and modify personal information on the personal page. The system background can add and delete users directly.

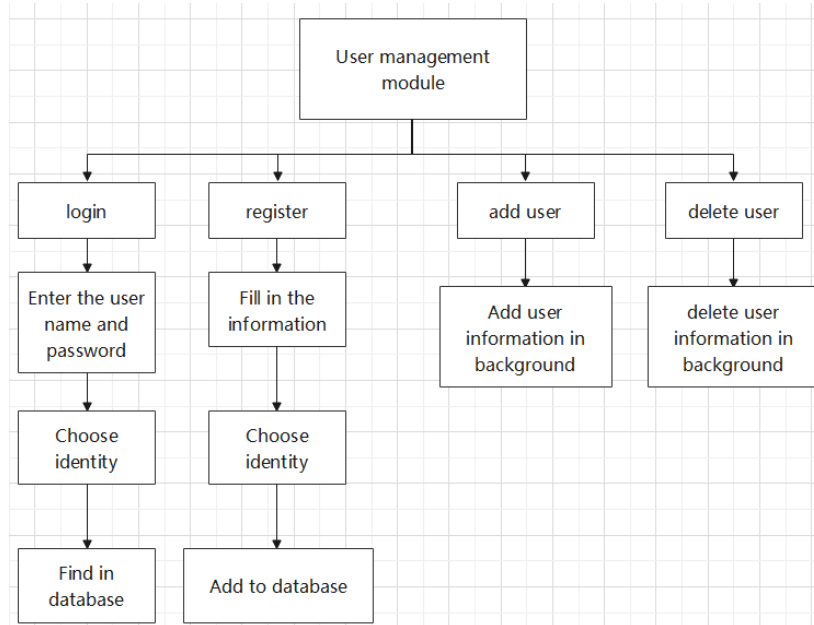


Figure 9. User Management Module

4. SYSTEM IMPLEMENTATION

4.1. Internet Worm

Python language to write crawler program is an important way of data collection and analysis in the era of artificial intelligence big data. [4]This system uses Python language to design crawler . It crawls a large number of resources and information from the web page, and analyzes the epidemic visualization based on massive data. At the same time, in the student information management module, the system provide the information of teachers by crawling the information and contact information of college teachers on the school's official website for users to get contact with teachers.

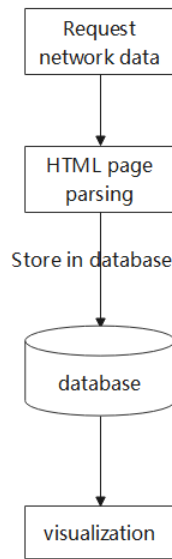


Figure 10. Internet Worm Process

4.2. Stream Data Processing

The real-time positioning part of the project uses big data stream processing technology. In order to realize the real-time response of the location information generated by the front-end users' login and check-in, we take the login and check-in event data as the event flow, and build a big data platform based on flume + Kafka + storm + zookeeper + Mysql to collect and process the event stream data in real time, and the data has been persistent and visualized. The overall framework is shown in the figure:

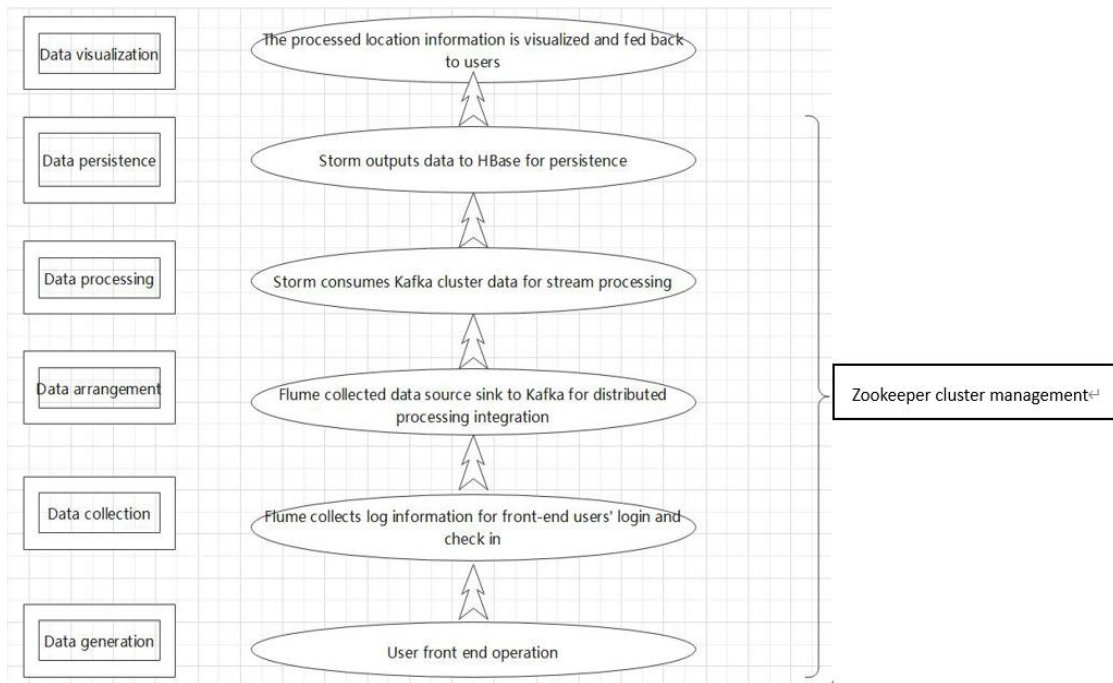


Figure 11. Stream Data Processing

Kafka and storm are the most important parts, and the main difficulties lie in the realization of data production, data consumption, data persistence and application scheduling. The system uses flume to monitor the customized log to collect the IP address, time and other data generated when users log in to the system in real time. The collected source data is sorted and transmitted to storm in the form of stream data through Kafka. In the storm part, the highly integrated Trident framework is used to realize the business logic. The Trident framework retains the accuracy and integrity of the data, In IP location, the IP geographic location library provided by Alibaba cloud is used to convert the IP address to geographic location, and then the geographic location and user basic information are synchronized and persisted to MySQL database for data processing and visualization.

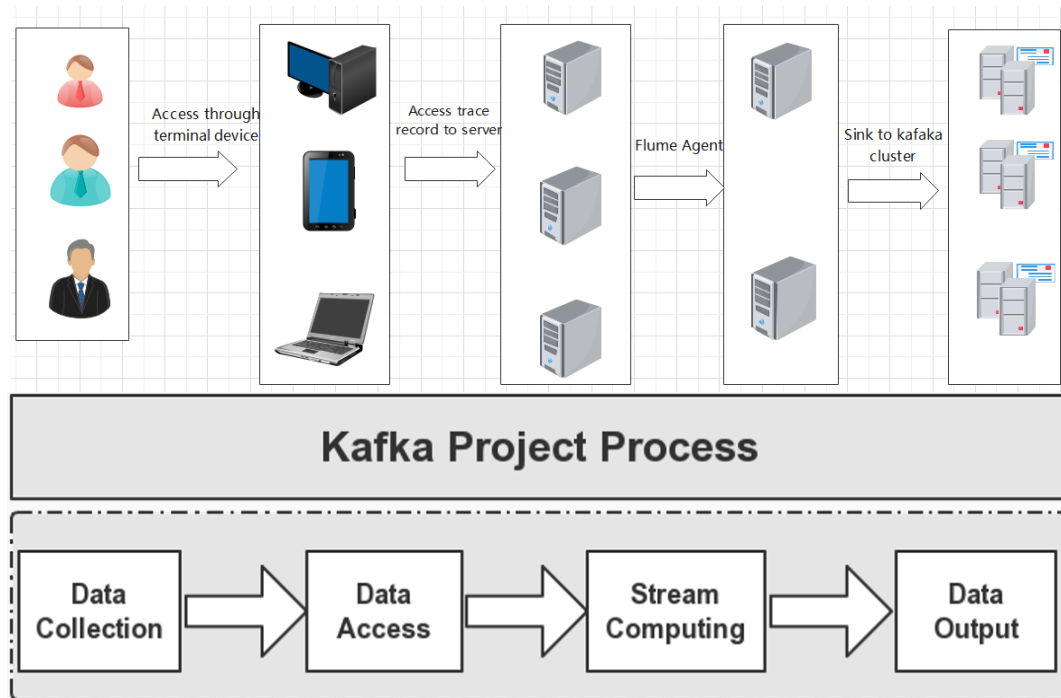


Figure 12. Kafka Project Process

4.3. Data Visualization

The purpose of data visualization is to visualize the abstract information content by means of graphics, so as to convey and communicate information clearly and effectively. In the visualization part of the system, the data visualization technology is widely used. The data of the epidemic is visualized in the form of scatter chart, color scale chart, sun chart and so on. The real-time data of the number of people diagnosed in all parts of the country is used to make the epidemic map, so as to clearly convey the intuitive feelings and information to users. In this project, many rendered HTML web pages are used to display the epidemic data. We also use the visualization method to show in several functions of the daily management.

4.4. Web Implementation

The web system has four kinds of permissions: student user, teacher user, instructor user and tourist. Visitors can enter the system visitors page to view the basic information of the home page, student users, teacher users and counselor users can use all the functions of the system. Different authorities have different functions in activity management, grade management and

track positioning. Different functions are linked by the page navigation bar, and the webpage is embedded with links that can jump through the page to achieve redirection access.

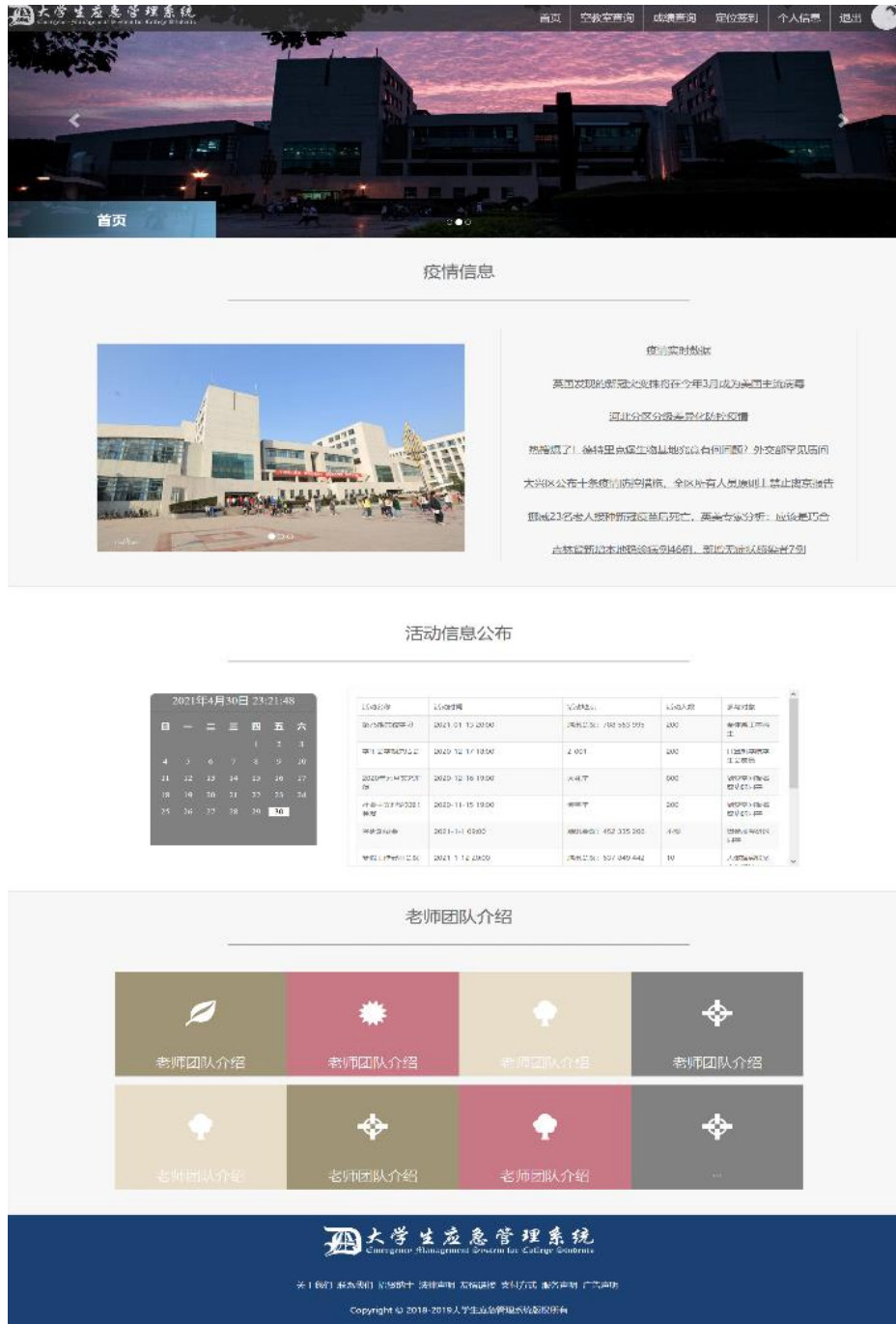


Figure 13. Webpage of the System

4.5. Deficiencies and Prospects

There are still some deficiencies in the current system, and we hope to improve it in the future. In the Grade management function, the results of data visualization are relatively rough, mostly in the form of tables and line charts, and the amount of data is relatively small. In the future, a grade

analysis module can be specially made for grade management to help users analyze grades with more diversified visualization forms and more comprehensive grade data. In the function of tracking Position information, the geographic location range of users we can locate is not accurate enough. In subsequent improvements, this function can be further expanded. For example, the system can collect and sort out the location information in recent 14 days and compare it with the existing risk areas, screen the users passing through the risk areas, and return the user information to the manager page. In the framework of the system, we can also try to use Vue framework.

5. CONCLUSIONS

Emergency system has been applied in natural disasters, public health, transportation and other fields, but there are few emergency management systems for college students. The current emergency system still has a lot of room for improvement in real-time and big data processing. The emergency system for college students proposed in this paper opens up a new way in the emergency system in terms of real-time and data processing. The application of big data technology makes the system more intelligent and practical. At the same time, the combination of web crawler and data visualization technology makes the information on the page of the system richer and have a better visual effect. Based on demand analysis, we combine daily management and emergency management to make the system more widely used. Using java web technology and SSH framework we complete the page design and function development. Of course, we also hope to continue to improve the areas that can be expanded mentioned in the article and provide help for emergency management.

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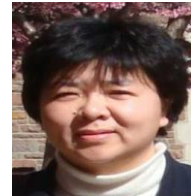
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AN INTELLIGENT QUESTION ANSWERING PLATFORM FOR GRADUATE ENROLLMENT

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ABSTRACT

To enhance the competitiveness of colleges and universities in the graduate enrollment and reduce the pressure on candidates for examination and consultation, it is necessary and practically significant to develop an intelligent Q&A platform, which can understand and analyze users' semantics and accurately return the information they need. However, there are problems such as the low volume and low quality of the corpus in the graduate enrollment, this paper develops a question answering platform based on a novel retrieval model including density-based logistic regression and the combination of convolutional neural networks and bi-directional long short-term memory. The experimental results show that the proposed model can effectively alleviate the problem of data sparseness and greatly improve the accuracy of the retrieval performance for the graduate enrollment.

KEYWORDS

Question Answering System, Graduate Enrollment, Deep Learning, Sentence Semantic Similarity.

1. INTRODUCTION

With the rapid development of NLP (natural language processing) technologies, the Q&A (question answering) system [1] is widely utilized in the real life. Q&A system is an human-machine dialogue service integrating knowledge base, information retrieval, machine learning, natural language understanding and other technologies [2]. It can effectively solve the problem of information overload and improve the efficiency of users' use of the system.

Recently, the number of graduate students across the country has been increasing greatly. To enhance the competitiveness of colleges and universities in the graduate enrollment and reduce the pressure on candidates for examination and consultation, it is necessary and practically significant to develop an intelligent Q&A platform for examination and enrollment in educational areas using NLP technologies, which can understand and analyze users' semantics and accurately return the information they need.

There are many traditional similarity algorithms such as SVM (support vector machine) [3], LR (logistic regression), KLR (kernel logistic regression), DT (decision tree), and NB (naive bayes) classification models. However, most of them are only suitable for specific types of data or output [4][5][6][7][8], and, have some problems such as ignoring the semantics of words or relying too much on semantic dictionaries.

With the in-depth study of deep learning, [9][10] utilized word embedding to construct word vectors to characterize the correlation between statements with vector similarity via some neural

network such as CNN [11], RNN(recurrent neural network) [12], LSTM(long short-term memory) [13], and other improved models to make much better performance in the field of the text similarity. However, these models often result in the slower response speed in the real Q&A system due to their complicated computation.

Inspired by the above approaches, this paper combines the advantages of both traditional method and DNN to propose a novel Intelligent Q&A platform for Examination and Enrollment in educational areas, IQ&AEE for short. In particular, IQ&AEE system proposes a crawler manager to crawl data in time to solve the problems of outdated information, develops a Q&A retrieval model based on DLR(density-based logistic regression) and CNN-BiLSTM (the combination of convolutional neural networks and bi-directional long short-term memory), and builds an intelligent Q&A robot, provides students with college introductions from all aspects through the web design of school information.

2. RELATED WORK

2.1. Introduction to the Question Answering System

Intelligent Q&A system refers to a system that accurately provides the knowledge required by users in the form of one question and one answer, and realizes interactive and personalized services for users.

The general architecture of the intelligent Q&A system can be divided into three parts: how to express natural language in the computer so that the computer understands its semantics, how to select the best answer, and how to map the answer to the natural language to express, namely question understanding, intelligent search and answer extraction.

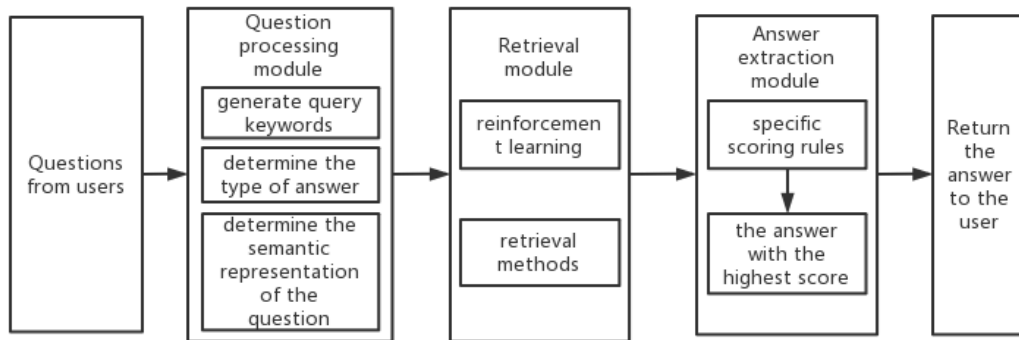


Figure 1. Q&A system flow chart

2.2. Sentence Semantic Matching Based on Deep Learning

Semantic matching based on deep learning is to model sentences directly, generate vectors of two sentence sequences, perform feature extraction and similarity calculation on the two sentences through the neural network mode, sort them according to the similarity score, select the most relevant pair return as the sequence pair with the highest semantic.

The framework focuses on how to efficiently use neural networks to take the semantic characteristics of sentences, such as using CNN with local perception mechanisms, or using LSTM with the memory to avoid long-term dependence problems of sentence sequences, or

using combined neural networks to learn local and contextual characteristics of sentences, construct feature vectors of sentences and learn the deep semantics of sentence sequences. Cosine similarity is calculated on the sentence characteristic vectors learned through various neural networks, and utilized to characterize the semantic matching degree of two sentence sequences. The framework is shown in Fig. 2.

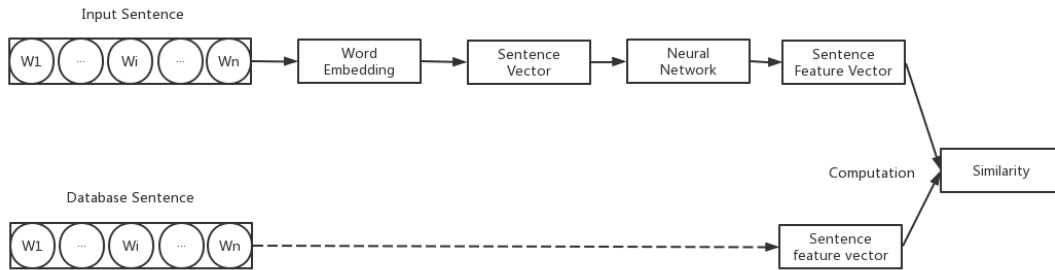


Figure 2. Semantic matching framework based on deep learning

3. REQUIREMENT ANALYSIS

The proposed IQ&AEE system contains three type of users: visitors, individual users and system administrators. Visitors can ask questions and get answers instantly on the web page. Individual users can not only ask questions, but also leave messages for unanswered questions. System administrators can manage users (add or delete users), manage messages (add, delete or reply messages, update answered messages to the Q&A database), manage the Q&A database (add, edit or delete questions). The overview of the basic functional requirements of the IQ&AEE system is shown in Fig. 3 to Fig. 5.

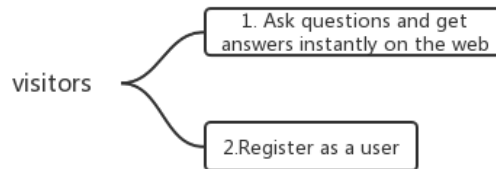


Figure 3. Functional requirements analysis diagram of visitors

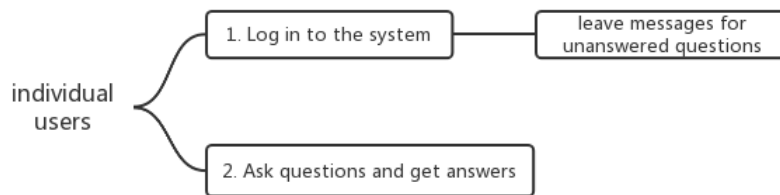


Figure 4. Functional requirements analysis diagram of individual users

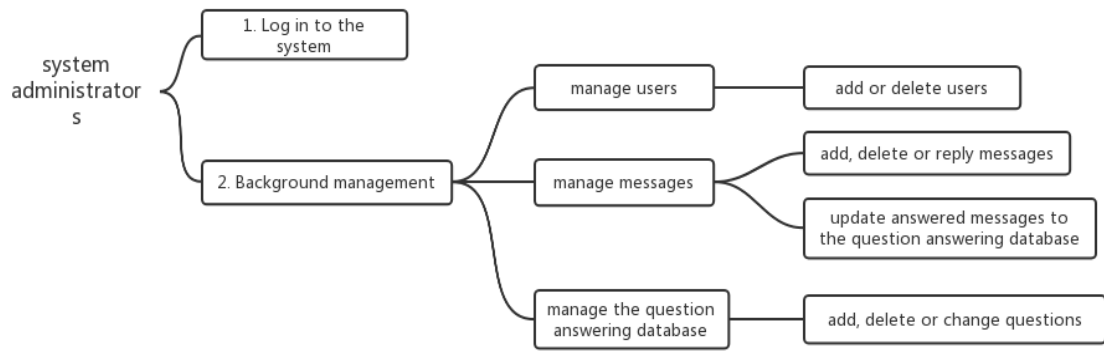


Figure 5. Functional requirements analysis diagram of system administrators

4. IQ&AEE DESIGN

4.1. IQ&AEE System Framework Design

According to the idea of software engineering MVC (model-view-controller), this paper divides the IQ&AEE system into three layers: application platform layer, functional module layer and database layer.

Among them, the application platform layer is the human-computer interaction interface layer, which embodies the operations provided by the system to the users, such as submitting questions, retrieving questions, obtaining answers and so on. The functional module layer implements crawler management, Q&A retrieval, knowledge base management and user management functions. The database layer is responsible for the storage of all the enrollment information of the school, and various types of databases. The framework design of the system is shown in Fig. 6.

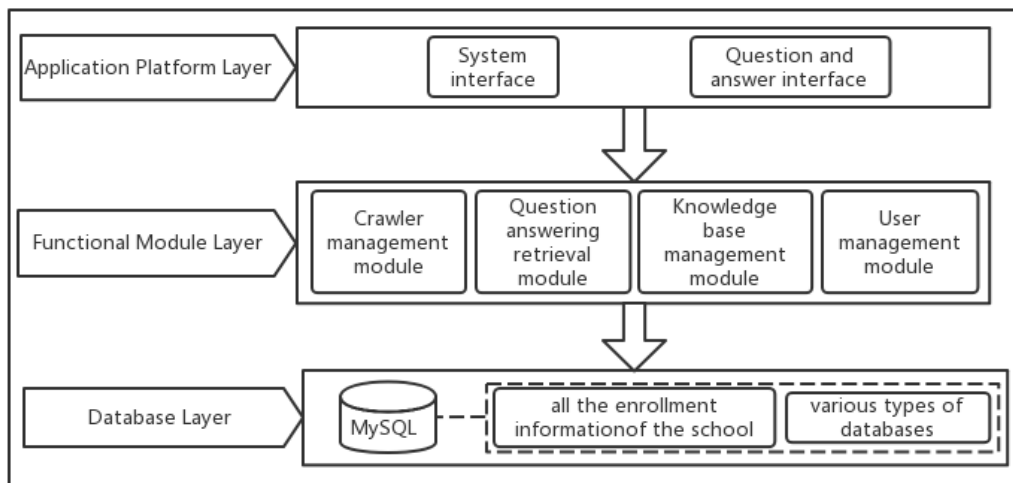


Figure 6. IQ&AEE system framework

4.2. IQ&AEE System Functional Design

As shown in Fig. 7, the functional modules of IQ&AEE system are mainly divided into four main modules, namely crawler management module, Q&A retrieval module, knowledge base management mould and user management module. Each module contains several sub-modules.

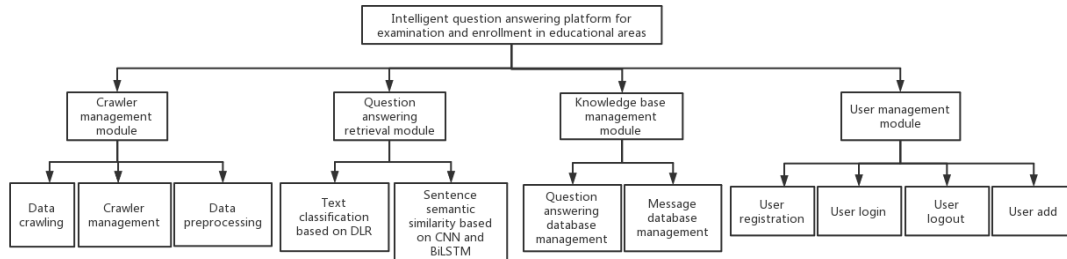


Figure 7. IQ&AEE system function module diagram

4.3. Detailed Design of Each Module of the System

Crawler management module: In order to obtain rich research data, the crawler management module uses the crawler technology to collect enrollment information data from authoritative websites of universities such as Yanzhao.com, which is utilized to build the system corpus.

Question answering retrieval module: As the critical module of the system, this module mainly provides the user with Q&A retrieval function based on frequently asked questions and knowledge, classifies the questions submitted by users, and matches the semantic similarity of the sentences in databases. The related core algorithms and experimental analysis are introduced in detail in Part 5.

Knowledge base management module: The Knowledge Base Management module provides the source of questions and answers in IQ&AEE system. Administrators can add, delete and modify questions and answers in the Q&A database, while the administrator is responsible for giving answers manually in the message database, and updating the questions and corresponding answers left by users to the Q&A database, convenient for other users to retrieve the answers to the corresponding questions.

User management module: The user management module can perform user registration, user login, user addition, and user logout operations. Administrators can reset the user's password, add users, or log off users in the background system.

5. RETRIEVAL MODULE OF IQ&AEE SYSTEM

As shown in Fig. 8, this paper develops a Q&A retrieval model based on two algorithms including DLR and CNN-BiLSTM.

After users enter questions, the Q&A retrieval model first uses the keyword table to classify the questions roughly, and divides them into 14 categories as a whole: thirteen school categories and one none category. Afterward, the DLR is utilized to determine the specific category to which the questions belong to school categories, and CNN-BiLSTM judges the semantic similarity of questions belong to unknown category and the none category.

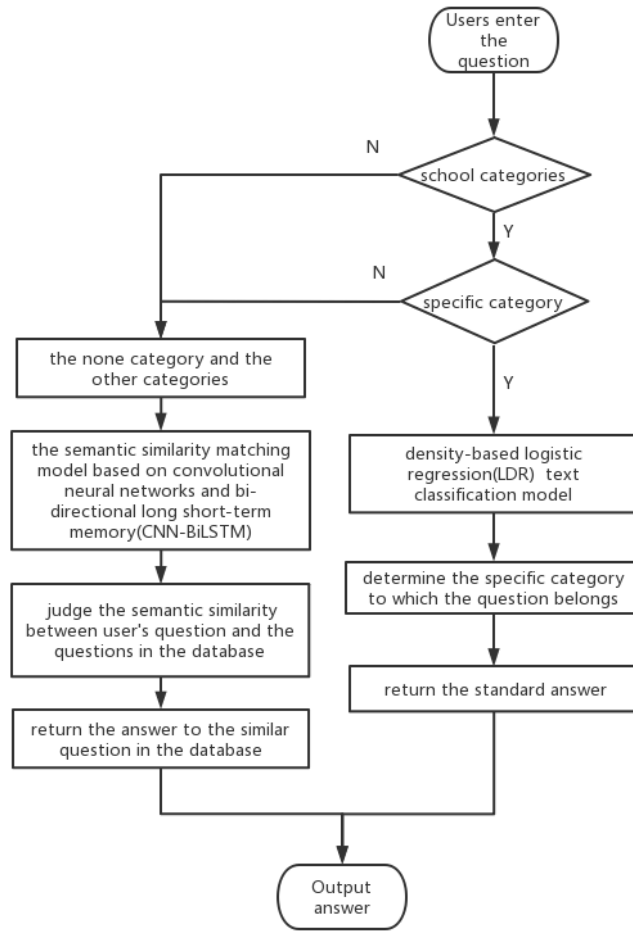


Figure 8. IQ&AEE retrieval module flow chart

5.1. DLR Algorithm

DLR is a binary basic model based on LR, which is a novel type of nonlinear classifier, which is much more efficient than other nonlinear models and can naturally handle mixed data types. It also offers good interpretability and support for multiway classification [14].

The main idea of DLR is to map the training data to a specific feature space according to Nadarays-Watson density estimation algorithm, and then to build an optimization model to optimize feature weight and the width of the Nadarays-Watson density estimation algorithm. The DLR model first obtains the definition of the mapping function by calculating the probability as follows:

$$\varphi_d(x) = \ln \frac{p(y=1|x^{(d)})}{p(y=0|x^{(d)})} - \frac{D-1}{D} \ln \frac{p(y=1)}{p(y=0)} \quad (1)$$

Then, it is estimated by the Nadaraya-Watson estimator, and the result is obtained (2):

$$p(y = k | x^{(d)}) = \frac{\sum_{i \in D_k} K\left(\frac{x^{(d)} - x_i^{(d)}}{h_d}\right)}{\sum_{i=1}^N K\left(\frac{x^{(d)} - x_i^{(d)}}{h_d}\right)} \quad (2)$$

By this formula, the density of a given instance x can be calculated. Then the final result can be get by substituting the standard LR. Self-adjustment of parameter is done by calculating the loss of the bias derivative.

The calculation process is shown in Eq.(3):

$$\frac{\partial E}{\partial h_d} = \frac{\partial E}{\partial r_d} \cdot \frac{\partial r_d}{\partial h_d} = \frac{1}{h_d^3} \sum_{i=1}^N (b_i - y_i) \omega_d \frac{\partial \varphi_d(x_i)}{\partial r_d} \quad (3)$$

Among them:

$$r_d = -\frac{1}{2h_d^2} \quad (4)$$

$$\frac{\partial \varphi_d(x)}{\partial r_d} = \frac{\partial g_1}{\partial r_d} - \frac{\partial g_0}{\partial r_d} \quad (5)$$

$$\frac{\partial g_i}{\partial r_d} = \frac{\sum_{i \in D_j} [(x^{(d)} - x_i^{(d)})^2 \cdot \exp(r_d (x^{(d)} - x_i^{(d)})^2)]}{\sum_{i \in D_j} \exp(r_d (x^{(d)} - x_i^{(d)})^2)} \quad (6)$$

Through this series of calculations, the partial derivative of the loss can be obtained, and then the loss can be minimized through the gradient descent and adjustment.

5.2. CNN-BiLSTM Algorithm

As shown in Fig. 9, since CNN is capable of extracting local features and BiLSTM can extract global features (or context features) of a sentence, the paper combine them together to generate high-quality sentence representations for measuring sentence similarity [15][16][17][18].

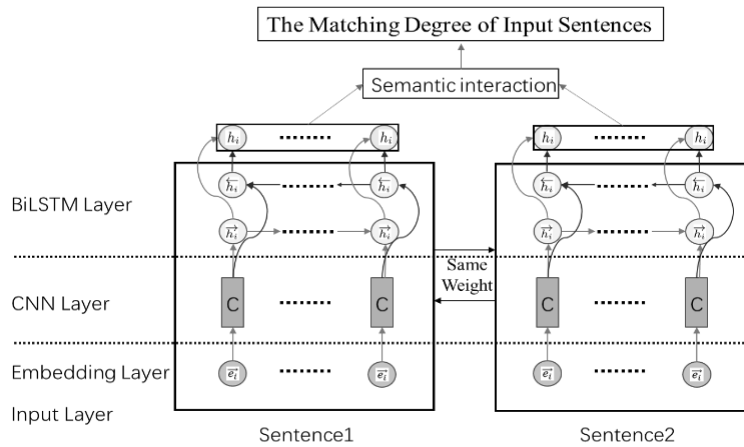


Figure 9. CNN-BiLSTM architecture

5.2.1. CNN Layer

As shown in Fig. 9, CNN is utilized to extract local features of sentences and its structure. The characteristic S_{ik} of the i^{th} word in the sentence obtained through the convolution operation can be expressed in the Eq.(7):

$$S_{ik} = f(w_k \cdot x_{i:i+h-1} + b) \quad (7)$$

Where w_k represents the weight matrix of the convolution filter k , and b represents the deviation term. $f(\cdot)$ is a nonlinear function, and Tanh is used in this paper.

After the convolution operation, the max-pooling method is adopted here to extract the important features of the sentence through a max pooling layer after the convolution layer, as following Eq.(8):

$$c = \max(c) \quad (8)$$

Where c is the vector after the convolution operation.

5.2.2. Bi-LSTM Layer

In this paper, Bi-LSTM is utilized to extract the global features of the sentence and expressed in the Eq.(9-10):

$$\vec{h}_i = \overrightarrow{LSTM}(a_i, \vec{h}_{i-1}) \quad i = 1, \dots, N \quad (9)$$

$$\overleftarrow{h}_i = \overleftarrow{LSTM}(a_i, \overleftarrow{h}_{i-1}) \quad i = N, \dots, 1 \quad (10)$$

Where \vec{h}_i represents the output of forwarding LSTM at t^{th} time step, and \overleftarrow{h}_i represents the output of backward LSTM at t^{th} time step. The result of connecting \vec{h}_i and \overleftarrow{h}_i is the output result of Bi-LSTM at t^{th} time step.

5.3. Experimental Results and Analysis

The system DLR text classification experiment and the CNN-BiLSTM sentence semantic similarity experiment both adopt the accuracy evaluation method. The accuracy calculation formula is as shown in Eq.(11):

$$Accuracy = \frac{n_{correct}}{n_{total}} \quad (11)$$

Among them, $n_{correct}$ represents the number of records with correct classification, and n_{total} represents the number of all test data.

5.3.1. Data Collection

The text classification corpus utilized in this project is shown in Table 1, which is divided into three columns: index, question and category. If the question contains "reexamination", it will be marked as "0", the "adjustment" will be marked as "1". The number of data is 540.

Table 1. Text classification corpus.

Index	Question	Category
0	复试名单或者复试线多久可以看见? (How long will the reexamination list or reexamination line be visible?)	0
1	今年该校还会招收会计专硕（全日制）的调剂生嘛? (Will the school enroll accounting adjustment students (full-time) this year?)	1
2	调剂考生有可能在调剂系统打开前完成复试吗? (Is it possible for the transfer candidate to complete the reexamination before the transfer system is turned on?)	0
...		
539	贵校今年的复试时间在 5 月 20 日之前还是之后? (Is your school's reexamination before or after May 20th this year?)	0
540	今年复试是线上还是线下? (Is this year's graduate reexamination online or offline?)	0

The semantic similarity matching corpus utilized in this project is shown in Table 2, which is divided into three columns: question 1, question 2 and semantic match degree. The number of data is 1800.

Table 2. The example of question pair corpus.

Question1	Question2	Semantic match degree
推免是否会影响到考研名额? (Will the guaranteed acceptance affect the number of the postgraduate entrance examination?)	推免接受人数有多少? (How many people can get guaranteed acceptance?)	0
可以转专业吗? (Can I switch to a major?)	能否转专业? (Can I switch to another major?)	1

5.3.2. The experimental results of the DLR

The number of the above text classification corpus is compared through the existing classification model, and the accuracy is utilized as the evaluation index for calculation. The results of each algorithm are shown in Table 3.

Table 3. Text classification experiment on our corpus.

Model	Accuracy
KNN	75%
SVM	74.2%
Nbaves	75.7%
RanfomForest	78.6%
LR	92.13%
DLR	93.98%

As can be seen from the table above, the results obtained by DLR text classification algorithm utilized in this module are significantly improved compared with the results of other traditional classification algorithms. Using DLR text classification algorithm can get better and more accurate experimental classification results.

5.3.3. The experiment results of the CNN-BiLSTM

The paper selects 1500 statements in the above semantic similarity matching corpus as the training data set and 300 sentences as the test data set. The unsupervised methods and supervised methods are compared with CNN-BiLSTM, and accuracy is utilized as the evaluation index for calculation. The results of each algorithm are shown in Table 4.

Table 4. Sentence semantic similarity matching experiment on our corpus.

Model	Accuracy
One-hot+cos	66.5%
Bert+cos	67.5%
W2V+cos	71.9%
W2V+tf-idf+cos	71.2%
CNN	67.3%
LSTM	72.7%
BiLSTM	70.6%
BiLSTM+CNN	70.0%
CNN+BiLSTM	80.7%

Through the above comparative experiments, it can be found that the effect of CNN-BiLSTM is better than other methods. Compared with a single CNN model and a single BiLSTM model, the fusion of these two models achieves better experimental results.

6. IQ&AEE SYSTEM IMPLEMENTATION

6.1. Experimental Environment

System hardware requirements: 64MB or more memory, 1024*768 resolution monitor, 24x speed CD-ROM or DVD-ROM drive, 50G or more available hard disk space, keyboard and mouse. The above is a test run server environment.

System web front-end development requirements: Window10, Eclipse javaee integrated development environment, apache-tomcat-9.0.16, Navicat Premium 12, MySQL 5.7, neo4j-community-3.3.5.

System background development requirements: python3.5, PyCharm2017 (includes library functions: Tensorflow 2.1.0, pymysql, sys, numpy, pandas, re, time).

6.2. Web Implementation

The Web is divided into a visitor part and a background administrator part. After entering the main web page, visitors can learn about the school through real-time information, popular professional introductions, topical news, popular activities and so on. As shown in Fig. 10. The real developed IQ&AEE system is shown on the website of : <http://59.110.13.80:81/>.

Visitors can enter the consultation page when they click on the page "school consultation" or "examination and enrollment consultation". On this web page, visitors can enter questions about the examination and enrollment, and can see the users' common questions, help, registration, login and other options. After testing, the Q&A function can be utilized normally. The consulting interface and the visitor inquiry question interface are shown in Fig. 11 to 12.

The administrator can manage the Q&A database through the knowledge base management module. On this web page, administrators can edit and delete questions in the Q&A database, or edit and delete answers in the Q&A database, and add keywords for the questions. At the same time, the administrator can edit, delete, add and do other operations to the message database and the user database through knowledge base management module and the user management module.



Figure 10. Display of the main page of the visitors



Figure 11. Display of the school consultation page



Figure 12. Display of the school consultation message function

7. CONCLUSIONS

The Q&A system has experienced years of development and made some achievements. Compared with the Q&A system in the popular research domains, the Q&A system in the restricted domains such as the examination and enrollment, has the biggest problem, e.g. it is impossible to build a large corpus. Therefore, this paper proposes a novel Q&A retrieval model based on CNN-BiLSTM and DLR, which contains the ability of LR to deal with imbalances and the ability of NB to derive, solving the problem of the data sparseness, and opening up a novel way for the design of Q&A system in restricted domains.

This paper studies the technology of question classification, question component extraction and answer selection for question answering. However, due to the small data set for college examination and enrollment questions, the model CNN-BiLSTM is not adequately trained in question component extraction. On the basis of this paper, we can further study the addition of corpus automatic growth, corpus automatic error correction design, high-efficient and accurate short text similarity matching algorithm and the development of depth reasoning in Q&A systems, so that to make the Q&A system for the specific area of examination and enrollment with higher wisdom. Although there have been some achievements in the construction of the Q&A system, with booming development of big data and artificial intelligence, there are still more construction details for the Q&A system in the restricted domains, which urgently needs to be considered and explored by the developers.

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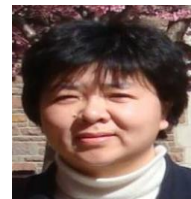
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CURRICULUM SEMANTIC RETRIEVAL SYSTEM BASED ON DISTANT SUPERVISION

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ABSTRACT

Knowledge Graph is a semantic network that reveals the relationship between entities, which construction is to describe various entities, concepts and their relationships in the real world. Since knowledge graph can effectively reveal the relationship between the different knowledge items, it has been widely utilized in the intelligent education. In particular, relation extraction is the critical part of knowledge graph and plays a very important role in the construction of knowledge graph. According to the different magnitude of data labeling, entity relationship extraction tasks of deep learning can be divided into two categories: supervised and distant supervised. Supervised learning approaches can extract effective entity relationships. However, these approaches rely on labeled data heavily resulting in the time-consuming and labor-consuming. The distant supervision approach is widely concerned by researchers because it can generate the entity relation extraction automatically. However, the development and application of the distant supervised approach has been seriously hindered due to the noises, lack of information and disequilibrium in the relation extraction tasks. Inspired by the above analysis, the paper proposes a novel curriculum points relationship extraction model based on the distant supervision. In particular, firstly the research of the distant supervised relationship extraction model based on the sentence bag attention mechanism to extract the relationship of curriculum points. Secondly, the research of knowledge graph construction based on the knowledge ontology. Thirdly, the development of curriculum semantic retrieval platform based on Web. Compared with the existing advanced models, the AUC of this system is increased by 14.2%; At the same time, taking "big data processing" course in computer field as an example, the relationship extraction result with F1 value of 88.1% is realized. The experimental results show that the proposed model provides an effective solution for the development and application of knowledge graph in the field of intelligent education.

KEYWORDS

Knowledge Graph, Curriculum Points, Distant Supervision, Relation Extraction, Sentence Bag Attention Mechanism, Ontology Construction.

1. INTRODUCTION

As the knowledge base of the Semantic Network, the knowledge graph (KG) is becoming one of the important education applications using artificial intelligence technology due to its significant capability[1][2][3][4][5]. In particular, relation extraction is an important part of information extraction technology. It refers to the modeling of text information to automatically extract the semantic relationship between entity pairs and extract effective semantic knowledge. It is a very critical part of the construction of knowledge graphs[6].

According to the difference of data set labeling magnitude, entity relationship extraction tasks of deep learning can be divided into two categories: supervised and distant supervised [7]. Supervised learning approaches can extract effective entity relationships. However, these approaches rely on labeled data heavily resulting in the time-consuming and labor-consuming. The distant supervision combines the advantages of semi-supervised learning and unsupervised learning and uses existing structured data to automatically annotate the data to generate training data [8]. In 2009, Mintz proposed the idea of distant supervision, that is, if two entities do not contain a certain relationship, all sentences involving these two entities represent the relationship, and the data for training the relationship extraction model can be automatically generated [9]. In 2016, Chris Quirk and Hoifung Poon proposed the first approach for applying distant supervision to cross sentence relation extraction, which can incorporate both standard dependencies and discourse relations, thus providing a unifying way to model relations within and across sentences [10]. However, the development and application of the distant supervised approach has been seriously hindered due to the noises, lack of information and disequilibrium in the relation extraction tasks.

Distant supervision methods based on deep learning are mainly improved network structures such as CNN, RNN and LSTM [11][12], such as the fusion method of PCNN and multi-example learning [13], and the fusion method of PCNN and attention mechanism [14]. In 2017, Ji et al. proposed a sentence-based attention mechanism and entity description, which reduced the noise problem and obtained semantic information in different sentences [15]. In 2018, Qu et al. proposed a relation extraction model of the word attention mechanism, which can improve the accuracy of relation extraction while reducing noise [16]. Fan et al. [17] solve the problems of sparseness and noise through matrix factorization and completion methods. In 2019, Craven et al.[18] proposed the idea of weakly supervised machine learning to extract the relationship between proteins and genes. However, for entity relationship extraction in a specific field, these research methods also need to solve the problem of domain knowledge base construction.

The KG is a series of different graphs that show the relationship between knowledge structure and the development process. It uses visualization technology to describe knowledge resources and carriers, excavates, analyses, and draws the connections between knowledge and them[19]. In general, KG is expressed by semantic standard language or ontology language. Ontology refers to a formal, clear and detailed description of a shared conceptual system[20]. The construction of the domain KG is usually based on the concept of domain knowledge ontology[21][22][23]. However, most of these systems only want to achieve query expansion with the help of ontology, and does not combine semantic retrieval with KG to improve the quality and efficiency of retrieval.

Information retrieval refers to the process and technology of organizing information in a certain way and finding out relevant information according to the needs of information users [24]. The library information retrieval model proposed by Bu Yanyan creates ontology through standardization and planning, and processes user input requests through semantic logical reasoning, extraction, and query, and seeks ideal results from the knowledge base. It has a high recall rate and accuracy rate [25]. XiongWanying combined competitions and information literacy classes and proposed a curriculum content design based on information retrieval competitions to enrich the curriculum and enhance the teaching effect[26]. Obviously, data retrieval and visual display are major trends in the development of information retrieval in the future.

Therefore, the paper proposes a novel Semantic Retrieval System model of “BigDataProcessing” course (BDP-SRS). In particular, the paper firstly proposes the system developed Distantly Supervised Relation Extraction Model based on Sentence Bags Attention (DSRE-SBA) to extract the relationship of curriculum points. Use statistics and deep learning methods to extract key

words of course knowledge points, obtain knowledge point entities through domain entity optimization, and use remote supervision-based intra-pocket attention mechanism [27] to reduce the noise of the large amount of training data obtained, and then the denoised data is sent to Bi_LSTM (Bidirectional LSTM Networks with Entity-aware Attention using Latent Entity Typing) [28] for relation extraction. Secondly, the paper researches of knowledge graph construction based on the knowledge ontology. Thirdly, the paper develops a curriculum semantic retrieval platform based on Web. Compared with the existing models, the AUC of this system is increased by 14.2%; At the same time, taking "big data processing" course in computer field as an example, the paper implements the relationship extraction result with F1 value of 88.1%.

The main contents of the paper are as follows: Section 2 introduces the concepts of knowledge graph and semantic retrieval, as well as the method used in this paper; Section 3 mainly presents the overview of the system design, which mainly includes the design of two subsystems: relation extraction and knowledge graph semantic retrieval; Section 4 presents the experiment, comparative analysis of representative models and the implementation of the retrieval system; Section 5 is the conclusion.

2. RELATED WORK

2.1. Knowledge Graph Construction

KG is a knowledge base that represents entities (or concepts) and their relationships in the real-world in the form of graphs. There are two main ways to construct a KG: top-down approach and bottom-up approach. The top-down approach is to define the ontology and data schema for the KG and then add the entities to the knowledge base, which needs to utilize some existing structured knowledge base as its basic knowledge base. The bottom-up approach is to extract entities from some open linked data, select the entities with high confidence to join the knowledge base, and then construct the top-level ontology pattern. The flow chart of KG construction is shown in Figure 1.

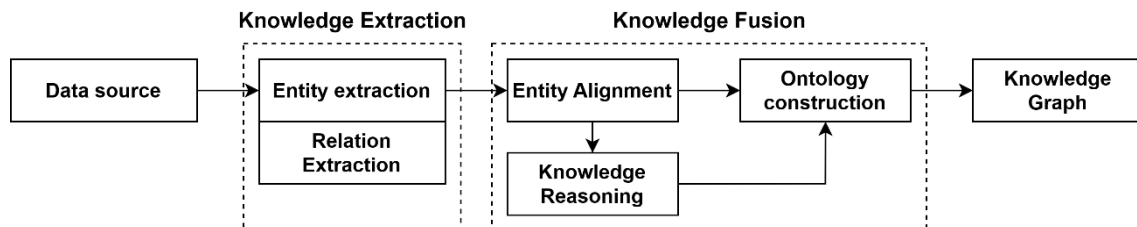


Figure 1. The flow chart of KG construction

As shown in Figure 1, there are three steps of KG construction including knowledge extraction, fusion and reasoning. Semi-structured and unstructured data have poor standardization, and it is difficult to obtain knowledge directly. Therefore, the entity extraction and relation extraction are needed to extract knowledge entities and relationships between entities, and then add them to the KG. The construction process of KG is continuous and cyclic.

2.2. Introduction to Semantic Retrieval

Semantic retrieval enhances the conceptual understanding and analysis ability of the information retrieval system, understands and processes users' retrieval requests from the level of word meaning, and organizes information sources [29]. According to the retrieval effect and

understanding degree, semantic retrieval can be divided into concept-based semantic retrieval and rule-based semantic retrieval [30].

- Concept-Based semantic retrieval. Through concept graph and attribute expansion based on the concept model in ontology, the search engine can accurately match the concept corresponding to the user's question, and then get the user's retrieval intention.
- Rule-Based semantic retrieval. The rule based on concept definition is utilized to judge whether or not the concept represented semantically is correct, and then form the inference function [31].

This paper adopts a concept-based semantic retrieval method. This is because its triples can represent the attributes and relationships of the concepts in the semantic layer.

3. OVERVIEW OF SYSTEM DESIGN

As shown in Figure 2, the semantic retrieval system model of “big data processing” course (BDP-SRS) can be divided into the following two modules.

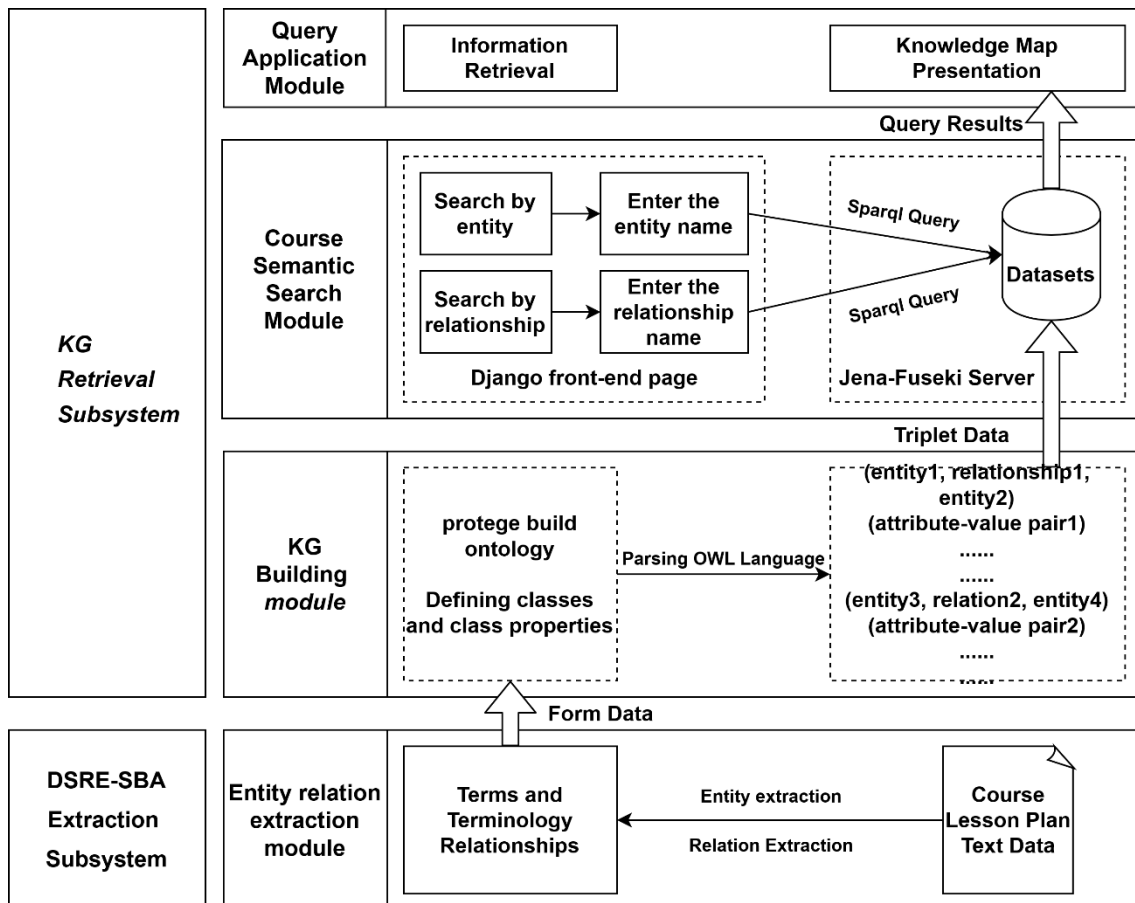


Figure 2. BDP-SRS Model Framework

3.1. Distantly Supervised Relation Extraction Model Based on Sentence Bag Attention

In the relation extraction module, the system develops Distantly Supervised Relation Extraction Model based on Sentence Bags Attention (DSRE-SBA) to obtain data. As shown in Figure 3, DSRE-SBA model includes four parts: Extraction of curriculum knowledge entity; Build a large number of training data; Data noise reduction; Relation extraction.

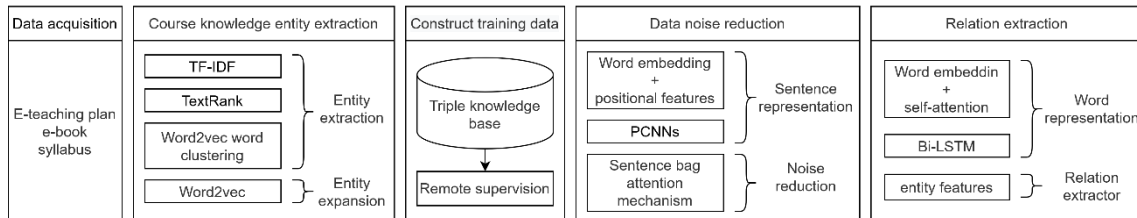


Figure 3. DSRE-SBA model frame diagram

3.1.1. Course Knowledge Entity Extraction

This model adopts Jieba, an open-source Chinese word segmentation tool, and constructs its word segmentation dictionary by using NLPiR Chinese stop word list and adding computer subject words. Then, the TF-IDF algorithm, TextRank algorithm, and Word2Vec word clustering are combined together to extract the curriculum knowledge entity keywords from the text that has been segmented.

3.1.2. PCNNs-based Feature Extraction

This model uses the neural network structure of PCNNs to automatically learn text features, instead of complex artificial features and feature processing procedures. Figure 4 is the model frame diagram of PCNN.

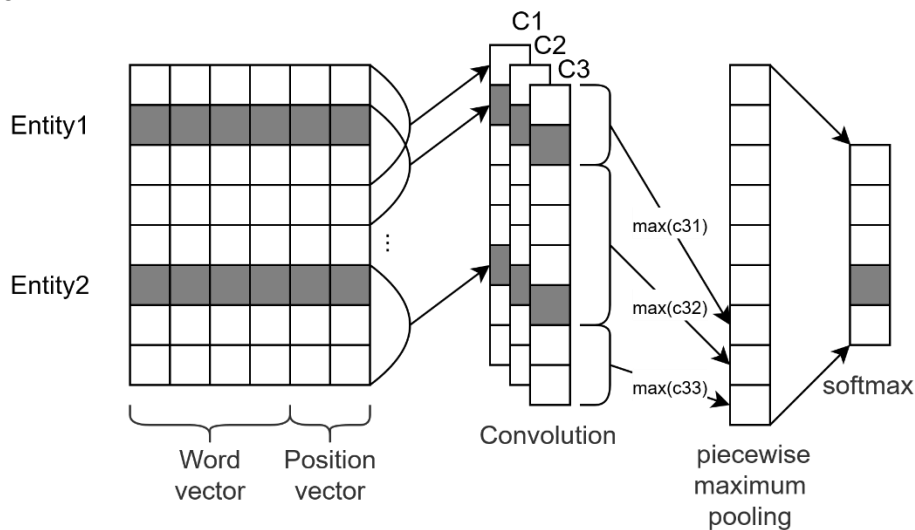


Figure 4. PCNN model frame diagram

3.1.3. Sentence Bag Attention Model

The proposed sentence bag Attention model (SBA) utilized the similarity-based attention mechanism to express bag groups by weighting the bags., and took a relation-aware approach to calculate the weight of sentences in the each bag to represent a bag and set the noisy sentence to a smaller weight. The frame diagram of the SBA model is shown in Figure 5 the meaning of parameters is described as follows.

$g = \{b^1, b^2, \dots, b^n\}$, represents a bag group, which contains multiple bags with the same relationship label marked by the distant supervisor, and n is the number of bags in a bag group.

$b^i = \{x_1^i, x_2^i, \dots, x_{m_i}^i\}$ Means all sentences in a bag, and m_i is the number of sentences in a bag b_i .

$x_j^i = \{W_{j1}^i, W_{j2}^i, \dots, W_{jl_{ij}}^i\}$ represents the j sentence in the i bag, and l_{ij} is the length of the sentence.

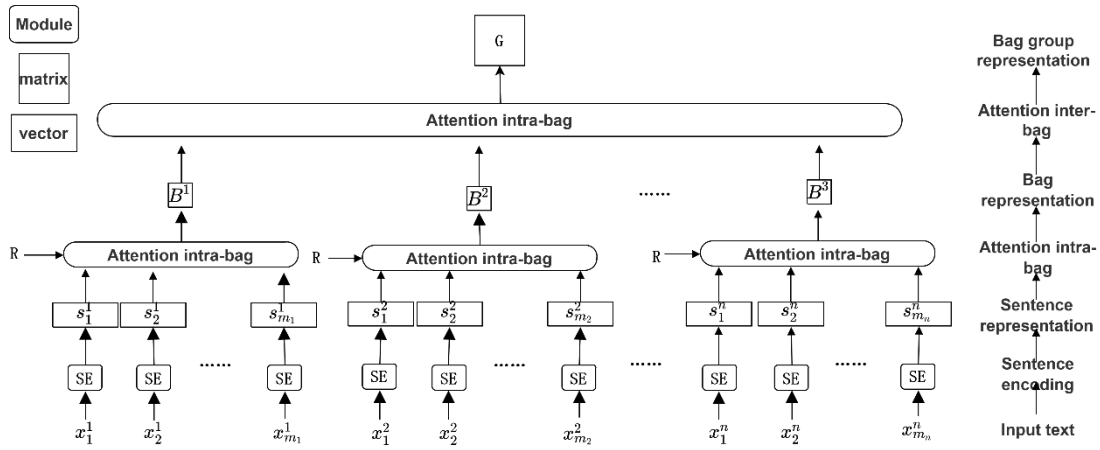


Figure 5. Sentence bag attention model frame diagram

3.1.4. Bi_LSTM Based on Entity Perception Attention

A Bidirectional LSTM Networks with Entity-Aware Attention (EA-BI_LSTM) model is proposed to classify the knowledge points of the course. This model is an end-to-end recursive neural model proposed by Joohong Lee et al. It combines an Entity perceptive attention mechanism with Latent Entity Typing[28]. The attention based on entity perception makes the model focus on the most important semantic information. The framework diagram of EA-BI_LSTM model is shown in Figure 6.

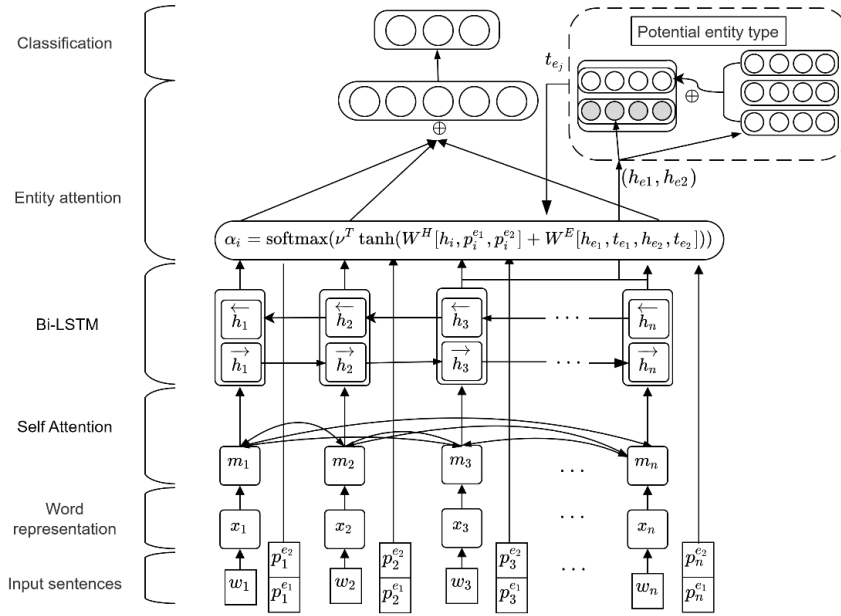


Figure 6. The framework diagram of EA-BI_LSTM model

The three characteristics of entity perception attention include:

- Hidden layer state of Bi_LSTMH = {h₁, h₂, ..., h_n}.
- Relative location characteristics.
- Physical characteristics of LET. As shown in Formula (1)-(3).

$$u_i = \tanh(W^H[h_i; p_i^{e1}; p_i^{e2}] + W^E[h_{e1}; t_{e1}; h_{e2}; t_{e2}]) \quad (1)$$

$$\alpha_i = \frac{\exp(v^T u_i)}{\sum_{j=1}^n \exp(v^T u_j)} \quad (2)$$

$$z = \sum_{i=1}^n \alpha_i h_i \quad (3)$$

3.2. Knowledge Graph Retrieval Subsystem

3.2.1. Knowledge Graph Building Module

The output data of DSRE-SBA subsystem is imported into Protege, which defines classes and class attributes in advance to construct the course knowledge ontology, and the course knowledge triad data containing entity relations and attributes are obtained. Finally, the query statement is deployed to the Django framework, and the KG is visualized by using the Echarts component. Figure 7 is the general framework of KG construction.

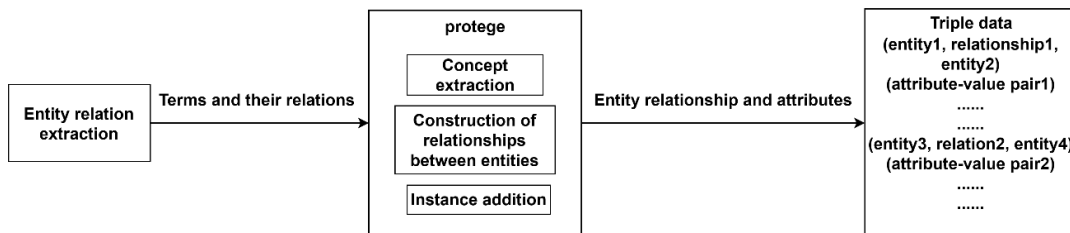


Figure 7. The general framework of KG construction.

3.2.2. Course Semantic Retrieval Module

The semantic retrieval module adopts the front-end separation technology. The front-end simulated SPARQL request corresponding to the retrieval model and sent it to the back-end Apache Jena Fuseki server to query relevant data. After the data is processed, it is returned to the front-end, and the ontology is visualized by the Echarts component. Figure 8 is the schematic diagram of the semantic retrieval system.

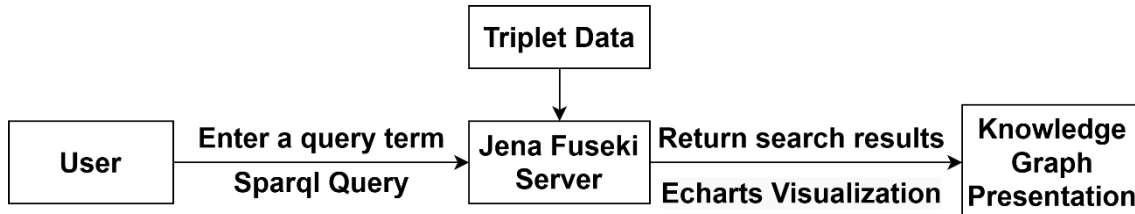


Figure 8. The schematic diagram of semantic retrieval system

3.2.3. Query Application Module

Deploy the query statement on the Web framework Django, and use the Echarts component to visualize the query result. Figure 9 shows the query application page.

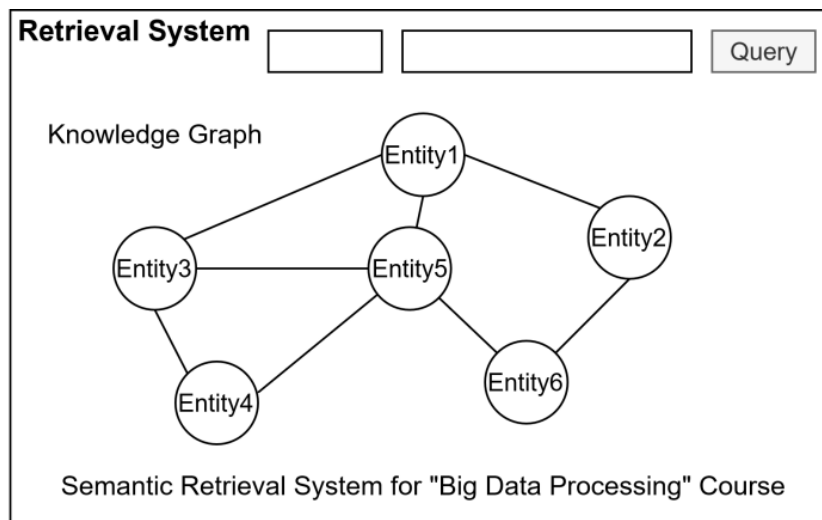


Figure 9. The query application page

4. SYSTEM IMPLEMENTATION

4.1. Implementation of Entity Relation Extraction

4.1.1. Entity extraction

Due to the limited data set acquired, the knowledge entities extracted are also limited, so the entity set needs to be expanded to ensure the integrity of the knowledge system. In this model, relevant teaching plans and books of “big data processing” courses are added into the wiki corpus to be trained as the training set of Word2vec, and then a new round of manual optimization is carried out. English Entities Extension are shown in Table 1.

Table 1. Example of an English entity extension result.

Number	English Entity
1	map hadoop mapreduce job text class value new task tracker reducer key mapper mapred public jobtracker context apache org string intwritableinput records list tracker implements
2	output conf apilinux jar int throws task hdfs HDFS args void path import max configuration streaming Streaming if xml static jvm line shuffle extends http setmapperclass default uri missing

4.1.2. Relation extraction

According to the characteristics of knowledge, this model defines five kinds of relations between entities: description relation, leading and following relation, inclusion relation, parallel relation, and correlation relation. Then, a small knowledge base is built according to the five relationships, and the remote monitoring combined with the intra-bag attention mechanism is utilized for noise reduction. Finally, the relationship extractor is trained by Bi_LSTM. This knowledge base is automatically aligned with 10,728 unstructured texts, and 25,520 annotated data are obtained.

4.1.3. Noise reduction experiment of sentence pouch attention mechanism

In this paper, the sentence bag attention machine is used to reduce the noise of the data obtained by distant supervision. The experimental parameter settings are shown in Table 2.

Table 2. Parameter setting of sentence bag model

Parameter		Value
Word vector dimension		400
Location feature	Maximum relative distance	30
	Dimension	5
CNN	Window size	7
	Feature maps	230
Dropout rate		0.5
Learning rate		0.1
Batch size	N_p	25
	N_t	5
Bag group size		5
Gradient clipping		5.0

This paper compares several examples of remote supervised noise reduction models. Table 3 shows the AUC values of different models. CNN and PCNN respectively represent the use of CNN or segmented CNN in the sentence encoder, ATT-BL represents the attention method proposed by (Lin and others, 2016)[32], ATT-RA represents the relational awareness in-bag attention method, while BAG-ATT represents the inter-bag attention method.

Table 3. AUC values of different models

Model	AUC
CNN+ATT-BL	0.3478
CNN+ATT-BL+BAG-ATT	0.3533
CNN+ATT-RA	0.3773
CNN+ATT-RA+BAG-ATT	0.3899

PCNN+ATT-BL	0.3900
PCNN+ATT-BL+BAG-ATT	0.3975
PCNN+ATT-RA	0.4477
PCNN+ATT-RA+BAG-ATT	0.4540

For a more intuitive effect, Figure 10 compares the PR curve:

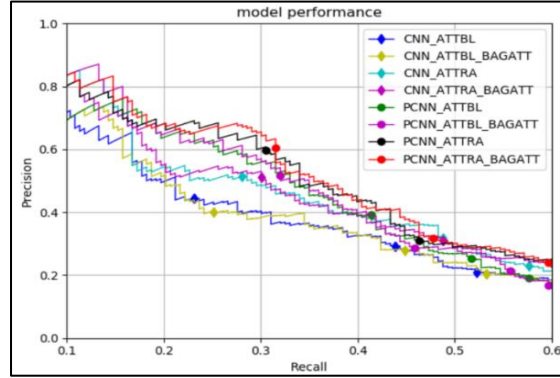


Figure 10. PR curves for different models

It can be seen from Figure 10 that the curves of PCNN_ATTTRA and PCNN_ATTTRA_BAGATT are basically above other curves, indicating that the in-bag and in-bag attention method is superior to the in-bag attention method proposed by Lin et al.

4.1.4. Relation extraction experiment

In this paper, the Bi-LSTM model based on entity perception concern is used for relation extraction, and the model method is tuned by K-fold cross validation. The experimental parameters are shown in Table 4.

Table 4. Test parameter setting

Parameter	Value	
Word vector dimension	400	
Position vector dimension	50	
Number of potential entity types	3	
Hidden layer size	400	
Attention layer size	50	
Batch size	20	
Learning rate	1	
Dropout Rate	Word embedding layer	0.3
	Bi_LSTM layer	0.3
	Physical attention layer	0.5
L2 regularization coefficient	10^{-5}	

Table 5. F1_score for different models

Model	F1_score/(%)	
	Undenoising corpus	Denoising corpora
CNN	76.4	84.9
Attention-Bi_LSTM	85.2	85.7
Attention-Bi_LSTM+LET	86.4	88.1

The experimental results of F1 of different models are shown in Table5. It can be seen that on the dataset of “big data processing” course, the sentence bag Attention mechanism still achieved certain effects, and the Attention-Bi_LSTM+LET model still performed the best.

4.2. Construction and Implementation of KG

Building KG based on domain knowledge ontology can be divided into three parts: concept extraction, Construction of relationships between entities and instance addition.

4.2.1. Concept extraction

The system customizes classes and attributes to build the curriculum ontology knowledge model. In the knowledge point of “big data processing” of this system, only one class MapReduce is designed.

4.2.2. Construction of relationships between entities

The relationship between entities in this system is divided into five types: Describe, Leading and succeeding, Contain, Parallel and Correlate.

4.2.3. Instance addition

In the process of constructing ontology, knowledge points need to be instantiated in the ontology knowledge model to realize relevant knowledge query.

4.3. Implementation of Semantic Retrieval

The system designs and implements the semantic retrieval system of the “big data processing” course, which is designed from two retrieval application modes of entity and relationship. This article uses Cellfie-ontology conversion domain specific language (MappingMaster DSL) to import excel table triple data to protégé. After completing the ontology construction, use the OntoGraf plug-in on protégé to display the overall ontology structure of the “Big Data Processing” course.

4.3.1. Entity retrieval mode

Take the entity “HDFS” as an example. Figure 11 shows the SPARQL query.

```

SELECT ?x WHERE {
  ?x
  <http://www.zsj.com#包含被包含>
  <http://www.zsj.com#HDFS>
}

```

Figure 11. SPARQL query statement for “HDFS”

4.3.2. Relational retrieval mode

Take the relationship “Correlate” as an example. Figure 12 shows the SPARQL query statement.

```

SELECT ?x ?y WHERE {
  ?x
  <http://www.zsj.com#相关相关> ?y
}

```

Figure 12. SPARQL query statement of “Relevant relevant”

4.4. KG Display Implementation

4.4.1. Entity retrieval graph display

Taking the entity “HDFS” as an example, Figure 13 shows the corresponding query result graph.

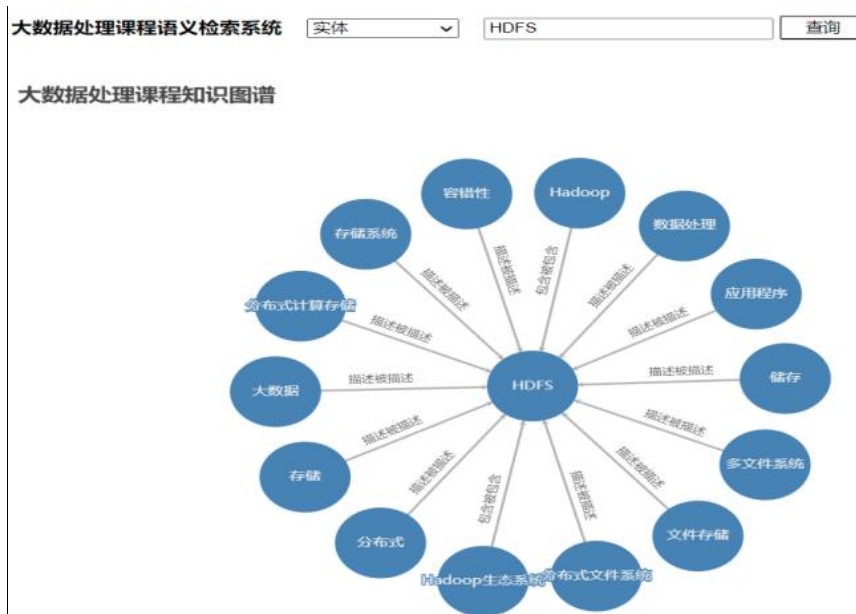


Figure 13. Relationship graph of “HDFS”

4.4.2. Relational retrieval graph display

Taking the relationship “Correlate” as an example, Figure 14 is the corresponding query result graph.

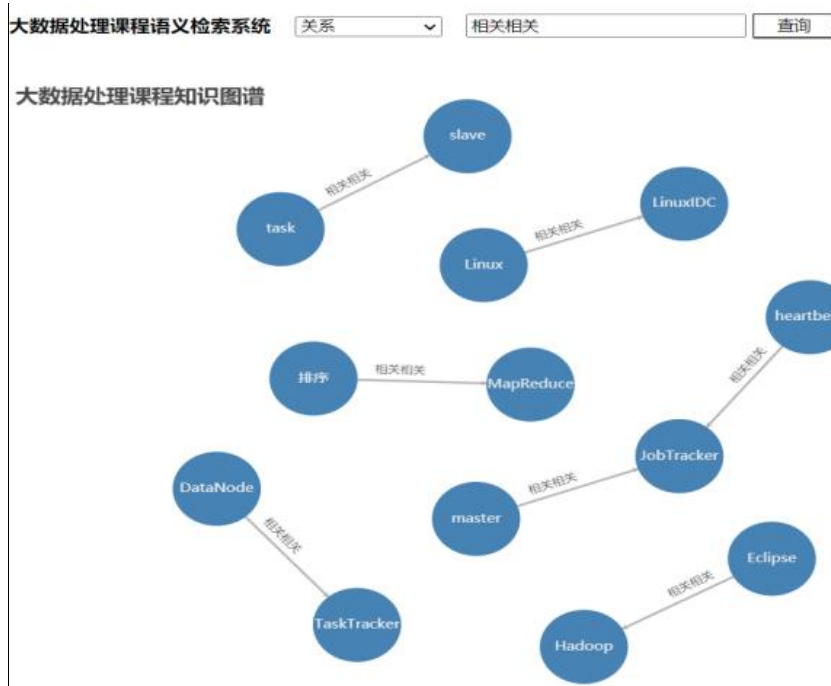


Figure 14. "Correlate" graph

5. CONCLUSION

This system extracts the knowledge points related to the "big data processing" course through the remote supervised relation extraction model DSRE-SBA based on sentence bag attention, constructs the course ontology knowledge model with the help of semantic ontology technology, extracts the terms and term relation data obtained through Cellfie import relation, and carries out semantic knowledge mining through SPARQL statement. Finally, the ontology knowledge model of "big data processing" course is designed and implemented by using two retrieval modes, entity, and relationship.

The limitation of this system lies in that only one class is created for the course knowledge points, and the non-hierarchical relation query is realized. Moreover, the limited course knowledge data leads to the incomplete ontology knowledge model of the "big data processing" course. On this basis, other course knowledge points will be added in the follow-up work to realize hierarchical relationship query, improve the course ontology, and establish a more comprehensive knowledge model of the course ontology.

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A DATA-DRIVEN PLATFORM TO COMPUTER PERFORMANCE ANALYSIS AND RECOMMENDATION USING AI AND BIG DATA ANALYSIS

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ABSTRACT

When I was assembling the computer, I found a problem. This problem is that we need to spend a lot of time and energy when we choose a desktop with a configuration and price that we are satisfied with [5]. Some computer websites will only recommend some ordinary desktops to users. Does not allow users to get what they really want, and some other shops that assemble computer mainframes use the characteristics of customers that do not understand computers to increase prices. So I wanted to create a software to help these people who need to assemble a computer to find the most suitable computer efficiently and in accordance with their requirements [6].

This program, according to the needs of users, artificial intelligence application crawler technology can help users find the most suitable computer parts based on big data, and help users get the most cost-effective self-assembled computer host. We applied our application to match a person in need of a computer host with My Platform and conducted a qualitative evaluation of the method [7]. The results showed that My Platform can efficiently and quality match the user's needs and find the best solution for the user.

KEYWORDS

Computer Performance, Big Data Analysis, Recommendation System, DATA Mining.

1. INTRODUCTION

Many people have high requirements for computer productivity, and many laptops cannot meet everyone's needs, so people need to put together a desktop computer according to their next needs, and then they need to choose the most cost-effective and best-performing desktop computer, and I designed a platform that allows people to efficiently find all eligible configurations and provide them to the user, so that the user does not have to spend a very long time to choose each accessory.

There are some problems with the first websites about computer assembly [8]. First, because of how well known these websites are, many items are in short supply and these shortages lead to many people who need a computer not being able to get a satisfactory computer. Second, many people who need a computer don't know where to get the best resources, which leads to many people who will pay high prices for accessories [9]. Many businesses are unable to provide users

with a comprehensive range of accessories because of their inventory, in which case users are unable to find the most satisfactory computer configuration.

Our goal is to find all parts that users need faster and more accuracy, I use a web crawler to find the availability of different sites, based on each site to help the user complete a set of what we think is best for the user's computer and show them what this computer needs to work and its efficiency and performance, in addition each component of the computer parts has a tab where the user can replace any of the parts that he is not satisfied with [10]. We do not limit the inventory of a site, all the sources available for crawling are displayed here and can help the user to find all the resources [11].

Experienced computer assemblers can use this site to find available computer parts and get some advice from us. For inexperienced computer assemblers, you can use this site to complete your personal computer assembly and thus learn about computers. Since my site is open to everyone, I will measure the extent to which this site is helpful and satisfying to everyone through a user survey.

The rest of the paper is organized as follows: Section 2 gives the details on the challenges that we met during the experiment and designing the sample (for example, web scraper); Section 3 focuses on the details of our solutions corresponding to the challenges that we mentioned in Section 2; Section 4 presents the relevant details about the experiment we did, following by presenting the related work in Section 5. Finally, Section 6 gives the conclusion remarks, as well as pointing out the future work of this project.

2. CHALLENGES

In order to build the tracking system, a few challenges have been identified as follows.

2.1. Solving problems for users

The first problem is how to solve the problem of finding the complete version for the user, because there are many different parts to build a PC and some of them are not needed, only certain core items are necessary and others are considered according to the user's budget, so I need to identify the key requirements of the user and find the relevant parts and then give the complete PC that is within the user's budget [15].

2.2. Choosing presentation type

The second question is when I find a suitable PC for the user, what kind of presentation should I use to show it to the user, when a person with some experience sees the configuration, even if it is not shown, but if a person who does not know anything about computers does not show them the corresponding data, it is not possible for them to use the computer with confidence.

2.3. How to implement the website

Our last challenge is how to implement this website? How to obtain more resources through different websites? Different resources will lead to different results for users. If the data obtained is not enough, it is impossible to provide users with the most complete configuration according to user requirements.

3. SOLUTION

Overall the system has three components, including User-interaction end, web-frame structure, and maintenance back-end. The user interaction end takes user input and sets triggers for the program to record user selection, where the user can choose different types of components they like [14]. Each of the selections will be then passed to the web server.

```

</section>
<div class="container" id="main-content">
  <!-- HEADER -->

  <div class="banner">
    <div class="center">
      <h2>CPP</h2>
    </div>
  </div>

  <div class="intro">
    <h2>Welcome to CPP Computer Builder!</h2>
    <p>Choose a PC part below to get started.
      All data from NewEgg.com</p>
  </div>

  <div class="grid">
    <div class="component_button">
      <a href="/cpu.html">
        <button type="button" class="btn btn-outline-secondary">
      </div>

    <div class="component_button">
      <a href="/fb.html">
        <button type="button" class="btn btn-outline-secondary">
        </a>
      </div>

    <div class="component_button">
      <a href="/memory.html">
        <button type="button" class="btn btn-outline-secondary">  
abc.com/get_cpu&xxx  
request: from 172.18.0.1
```

In the previous section we discussed having an index page to display the overall information for a user, here's how we actually implemented it. First we use HTML with header xxx, then we have bodies, inside bodies we have the components for each part of the PC [13]. The user's input (user selection) is recorded through xx.js, where the HTML includes this JavaScript at line xxx. This JavaScript also sends the recorded information to the back-end through Ajax.

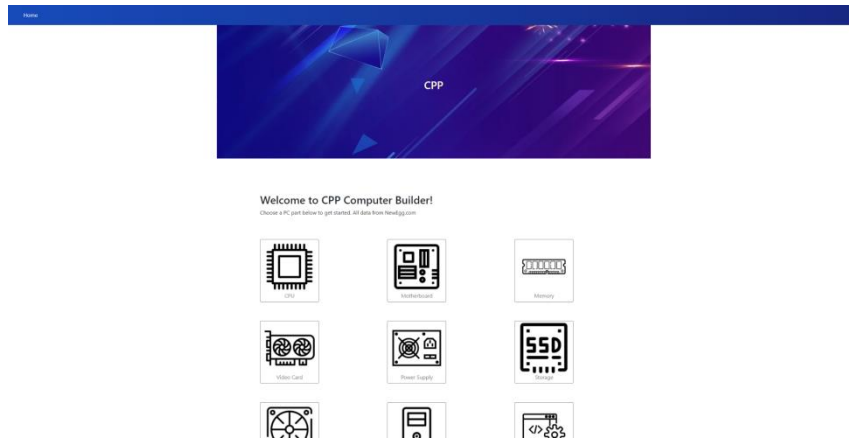


Figure 3. Screenshot of CPP computer builder

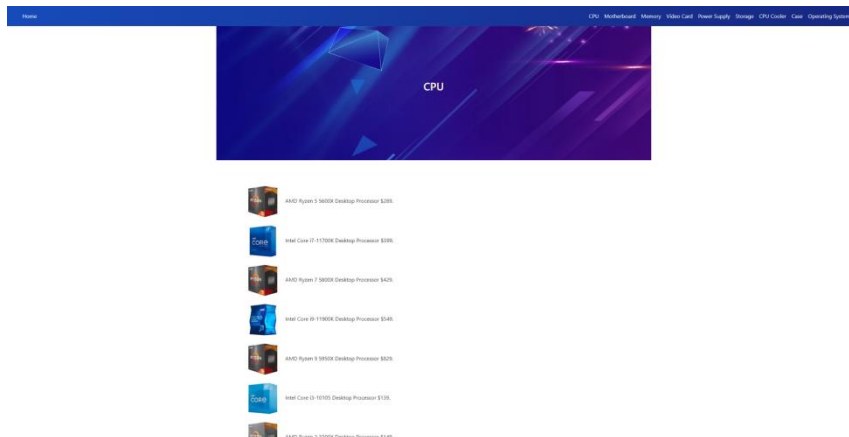


Figure 4. Screenshot of CPU

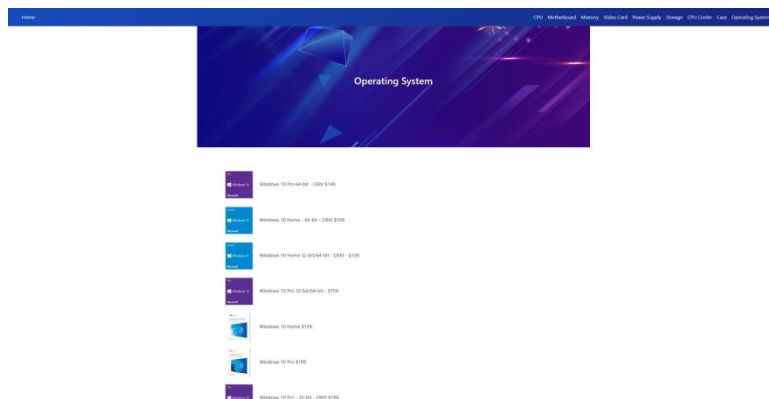


Figure 5. Screenshot of Operation System

```

38 <div class="container" id="main-content">
39 <!-- HEADER -->
40
41 <div class="banner">
42 <div class="center">
43 <h2>CPU</h2>
44 </div>
45 </div>
46
47 <div class="intro">
48 <h3>Welcome to CPU Computer Builder!</h3>
49 <p>Choose a PC part below to get started.
50 | All data from NewEgg.com</p>
51 </div>
52
53 <div class="grid">
54 <div class="component_button">
55 <a href="/CPU.html">
56 <button type="button" class="btn btn-outline-secondary"><br>CPU</button>
58 </a>
59 </div>
60
61 <div class="component_button">
62 <a href="/motherboard.html">
63 <button type="button" class="btn btn-outline-secondary"><br>Motherboard</button>
65 </a>
66 </div>
67 <div class="component_button">
68 <a href="/memory.html">
69 <button type="button" class="btn btn-outline-secondary"><br>Memory</button>
71 </a>
72 </div>
73 <div class="component_button">
74 <a href="/videocard.html">
75 <button type="button" class="btn btn-outline-secondary"><br>Video
76 Card</button>
77 </a>
78 </div>
79 <div class="component_button">
80 <a href="/powersupply.html">
81 <button type="button" class="btn btn-outline-secondary"><br>Power
82 Supply</button>
83 </a>
84 </div>
85 <div class="component_button">
86 <a href="/storage.html">
87 <button type="button" class="btn btn-outline-secondary"><br>Storage</button>
89 </a>
90 </div>
91 <div class="component_button">
92 <a href="/CPUcooler.html">
93 <button type="button" class="btn btn-outline-secondary"><br>CPU Cooler</button>
95 </a>
96 </div>
97 <div class="component_button">
98 <a href="/case.html">
99 <button type="button" class="btn btn-outline-secondary"><br>Case</button>
100 </a>
101 </div>
102 <div class="component_button">
103 <a href="/os.html">
104 <button type="button" class="btn btn-outline-secondary"><br>Operating System</button>
106 </a>
107 </div>
108 </div>
109 </div>
110 <!-- FOOTER -->

```

Figure 6. Code 2-Front end html (index.html)

This image describes the very first page of the website, index.html. It is made up with different layers of divs and html components. For each of the user's parts selection a separate div is created, inside it contains a "" tag which links to different urls to display the specific parts. For example, the storage button contains "" which means by clicking on this button the user will be redirected to the storage page, to look at potential storage items.

This image talks about how the front page looks and how all the buttons work, when a user clicks on a button it will send a request to.

```

4  from flask import Flask
5  import json
6  from flask import render_template
7  app = Flask(__name__,
8  template_folder='site/',
9  static_folder='static')

```

Figure 7. Code 3-Flask import

After the storage button is clicked, a request will be sent to the flask server. Flask is a lightweight web server package written in python. Line 4-8 described the import of such a package and the initiation of the object instance. The `template_folder` parameter decides where the server will look for different templates and the `static folder` will be where the server looks for static files.

```

54 @app.route("/storage.html")
55 def get_Storage():
56     |
57     |   return render_template('storage.html')
58

```

Figure 8. Code 3-APP route (1)

Inside flask, the user's url is parsed through view functions. We used `app.route` in this case to manage the views of the server. To continue with the example above, the user click on storage button, then it will be redirected to this function here, where it will return a rendered template of "storage.html".

```

19 |   <script>
20 |       function getResult() {
21 |           $.ajax({
22 |               url: "/getstorage",
23 |               success: function(result) {
24 |                   console.log("received result: " + result);
25 |                   $("#result").text(result);
26 |                   $.each(JSON.parse(result), function(index, item){
27 |                       $("#title"+index).text(item.name);
28 |
29 |                       $("#price"+index).text(item.price);
30 |                       $("#image"+index).attr('src', "/static/SiteFiles/"+item.image);
31 |                   });
32 |               });
33 |           }
34 |       });
35 |   }
36 |   </script>

```

Figure 9. Code 4 –Script

Inside the `storage.html`, besides the conventional header and footer, it uses a jquery ajax function to request for the specific items to be displayed in the front end. By calling a get request to "getstroage", it received the list of available storage item from the server.

```

105 @app.route("/getstorage")
106 def get_Storage_():
107     return get_item('StorageSearchHD.html')
108

```

Figure 10. Code 5-APP route (2)

On the server end, once received the request of “/getstorage”, it is parsed again using the view function. This time it is redirected to another one where it returns “get_item(‘storagesearchHD.html’”, which is a function that package the pre generated html and parse into readable json by the front end.

```

15
16 def get_item(part):
17     list_product = []
18     site_dir=path.join(path.dirname(__file__), 'site')
19     source=open((path.join(site_dir,part)), 'r')
20     soup = BeautifulSoup(source, 'lxml')
21     name = soup.findAll('div',class_="item-title")
22     price = soup.findAll('li',class_="price-current")
23     img = soup.findAll('div',class_="item-img")
24
25     for i in range(14):
26         product={}
27         product['name']=name[i].text[0:name[i].text.find("(")]
28         product['price']=price[i].text[0:len(price[i].text)-4]
29         product['image']=(img[i].find('img')).attrs['src']
30         list_product.append(product)
31     return json.dumps(list_product)

```

Figure 11. Code 6-Get item

In the get_item function, it opens local saved results, parses each component by the tag and its class. Our results as of now come directly from the new egg, hence after studying their naming patterns we extracted the image, price, and item title to be displayed. For each item, it is packed into a python dictionary, and passed to the front end as a json file.

In the above we discussed having a web server taking care of all URL requests, the implementation of the web server is done through flask. There are 9 URLs in total where each URL is dispatched through the dispatcher to each view function.

4. EXPERIMENT

4.1. Experiment 1

We have 30 users doing the survey in total, the results show below:

A	B	C	D	E	F
Index	Score 4 (strongly agree)	Score 3	Score 2	Score 1	Score 0 strongly disagree
Q1	19	0	0	1	0
Q2	17	3	0	0	0
Q3	19	0	0	0	1
Q4	18	1	1	0	0
Q5	19	0	0	1	0
Q6	20	0	0	0	0
Q7	19	0	1	0	0
Q8	15	2	2	0	1
Q9	20	0	0	0	0
Q10	19	1	0	0	0

Figure 12. Table of result

The results shows the system have a high score review from the users

According to my survey, the user's response to this website is that this website is easier to view and can find all the data directly and quickly. A lot of users think they don't need to learn anything to know how to use this web, it is steet forward to the point.

According to my survey, some users are foreign websites and should have more data so that they can access all the data more quickly and conveniently, so that they can get better information.

The way to solve this problem is to use crawler technology to find more data and store it in our database so that users can get more information.

4.2. Experiment 2

In the second experiment, we ask users to rate the most satisfy components they bought from the website, most of them choose cpu, which matches the algorithm we designed which make sure the performance of the CPU first, the second high score component is GPU.

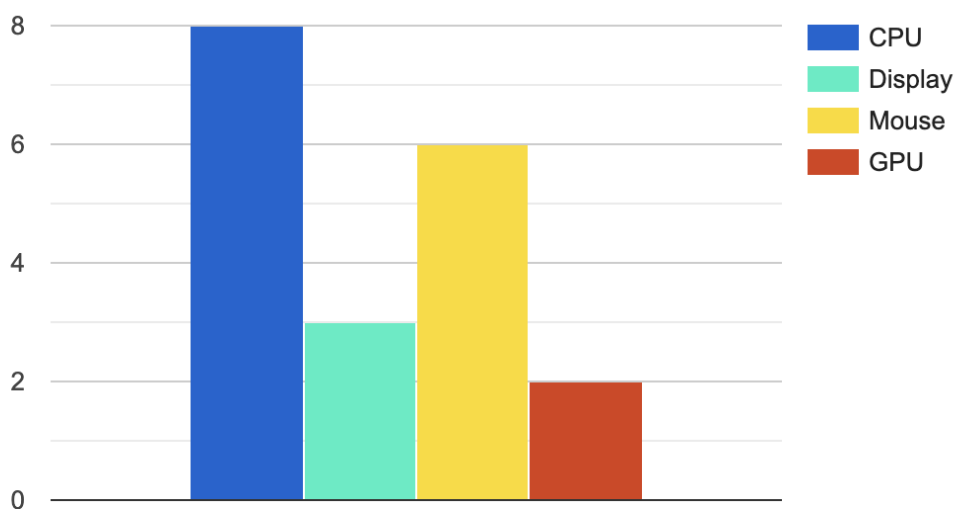


Figure 13. Score of each part

According to the two experiments, users prefer my website because my website is simpler and clearer, allowing users to directly find the information they want, and get all the data and prices from it. In addition, my website can provide him with datas. Also my website provides components lists with high performance with CPU and GPU.

5. RELATED WORK

The content of the web has increasingly become a focus for academic research [2]. Computer programs are needed in order to conduct any large-scale processing of web pages, requiring the use of a web crawler at some stage in order to fetch the pages to be analysed. The processing of the text of web pages in order to extract information can be expensive in terms of processor time. Consequently a distributed design is proposed in order to effectively use idle computing resources and to help information scientists avoid the need to employ dedicated equipment. A system developed using the model is examined and the advantages and limitations of the approach are discussed.

This paper describes Mercator, a scalable, extensible Web crawler written entirely in Java [3]. Scalable Web crawlers are an important component of many Web services, but their design is not well-documented in the literature. We enumerate the major components of any scalable Web crawler, comment on alternatives and trade-offs in their design, and describe the particular components used in Mercator. We also describe Mercator's support for extensibility and customizability. Finally, we comment on Mercator's performance, which we have found to be comparable to that of other crawlers for which performance numbers have been published.

Broad Web search engines as well as many more specialized search tools rely on Web crawlers to acquire large collections of pages for indexing and analysis [4]. Such a Web crawler may interact with millions of hosts over a period of weeks or months, and thus issues of robustness, flexibility, and manageability are of major importance. In addition, I/O performance, network resources, and OS limits must be taken into account in order to achieve high performance at a reasonable cost. In this paper, we describe the design and implementation of a distributed Web crawler that runs on a network of workstations. The crawler scales to (at least) several hundred pages per second, is resilient against system crashes and other events, and can be adapted to various crawling applications. We present the software architecture of the system, discuss the performance bottlenecks, and describe efficient techniques for achieving high performance. We also report preliminary experimental results based on a crawl of 120 million pages on 5 million hosts.

6. CONCLUSIONS

I found that when we need a computer, the laptops on the market cannot meet our needs. At this time we need to assemble a host computer that meets our needs, but it is a big challenge for a person who does not understand computers [1]. Because there are various accessories on the Internet, it is difficult to successfully assemble a computer that meets your needs if you don't know the computer. Now there are many websites that have some automatic configuration tools, but they can't provide users with them because of their imperfect inventory. The best service, so I thought of a way. I can use crawler technology to search the inventory of all websites on a large scale, and then according to the inventory and combined with the needs of the user, I recommend a computer that suits him and give him all the resources. Users, let users have more choices.

Sometimes it is limited by manufacturing capacity and no website provides usable products [12]. At this time, my solution is to give all available resources to the user for him to choose from, or if the user is not in a hurry, then he can wait until the resources are available before proceeding.

In the future, if possible, I hope to cooperate with different platforms to access limited stocks and obtain more resources for users.

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A Q-LEARNING BASED FAULT-TOLERANT CONTROLLER WITH APPLICATION TO CSTH SYSTEM

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ABSTRACT

Systems are continually subjected to faults or malfunctions because of age or sudden events, which might degrade the operation performance and even result in operation failure that is a quite important issue in safety-critical systems. Thus, this important problem is the main reason to use the Fault-Tolerant strategy to improve the system's performance with the presence of faults. A fascinating property in Fault-Tolerant Controllers (FTCs) is adaptability to system changes as they evolve throughout system operations. In this paper, a Q-learning algorithm with a greedy policy was used to realize the FTC adaptability. Then, some fault scenarios are introduced in a Continuous Stirred Tank Heater (CSTH) to compare the closed-loop performance of the developed Q-learning-based FTC with concerning conventional PID controller and an RL-based FTC. The obtained results show the effectiveness of Q-learning-based FTC in different fault scenarios.

KEYWORDS

Reinforcement Learning, Q-learning Algorithm, Fault-Tolerant controller, Adaptive Controller.

1. INTRODUCTION

In today's world, the correct functioning of complex industrial systems is required to ensure efficient and high-quality production. This is particularly important to those safety-critical systems, such as power systems, aircraft, autonomous transportation, or chemical system processing hazardous materials where a small component fault/failure may cause catastrophic effects. To avoid production deteriorations and enhanced system reliability, measures must be taken to stop the propagation of fault and restore the system as much as possible to satisfactory performance when the fault occurs. This practical requirement gives rise to lots of studies in Fault-Tolerant Control (FTC) from both industry and academia [1].

Modern systems try to use historical data in their processes. As a result, data-driven identifications, diagnosis, and FTC have become a hot research topic. Previous information could be used for learning to extract the knowledge base, such as using Fuzzy predictions, Neural Network (NN) based methods, k-clustering, and support vector machines (SVM) [2].

Both sensors and control systems will target the plant to obtain the maximization benefits by optimizing the performance indicator within the scope of safety. FTC is a good alternative that has the capability of approaching performance indicators without any fault by adjusting the system variables. In [3], a gradient-based optimization method was given to optimizing the

system performance using disturbance rejection. In [4], a recursive total principal component regression (R-TPCR)-based design and implementation approach was proposed for efficient data-driven FTC and optimization.

The performance indicator without any fault reflects the system's natural ability and is easy to be gained from obtained data. However, it becomes a challenge in the case of fault because the unexpected fault has changed the maps of system states, and there are not enough valid data to develop an FTC controller for an early fault. Reinforcement Learning (RL) inspires to solve the above problem. RL is about learning from the interaction how to behave to achieve a goal. The RL agent and its environment interact over a sequence of discrete-time steps and gain a series of optimal actions finally. If an unexpected fault is considered as the environment, and the system's performance under fault-free conditions is regarded as the desired goal, the controller can be designed by RL to achieve the optimal behavior. In this paper, we compare the use of Q-learning algorithm in FTC strategy with conventional PID-controller. Also, their performance was shown in the presence of varied fault scenarios.

2. BACKGROUND

2.1. Fault-Tolerant Control (FTC) strategy

Faults in automatic methods will frequently purpose undesired reactions and shut-down of a control plant to personnel or environment. Fault-tolerant control is the synonym for a set of recent techniques that were developed to increase plant availability and reduce the risk of safety hazards. The aim is to prevent that simple faults develop into severe failure [5].

When stability and closed-loop performance are maintained despite faults, the system is said to be fault-tolerant, and the control scheme that ensures the fault tolerance is the fault-tolerant controller. FTC relates to recovery from weakness such that the system is controlled under actual constraints without replacing part(s) of the faulty system. In general, FTCs fall into two types: passive and active FTC systems. In passive FTCSs, controllers are only able to process faults that were considered during the controller's design stage. This system requires no controller self-repairing/reconfiguration and therefore has limited fault-tolerant capabilities. Unlike passive FTCSs, active FTCSs react actively to system fault by control action reconfiguration, stability, and good performance can then be recorded. In active FTCSs, the main focus is to design the controller. The existing design approaches can be generally classified into two categories: model-based and data-driven (model-free) methods. In the model-based method, a precise model of the existing system should be known a priori, and fault identification is required no construct a post-fault system model before active FTCS controller design. In the data-driven method, unlike in the model-based one, the system model is identified using available historical data [1].

2.2. Reinforcement Learning (RL) Method

RL is the learning of behavior by an agent, or a controller, from feedback through repeated interaction with its environment [6]. RL is learning what to do -mapping situations to actions- to maximize a numerical reward signal (R) (an agent's objective). The learner is not told which actions to take but instead must discover which efforts yield the most reward by trying them. An agent (controller) is connected to (interacts with) the environment through its actions and perceptions. The change is perceived as an RL signal from the environment and the agent's measurements of the new state. The standard RL problems can be represented as Markov Decision Process (MDP). An MDP consists of a set of states (S), a group of actions (A), a reward function $R: S \times A \times S \rightarrow R$, which reinforces after each state change. The history of prior states

does not affect the value or reward of following states and actions. This is known as the Markov property [7]. In the most exciting and challenging cases, actions may affect not only the immediate reward but also the following situation and, through that, all subsequent rewards. These two characteristics -trial-and-error search and delayed reward- are the two most important distinguishing features of RL.

The value of a state ($V(S)$) is the maximum reward that an agent can expect from that state in the future.

$$V(S) = \max_{a \in A} (E[R(S, a, S_{t+1}) + \gamma V(S_{t+1})]) \quad (1)$$

Where γ is the discount factor that weighs delayed reward against immediate reinforcement and S_{t+1} is the next state.

Alternatively, an agent can learn the value of each action ($Q(S, a)$), the q-value, from a state:

$$Q(S, a) = E[R(S, a, S_{t+1}) + \gamma \max_{a \in A} Q(S_{t+1}, a)] \quad (2)$$

An agent can exploit either value function to derive a policy that governs its behaviors during operation.

Three fundamental classes of methods for solving finite Markov decision problems are Dynamic Programming (DP), Monte Carlo (MC), and Temporal Difference-Learning (TD-Learning). Each class of methods has its strengths and weaknesses. DP methods are well developed mathematically but require a complete and accurate model of the environment. MC methods do not require a model and are conceptually simple but are not well for step-by-step incremental computation. Finally, TD methods require no model and are incremental but are more complex to analyze.

3. RL-BASED FTC

Supervision uses a priori knowledge of the system to choose optimal actions when a fault occurs in the system. Fault-tolerant supervision is explored in several fields, including probabilistic reasoning, Fuzzy logic, and Genetic algorithms, and one of the supervision methods for FTC is RL-based control.

TD-based RL methods iteratively derive a controller's behaviors by estimating the value of states and actions in a system through exploration. During operation, the controller exploits the knowledge gained through exploration by selecting actions with the highest value, to the fact that tolled above, a stationary system was supposed in this paper. The agent or controller can achieve optimal control by exploring over multiple-episode and iteratively converging on the value function. The conservative learning rate can be used such that the value approximation is representative of the agent's history. Dynamic of the system is changed by fault. The extant value function may not reflect the most rewarding actions in the environment model. The optimal actions should be taken with the agent. Therefore, the agent must estimate a new value function by exploration when a fault occurs.

The TD-RL approach is inherently adaptive as it frequently updates its policy from exploration. Its responsivity can be enhanced by increasing the learning rate α . In the extreme case, $\alpha = 1$

replaces the last value of an action with the new estimate at that time step. However, large values of α may not converge the value estimate to the global optimum.

We used a reference model to detect the presence of a fault in the system. This model is obtained by Neural Network approximation and data in the state of no-fault.

In this paper, we consider the difference between the output of the system and the output of the reference model (Error) on time as our state in RL and consider reward according to our state that shows below:

$$R = \begin{cases} \text{If State} \leq 2 \rightarrow 1 \\ \text{If State} \geq 2 \rightarrow -1 \\ \text{If State} > 5 \rightarrow -100 \end{cases}$$

Figure 1 shows an overview of the system with an RL-based Fault-Tolerant controller. The following subsection discusses a practical approach of TD-learning in control theory.

3.1. Q-Learning: off-policy TD control

In the on-policy method, off-policy methods evaluate or improve a policy different from that was used to generate the data. The policy being learned about is called the target policy (π), and the policy used to generate behavior is called the behavior policy (b). One of the early breakthroughs in RL was the developing an off-policy TD control algorithm known as Q-Learning [8], defined by equation 3.

$$Q(S_t, A_t) = Q(S_t, A_t) + \alpha [R_{t+1} + \gamma \max_a Q(S_{t+1}, a) - Q(S_t, A_t)] \quad (3)$$

In this case, the learned action-value function Q directly approximates q^* , the optimal action-value function, independent of the policy being followed (b). This dramatically simplifies the analysis of the algorithm and enables an effect in that it determines which state-action pairs are visited and updated. The Q-Learning control algorithm is shown in Table 1 [9].

Note: in this algorithm, all that is required for correct convergence is that all pairs continue to be updated. Under this assumption and a variant of the usual stochastic approximation conditions on the sequence of step-size parameters, Q has been shown to converge with probability 1 to q^*0F^1 .

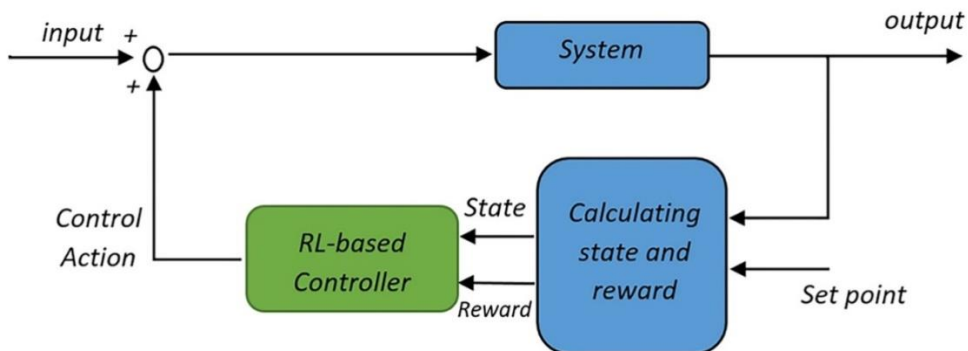


Figure 1. Block diagram of close loop system with RL-based FTC

¹∗: It is a symbol of optimality

4. CASE STUDY

CSTH is commonly used as a subsystem in heavy industrial processes [10]. A CSTH Process is depicted in Figure 2. We are interested in using a linear model of CSTH in Python application to be used in our closed-loop system. The total mass and energy balance equations for the process can be expressed as:

$$A_T \frac{dh_T}{dt} = q_i - q_o \quad (4)$$

$$A_j \frac{dh_j}{dt} = q_{ij} - q_{oj} \quad (5)$$

$$\frac{dT}{dt} = \frac{q_o}{V_T} (T_i - T) + \frac{UA(T_j - T)}{pCpV_T} \quad (6)$$

$$\frac{dT}{dt} = \frac{q_{oj}}{V_j} (T_{ij} - T_j) - \frac{UA(T_j - T)}{p_j C p_j V_j} \quad (7)$$

We assume that the level of the fluid in the tank and the jacket is constant either by process design or the use of a high gain controller. So it could be written as:

$$q_i = q_o = q \quad (8)$$

$$q_{ij} = q_{oj} = q_j \quad (9)$$

$$\frac{dT}{dt} = \frac{q}{V_T} (T_i - T) + \frac{UA(T_j - T)}{pCpV_T} \quad (10)$$

$$\frac{dT}{dt} = \frac{q_j}{V_j} (T_{ij} - T_j) - \frac{UA(T_j - T)}{p_j C p_j V_j} \quad (11)$$

Now we use steady-state analysis as follow,

$$\frac{dT}{dt} = \frac{q}{V_T} (T_i - T) + \frac{UA(T_j - T)}{pCpV_T} = 0 \quad (12)$$

$$\frac{dT}{dt} = \frac{q_j}{V_j} (T_{ij} - T_j) - \frac{UA(T_j - T)}{p_j C p_j V_j} = 0 \quad (13)$$

The steady-state value of above variable could be found in Table 2.

Table 1. Q-Learning Algorithm

Q-Learning (off-policy TD control) for estimating by $\pi \approx \pi^*$

Initialize $Q(S,A)$, for all $s \in S$, $a \in A(S)$, arbitrarily, and $Q(Terminal. all) = 0$.
Repeat (for each episode):
 Initialize S
 Repeat (for each step of episode):
 Choose A from S using policy derived from Q(e.g. ϵ -greedy)
 Take action A, observe R, S_{t+1}
 $Q(S_t.A_t) = Q(S_t.A_t) + \alpha [R_{t+1} + \gamma \max_a Q(S_{t+1}.a) - Q(S_t.A_t)]$
 $S = S_{t+1}$
Until S is terminal

Table 2. Steady-state value of variables

Variable	SS Value	Parameter	Value
T_{is}	50	UA	183.9
T_{ijs}	200	pCp	61.3
T_s	125	$p_j C p_j$	61.3
T_{js}	150	V_T	10
q_s	1	V_j	1
q_{js}	1.5	-----	----

By using Taylor series expansion for linearizing the system, the following state-space equations are obtained:

$$\begin{bmatrix} T \\ T_j \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} T \\ T_j \end{bmatrix} \quad (14)$$

$$\begin{bmatrix} \dot{T} \\ \dot{T}_j \end{bmatrix} = \begin{bmatrix} -\frac{q}{V_T} - \frac{UA}{pCpV_T} & \frac{UA}{pCpV_T} \\ \frac{UA}{p_j C p_j V_j} & -\frac{q_j}{V_j} - \frac{UA}{p_j C p_j V_j} \end{bmatrix} \begin{bmatrix} T \\ T_j \end{bmatrix} + \begin{bmatrix} \frac{q}{V_T} & 0 & \frac{(T_i - T)}{V_T} & 0 \\ 0 & \frac{q_j}{V_j} & 0 & \frac{(T_{ij} - T_j)}{V_j} \end{bmatrix} \begin{bmatrix} T_i \\ T_{ji} \\ q \\ q_j \end{bmatrix} \quad (15)$$

Substitute given values:

$$\begin{bmatrix} \dot{T} \\ \dot{T}_j \end{bmatrix} = \begin{bmatrix} -0.4 & 0.3 \\ 3 & -4.5 \end{bmatrix} \begin{bmatrix} T \\ T_j \end{bmatrix} + \begin{bmatrix} 0.1 & 0 & -7.5 & 0 \\ 0 & 1.5 & 0 & 50 \end{bmatrix} \begin{bmatrix} T_i \\ T_{ji} \\ q \\ q_j \end{bmatrix} \quad (16)$$

The control tank's output temperature (T) was studied by adjusting the jacket's output flow (F_j). Thus, the transfer function was shown in equation 17.

$$T = \frac{15}{s^2 + 4.9s + 0.9} \quad (17)$$

Finally, we use the Scipy library in Python to implement our system.

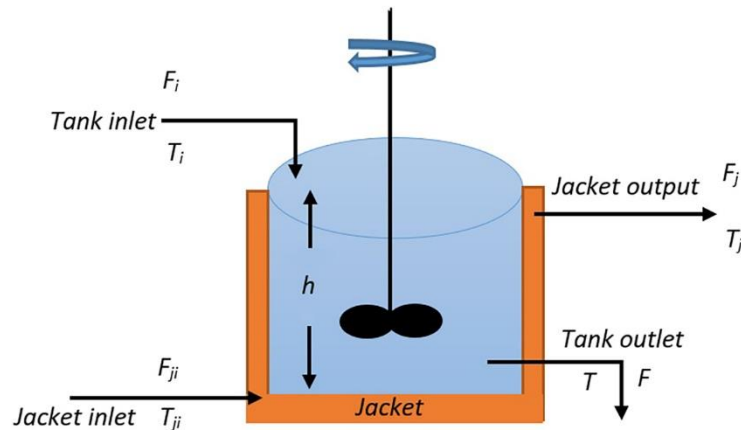


Figure 2. CSTDH system

5. RESULT AND DISCUSSION

The RL-based fault-tolerant controller was evaluated with the presence of three fault scenarios, which were discussed in the following subsections. In addition, we run the program for 100 loops, and results were presented.

5.1. Sensor Fault Scenario

A time incipient fault with an amplitude of 5 and slope of 0.01 was added to the control system that is shown in Figure 3 [11]. The result was shown in Figure 3, and the total MSE was written in Table 3. According to

Figure 4 and Table 3, the performance of the system was evaluated with two controllers, conventional PID-controller and Q-Learning-based FTC, in the presence of the sensor fault. The performance of a closed-loop system with the proposed method is quite efficient than another controller.

5.2. Actuator fault scenario

According to Figure 3, a constant fault with an amplitude of 0.4 was added to the actuator, moreover, the result was picketed in

Figure 5, and the total MSE could be found in Table 3. As shown in

Figure 5 and Table 3, the Q-learning controller performed flawlessly, and the output remained at the optimal point.

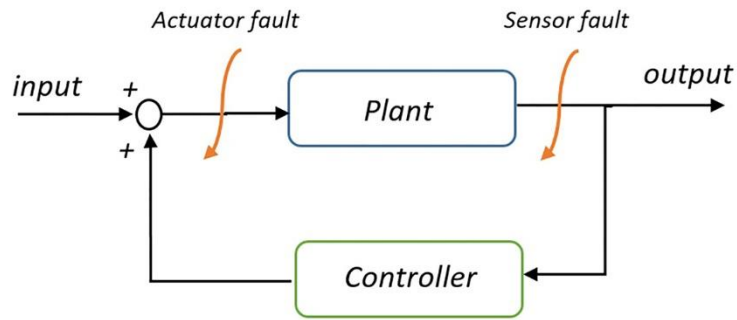


Figure 3. Location of actuator and sensor fault

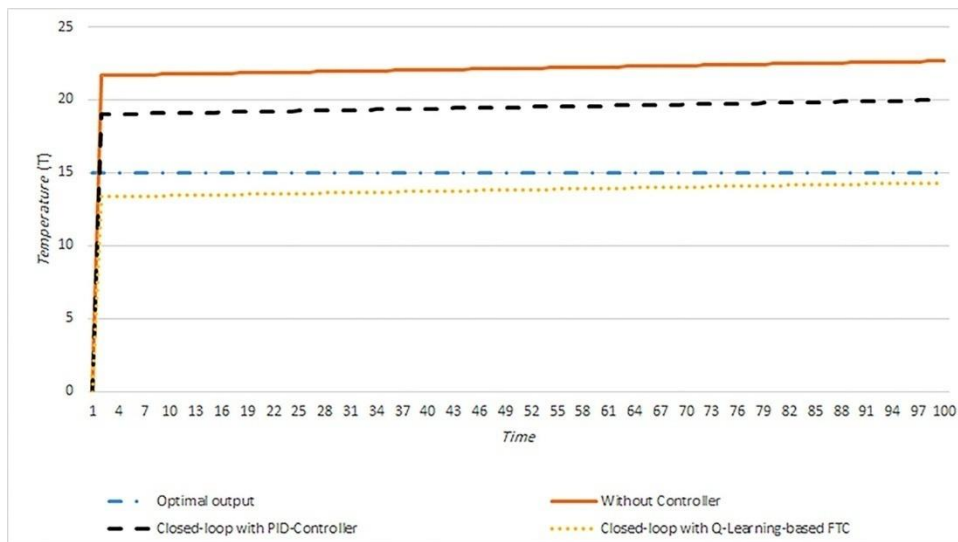


Figure 4. Sensor fault scenario

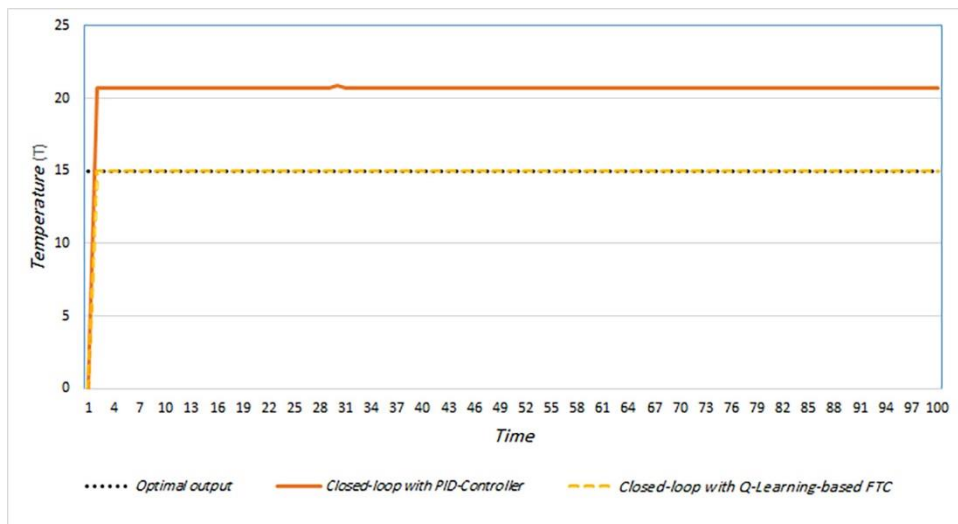


Figure 5. Actuator fault scenario

5.3. Actuator and Sensor Fault Scenario

In this section, a constant actuator fault with an amplitude of 0.1 plus a time incipient sensor fault with an amplitude of 4 and slope of 0.01 were added to the closed-loop system. Their location could be found in Figure 3. In addition,

Figure 6 shows the performance of closed-loop with conventional PID-controller and closed-loop system with Q-Learning-based FTC. Also, the total MSE was shown in Table 3. The results show that the Q-learning controller could find optimal actions to be stable the closed system as well as possible, and its performance is much better than PID-controller.

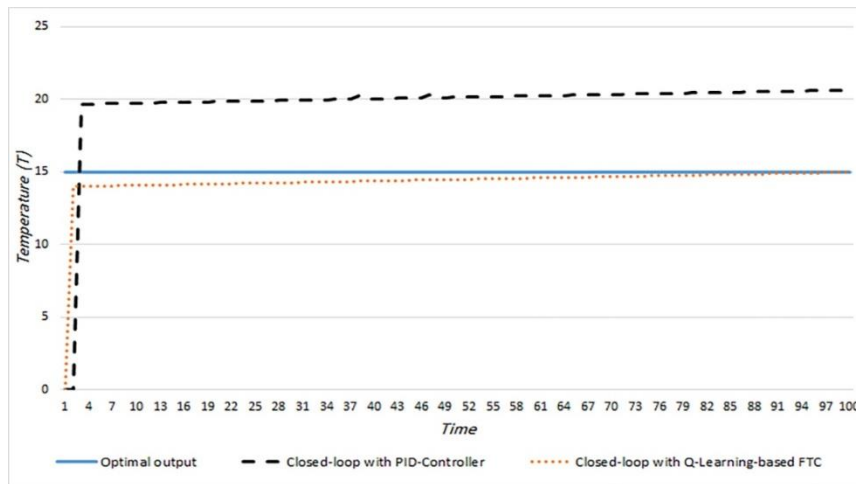


Figure 6. Sensor and actuator fault

6. CONCLUSION AND FUTURE WORK

A Q-learning algorithm with a greedy policy is used in the FTC framework. The result is a data-driven online method, which directs to the goal without knowing any system dynamic characteristics that are difficult to understand at the beginning when a fault occurs. A CSTR process was used to test the control systems. The comparison results showed that Q-learning algorithm-based FTC presents an efficient methodology to stabilize the CSTR performance when sensor and actuator faults occur in a closed-loop system. In addition, we compared its performance with conventional PID-controller, and the superiority of the proposed method was shown in the result section. In this paper, we used the greedy policy for the Q-learning algorithm. For further work, it would be interesting to search for another policy to obtain more efficiency and get a better result with respect to the RL-based FTC.

Table 3. Total MSE

Controller \ Scenario	PID	Q-Learning
A	4.4938	1.2223

B	5.6672	0.0845
C	0.5691	0.051648

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AN INTERNET-OF-THINGS (IOT) SYSTEM TO AUTOMATE THE PET DOOR CONTROLLING USING ARTIFICIAL INTELLIGENCE AND COMPUTER VISION

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ABSTRACT

Pets are cute and fun, but sometimes it gets annoying when you are trying to get some sleep in [14]. Also the population of people who would like to be accompanied by pets is rising rapidly. However, people these days lack time to meet all requirements of pets, which causes plenty of tragedies [3]. In this paper, we designed an application/tool called Automate the Pet Door Controlling which is using artificial intelligence and Computer vision to create a better living condition for pets, and a easier life for people who love their pets, especially for those who cannot spend a lot of time or physically hard to open doors for pets. My design builds an integratable system which is available for most smart home systems, also this design supports extra datasets imported to enlarge the types of pets.

KEYWORDS

IoT, Mobile, Machine Learning.

1. INTRODUCTION

Having a pet is fun and painful at the same time, because it bothers you sometimes when you do not want them to be there [15]. Yet they also get lonely when you lock them in one place. Yelling and breaking things is what they often do when they want your attention. Aside from that, keeping them away from danger is being responsible to them.

Most of the pet doors on the market are designed for dogs and large animals/pets. The issue with all the existing products is that using a pet collar is the key to exiting or entering the pet door. If the battery of the pet collar ran out, pets wouldn't be able to enter or exit the door. There are also safety issues with this kind of automatic pet door; An intruder can easily access or break into your house if they gain access to the pet collar. They also take up a lot of space because it is using the method of sliding up and down. Most important issue of existing pet doors on the market is the price. Price points vary from \$250 to \$600, which makes a lot of pet owners not be able to own one.

The automatic pet door I designed is through artificial intelligence and computer vision [4]. It uses a camera as a detection tool to locate whether pets are staying in an assigned area. The door only opens when your pet is detected. Therefore, the problem of intruders wouldn't happen. Second, this design of pet door uses a flipper door, it goes both ways so pets can both enter or

exit. Flipper door design takes up less space compared to the sliding door method. Lastly, the cost of this design is economically friendly, all the parts needed for this design are easily accessible to everyone.

In two applications, we demonstrate how the combination of Internet of Things and Artificial Intelligence techniques would increase the quality of living for both pets and the person who keeps them. First, the pet door is fully controlled by an intelligent system with Raspberry Pi and AWS server [5]. In this way, after the camera captures pictures, these pictures are sent to the AWS server and get recognized by trained AI, thus, the whole system will not require any physical assistance as long as it gets well installed. Second, this system is economically friendly, since we have analyzed the evaluation of any part to create this embedded system, we try to approach the most efficient cost for each component by comparing the popular productions in the market, and have the highest ratio of performance and price [6]. Additionally, those parts we use are easy to obtain and replace, so even if some exceptional situations happen, our automatic pet door could be maintained with much less effort and cost compared to other existing smart pet door productions. Therefore, we believe that our automatic pet door's functionality would be proved by a fully self-implementation system and an easily accessible components structure design.

The rest of the paper is organized as follows: Section 2 gives the details on the challenges that we met during the experiment and designing the sample; Section 3 focuses on the details of our solutions corresponding to the challenges that we mentioned in Section 2; Section 4 presents the relevant details about the experiment we did, following by presenting the related work in Section 5. Finally, Section 6 gives the conclusion remarks, as well as pointing out the future work of this project.

2. CHALLENGES

In order to build the tracking system, a few challenges have been identified as follows.

2.1. Building environment for Raspberry Pi

One challenge I face during the process of demo design is having trouble installing the environment on Raspberry Pi [7]. Without everything installed and up to date, our code would not be working. For example, torch is a library for Python that facilitates building deep learning projects [8]. Torch cannot be installed correctly because Raspberry Pi uses Raspbian, which is a special version of Debian, as its operating system [9]. Normal packages that are made for Linux or MacOS cannot be used for Raspbian.

2.2. Training AI

Using AI training was the second challenge during the design process. Finding good datasets was not easy. Even though cats are a popular pet around the world, there is a lot of data set online. Most of the data sets either have less amount of training because a normal computer doesn't have power to compute and process large datasets. When an AI model is used to train our AI, it will return a lot of outputs, and not all of them are useful output. Sorting all the data and determining whether it is useful or not will help with the accuracy of detection.

2.3. Testing cases

Test cases were the last challenge during the process of demo design. Manual testing takes up a lot of time and some mistakes are hard to find. First problem with the test case is not being able to recognize the cat when it appears in the camera frame. What I figure is that not having enough light will hardly affect the outcome. The second problem is that the program cannot recognize the cat's face is not facing the camera. The chance of the program recognizing when the cat is facing towards the camera is high. When the cat is facing the camera diagonally, the accuracy is lower. The program has a really low chance of recognizing the cat when it is completely facing backward.

3. SOLUTION

This system is an object detection system that uses a camera to capture the environment and receive messages back to Raspberry Pi. The camera records video as the pet approaches a certain location [1]. All the information is sent to a server through Raspberry Pi. The server has a database which processes the video and sends its result to the application. In this application, you can set whether it is automatic, or manually open the pet door. Multiple settings can be controlled from the application: the detection time range in a day, how long it takes to close the door after each opening, and record how many times a door is open each day. From the application, the signal is sent back to the Raspberry Pi, and it would be able to control the door through its motor which is connected to a 3D-printed Door. The pet door is designed to be a secondary door of your room door [2].

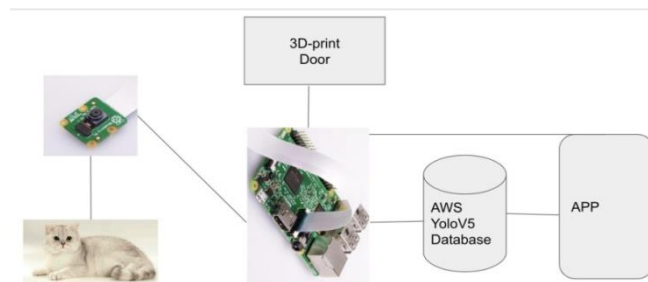


Figure 1. Overview of the whole system

```

7 camera.resolution = (1024,768)
8 camera.start_preview()
9 #camera.capture('/home/pi/Desktop/picamera/img.jpg', resize=(320,240))
10 camera.exposure_mode = 'antishake'
11 camera.capture('/home/pi/Desktop/picamera/img1.jpg')
12 camera.stop_preview()
13 sleep(4)
  
```

Figure 2. Code of camera

This section of the code is the setting for the camera. The resolution is set to the highest for better detecting results. Camera supposedly captures an image every four seconds.

```

15 url = 'https://flask.codingmindsrepo.repl.co/handleimage'
16 files = {'media': open('/home/pi/Desktop/picamera/img1.jpg', 'rb')}
17 requests.post(url, files=files)
  
```

Figure 3. Code of url, files, and request

In figure 2, url is the link to the server; files is used to make the captured image into a file; I use a request to send the picture to the server.

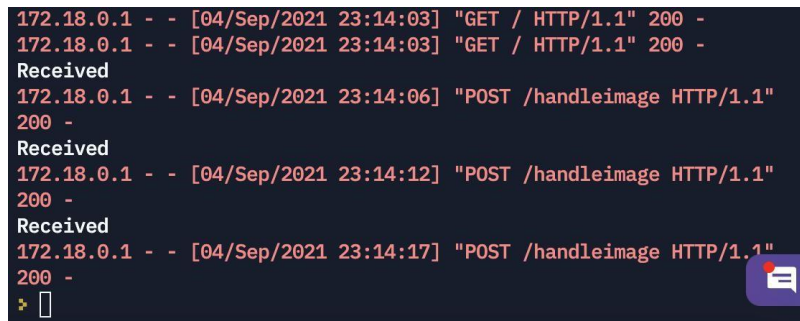
```

9
10 app = Flask(__name__)
11
12 @app.route("/")
13 def root_index():
14     return "Server is on..."
15
16 @app.route("/handleimage", methods = ['GET', 'POST'])
17 def handle_image():
18     if request.method == "POST":
19         if 'file' not in request.files:
20             print('No file part')
21             return "no file"
22         file = request.files["file"]
23         input_path = os.path.join("input", file.filename
24                                 [-8:])
25         str_filename = file.filename[-8:]
26         file.save(input_path)
27
28         #input path
29         print("Received")
30         return "Yes"
31
32     return "res"

```

Figure 4. Code of APP flask

Use Flask to set up a server in order to receive the image sent from figure 3, and check if the image is available for the recognition process.



```

172.18.0.1 - - [04/Sep/2021 23:14:03] "GET / HTTP/1.1" 200 -
172.18.0.1 - - [04/Sep/2021 23:14:03] "GET / HTTP/1.1" 200 -
Received
172.18.0.1 - - [04/Sep/2021 23:14:06] "POST /handleimage HTTP/1.1"
200 -
Received
172.18.0.1 - - [04/Sep/2021 23:14:12] "POST /handleimage HTTP/1.1"
200 -
Received
172.18.0.1 - - [04/Sep/2021 23:14:17] "POST /handleimage HTTP/1.1"
200 -
> []

```

Figure 5. Screenshot of the server

This shows the server has successfully received the post images every 5-6 seconds.

```

67     label = "empty"
68

```

Figure 6. Code of label

```

246     print(f'Done. ({time.time() - t0:.3f}s)')
247     print(label)
248     if 'cat' in label:
249         return "True"
250     else:
251         return "False"

```

Figure 7. Code of print

Variable label is used to determine whether the cat showed up in the assigned area. Variable label contains two parameters: one is cat or empty and the other one is accuracy. If a cat is detected, it will return “True” and proceed to the next step which is sending a signal to the application.

```

172     # Process predictions
173     for i, det in enumerate(pred): # detections per image
174         if webcam: # batch_size >= 1
175             p, s, im0, frame = path[i], f'{i}: ', im0s[i].copy(), dataset.count
176         else:
177             p, s, im0, frame = path, '', im0s.copy(), getattr(dataset, 'frame', 0)
178
179         p = Path(p) # to Path
180         save_path = str(save_dir / p.name) # img.jpg
181         txt_path = str(save_dir / 'labels' / p.stem) + (' if dataset.mode == 'image' else f'_{frame}') # img.txt
182         s += '%gx%g ' % img.shape[2:] # print string
183         gn = torch.tensor(im0.shape)[[1, 0, 1, 0]] # normalization gain whwh
184         imc = im0.copy() if save_crop else im0 # for save_crop

```

Figure 8. Code of process predictions

Through AI training, it processes the input image to determine whether the image captured contains a cat or not, by using the certain data-set machine learning model.

4. EXPERIMENT

4.1. Experiment 1

After completing the demo, I used my cat to test out the accuracy. The experiment was set up in two different locations, one with black wood floor and one with white wood floor. Each scenario was tested 50 times. The test participant was a white British shorthair. This experiment is designed to solve the problem with how lighting and background color affect the result.

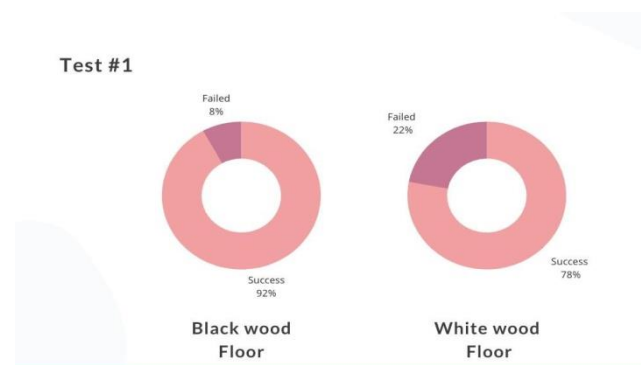


Figure 9. Test #1 result

From the graph above, we can see that a white British shorthair has a higher passing rate on the black wood floor and a lower rate on the white wood floor. The average is 85%. The result shows that the color of the background does affect the accuracy. The color back has a good contrast with the color white, which makes the result more accurate. Same color cat and floor would affect the accuracy because the cat blends into the color of the floor, which makes it harder to detect.

4.2. Experiment 2

In the second experiment, two more different kinds of cat become the participants. One of the participants is a gray/white persian cat. The second participant is a mixed Persian-American gray shorthair cat. Both participants are tested on both black and white wood floors. This experiment is designed to show how a different kind and color of cat will affect the accuracy of the result. Gray hair color cat can contrast with both black and white floor, it won't blend into either of them.

Test#2: Persian Cat

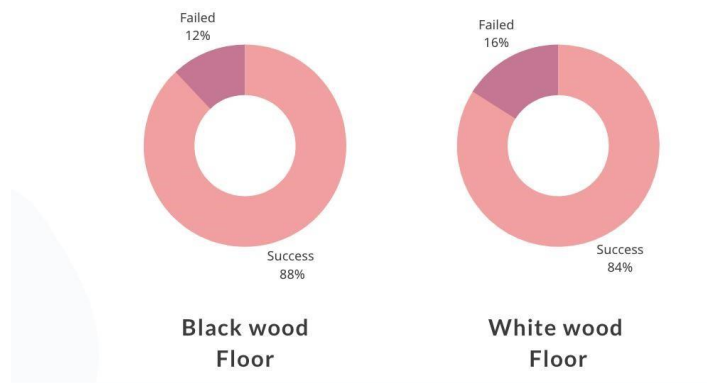


Figure 10. Test #2 result (1)

Test#2: Mixed Persian-American shorthair

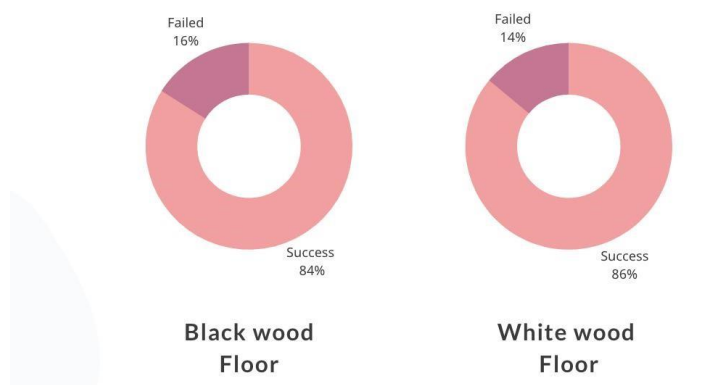


Figure 11. Test #2 result (2)

The graph above shows an average of 86% passing rate and 85% passing rate for Persian cat and the mixed cat. The breed of a cat does not affect the accuracy of the result. The main reason that affects the accuracy is the color of background and the color of the cat. If the background and cat

have a similar color, the cat will blend into the environment. Therefore, the result will be affected.

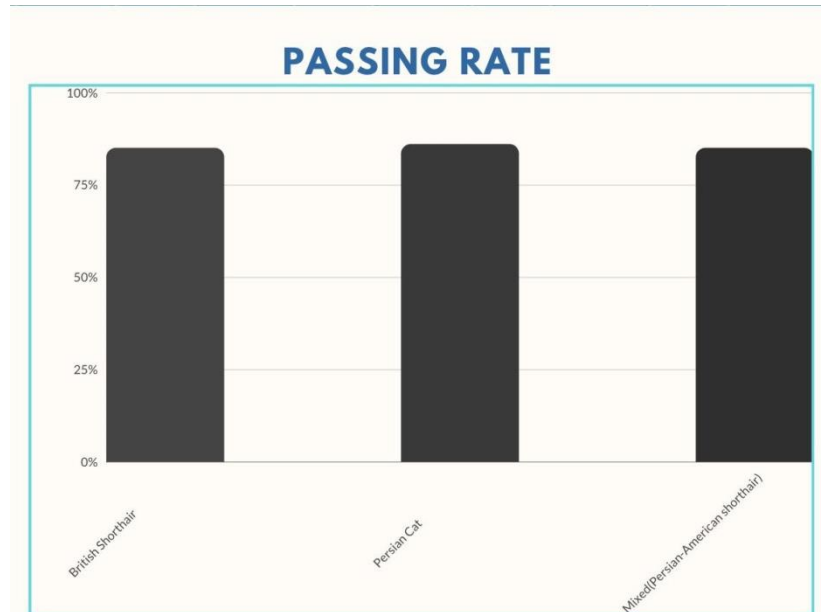


Figure 12. Compare two experiment

The result of two experiments shows an average passing rate of 85.3%. The rate of passing of British shorthair and the mixed is 85%. The rate of passing is 86% for the Persian cat. The final result is consistent and the passing rate between different breeds/colors of the cat does not affect the accuracy. The error is in between 1%.

5. RELATED WORK

Raza and Syed mention that camera calibration is important for collecting more precise data [11]. Three dimensional data is harder to collect because most of the cameras are designed to collect two dimensional images. Computer vision system won't function properly if the three dimensional image can't be captured correctly.

In Artificial Intelligence based Camera Calibration, writers stress that database learning is the principle of maximum entropy to produce answers [11]. The expectation is to be more and more accurate than those previous samples. Experiment should be on a very large dataset.

Bergström tests the detector positron camera by integral transformation of projections [10]. It used multiple sets of conditions to get a more accurate result. Control groups would get you a more accurate result and avoid some unexpected errors.

6. CONCLUSIONS

The pet door uses artificial intelligence and computer vision to process the image or video into a signal which opens and closes the door [12]. Pets can often be distracting when you are trying to focus on something. The pet door is designed for your pets to enter and exit safely. Most of the pet doors on the market use a pet collar to enter and exit the door. The collar can run out of battery or someone with it can access the pet door easily which will cause safety issues to your

pet and you. In this case, a camera operated door would be much safer compared to the regular pet doors they have on the market.

The current limitation of the product is the accuracy when the color of the pet is similar to the background color [13]. If there is a low contrast between the two, the accuracy would be 10% to 20% lower than before. It is hard for the pet door to process smoothly when the internet signal doesn't have a strong connection. Can't control the door manually.

I plan to solve the limitation of accuracy by running more datasets through AI training. Controlling the door manually through an application which allows you to keep track of your pet.

It notifies if your pet has exited the door.

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AN INTELLIGENT AND DATA-DRIVEN MOBILE PLATFORM FOR YOUTH VOLUNTEER MANAGEMENT USING MACHINE LEARNING AND DATA ANALYTICS

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ABSTRACT

In Lewis and Clark High School's Key Club, meetings are always held in a crowded classroom. The system of eventsign up is inefficient and hinders members from joining events. This has led to students becoming discouraged fromjoining Key Club and often resulted in a lack of volunteers for important events. The club needed a more efficientway of connecting volunteers with volunteering opportunities. To solve this problem, we developed a Volunteer Match Mobile application using Dart and Flutter framework for Key Club to use. The next steps will be toadd a volunteer event recommendation and matching feature, utilizing the results from the research on machine learning models and algorithms in this paper.

KEYWORDS

Volunteering support platform, Machine Learning, cloud computing.

1. INTRODUCTION

Club meetings for LC Key Club [15] have always been held in a crowded classroom. The upcoming volunteer events would usually be written on the whiteboard, and members always had to jostle our way around each other just to reach the single event sign-up sheet. If someone missed a meeting, there was a low chance that they could find out what the events were or even get a chance to sign up for them.

Members missing meetings often resulted in low volunteer numbers for certain opportunities that needed as many people helping out as possible. Key Club needed a more efficient system that would allow members to easily view and sign up for whichever volunteering opportunities were coming up. It would benefit both the events our club members volunteered at by providing more volunteers and also giving club members greater opportunity.

One of the techniques that was proposed to solve the issue of missing meetings and missing the chance to sign up for an event was the use of the Remind messaging app [16]. Remind allows school organizations to mass communicate with all their members. Each club or organization, such as Key Club, creates a channel with the club officers as the channel managers. Channel managers could send out separate messages on Remind, regarding club meeting time updates, and also the dates and details of volunteering opportunities. The issue with this system, unfortunately, was that when one club officer sent a message, it created a different message channel. So, with

multiple messages regarding volunteer events showing up on different message channels, members could never see them all clearly in one place. When the pandemic interfered with Key Club's in-person meetings, club officers resorted to using the method of Remind to update members about events [1]. The confusing nature of multiple message channels further discouraged sign ups.

In this paper, we present a new approach for the Key Club volunteer opportunity sign up system. Our goal is to streamline the process of signing up for a volunteering event [2]. So, we have developed an application where, once they have signed up for an account, Key Club members can easily view volunteering opportunity details and sign up for the upcoming events.

There are several other important, and useful features of this application. First of all, not only will club members be able to view the date, time, location, and other details of a volunteer event, they will also be able to see what other Key Club members have signed up for that event. Another feature of the app is the limit to the number of sign ups for each volunteering event, which prevents any confusion from too many volunteers signing up. The application also features the ability for members to invite each other to specific volunteering events. Each club member has a Invites page where they can either choose to ignore or accept any pending invites to a volunteer opportunity. Finally, this application has two different types of user roles - admin and member. The admin role is assigned to Key Club officers, who have additional features to add, delete, or edit volunteering opportunities. This new approach is much better than the previous methods our club used because now, club members can see and sign up for events all in one place. With this application, there will be no need to scrounge around various message channels or jostle around a crowded classroom just to find or put your name down on an opportunity. Therefore, we believe that this application will increase the number of Key Club members signing up for events because club members can do it wherever is convenient for them.

Our related experiment evaluates the factors needed in the process of building a volunteering event recommendation engine for the application users. This recommendation engine is part of a future feature of the application that will recommend certain opportunities based on the user's profile.

The rest of the paper is organized as follows: Section 2 gives details on the challenges that we met during the design and development of the application and a subsequent experiment to determine details of a future recommendation feature of the app; Section 3 focuses on the details of our solutions corresponding to the challenges that we mentioned in Section 2; Section 4 presents the relevant details about the experiment we did, following by presenting the related work in Section 5. Finally, Section 6 gives the conclusion remarks as well as pointing out the future work of this project.

2. CHALLENGES

In order to build the tracking system, a few challenges have been identified as follows.

2.1. Deciding the logistics of the application's features

The first challenge of the application development was figuring out the specific logistics of features, such as the invite other members feature [4]. The initial idea was quite simple: members would be able to search up other members and invite them to a volunteer event. As we delved further into coding this feature, however, we realized there were some important questions that needed to be answered. Would users only be able to invite their friends to an event? Would this

mean we needed to implement a “friends” system on the app? We also had to consider the complexity of the solutions, as ideas that involved more extensive coding would take much longer to implement, and we were in a bit of a time crunch [3]. Eventually, after discussing with other Key Club officers, we came up with a simpler solution to the invite feature. Users could invite any of the other users to an event, and users that got invited would be able to view who invited them. Other questions regarding the logistics that still need to be considered involve how the app will be reused in future, subsequent years, especially since the roster of Key Club members changes each year.

2.2. Designing the UI

Another challenge we struggled with was designing the UI to be the most user-friendly for each of the features the app was meant to include [18]. We had to learn the Dart programming language and understand how we could use various objects provided by Dart to make the screens look like how we wanted them to look [17]. Whenever we got an idea for a page’s design, research had to go into seeing which Dart widgets could be used to produce that design.

It was a challenge to design the Home page, especially because it contained the most important information - the list of volunteer opportunities. The Home page design planned for a section each for all the events and for the user’s events, but an obstacle we had to overcome was deciding which way to present the information that would make it most user-friendly.

There was lots of debugging that went into the UI code. For example, when designing the bottom navigation bar to be different for users under the role of admin, the Dart code became finicky and it took us a while to work through the problem [5].

However, UI design is important because it has to be user-friendly and make those who download the application want to actually use it.

2.3. Connecting each screen to the database

A third challenge we encountered while developing the application was when we had to connect each of the application screens to the back-end database [7]. This was a significant challenge to overcome because it was key to making the app function correctly. The app needed to be able to communicate data with the database and also update important sections when actions were taken on the front end. The database had two main sections of User data and Events data, and their interconnectedness had to be taken into account [6]. For instance, whenever a user signs up for an event, the event has to be added to the User data and the Events data has to be updated with the user’s info. There were also many Null pointer errors and such that came up in the process of coding and testing that had to be understood and addressed. Additionally, important data had to be saved/sent whenever the application page was switched. For example, from the Home Page to the Details page of a certain event, we had to ensure that the information about which specific event it was, was sent to the next screen.

3. SOLUTION

The LC Key Club Application provides an efficient system of updating, viewing, and signing up for Key Club members. It’s main features are on the Home page, Event Details page, Invite and Pending Invites page, and the additional Edit/Add Events pages for accounts assigned to the Administrative role.

When users first download the app, they need to create an account by simply inputting some quick personal info and their intended username and pass code. Once logged in or signed up, club members can immediately view the upcoming volunteering opportunities on the Home page. In the event list on the Home page, the most important information regarding events - date and time- are already displayed. Additionally, the number of volunteer spots filled is shown.

From the Home page, Users can easily navigate to a specific opportunity's Details page. On the details page, more information is displayed, like the location of the volunteering event and also which other Key Club members have signed up for the event. Once a user has decided to sign up for an opportunity, they can now invite other fellow Key Club members. Their name will also be added to the volunteer list and the event will now show up on the Homepage in the My Events section.

If a user has been invited to a volunteering event, a notifying icon will show up in the Invites tab on the bottom navigation bar. Here is where club members can view the volunteering opportunities they have been invited to along with who has invited them. Users can choose to accept or ignore the invite and the pending event will be removed from the page.

One final significant component of the application is the ability of users assigned the Admin role to add new volunteering events and edit or delete current opportunities. The following diagram illustrates the connections and relationships between each screen of the application.

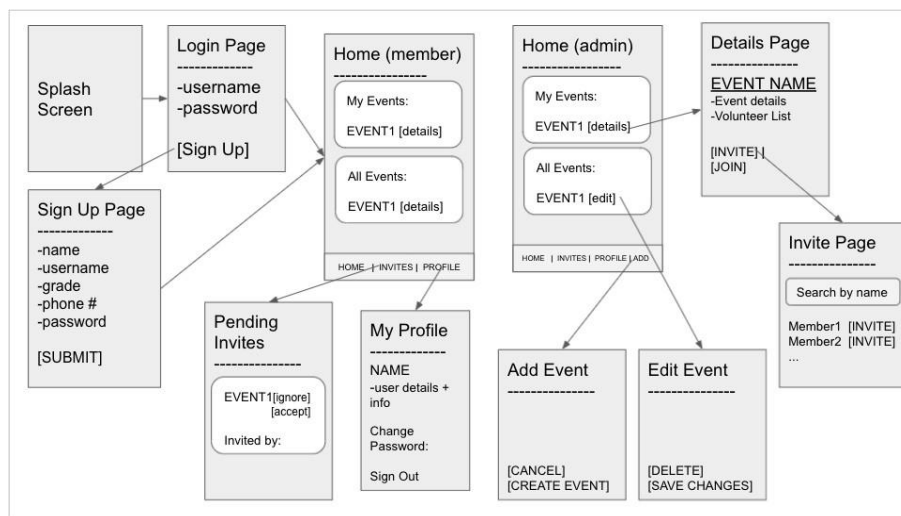


Figure 1. The overview of the project

In the next section, the code implementation of each component is discussed.

Component 1 - Home Page

The most important code of the Home Page component was the retrieval and organization of volunteering events data from the database. The `getAllEvents()` method first gets the information of each event from the database. Once all the data is retrieved, the code loops through the date attributes of each event to ensure that only events that have not occurred yet appear on each user's Home page. From there, the events are stored in a map that is later iterated through in a `ListBuilder`

to display on the application screen. The `getUserEvents()` method takes the information from the newly created `allEvents` map to gather a list of events that the user is currently signed up for. This eliminates any extra code needed to filter out past volunteering events in the `getUserEvents()` method since `allEvents` is already filtered.

```

void getAllEvents() async {
  _resetEvents();
  database.get<Map<String, dynamic>>('Events').then((value) {
    if (value != null) {
      setState(() {
        allEvents = {};
        value.forEach((key, value) {
          DateTime now = DateTime.now();
          String date = value['date'];
          final DateFormat formatter = DateFormat('MM-dd-yyyy');
          DateTime dt1 = formatter.parse(date);
          if (!dt1.isBefore(now) ||
              (dt1.day == now.day &&
               dt1.year == now.year &&
               dt1.month == now.month)) {
            allEvents[key] = value as Map<String, dynamic>;
          }
        });
        allEvents = sortEvents(allEvents);
        getUserEvents();
      });
    } else {
      setState(() {
        isDone = true;
      });
    }
  });
}
}

```

Figure 2. The code of `getAllEvents`

```

Future<void> getUserEvents() async {
  isDone = false;
  database
    .get<Map<String, dynamic>>(
      'Users/' + user.info!['username'] + "/events/"
    ).then((value) {
    if (value != null) {
      setState(() {
        userEvents = {};
        value.forEach((eventkey, userEventInfo) {
          userEvents[eventkey] = allEvents[eventkey]!;
        });
      });
      userEvents = sortEvents(userEvents);
      isDone = true;
    } else {
      setState(() {
        isDone = true;
      });
    }
  });
}
}

```

Figure 3. Code of `get User Events`

A challenge of the Home page UI was mentioned in Section 2, regarding the collapse function of the containers where the User Events and All Events are displayed. To solve this issue, we used the SharedPreferences object. Now, whenever a user switches away from the Home page tab and back, the collapsed or un-collapsed state of the MyEvents and AllEvents containers is saved and maintained. The code for the functions used can be seen in the figure below.

```

void saveCollapsedValues(String key, bool value) async {
  SharedPreferences prefs = await SharedPreferences.getInstance();
  prefs.setBool(key, value);
}

Future<void> getCollapsedValues() async {
  SharedPreferences prefs = await SharedPreferences.getInstance();
  setState(() {
    if (prefs.containsKey(user.info!['username'] + '/userEventsCollapsed')) {
      userEventsCollapsed =
        prefs.getBool(user.info!['username'] + "/userEventsCollapsed")!;
      collapseUsers = setCollapseIcons(userEventsCollapsed);
    }
    if (prefs.containsKey(user.info!['username'] + '/allEventsCollapsed')) {
      allEventsCollapsed =
        prefs.getBool(user.info!['username'] + "/allEventsCollapsed")!;
      collapseAll = setCollapseIcons(allEventsCollapsed);
    }
  });
}

```

Figure 4. Code of save Collapsed Values

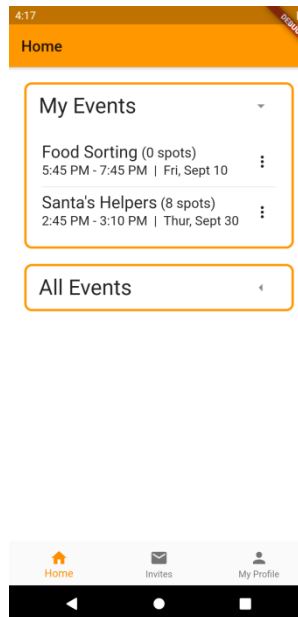


Figure 5. Screenshot of App(1)

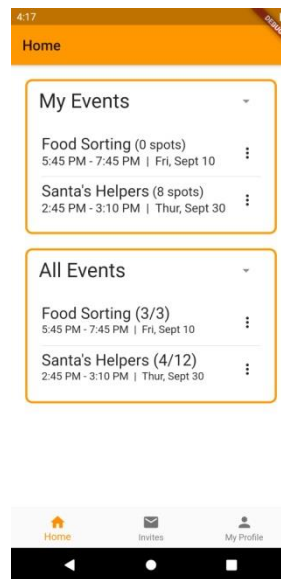


Figure 6. Screenshot of App (2)

In the application screenshots above, the UI design of the Home page can be seen, where users can choose to collapse or uncollapse the My Events and All Events section. To reach the Details page for each event, users simply need to click on the three dots on the side of each listed volunteer opportunity.

Component 2 - Event Details Page

An important code component of the Event Details page was the function that retrieved the event's list of volunteers from the database. The figure below shows how each volunteer name retrieved is placed into an outside volunteerList variable. In the UI build code, the volunteerList is iterated through and displayed as a list on the screen.

```

void getVolunteers() {
  database
    .get<Map<String, dynamic>>("Events/" + widget.eventKey + "/volunteers/")
    .then((value) {
      flag = true;
      setState(() {
      });
      if (value != null) {
        setState(() {
          value.forEach((key, name) {
            if (user.info!['name'] == name['name']) {
              joinedEvent = true;
            }
            volunteerList.add(name['name']);
          });
        });
      }
    });
}
}

```

Figure 7. Code of get Volunteers

Another important part of the Event Details page is the ability to sign up for the opportunity, then invite friends or cancel the sign up. Once a user has signed up, their name is added to the “Members Signed Up” list, which is also immediately displayed on the screen.

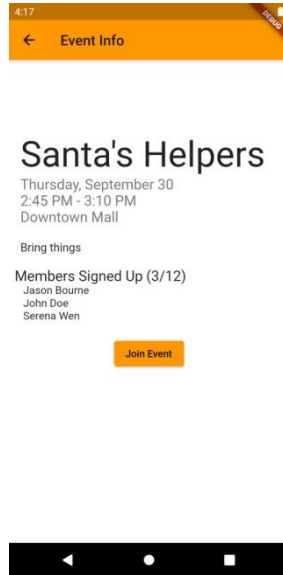


Figure 8. Screenshot of event info (1)

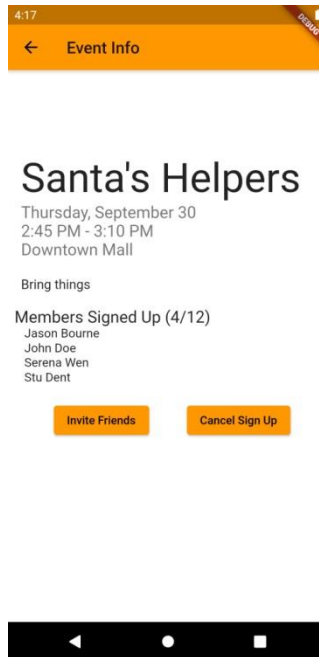


Figure 9. Screenshot of event info (2)

The Invite Friends button leads to the Invite Friends screen page, where the `getNames()` function retrieves the list of Key Club members and then filters the list into only members that are not yet signed up for the specific event. There is also the feature to search a specific member up, and the code for that is also shown, with the two separate maps - 'names' and 'filteredNames'.

```

Future<void> _getNames() async {
  Map<String, Map<String, String>> tempMap = {};

  database.get<Map<String, dynamic>>('Users').then((users) {
    users!.forEach((key, userInfo) {
      if (!users[key].containsKey('events') ||
          (users[key].containsKey('events') &&
            !users[key]['events'].containsKey(widget.eventKey))) {
        tempMap[key] = {
          "name": titleCase(userInfo['name']),
          "invitedByYou": 'false', "pendingTrue": 'false'
        };

        if (users[key].containsKey('pending'))
          if (
            users[key]['pending'].containsKey(widget.eventKey) &&
            users[key]['pending'][widget.eventKey]['inviters']
              .containsKey(userInfo['username'])) {
            tempMap[key]['invitedByYou'] = 'true';
          }
        tempMap[key]['pendingTrue'] = 'true';
      }
    });
    var sortedKeys = tempMap.keys.toList(growable: false)
      ..sort(
        (k1, k2) => tempMap[k1]['name']!.compareTo(tempMap[k2]['name']!));
    LinkedHashMap<String, Map<String, String?>> sortedMap =
      new LinkedHashMap<String, Map<String, String?>>.fromIterable(
        sortedKeys,
        key: (k) => k,
        value: (k) => tempMap[k]);
    print(sortedMap);

    setState(() {
      names = sortedMap as Map<String, Map<String, String>>;
      filteredNames = names;
    });
  });
}

```

Figure 10. Code of `getNames`

Once a user invites another user using the “INVITE” button, the text changes to “INVITED”.

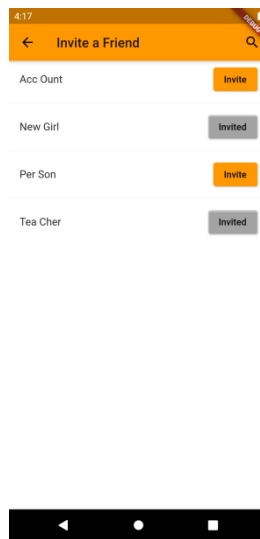


Figure 11. Screenshot of Invite a friend

Component 3 - Event Invites Page

In the second tab on the bottom navigation bar, there is the Pending Invites page. Here, as you can see in the screenshot image below, the events a user has been invited to is listed out with the options to ignore or accept the invitation. Users can also view who their inviters are (if there are multiple).

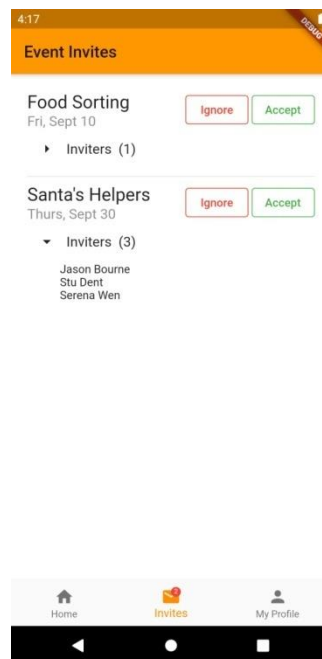


Figure 12. Screenshot of event invites

Figure 13. Screenshot of add event

Users with the admin role (reserved for Key Club officers), have the additional features to create a new event to add to the “All Events” section for every single user. The inputs include the event name, location, date, time, volunteer limit, and any additional details. The UI for inputting date and time is an easy-to-use selection input that doesn’t require any typing or misformatting.

For admins, there is an edit button that appears next to the volunteer opportunities in the “All Events” section. From there, the editing screen is similar to the create event screen other than the DELETE EVENT button in case of cancellation [8].

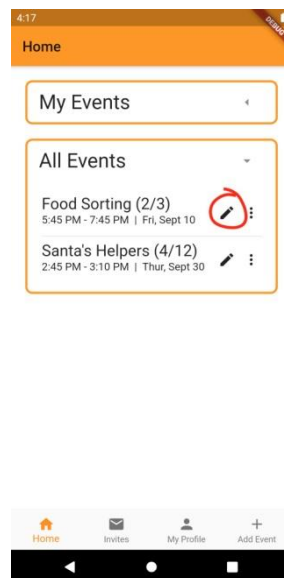


Figure 14. Screenshot of App home

Figure 15. Screenshot of edit event

4. EXPERIMENT

Overall, the purpose of the 4 experiments performed was to answer the question of how we should utilize the machine learning models to recommend volunteering events to users based on their profile. First, we decided which attributes (inputs) would be used to determine which volunteer opportunity to recommend to the user. The 5 attributes are gender, grade, main interest/hobby, and personal availability (based on morning, afternoon, evening). There were 6 possible output values for the preferred event type.

We then generated random dummy input data and partially random dummy output data in order to test the accuracy of each machine learning classification algorithm model [12]. The 4 models we used were Support Vector Machine (SVM), Random Forest Classifier (RFC), Gaussian NaiveBayes (GNB), and Stochastic Gradient Descent Classification (SGDC).

The main question we sought to answer with these experiments was how we should recommend events to application users based on their profile

4.1. Experiment 1-Which machine learning algorithm provides the highest learning accuracy?

Answering this question of the experiment was necessary to decide which machine learning algorithm was the best to use. We tested each model with a dummy dataset size of 1000. For the RFC machine learning model, we used an RF depth of 10. The datasets were divided into training and testing data with which the models were fit and tested. The score was calculated for each model's accuracy and we gathered the average score data from 20 trials of dummy data. The graph below compares the average accuracy score for each model.

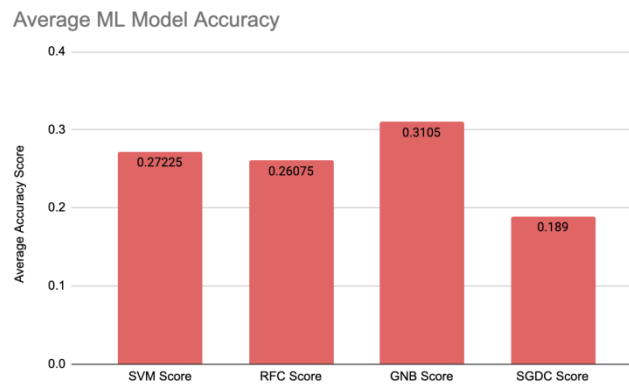


Figure 16. Average ML Model Accuracy

As shown in the figure, the most accurate was the Gaussian NB classification model with a score of 0.315 in comparison to the lowest score (from the SGDC model) of 0.189. Therefore, for the development of the recommendation engine in the future, the Gaussian Naive-Bays machine learning algorithm should be used to analyze the inputs.

4.2. Experiment 2-Which algorithm parameters provide the highest accuracy?

While the previous experiment already showed the best learning accuracy in the Gaussian NB algorithm, We used the Random Forest Classifier model for this experiment, as it had the RF_max_depth parameter to work with [20]. We, again, used dummy data set sizes of 1000, split the data into training and testing, fit the data to the model, then calculated the score of 20 trials for each RF_max_depth. The values used were 1,2,5,10,15, and 30 and the results can be seen in the graph below.

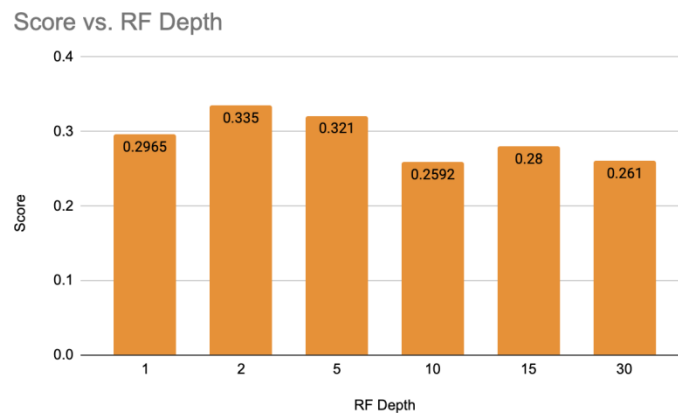


Figure 17. Score vs. RF Depth

Surprisingly, the RF depth of 2 provided the highest accuracy out of the trials performed. Interestingly, the learning accuracy appears to decrease as the max depth increases. This could be due to the fact that the partially random output data generation used a relatively simple line of reasoning to determine the output, and the RFC model did not need the greater depths.

4.3. Experiment 3-How does the size of the dataset affect the accuracy?

The purpose of answering this experiment question was to further understand the factors that lead to the highest accuracy in training and testing the machine learning models. In this case, we studied how the factor of data-set size affected accuracy. We varied the data-set size with values ranging from 50 to 1000 and tested it for each of the machine learning algorithms. After going through the same process of generating dummy input and output data and training and testing it, we recorded the average accuracy score for each set size for each model from trials of 20.

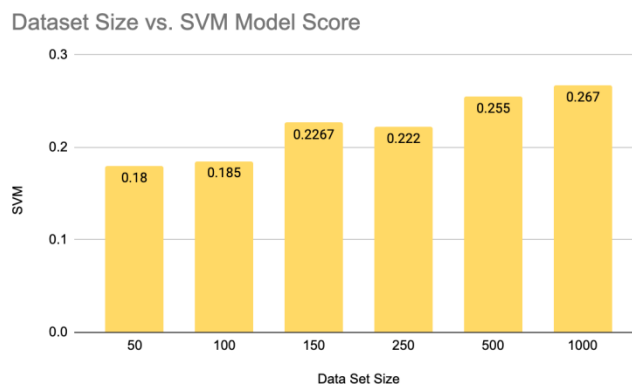


Figure 18. Data-set Size vs. SVM Model Score

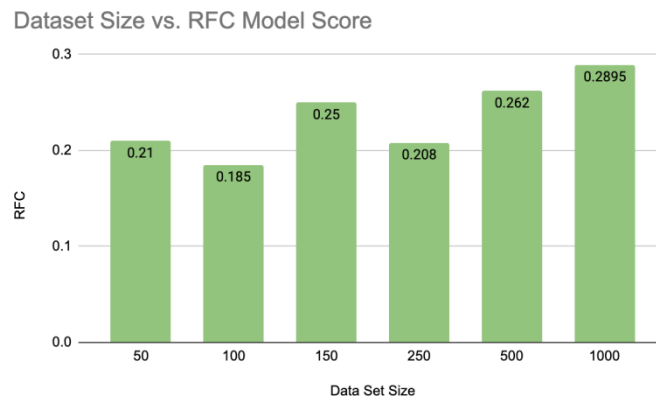


Figure 19. Data-set Size vs. RFC Model Score

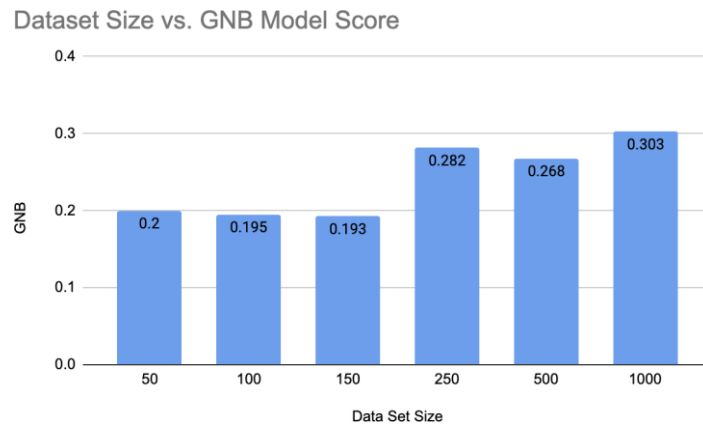


Figure 20. Data-set Size vs. GNB Model Score

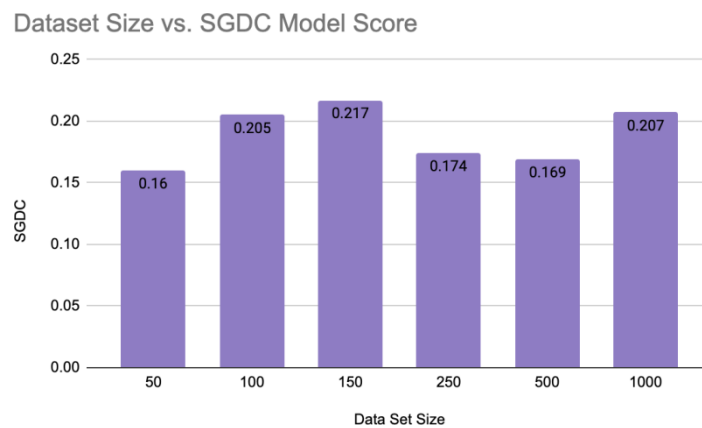


Figure 21. Data-set Size vs. SGDC Model Score

For the SVM model, it's highest score was 0.267 at a data set size of 1000. For the RFC model, it had a score of 0.2895 and the GNB algorithm had a high score of 0.303, both occurring with the data-set size of 1000. Only the SGDC Model was out of pattern, with its highest learning score of 0.217 coming from the data set size of 150. The resulting figures above show that in general, the larger the data set, the higher the learning accuracy, with the highest accuracy being at a data set size of 1000.

4.4. Experiment 4-What attribute input combinations will provide the highest accuracy?

To test this question, we used 6 different attribute combinations. One combination included all 4 attributes (Gender, Grade, Main interest/Hobby, Availability) and the others were a combination of 3 different attributes. The final combination was simply the interest attribute, as it held the highest weight in the partially output data generator we had initially coded.

We utilized the Gaussian NB model since it had overall produced the highest learning score in previous experiments. The data-set size was 1000 and the average of 20 trials was taken.

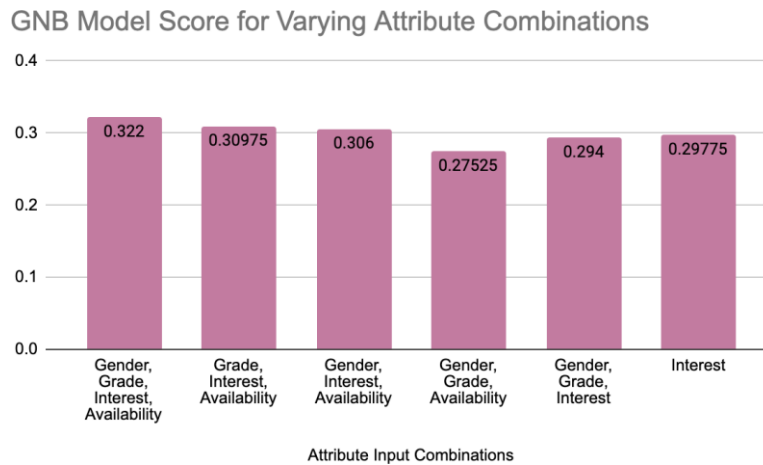


Figure 22. GNB model score for varying attribute combinations

As seen in the graph above, the combination that included all 4 of the input attributes produced the highest score of 0.322, though the other combinations were not too far behind. The lowest model score was 0.27525 with the combination that did not include the main interest/hobby. The single attribute combination of main interest produced a higher score of 0.29775. This follows along with the logic we took in the partially random generation code for output data, as we made it so the main interest input held the most weight. This is significant because it shows that the machine learning algorithm was able to recognize the pattern.

Drawing from the results of each experiment performed, the classification machine learning algorithm that would produce the highest accuracy for future development of a recommendation engine is the Gaussian Naive-Bayes model [19]. The model should be used with data sets of size 1000 and with inputs of all four of the attributes of a user: gender, grade, main interest/hobby, and availability.

5. RELATEDWORK

Butgereit, L presented research on developing a virtual volunteering platform, specifically focusing on the characteristics that made up a successful volunteer platform [9]. Her research was based around the idea of an online tutoring platform that would open up volunteer opportunities for those who cannot always donate their time to volunteer physically.

Butgeriet's work is similar to the research we did here, as we are both trying to solve a problem related to lack of access to volunteering events/opportunities. One of the seven key characteristics the author discusses is "Easy Scheduling", which is also interconnected with the purpose of the application we built - to provide a simple platform where volunteers can view and sign up for events.

Reuter, C, et al presented their research on the use of social media during a specific disaster, the 2013 European floods [10]. The paper's goal was to discuss how they used the research to develop a "cross-platform" social media application called XHELP. XHELP will help

organizations coordinate volunteers and relief aid during disasters by compiling relevant data and information from social media in one place.

Both of our work involves understanding and helping coordination of volunteer activities but Reuter, C et al. is more about gathering information that would help the coordination.

Gudmunds, Emma et al.'s paper discusses their research on the barriers that prevent/hinder people from starting volunteering or "continue[ing] engagement" with it [11]. The paper proposed an application be developed that would provide a platform would-be volunteers could use to start their community service. Gudmunds' development of the app was focused on the user experience that would encourage them to search for opportunities.

Both of our research and methodology involves an application that lowers the barriers to volunteering opportunities, but this paper focuses on motivating potential volunteers to take action, while mine provides a means for them to take that action.

6. CONCLUSIONS

In this paper, we proposed a solution designed to address the barriers to taking part in volunteering opportunities provided at Lewis and Clark High School's Key Club. A mobile application has been developed that provides Key Club members easy access to the details and sign-up areas of all the upcoming events. Key Club officers can also conveniently add and edit the current volunteer events that appear. The application will also, in future updates, be able to further encourage volunteer sign ups by recommending relevant events to users based on their profile. In our experimental research, we studied the accuracy of specific machine learning algorithms in developing this recommendation engine, focusing on which combination of factors would produce the highest learning accuracy in recommending an event. Through the experiment, we discovered that the Gaussian Naive-Bays machine learning model produced the highest accuracy in predicting which volunteering event types a user would prefer.

The application has a couple of current limitations that we seek to resolve in future work. One feature we plan to add on is a wait-list system for various opportunities when the volunteer limit has been reached. It is common for a user to want to sign up for an event when it is full, and they never find out if someone already signed up decides to cancel, leaving a spot open. A wait-list would be a great way to notify members of this.

Another limitation of the current app is it is just a view and sign-up system with no form of reminding volunteers of an upcoming event they are signed up for, or if there are any changes to the event. We plan to implement a push notifications system within the application to overcome this limitation.

We also plan to work more in the future on improving the user-friendliness of the application, such as enhancing the UI design and implementing the recommendation engine that was a part of our research [13]. This would enhance the user experience on the app and motivate them to continue using it.

Finally, we plan to expand the application, so it can be used for all types of volunteering organizations or clubs [14]. This will be done by making the app into a template that can be customized and then utilized by different groups to help them coordinate events and sign ups.

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MILITARY SUPPLY CHAIN MANAGEMENT AND BLOCKCHAIN DEVELOPMENT

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ABSTRACT

Blockchain has become a powerful technology and when it comes to supply chain management, blockchain has a lot to offer which could contribute to its development and make the supply chain more effective. The same benefit could be also gained when blockchain is incorporated in the Military Supply Chain Management (MSCM). The aim of this paper is to develop and integrate blockchain in the MSCM. The developed MSCM is focusing on three (3) main blockchain components, which are transparency, integrity and secure communication. The methodology to develop the MSCM blockchain similar to UnicalCoin. The findings show that incorporating blockchain into the MSCM enables transparency, integrity and secure communication. Thus, blockchain may reduce fraud, improve communication between parties and made end-to-end tracking transparency in MSCM. Future work is to embed a smart contract feature to automate some processes in MSCM.

KEYWORDS

Blockchain, distributed ledger technology, smart contract, supply chain, nodes.

1. INTRODUCTION

Supply chain management (SCM) has been widely used in various industry sectors. SCM is a complex distribution process involving cross functional approaches in managing the product chain from the starting point (i.e., raw material) until the ending point (i.e., consumer) [1]. The ultimate supply chain management components comprise of manufacturers, suppliers, distributors, and consumers as well as other service providers such as finance, logistics, and market research firms.

Security and defence sectors are also adopting SCM. For instance, military supply chain management (MSCM) is focused on manufacturing, distributing and shipping military materials, parts or applications. In order to maximize its effectiveness and efficiency, these processes must be transparent, highly integrity and good communication between SCM components. However, the current conventional SCM methods failed to meet these three key aspects [2].

The first key, transparency, allows all the parties that are involved including the consumer to know the status of the product [3]. This problem is related to traceability and auditing. Without transparency and traceability, any product which encounters problems during manufacturing, distribution and shipping will result in delay or late product delivery [4]. While the second key, integrity, ensures every transaction record that has been made should not be tampered with or counterfeited [5]. Currently, every transaction record between military and other components in the MSCM is saved in a database. The database is vulnerable to data tampering either from an insider or a malicious party. For instance, changing (i.e., modify, delete, and add) transaction records for bad intentions. This caused inconsistency of the transaction records. Another problem arises with counterfeit products. Delivering counterfeit products affect a wide range of industries. For example, distribution of counterfeit COVID-19 vaccines has potential for health risks globally. Thus, MCSM must eliminate distribution of military counterfeit parts to avoid failure in battlefield missions and compromise the security of a nation [6].

The last key is communication where every party should communicate with each other on updating the status of the product and record it [7]. Communication is important to ensure a smooth product distribution at all levels. Another contribution to product shipment delay is miscommunication [8]. These MSCM problems could be overcome by integrating blockchain technology.

Blockchain is a digitized public ledger of all transactions. This public ledger has been conducted and shared within the blockchain community. Blockchain is designed to work in a decentralized manner. Each transaction conducted within the public ledger is confirmed by the community who owns a node in the blockchain [9]. Once a transaction is recorded in the public ledger, the information is immutable which means it cannot be changed. Figure 1 shows the transaction process of Blockchain. Blockchain always records every confirmed transaction that has been made in the community and the record is kept across the nodes.

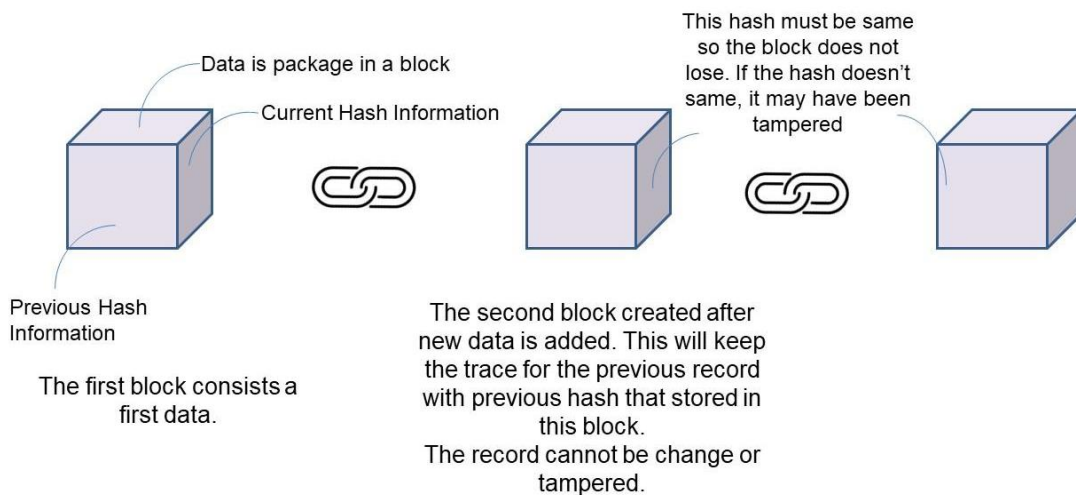


Figure 1. Transaction process in Blockchain

There are two types of blockchain that are private and public blockchain [10]. A blockchain is considered to be public if any individual can access it and use it to conduct transactions as well as when there is a consensus mechanism involved in verifying the transaction made. As an incentive for the community to use their resources to verify a transaction, a token or cryptocurrency will be earned. On the other hand, blockchain is considered to be private when only a certain individual

or organization owns the nodes and verifies the transaction. The permission to perform a transaction is given by an authority of an organization who owns the blockchain. In blockchain there are three main components of cryptography that plays an important role which are (i) the hashing mechanism where the hash of the predecessor block is stored in header of the new block, (ii) Merkle tree where all the transaction hashes are combined to form on hash and kept in the block, and (iii) digital signature is used for non-repudiation [10], [11].

Table 1. Differences between private and public blockchain

Characteristic	Public Blockchain	Private Blockchain
Level of access to the Blockchain	Anyone can be a part of the community and make transactions. Nodes owned by multiple parties can verify the transaction via consensus mechanism applied in a blockchain network.	Only authorised individuals can access the community and make transactions. Nodes only owned by a certain party can verify a transaction and usually consensus mechanism is not needed.
Authority	Decentralized	Centralized
Consensus	Permissionless	Permissioned
Number of transactions per second	High	Low
Immutability	Full	Partial
Transparency	Yes	Yes

In 2019, a group of researchers did an experiment by incorporating blockchain into the supply chain to reduce false information that spread over the networks of a supply chain and also to prevent companies from any moral misconduct such as counterfeiting or changing any data in the database [12]. The findings of this experiment show incorporating blockchain into the supply chain is worth the cost for a supply chain that requires trustworthy data and counterfeit data can be prevented. However, in a real time SCM it is unavoidable. Therefore, it is advisable only authorized agents are allowed to access the blockchain. A recent survey [13] shows that incorporating blockchain in the manufacturing domain and logistic domain can be very useful. The findings of the manufacturing domain reveal the cost is economical and it could fight counterfeiting too. This is due to the blockchain feature in providing history to consumers. Similarly, the results in the logistic domain are showing blockchain integration is useful.

Some of the benefits that can be achieved by applying blockchain includes reducing delivery delay time and avoiding any human errors thus enhancing the efficiency of agreements between manufacture and consumers [13]. Considering the benefits of blockchain technology, thus the current issues of MSCM could be eliminated. Therefore, this paper presents MSCM development using blockchain technology.

2. METHODOLOGY

This study is applying a similar methodology of (UnicalCoin). Instead of using UnicalCoin, this study is using ProximaX blockchain platform, Sirius Chain to integrate with MSCM. There are three main stages in this development as shown in Figure 2.



Figure 2. System Methodology

Sirius Chain is blockchain technology that is developed by ProximaX's company. The Sirius Chain generate a new block that records transaction data for every 15 seconds, by default. Once the Sirius Chain algorithm has been implemented in the nodes some modifications are done as it is operating in a private network, own by Military. Among the modifications is no crypto currency used in the MSCM blockchain environment. Due to MSCM private blockchain environment, there is no incentive mechanism to reward the node that validate the blocks. Another modification is the addition of a message authentication mechanism, external parties cannot access the nodes without permission. Thus, any transaction receipt that comes from the node needs some form of authentication.

Then, the second step is to create a supply chain simulation model that recreates a model company with networks. For the supply chain model, several different computers/ machines are selected and used to test out the supply chain management. Some machines represent the external parties, i.e., product manufacturer, and the machines have been installed with the client application. The client application establishes interaction between externals' machine the with the server. Furthermore, the client application acts as a mediator and sends the information to the nodes that are operated by Sirius Chain. The snippet of pseudocode for the client application as follows:

```

import modules

generate panels with different service for selection
process the service selected by the clients

if client app connected to server:
  show panels related to specific service

if information is given:
  send information to the server
  receive response from the server
  show the information received to client
else:
  show error message from the server

else:
  tell client that server is not running
  
```

The last step is to generate a connector. Generating a connector to connect the blockchain network to the simulated model, i.e UnicalCoin to the connector software that was written in Java [12]. In this study, server is the connector between the blockchain and MSCM. Every information that is sent via client application to the Sirius Chain go through the server, first. The server is the gateway between the nodes and client application. The server checks the validity of the message that it has received. If the message is valid, the message is sent to the Sirius Chain, otherwise the message will be discarded. The pseudocode for the server is as follows:

```

import modules

connect to client database
receive message from client app

check service selected by client

select the service selected by client
check message validity in database

if message = valid
    Send the transaction to Sirius Chain
else :
    Send an error message

```

For security and confidentiality of sensitive military data, MSCM is a private blockchain as suggested by [14]. The following flowchart (Figure 3) shows a detailed overview on how MSCM has incorporated the ProximaX Sirius Chain. In the MSCM environment, all the parties that are involved will be given a client application. Once each party has received the client application they can start to interact with the server. The client app will send this information that is given by the client to the server where the server acts as a gateway and checks the validity of the information that is given by the client, if the information is valid, it will send the information to the nodes and will be recorded in the Sirius Chain. Clients can use this client app to update the status of the assets and for the military staff they have the option to see their entire transaction history with other companies as for parties that are not military affiliated can only see their personal transaction history to prevent any information leakage.

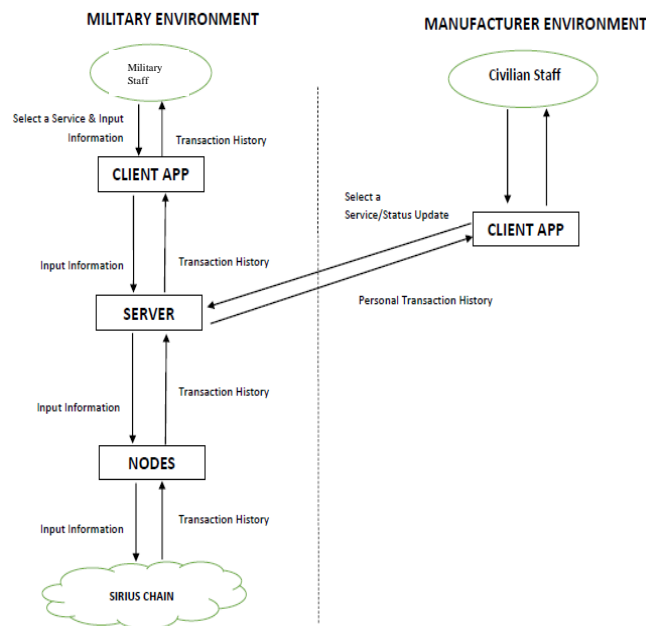


Figure 3. MSCM System Overview

The owner of the MSCM is the military department. They must prepare the nodes to store every transaction on the blockchain. The preparation of the nodes, especially its location is very crucial as setting all the nodes into one specific location can lead to single point failure. Therefore, the nodes are advisable to be installed at different locations in the military compound. Once the nodes have been set up, then MSCM blockchain is embedded into the installed nodes and perform a test run. Then, the military department creates a server that processes all the

information and requests to check its credentials and validity before sending the transaction to the ProximaX Sirius Chain. Once a server has been built, a simple client application should be created. As mentioned previously the client application is the communication medium for all the involved parties to connect to the server.

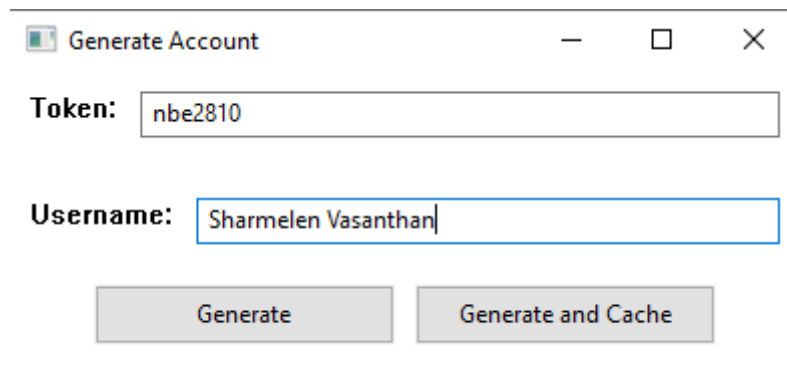
MSCM is using the default time duration to generate blocks. Each block in Sirius Chain is linked by the hash of the predecessor block in its header. When the required criteria are met and the Sirius Chain has been installed in the nodes of the Military department, other parties that are required to be in the chain such as manufacturer can be integrated in the chain as well. All the parties that are involved in the chain can create a transaction and record it in the chain across the nodes. Due to the confidentiality, only military personnel that are involved in the supply chain are allowed to see all the transactions that happen with the manufacturer during the manufacturing, distribution and shipping of the military material, parts or application. Specific manufacturers can only access their own transaction record.

3. RESULTS AND DISCUSSIONS

3.1. Result Analysis

MSCM has been tested to find out its capability in terms of traceability, integrity and secured communication. Several test runs have been done using Sirius Chain and the results have been recorded and explained as follows.

The first test was when a client tries to generate an account for MSCM (Figure 4).



The screenshot shows a window titled "Generate Account" with standard window controls (minimize, maximize, close). Below the title bar, there are two input fields. The first is labeled "Token:" and contains the text "nbe2810". The second is labeled "Username:" and contains the text "Sharmelen Vasanthan". Below these fields are two buttons: "Generate" and "Generate and Cache".

Figure 4. Generate User Account

First for account generation, there two textboxes that require a token and a username. The token is used like a SWIFT code where only an individual that has received this token can actually create an account to prevent an unwanted party from generating an account and username is used to identify the individual who generated this account. Then, there are two buttons, "Generate" and "Generate and Cache". The "Generate" button is used for only generating the account, While the latter is used to cache the generated information into the machine. Every time a user makes a transaction, they do not have to enter the private key, but this is not a safe practice.

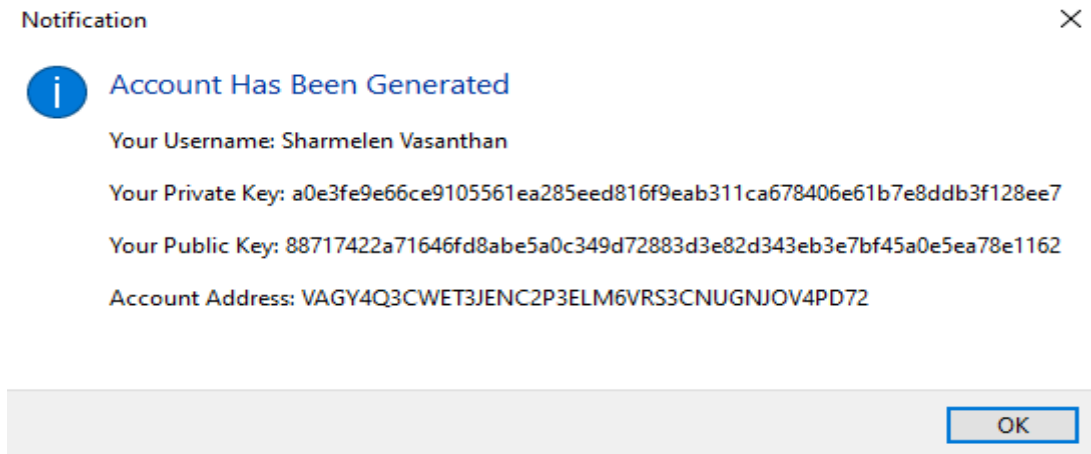


Figure 5. Account Information Generated

The user will receive a notification (Figure 5) saying the account has been generated along with their credentials. This information is crucial, especially the private key. The private key must be entered every time the user makes a transaction.

Next is client application. The user can use the client application to get information about their account (Figure 6).

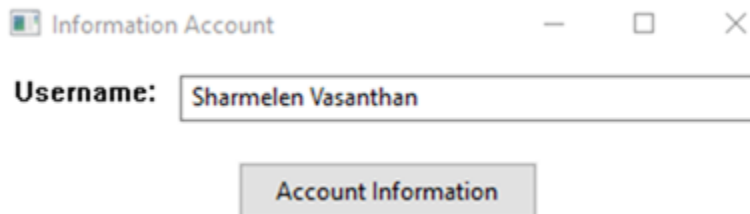


Figure 6. Login to Account Information

By entering the username, user can obtain the information about their account (Figure 7).

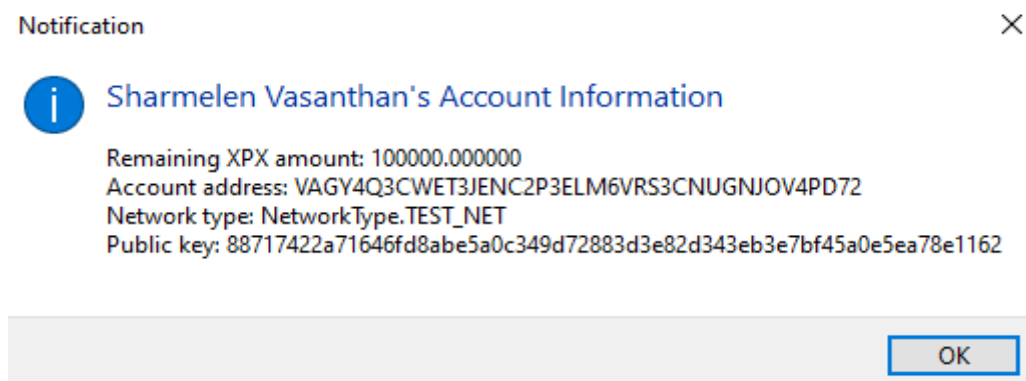
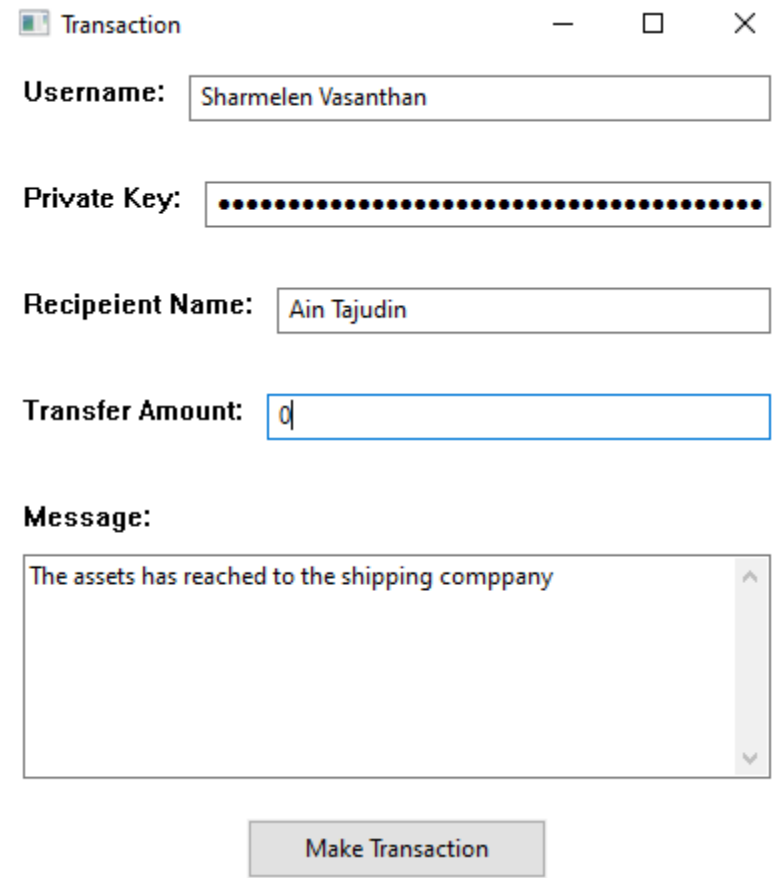


Figure 7. Account Information

The notification shows the information of the account that is associated with this account.

On top of that, users can also send messages to update the status of the assets in the MSCM environment.



The screenshot shows a window titled "Transaction" with standard window controls (minimize, maximize, close). The form contains the following fields:

- Username:** Sharmelen Vasanthan
- Private Key:** A field filled with 25 black dots, representing a masked private key.
- Recipient Name:** Ain Tajudin
- Transfer Amount:** 0
- Message:** A text area containing the message "The assets has reached to the shipping comppany".

At the bottom of the form is a button labeled "Make Transaction".

Figure 8. Make Transaction

Once the required information has been added the user can press the “Make Transaction” (Figure 8) button to send the status update to the related party and the message will be recorded in the Sirius Chain. As for the amount the user can set it to 0 transaction fee since the main objective of this private blockchain is to ensure the integrity and transparency of the data among the MSCM community.

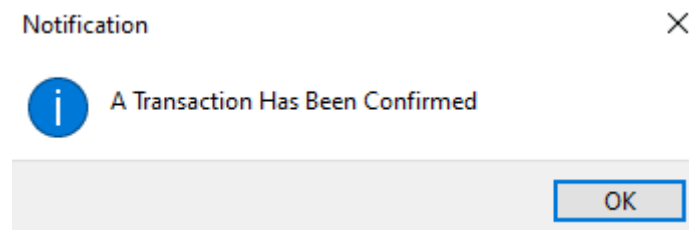


Figure 9. Transaction Notification

Once the transaction has been confirmed the server will send a notification saying that transfer was successful (Figure 9).

Finally, the party who is involved in the MSCM can also get their personal transaction via client application.

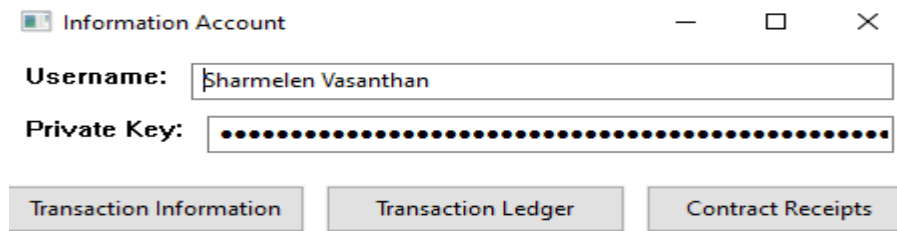


Figure 10. Information Account

Figure 10 shows Information Account has three buttons. The first button, “Transaction Information” button is to get a personal transaction that has been done between one-to-one transactions i.e. from sender to receiver. Then, “Transaction Ledger” button is used to get transactions that have been recorded from the beginning to the current validated block which has many to many transactions and is only available to ATM staff. The last button is the “Contract Receipts” for getting the contract that has been generated so far.

Here is the example of a normal transaction receipt (Figure 11).

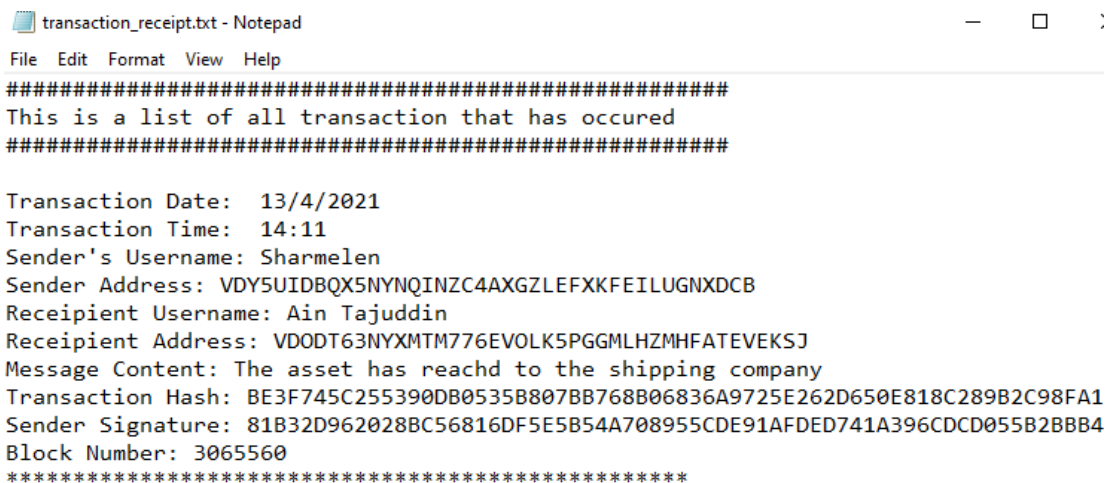
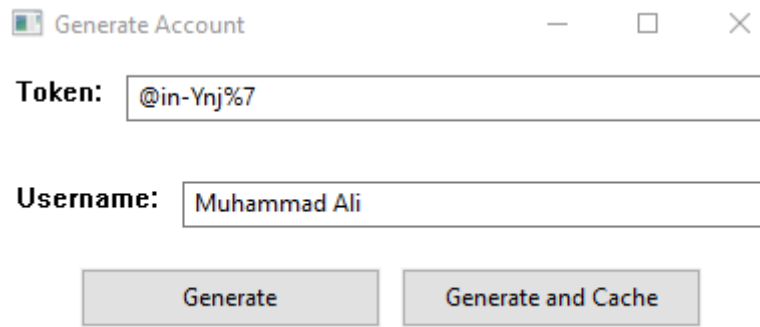


Figure 11. Transaction Receipt

Further system evaluations are using incorrect information into the client application. The objective to reveal that the server can check the data validity with the database and discard the information.

During the account generating process in the client application, invalid token have been inserted in the token textbox (Figure 12).



Generate Account

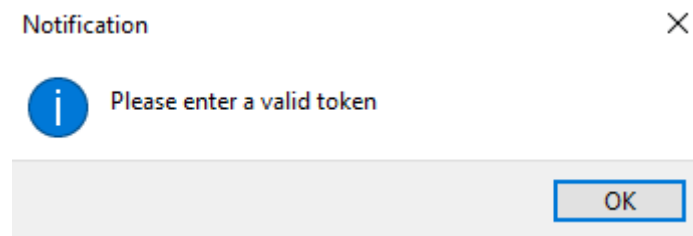
Token: @in-Ynj%7

Username: Muhammad Ali

Generate Generate and Cache

Figure 12. Inserting Invalid Token

Figure 13 shows the notification that token inserted was invalid. Because the server checks the validity of the token, and the token does not correspond as the one in the database.



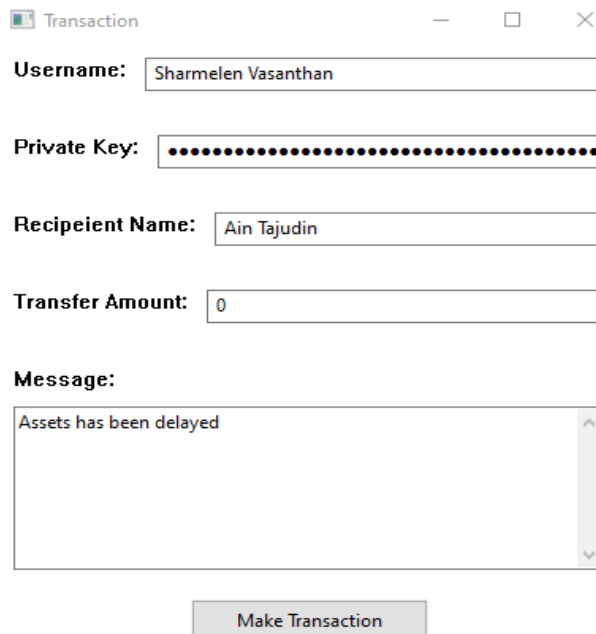
Notification

Please enter a valid token

OK

Figure 13. Invalid Token Notification

Next, insertion of the wrong private key in the panel during the transaction and the response was as follows (Figure 14).



Transaction

Username: Sharmelen Vasanthan

Private Key:

Recipeint Name: Ain Tajudin

Transfer Amount: 0

Message: Assets has been delayed

Make Transaction

Figure 14. Entering a Wrong Private Key

The server sends a notification saying that the private key that was entered is invalid (Figure 15).

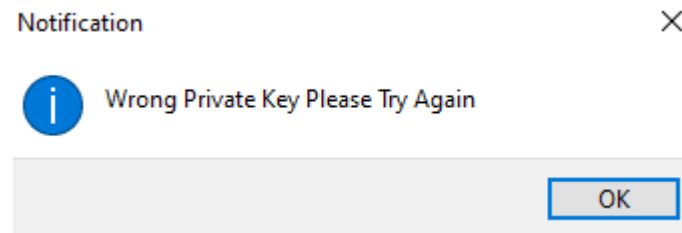


Figure 15. Wrong Private Key Notification

In conclusion, this experiment (testing and evaluation) shows the server is quite resilient in filtering invalid data and runs smoothly even if the data that was entered is invalid.

4. FINDINGS

This study reveals the integration of MSCM with blockchain technology is beneficial to all SCM components. Every single transaction recorded in the blocks is immutable. Furthermore, this transaction is transparent and anyone who got access to the blockchain is able to see it. The transaction record that happens between the parties who are involved in the MSCM can be accessed by those in the chain and can stay updated about the ongoing business transaction. Communication or error in data transfer is avoided as the party involved in the supply chain can send messages in the chain instead of sending the message personally between any party. Moreover, digital signatures are offered in the blockchain technology making sure that the message to be sent is non-repudiation. Incorporating blockchain in MSCM also allows parties involved in the supply chain to trace back the source of the problem if the asset that is bought had issues in receiving or delivery. Adaptation of blockchain in supply chain management system assuredly can improve supply chain traceability [18], [19]. Lastly, integrity issues can be resolved since every single transaction that has occurred is recorded across the nodes and it is impossible to tamper them.

5. FUTURE RESEARCH

MSCM will be expanded using Smart contract in the future. Smart contract is a self-executing term of agreement between buyer and seller. Without any intermediary's involvement and time loss, the agreement is directly written into a line of code and stored on a blockchain. The codes of agreements exist across a distributed, decentralized blockchain. There are many benefits that can be obtained from smart contracts. As no single entity owns the record, all relevant parties can access the information and investigate how the transaction was made or how value is processed. The distributed and decentralized structure ends the requirement of middleman therefore making transactions less vulnerable to corruption. Smart contract allows two parties which are in this case the military and suppliers to record their business agreement on a blockchain. Both parties will hold the encryption key and anytime can give authorized users to review the contract or agreement. [15], [16]. Contract written in blockchain is immutable which means they could not be tampered with thus the integrity of the contract can be maintained. Another benefit that is offered by smart contracts is transparency, where the parties that are involved in the MSCM environment can see the transactions that have been done so far and get access to the contract [17]. Smart contract can be fit in along with the proposed incorporated MSCM environment which is an ongoing future research.

6. CONCLUSION

As a conclusion, implementing blockchain in the MSCM environment is promoting transparency within the parties that are involved in the chain. Moreover, the communication between parties can be also more efficient since the communications that happened are considered as a transaction and recorded in the ledgers of the blockchain. Lastly, integrity in the MSCM can be tremendously improved by applying blockchain since data that is recorded is immutable. Future work is to expand this blockchain technology to other domains in the military environment such as logistics and finance.

7. AUTHOR CONTRIBUTIONS

Syarifah Bahiyah Rahayu led the research; Sharmelen has developed the blockchain system software using SDK provided by ProximaX; Joe is the expert of Sirius Chain and assists in blockchain platform; Sharmelen, Syarifah Bahiyah Rahayu and Afiqah M. Azahari wrote the paper, all the authors had agreed and approved the final version of the paper.

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THE OPTIMIZED CELL CONFIGURATION METHOD OF AVOIDING SRS INTER-CELL INTERFERENCE

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ABSTRACT

The issue of cell-to-cell interferences is a serious problem that has always been raised in digital communication system such as NR. The communication method of NR and LTE is OFDM. OFDM has many advantages, but has fatal disadvantage called ICI (Inter-Cell Interference) because resources among cells are always overlapped. For example, NR's typical interferences are ICIs among PDSCH (Physical Downlink Shared Channel), PDCCH (Physical Downlink Control Channel), PUSCH (Physical Uplink Shared Channel), PUCCH (Physical Uplink Control Channel), CSI-RS (Channel State Information-Reference Signal) and SRS (Sounding Reference Signal). Among them, it is important to determine the correct beamforming weight factor value by estimating the channel with SRS. Therefore, the ICI of SRS degrades the performance of downlink throughput. This paper analyses the impact of SRS's ICI in conventional scheme, introduces the proposed AC-CS (Auto-Correlation Cyclic Shift) schemes by the Zadoff-Chu sequence to overcome the ICI of SRS and analyses their performance. The method used for performance analysis is determined by the detection abilities, which are missing probability and false alarm probability.

KEYWORDS

SRS, beamforming, auto-correlation, missing probability, false alarm probability

1. INTRODUCTION

In digital communication system such as LTE and NR, the inter-cell interference issue is a problem that has always been raised particularly. In order to solve this interference problem in the OFDM communication method, but the like algorithms such as ICIC (Inter-Cell Interference Cancellation) or CoMP (Coordinated Multi-Point) are emerged as a solution, there are disadvantages such as dividing the resources used.

In particular, the estimated performance by the received SRS (Sounding Reference Signal) distortion in the serving cell due to the SRS of the adjacent cells to derive a weight factor of the inaccurate beamforming is significantly reduced in condition of the low power or interference.

Thus, first of all, this paper analyses the performance degradation of estimated SRS due to adjacent cell's SRS in the conventional conditions that are currently commercialized 5G system, compares the simulation results in the proposed AC-CS (Auto-Correlation Cyclic Shift) schemes

of the Zadoff-Chu sequence and the conventional scheme in the cell's configuration and recommends the conditionally-fitted schemes of each a morphology.

2. BACKGROUND

2.1. Sounding Reference Signal

SRS is the acronym of Sounding Reference Signal. When the UE transmits to gNB to estimate the status of the uplink channel sent to gNB, gNB uses a way to report to the UE based on the channel status it currently identifies and reflect on future UL. In particular, it is importantly used in MIMO (Multi-Input Multi-Output), which is referred to as the leading technology in NR.

First of all, the UE can transmit the SRS to beam in several directions. gNB understands the channel status in each direction based on SRS of receiver, which gives the uplink channel the information it needs, such as which beam to use and how much rank to use. Based on the reporting result of the received gNB, the UE proceeds uplink process. Here's one thing to go through about DL/UL's CSI (Channel State Information).

If UL and DL in FDD use different frequencies, each sub-band CSI is different. However, in UL and DL in TDD using the same frequency band divided only in time, there is a point to consider. Since the factors that determine the channel state are largely composed of interference and obstacles of the frequency, there is a concept called channel reciprocity in TDD.

2.2. Zadoff-Chu Sequence

Zadoff-Chu sequences exhibit the useful property that cyclically shifted versions of themselves are orthogonal to one another, provided that each cyclic shift, when viewed within the time domain of the signal, is greater than the combined propagation delay and multipath delay spread of the signal between the transmitter and receiver.

A generated Zadoff-Chu sequence that has not been shifted is known as a root sequence. The complex value at each position n of each root Zadoff-Chu sequence parametrized by u is given by

$$x_u(n) = e^{-j\left(\frac{\pi un(n+1)}{N_{ZC}}\right)} \quad \square\square\square(1)$$

Where $0 \leq n < N_{ZC}$, $0 < u < N_{ZC}$, $\gcd(N_{ZC}, u) = 1$ and $N_{ZC} = \text{length of sequence}$.

2.3. Properties of Zadoff-Chu sequence

- They are periodic with period N_{ZC} if N_{ZC} is odd.
- If N_{ZC} is prime, the DFT (Discrete Fourier Transform) of a Zadoff-Chu sequence is another Zadoff-Chu sequence conjugated, scaled and time scaled.
- The auto correlation of a Zadoff-Chu sequence with a cyclically shifted version of itself is zero, i.e., it is non-zero only at one instant which corresponds to the cyclic shift.
- The cross-correlation between two prime length Zadoff-Chu sequences, i.e. different values of u , $u = u_1, u = u_2$, is constant $1/\sqrt{N_{ZC}}$, provided that $u_1 - u_2$ is relatively prime to N_{ZC} .

2.4. Auto-correlation

Auto-correlation is an indicator of the similarity between source sequence and sequence of added noise channel. Also, it is a time series and its simple linear correlation with its own past.

Basically, the value $x(t)$ means the correlation with the sequence of the sequence and the value $x(t+\theta)$ after the θ in hours. The time displacement θ is called time difference. Auto-correlation function is a correlation related to variable time. The coefficient of auto-correlation relates to the variable $x(t)$ and the variable $x(t+\theta)$ as a product-moment correlation coefficient.

2.5. Cross-correlation

In digital signal processing, cross-correlation is a level of similarity of two different sequences as a function of one another relationship. Simply, it is a correlation between two sequences $x(t)$ and $y(t)$.

Two sequences are the same variable measured in different places or the same variable observed in the same place, which may have different observation times. As an example, $y(t)$ may represent $x(t+\theta)$, wherein θ means a time delay.

3. SRS SEQUENCE GROUP IN NR

For example, the sequence group $u = (n_{ID}^{SRS}) \bmod 30$ if *groupOrSequenceHopping* equals 'neither', neither group, nor sequence hopping shall be used. The SRS sequence identity n_{ID}^{SRS} is given by the higher layer parameter *sequenceId* in the *SRS-Config* IE, in which case $n_{ID}^{SRS} \in \{0, 1, \dots, 1023\}$ and is PCID (Physical Cell Identifier) generally.

4. CONVENTIONAL CELL CONFIGURATION BY SRS

The 5G commercialized vendors around the world use n_{ID}^{SRS} to PCID (Physical Cell Identifier) generally.

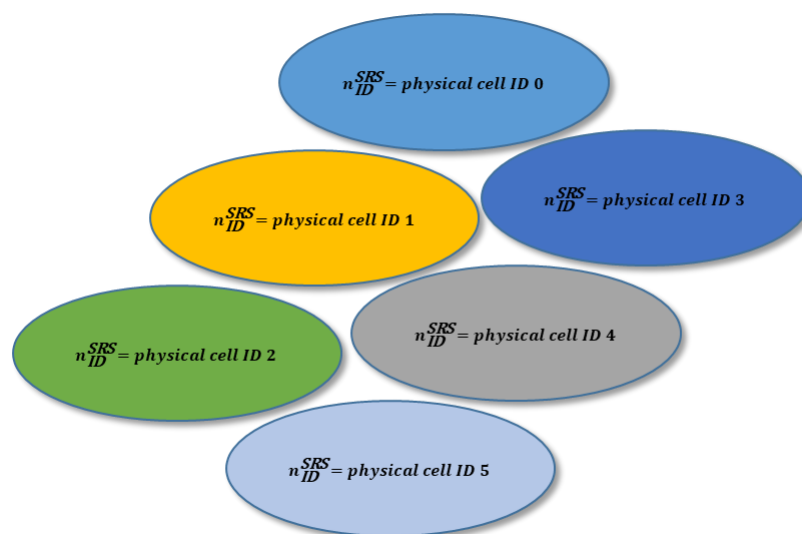


Figure 1. Conventional sequence group ID by SRS

In this case, the group ID is used differently between cells, so the type of Zadoff-Chu sequence is different between cells, as expressed in different colours, such as Figure 1. When decoding the received signal from the position of the base station, the signal coming from the other cell is to act as interference. In an environment such as Figure 1, because the SRS group id is different for each cell, it has the characteristics of cross-correlation rather than the characteristics of auto-correlation.

Since Zadoff-Chu sequence of other cell using other SRS group ID increases noise by $\frac{1}{\sqrt{N_{ZC}}}$ as mentioned above, the performance can only be degraded in environments such as UMa (Urban Macro) with many surrounding cells. Vendors are to configure the settings differently according to morphology, such as RMa (Rural Macro) or UMa (Urban Macro), so it has a very complex configuration, from a commercialization point of view.

All currently commercialized vendors want to be a stable and simple configuration. Therefore, they choose to configure the SRS group ID with PCID (Physical Cell ID). However, this method will reduce performance in the cell edge in an environment such as UMa (Urban Macro). Performance decreases with the number of nested cells is in the simulation results in the performance section below.

5. PROPOSED CELL CONFIGURATION SCHEMES

In order to overcome the degradation of conventional scheme such as Figure 1, two new schemes are proposed. Conventional method, the more nested cells, is the more disadvantageous of increasing the noise by the cross-correlation characteristics.

The two newly proposed methods are using the same SRS sequence to reduce the noise due to cross-correlation of the surrounding cells to overcome the conventional disadvantages, and between cells using the same sequence is applied a method of minimizing interference using a cyclic shift.

5.1. 1st Proposed Scheme

In the cell configuration, as shown in the example of Figure 2, 1st proposed scheme is a method of using the same SRS group ID in three cells' unit. That is, this scheme uses the same SRS sequence in three cells' unit, and they use a same sequence applied to different cyclic shift. At this time, other three cells can be deployed by same configuration. Blue cells use the same SRS sequence having the same SRS group ID, and that sequence is done by different cyclic shift. Green cells also use the same configuration.

The NR RRC message used can be configured as Table 1 with the PCID (Physical Cell Identify) of each cell, which is constituted by the cyclic shift with modulo 3. At this time, the shifted sequence should be configured as far away as possible for a good performance. For example, it is best as far as 4 units of 12 intervals to maximize performance in this condition of NR. The reason is that the peak by auto-correlation of the same sequence is not ideal and the peak is gradually growing. This shows in the simulation results' section below. The *combOffset-n4* and *cyclicShift-n4* are RRC Messages for the distinction of UEs.

If the cell is configured as the same SRS Group ID of three cells' unit, when there are many adjacent cells, such as Figure 2, there is still disadvantage that noise is increased by the interference of cross-correlation from cells of different colour.

The way to overcome this disadvantage is a 2nd proposed scheme.

Table 1. 1st proposed cell configuration

SRS RRC Message	Usage	Value	
<i>combOffset-n4</i>	Intra-Cell UEs	0, 1,2, 3	
<i>cyclicShift-n4</i>	Inter-Cell UEs	PCID % 3 = 0	0
		PCID % 3 = 1	4
		PCID % 3 = 2	8

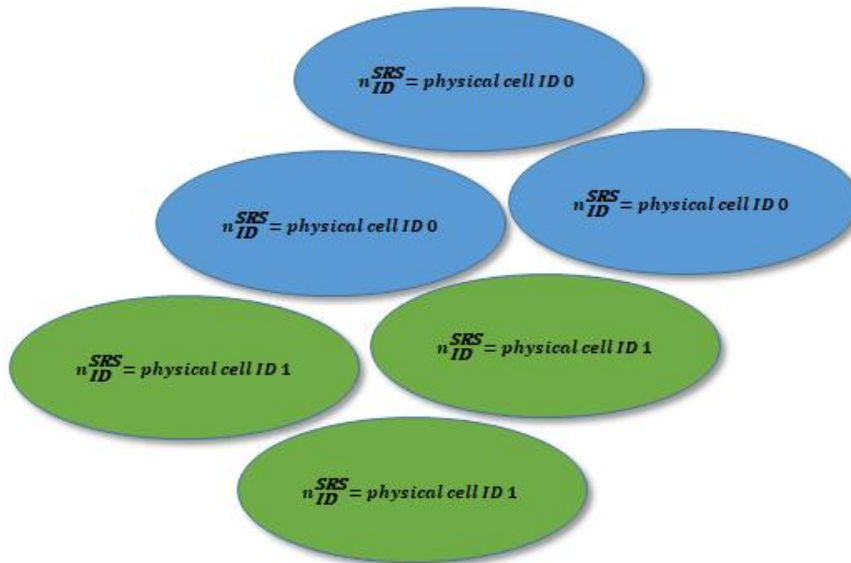


Figure 2. 1st proposed cell configuration by SRS sequence group ID

5.2. 2nd Proposed Scheme

As in the example of Figure 3, the 2nd proposed scheme is a method of using the same SRS group ID in six cell's unit in the cell configuration. That is, this scheme uses the same SRS sequence in six cells' unit, and they use a same sequence applied to different cyclic shift. At this time, cells of different colour can be deployed by same configuration. That is, blue cells are the same SRS sequence using the same SRS group ID and the sequence is done by different cyclic shift.

Table 2. 2nd proposed cell configuration

SRS RRC Message	Usage	Value	
<i>combOffset-n4</i>	Intra-Cell UEs	0, 1, 2, 3	
<i>cyclicShift-n4</i>	Inter-Cell UEs	PCID % 6 = 0	0
		PCID % 6 = 1	2
		PCID % 6 = 2	4
		PCID % 6 = 3	6
		PCID % 6 = 4	8
		PCID % 6 = 5	10

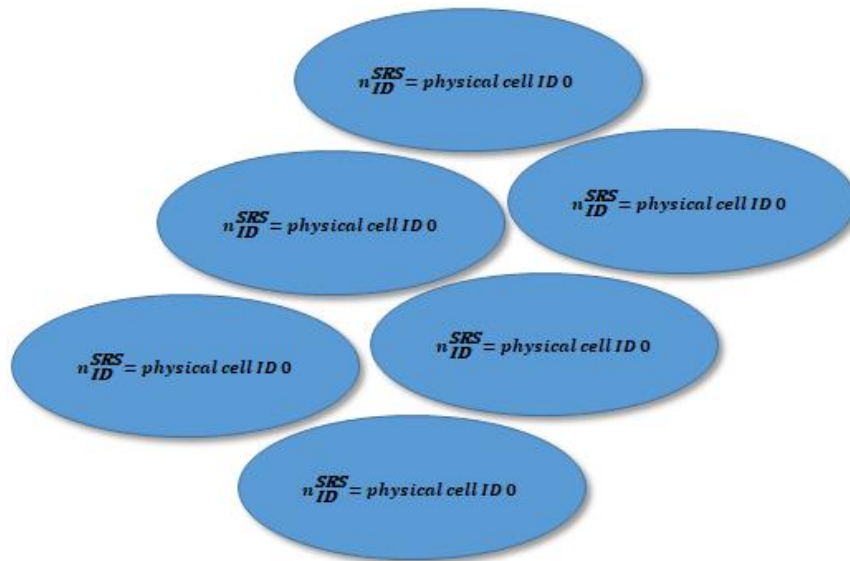


Figure 3. 2nd proposed cell configuration by SRS sequence group ID

The NR RRC message used can be configured as Table 2 with the PCID (Physical Cell Identify) of each cell, which is constituted by the cyclic shift with modulo 6. At this time, the shifted sequence should be configured as far away as possible for good performance. For example, it is best as far as 2 units of 12 intervals to maximize performance in this condition of NR. The reason is that peak by auto-correlation of the same sequence is not ideal and the peak is gradually growing. This also shows in the simulation results' section below.

5.3. Pros and Cons

The pros and cons for each scheme are expressed as table 3. Conventional scheme has an advantage that the cell configuration is simple, but there is a disadvantage that the SRS cross-correlation interference between cells is increased. To compensate for this disadvantage, the 1st proposed scheme has the best auto-correlation characteristics, but since only three cells are the same sequence, there is some SRS cell-to-cell interference. The 2nd proposed scheme is that configured all the cells (6 cells) have the same sequence. This method has an advantage that SRS inter-cell interference does not exist and the disadvantage that the characteristics of auto-correlation of closer peak by cyclic shift in same sequence may be worse.

Table 3. Each Scheme Comparison

Scheme	Comparison	
	Advantage	Disadvantage
Conventional	Easy cell configuration	High SRS ICI ^a
1 st Proposed	Good auto-correlation	Medium SRS ICI ^a
2 nd Proposed	Low SRS ICI ^a	Medium auto-correlation

^aInter-Cell Interference

6. PERFORMANCE COMPARISON

Based on what we've described so far, compare the performance of the conventional, 1st, and 2nd proposed scheme.

First of all, Figure 4 is the channel correlation of 1st proposed scheme and Figure 5 is the channel correlation of 2nd proposed scheme. According to Figure 4 and Figure 5, the 1st proposed scheme is cleaner around peak than the 2nd proposed scheme. The reason is that the 1st proposed scheme has low number of cyclic shift, so the overall noise can be elevated, but false alarm probability is reduced than 2nd proposed scheme such as Figure 7.

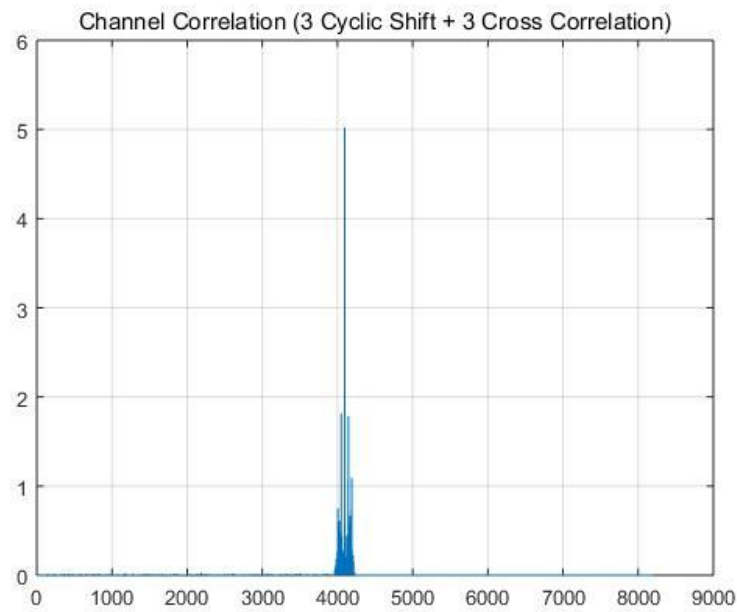


Figure 4. The channel correlation property of 1st proposed scheme

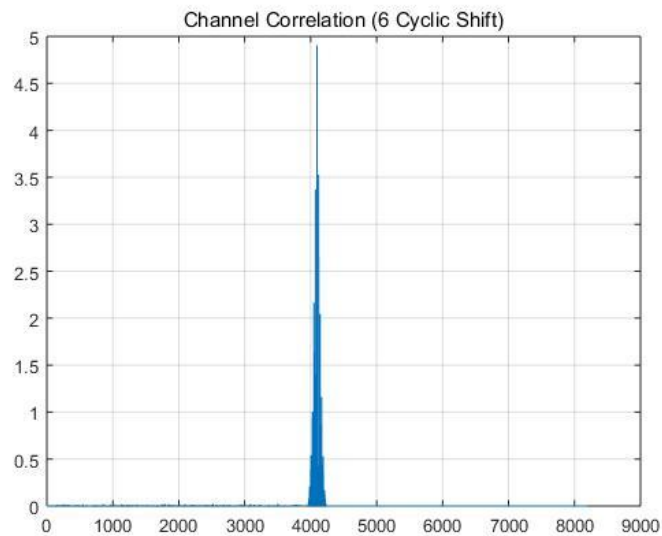


Figure 5. The channel correlation property of 2nd proposed scheme

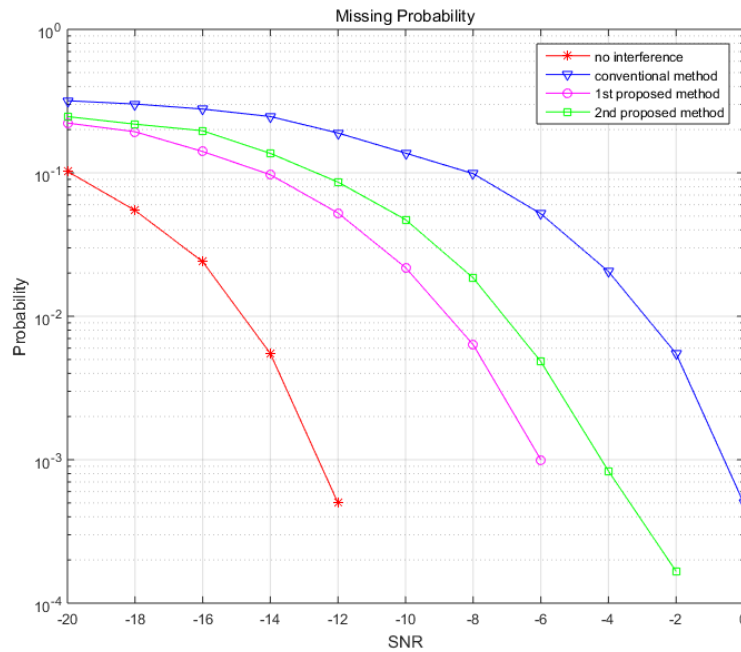


Figure 6. The Performance of no ICI, conventional and proposed scheme

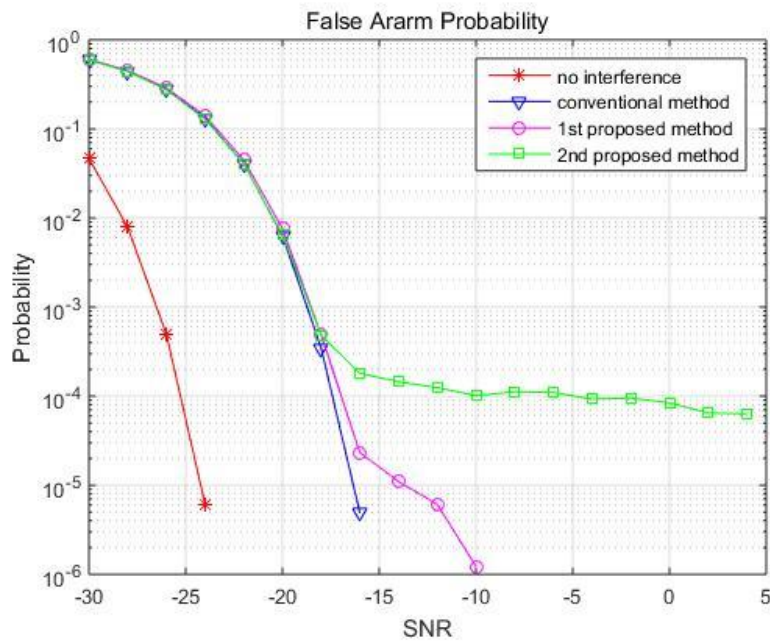


Figure 7. The False Alarm of no ICI, conventional and proposed scheme

The graph of comprehensive performance is Figure 6. Based on 1% missing probability, the conventional scheme has bad performance by 12 dB compared to no interference. However, 1st proposed scheme has good 6dB performance compared to a conventional scheme, and 2nd proposed scheme has 4dB gain compared to a conventional scheme.

Figure 7 is the comparison of false alarm probability in same condition of Figure 6. The 2nd proposed scheme looks relatively poor in good SINR conditions. The reason is that there are a lot of small peaks in addition to real peak due to the cyclic shift of same SRS sequence. However,

there is no issue of performance degradation since 3GPP standard recommends the false alarm conditions satisfy 0.1% generally.

Based on the performance graph, the morphology which 1st scheme is used in commercial environment is appropriate urban regions in typical, and 2nd scheme is a more suitable method in dense urban region where cells are tighter. Because, the tighter the cell, the worse the cross-correlation characteristics, so dense urban region is good to use the method of cyclic shift as much as possible with the same SRS sequence.

7. CONCLUSIONS

It is very important in digital beamforming algorithm to determine the correct beamforming weight factor by estimating the channel with uplink SRS. Thus, this paper analysed the level of interference between the cells receiving the SRS in various ways.

Using the new proposed AC-CS (Auto-Correlation Cyclic Shift) of Zadoff-Chu sequence, base station can overcome inter-cell interference when it receives SRS. Also, we compared its performance with conventional and proposed schemes. In order to maximize performance in the actual commercial environment, 1st and 2nd proposed schemes can be selected depending on the specific morphology.

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A SOCIAL-BASED GAMING SYSTEM TO MOTIVATE THE DOG WALKING AND COMMUNITY USING INTERNET-OF-THINGS (IoT) AND AI

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ABSTRACT

In recent years, society has shown an increase in pet ownership, however, only a few companies exist to help pet owners keep track of their pet's health. This paper designs a tool to help track pet owners measure the amount of steps their dogs have taken to measure their pet's health. We applied our application to our dogs and conducted a qualitative evaluation of the approach. The results show that the tool indeed works and will track the pet's steps taken, location, and provides a fun and engaging way to interact with the app.

KEYWORDS

IoT, Gaming System, Machine Learning.

1. INTRODUCTION

The device is made solely for the purpose of tracking the steps and locations of a dog. The owner attaches the device to the dog when they are out on a walk, the device tracks the steps and location of the dog then draws a path and counts how many steps they have taken. The owner can then open up the pedometer app to see how many steps the dog has taken.

Some similar techniques and systems have been proposed to track the human's steps taken then convert them into their dog's steps, which allows the user to have a less range of error.[10] However, these proposals assume that dogs' steps are always proportional to the user's step, which is rarely the case in practice. Their implementations are also limited in scale. Other techniques, such as tracking the dog's GPS location and drawing a path to convert it into dog steps, have shown to be ineffective.[11] This is because the method used is inaccurate and often results in calculation errors. A second practical problem is that some users find it hard to understand the interaction between the GPS location and the steps taken.

In this paper, our goal is to test out different methods and tools that exist and compare it with each other to see the features and strengths of each. There are some good features of Pedometer. First, the device shows the gps location of its pet. Second, it uses the motion of the dog to track the amount of steps taken. Third, the app uses a fun way of interaction between the user and the device. Therefore, we believe that our device will be on par with some of the better devices on the market.

In two application scenarios, we demonstrate how the use of both the device and app collects data from the user and the dog.[12] First, we show the usefulness of our approach by a comprehensive case study of the device being used on different dog breeds. Second, we analyze the data and compile a result of what the device excels at and what it does not.[13]

The rest of the paper is organized as follows: Section 2 gives the details on the challenges that we met during the experiment and designing the sample; Section 3 focuses on the details of our solutions corresponding to the challenges that we mentioned in Section 2; Section 4 presents the relevant details about the experiment we did, following by presenting the related work in Section 5. Finally, Section 6 gives the conclusion remarks, as well as pointing out the future work of this project.

2. CHALLENGES

In order to build the tracking system, a few challenges have been identified as follows.

2.1. Organizing Ideas

When creating a new device, there are many factors to consider, some of which are device features, app features, and ways to implement the system. This process usually takes a couple of weeks and is sometimes hard to finalize, since there are no limitations or requirements to make when developing an app and device from scratch.

2.2. Creating the Device

Development of the device will often run into problems, one of many problems is the placement of the GPS and batteries to make sure the device is as compact as possible. The device also needs to be coded from scratch to ensure that everything will work.

2.3. Creating the App

The Pawdometer app needs to interact with a online database, meaning that the database needs to be created somehow. Additionally, the app needs a way to activate the device to track its steps. It will also need features such as a way to display the amount of steps taken, and a leaderboard to show who has the most steps taken.

3. SOLUTION

In order to fulfill all the challenges met above and provide an interactive way to use the app, the Pawdometer has 3 major parts, the tracking app, the game, and the tracking device. The three apps interact with each other to form a working system that allows the user to track their dog. The process of how this system works comprises 3 major steps. The tracking device first records the steps taken and flashes (sends out a signal containing the steps) every couple minutes. The tracking app then receives the signal, then stores it in the database. The app then displays the steps shown in the database to the app itself, allowing the user to see how many steps the dog has taken. The tracking device has three major components: the battery, the motherboard, and the gyroscope. The gyroscope's sensitivity is modified where it can track dogs' steps, in addition. The battery powers the motherboard, which powers the gyroscope. The motherboard has an additional function, which is to send out signals to the device.

The first component is the pedometer device. For this project, I used particle.io's hardware, which

is very similar to a raspberry pi 4. The hardware consists of a motherboard, a pedometer, GPS tracker, and a lithium battery pack. The device has a small antenna that sends out data to the particle.io server, which is retrieved by the pawdometer app.

The second component is the pawdometer app, which receives the data sent by the device and displays it on the app screen. The app has many features, including the main screen, sign up page, log in page, leaderboard, gps location of the device (if the device is online), and a graph that shows the progress of how far a dog has walked.

The last component is the pawdometer game. This game is a simple match-3 mobile game on a different app, it uses the data stored in a google firebase to verify if the user exists or not, the app features a leaderboard, login page, and the main game itself. Currently, we are attempting to connect the game to the main app, which allows the conversion of steps into points, and these points can be multiplied by playing the game.

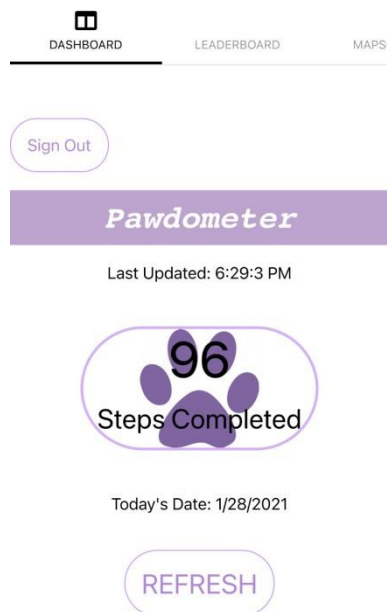


Figure 1



Figure 2



Figure 3

4. EXPERIMENT

Experiment 1

For the first experiment, I attached my device to different dog breeds. For each dog breed, I will count the amount of steps taken while the device also tracks. The device should show little to no error from the manually counted steps.

Table 1

Dog Breed	Steps Tracked	Steps Taken
Golden Retriever	15	15
Poodle	50	50
Golden Retriever	106	100
Poodle	97	100
Dachshund	30	30
Dachshund	100	100

The same breeds were tested for different amounts of steps. As the table shows, the device works fine with smaller breeds, however, the device will show a bit of error for larger breeds.

Experiment 2

In this experiment, I used the tracking device on the same dog on different days to check the consistency of the device. The tracked steps should not differ much from the actual steps taken.

Table 2

Day	Steps tracked	Stepstaken
1	15	15
2	18	15
3	15	15
4	14	15
5	13	15
6	15	15

The table has shown that the tracking device is sometimes accurate, other times it will show inaccuracies that are not too large.

The experiment result has shown that the tracking device works better on small dogs over long distances, it also shows that the device will track differently each time depending on the day. I believe this is because the device is put in different positions each day. However, despite it showing a little bit of error, the device works up to my expectation.

5. RELATED WORK

Related Work 1

In a study conducted by Bassett DR Jr and his team, a total of 96 men and women wore pedometers for 7 days, and at the end of the week, data was collected from both the estimation made by the participants and the actual data from the pedometer. This research is similar to the experiment part of this paper, as different subjects from both papers wore a pedometer device and were tracked on different days.

Related Work 2

In the second research conducted by Tudor-Locke C and his team, an experiment was conducted on two different types of sensors. In the research, data were analyzed from 52 participants, who wore both motion sensors for 7 consecutive days. Locke's experiment is similar to this paper's experiment in that both were tested on different days on different subjects. However, Locke's experiment is more sophisticated as different motion sensors are used.

Related Work 3

In the third research conducted by Patrick L. Schneider, multiple brands of pedometers were used to track 10 males and 10 females over a 24 hour period. The experiment shows that out of the 13

pedometers used in the experiment, five show mean values that were not significantly different from the actual value. While the difference between this paper's experiment and Schneider's research is minimal, there are some comparisons worth noting. One of them is that Schneider's experiment is conducted on humans and for human use, while this paper's research is conducted on different dog breeds. Schneider's experiment differs from this experiment, in his experiment, the pedometers are from different successful brands.

6. CONCLUSIONS

In this research, I developed a device and an app to track the amount of steps a dog has taken. I applied the device to dogs of different kinds in an experiment to track if it is accurate in tracking the steps of dogs.[14] The experiment indicates that the device is somewhat effective in tracking the steps, and solves the problem of not knowing how much the dog has walked and whether if it is healthy or not.

The current limitations of this device is in its limited battery lifetime, the rather big size of the device when compared to a small dog, and its limited accuracy as shown in experiment one. The device is optimized for small dogs but is still a bit large.

In the future, I plan to change the code in order to track the steps of larger dogs more accurately, in addition, I plan to change the hardware in order for it to be smaller while retaining the same function and possibly more battery life.[15]

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SYSTEM END-USER ACTIONS AS A THREAT TO INFORMATION SYSTEM SECURITY

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ABSTRACT

Information system security is of paramount importance to every institution that deals with digital information. Nowadays, efforts to address cybersecurity issues are mostly software or hardware-oriented. However, the most common types of cybersecurity breaches happen as a result of unintentional human errors also known as end user actions. Thus, this study aimed to identify the end-user errors and the resulting vulnerabilities that could affect the system security requirements, the CIA triad of information assets. The study further presents state-of-the-art countermeasures and intellectual ideas on how entities can protect themselves from advent events. Adopted is a mixed-method research approach to inform the study. A closed-ended questionnaire and semi-structured interviews were used as data collection tools. The findings of this study revealed that system end user errors remain the biggest threat to information systems security. Indeed errors make information systems vulnerable to certain cybersecurity attacks and when exploited puts legitimate users at risk.

KEYWORDS

Information security, Information Systems, End-user errors.

1. INTRODUCTION

1.1. Background

The University of Namibia (UNAM) collect different type of data and information from its stakeholders, be it staff members, students or education partners. The amount of data and information collected therein is a very important resource to the university, hence, safeguarding and protecting it and securing the University information systems is crucial [1]. The university's information systems here refers to email systems, integrated tertiary system (Self Help enabler), staff computers and corporate network (internet). In carrying out this mandate, however, the university's responsible division, Computer Centre, need to ensure full implementation of the three information security requirement: confidentiality, integrity and availability of the information, also known as the CIA triad. The CIA Triad assure users that information is correct, timely, reliable, and free from modifications, destruction, unauthorized access, misuse and disclosure [2], [3].

Ensuring data protection, however, has no one way to fix. This difficulty could be attributed to the fact that there is a myriad of end user actions and mostly human errors are overlooked. End-user (human) errors refer to possible actions by logged in users. Such errors or acts could occurs as a deliberate act, accidentally or a result of negligence or simply a mistake without intent to cause harm or malicious purpose by an authorised user of an institution. Human errors are infinite may include but not limited to using the same credentials on different accounts, not logging out

of the system, sharing the password with colleagues, clicking links from an unknown sender, weak password, lack of experience in technology use, and improper training and lack of strong ICT security policy and practices for computer security. System end user errors lead to vulnerabilities and create room for attackers to penetrate the information system and get access to sensitive information.

Educational institutions will always face security challenges regardless of their financial status reserved for technical controls [4]. Research shows that 52% of users experience viruses and malware infection although 98% of the users had anti-virus software [4]. This is a clear and lucid manifestation that information security is not all about technology integration but it also entails user-centric since technological cannot protect a system one-hundred percent. Neely [4] and Global Security Survey [20] agreed that that the main loose end of information security is the end-users who interact with the information system. On the other hand, Hadlington [19] argued that user's undeliberate actions such as incompetence and lack of knowledge towards information security approaches are the weakest component in information security and the main cause of cybersecurity breaches. Safianu [5] further disputed that an institution might have installed the optimum security technologies in existence and defend its physical structures but it is still completely vulnerable to attacks.

1.2. Problem

According to the UNAM Computer Centre Report of 2019, over one million spam emails have been detected directed to various user accounts. The report further stated that spammers were using advanced technics by using compromised accounts of legitimate UNAM users to send out impersonating emails with links to upgrade email account or to change their password. In addition, although UNAM has technological measures in place like firewalls, Intrusion Detection System and antivirus to curb loopholes in the network, user accounts are still being compromised resulting in spammers using legitimate UNAM user account to obtain sensitive information from end-users. These security events happen because current efforts to advance information security and address cyber-security had been mainly focusing on software and hardware, with little or no efforts directed at addressing the users' aspect of information systems [5].

1.3. Objectives

The overall purpose of this study was to:

1. Identify system end-user errors, as part of end user actions that could lead to information security threats and vulnerabilities.
2. Present state-of-the-art countermeasures and intellectual ideas on how to deal with human errors to protect the universities' information systems.

1.4. Significance

This research is solicited to contribute to the body of knowledge by presenting original results and disseminate new ideas and significant advances on how to respond to cybersecurity attacks arising from end-user actions.

2. LITERATURE REVIEW

2.1. Related Work

There are a number of different studies carried on information system security and end user errors. Researchers have slightly different argumentation, interpretation and perspectives, in their literature reviews. For instance, a study by Pill [9] asserted that information stored in databases is susceptible to a multitude of attacks, however, it is possible to alleviate risks by addressing the most critical threats. Silver [10], also conducted a study on evaluating technological vulnerabilities and found that to protect against targeted attacks, institutions could configure a scanner to check web applications for vulnerabilities such as SQL injection, cross-site scripting and forceful browsing. The study recommended the use of a web application firewall to protect against vulnerabilities. Lamar [11] argued that database attacks are prevailing nowadays because of the vulnerabilities in Operating Systems. The study also outlines that database rootkits and services associated with the databases could create a loophole for illegal access which may lead to a Denial of Service (DoS) attack. Kamara [12] suggested a taxonomy to comprehend firewall vulnerabilities in the framework of firewall implementations as it is not always practical to analyse and test each firewall for all potential issues. Hence, the study scrutinised firewall features and cross-referenced each firewall operation with the causes and effects of faults in that operation, evaluating twenty recognised flaws with prevailing firewalls.

The work by Kashefi [13] examined vulnerabilities in software and hardware firewalls and discovered that there are four common vulnerabilities in firewalls. (1) Insider attacks, (2) network traffic, (3) tunnelling, and (4) internet threats. Another study by Soomro [14] established that cryptosystems are even more vulnerable to attack when they are handling little amounts of data. Soomro [14] recommended a technique to reduce the inefficiency in the algorithm by introducing XOR operation in the major steps of the symmetric algorithm to alleviate communication overhead in transmitting small amounts of data. According to Kaspersky Lab [15] report on software vulnerabilities, it was found that software vulnerabilities exist because of improper process, poor design and programming errors. Despite the sophisticated design of modern encryption and cryptosystems, they still exhibit the same flaws that the first systems contained many years ago. According to Hadlington [19], a lack of understanding of security problems makes people think that technology alone could solve security problems. Furthermore, Kizza [12] proffered that technology-focused security alone was insufficient as users were being targeted when the technological attacks did not succeed. Safianu [20] narrated that even though many institutions made use of an extraordinary number of technical security controls, the non-proportional number of security breaches still prevail.

In summary, all literature stated explores the vulnerability studies in software and hardware aspects of information assets, ignoring end-user actions as a potential threat to information security. For this reason, this study urgently investigated the matter intending to close the gap in knowledge on the topic under discussion. Researchers assume there is a great need to address this problem of end-user error induced vulnerabilities, which had been overlooked by many computer security researchers.

3. METHODOLOGY

3.1. Research Design Methodology

The study applied a mixed research methodology with an experimental research design. Such an approach allowed the researcher to present theoretical and practical aspects of system security. In principle, the qualitative research approach has been used through analysis of reviewed thoughts as expressed in literature, interpretation and synthesis of information in secondary and tertiary sources such as related textbooks, reports and scholarly articles. The qualitative data involve the original outcome of the questionnaire and semi-structured interviews.

An experimental study using Penetration Testing as a hacking method was undertaken. This form of attack constitutes social engineering, phishing and penetration attempts. The experiment (attack) using a phony phish system has been directed on employees to find out if they follow security standards and policies as stipulated in the UNAM ICT policy. The phony phish system has been used to send phishing emails and that outcome has been used to measure the accuracy and validate the result of research. Figure 1 shows the architectures and design of the phony system.

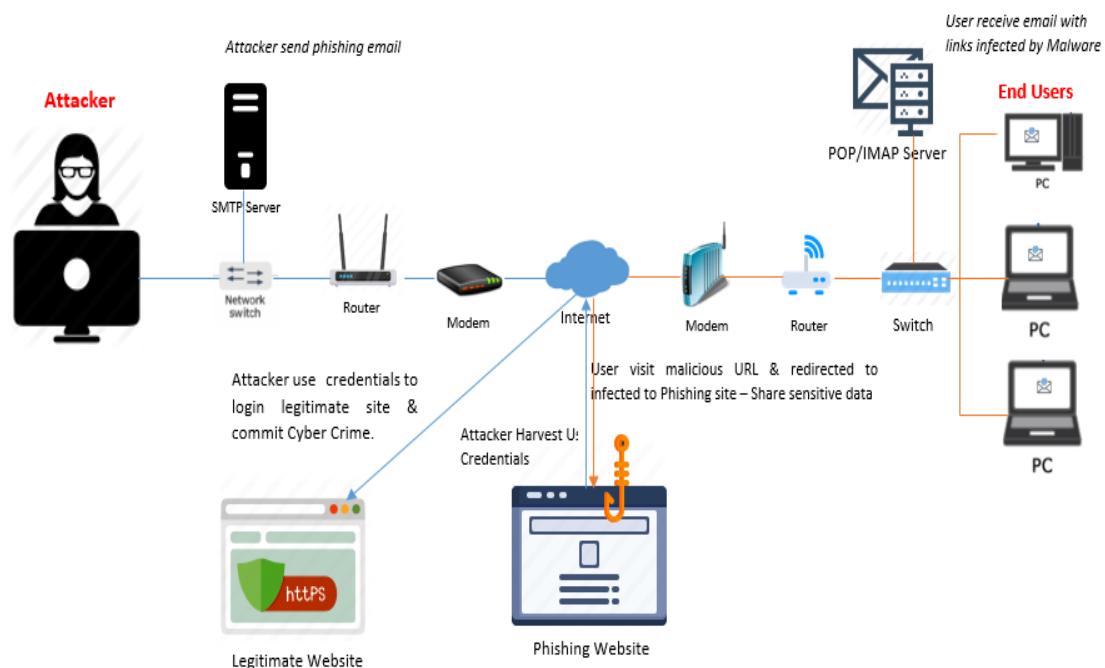


Figure 1. Phony Phish System Architecture and Design

As illustrated above, an attacker sends solicit emails to UNAM staff members and requested them to the respondent by visiting a phishing web page and download an application for removing malware. The email was formulated as follows:

Dear UNAM Network User,

Your computer has been infected with a virus and to remove the virus downloads and installs the tool from this link herein <https://leancoding.co/70TIYR> with the institution's authorized PC cleaner to eliminate the virus from your computer. Have a nice day.

Kind regards,

IT Technician, UNAM Computer Centre

3.2. Data Collection

The data collection for the study consisted of a survey using an online questionnaire. The questionnaire consisted of open-ended questions. Also, a semi-structured interview was organised to collect the expert's primary data.

3.3. Population and Sampling

The survey targeted the entire University of Namibia staff members who frequently use information systems. A significant number of staffs have participated. This includes ten (10) IT professionals at Computer Centre Division and 300 other staffs members such as academics and administrative staffs.

4. RESULTS AND DISCUSSIONS

This section presents different types of end user errors discovered.

4.1. Following links via mail from unknown senders

Institutions that use secure communication network protocols such as IP Security, Secure Socket Layer(SSL), Transport Layer Security (TLS), HTTPS, Secure Shell (SSH)and guide employees to follow security procedures and policy tend to have secure hardware and software, hence not vulnerable to vulnerable attacks comparing to those organisations that lack technical and computer security [16]. Phishing and social engineering are some of the most effective routes to stealing confidential information from organisations.



Figure 2. Response to an online request

The questionnaire results showed that 233 participants (77.7%) followed a link that requested them requested to change their credentials by providing their UNAM account details such as UNAM E-mail address and password) and only 67 (22.3%) of the UNAM staffs followed a link that requested them to download updates. It was also discovered that the majority (65%) of the

respondents hardly check if the link where they enter their login details starts with 'HTTPS'. This tendency of system users can give a hacker a way to steal sensitive information. Moreover, by attacking the right people, attackers can gain access to unauthorized users. Hence, educational institutions and individuals must adopt a combination of both technology solutions and user awareness to help protect sensitive information. The findings above corroborate with the findings of Van-Zedlhoff [16], who noted that clicking on links from unconfirmed sources can lead to security breaches.

4.2. Lack of strong password and inappropriate use of password

A password rule is very important. The complexity of passwords is one of the recommended measures in the information security industry. Preferably, a password should be difficult to guess which also implies that it should not be a phrase or word or a number that can be easily remembered such as ID, birth date or telephone number [4]. Studies revealed that 55.3 % of the participants change their passwords only when the system requires them to do so and 44 % indicated that they change their password after 3 months or more.

Results of this study indicated that 72.3 % of the participants use up to 7 characters as their password and 8.3 % mostly set their passwords short. Furthermore, 74 % of the participants indicated that they use personal information such as name, date of birth, place of birth, address etc. to generate their password while 11 % use only upper letters. Moreover, 83.3 % of participants indicated that they do write their password down when it is difficult to remember. Indulging in these practices such as the use of a weak password, writing down and sharing of passwords with others, and reusing the same password on different systems are some of the bad practices that could compromise user accounts and put systems at risks of attacks. Like a PIN, passwords must be a secret known to only users to protect data from access from unauthorised individuals. If the password is compromised, the security of the system is at stake. The findings above conform to the findings of Neely [4], who noted that using a weak password, writing down and sharing passwords with others, and reusing the same password on different systems are some of the bad practices that have the potential to put information at risk. Therefore, users must create strong passwords and log out properly on any system they are interacting with.

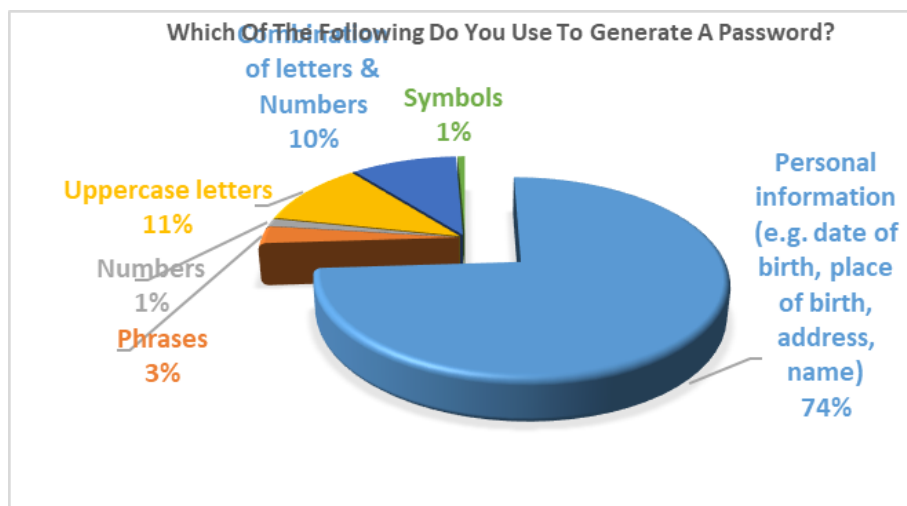


Figure 3. Generation of a password

4.3. Reckless Handling of Computers

Threats and vulnerabilities can be avoided if employees respect to log out or lock their devices whenever they leave their desks. Moreover, a session timeout could limit the risk to unattended computers [17]. In many instances, people do leave their computers idle when leaving the work premises or unattended when attending meetings. Also, some do not log off their computers when visiting the bathroom. These actions such as misconduct of computer-related equipment could jeopardise data security. Insiders attacks are mostly associated with employees leaving their PCs unattended yet with active sessions running hence threaten the viability of the university in protecting its information.

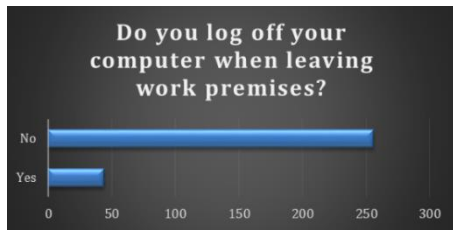


Figure 4. Logging off a computer when leaving work premises

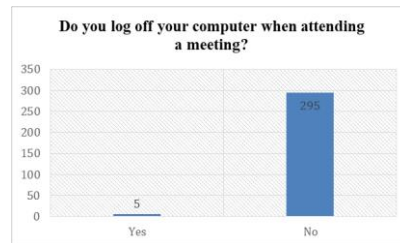


Figure 5. Logging off a computer when attending a meeting

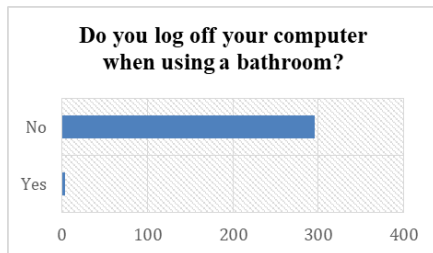


Figure 6. Logging off a computer when using a bathroom

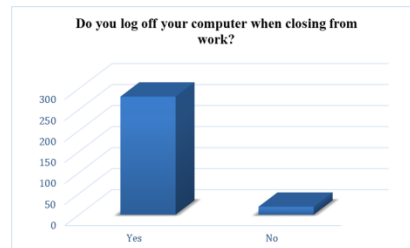


Figure 7. Logging off a computer when closing from work

Figure 4-7 shows the results of UNAM employees who participated in the study. About 256 do not log off their computers when leaving work premises and only 44 of the participants indicated that they log off their computer even when their workplace. It has been noted also that around 295 UNAM employees hardly or do not log off their computers when attending a meeting. However, 5 of the participants indicated that they log off their computer even when attending a meeting. Similarly, 296 UNAM employees do not log off their computers when visiting a bathroom and only 4 of the participants indicated that they log off their computer even when using a bathroom. Out of the total, 281 UNAM employees do log off their computers when closing from work and 19 of the participants indicated that they do not log off their computer when closing from work. These findings concur with the earlier findings by Evans [18] who indicated that computers that are left idle and unattended may pose a threat to information. Hence, employees should not leave their computers unattended this could put information at risk of being exposed and altered.

4.4. Connecting to networks outside the institutional infrastructure

The lack of consistency in privacy settings gives attackers room to operate. End users are strict on security on one network but are inconsiderate on what information they post online. System administrators need to be careful as hackers can gather and use any piece of information available

to search for their victims, the most popular source for such a search being the internet and social networks. The study discovered that email is one of the routes attackers use to access a network. When users use the institution network to send and receive emails they are putting the network and information in jeopardy. As employees connect to both the private (corporate) and public (internet) networks, their computers become less secure as they can run malicious applications it was further discovered that some UNAM staffs are irresponsible when using the institution's computers. They often leave their computers unattended and without the proper password. All these behaviours make data and information vulnerable to attacks. These findings substantiate the findings of Gyunka & Christiana [23] who indicated that the lack of consistency in privacy settings gives attackers room to operate and phish information to attack the network [19, 21].

4.5. Deficiency of well-formulated personal security and Unlawful application usage

Lack of strong passwords to social media accounts such as Facebook and Twitter could be an entry point for hackers. Also, unauthorised applications used by users in the university network could compromise the security of the university networks. The institution and worker's personal information could be in jeopardy when unofficial applications are used on the institution network [23]. The unauthorised applications are mostly downloaded from malicious websites. This application can come along with viruses, Trojan Horses or worms. The study found out that malicious programs could be spread over the university network when files are downloaded from unknown and untrusted web sites. This could cause a serious security breach. These findings concur with the findings of the study conducted by Gyunka & Christiana [23] which indicated that unauthorised applications used by users in corporate networks could compromise the security of these networks.

4.6. Distant employee security

As institution's operations become more and more dispersed and transition online, mobile workers increase the potential threat for data [19]. Employees tend to move unfinished work to their devices and take it along at home so that they could work on it later. This is quite risky because often personal computers and devices are less secured compared to corporate ones. The study has shown that improper handling of data, such as moving files from an office device to a home computer that does not have proper IT security measures attracts information theft. Hadlington [19] also indicated that one of the hazardous behaviours of exposing information to attacks is sending them home with an employee. This tendency can turn all of the security measures in an institution into a useless process and could put information at risk of theft and other threats.

4.7. Threats from within the institution (inside attackers)

When workers are discontented with their jobs, peeved with their boss, or sentimental for any reason, they can become insider threats who can purposely damage or leak data [19]. The study established that when employees are unhappy with their jobs, angry with their boss, or sentimental for any reason, they could become insider threats who can purposely damage or leak information. Therefore, users could expose information deliberately to hurt the institution because of some reason as stated above. Hadlington [19] indicated that sometimes the problem is not that users ignore security threat but the users are the threats themselves they have the potential to deliberately expose information. Hence is crucial to come up with hiring and termination procedures to avoid attack from disgruntled employees.

5. CONCLUSION AND RECOMMENDATION

Cyber-attacks increasingly became more and more sophisticated as systems get dispersed and distributed over the internet and its root causes are system end-user errors. Hence, this study aimed to identify human errors and recommend possible countermeasures. It was concluded that entities need to address human actions and not only technologies. Even though the technology is indispensable in the information security structure, relying on technology alone is insufficient to safeguard the university's information system from data breaches. End-users need to be incorporated into an information security model to make the security framework complete. It is not a sensible idea to think that the role of people is to run the applications only but people must be considered in terms of security. System end-users can be the weakest or the strongest aspect in the security framework and therefore should alleviate the deficiencies in the prevailing security technology. For that reason, the study concluded that there is a need for the university to integrate IT technological solutions, however, technology alone is not a complete solution to mitigate cyber-security risks and attacks, rather, consider both software, hardware and human actions to achieve an effective information security management system in the university setting. It is recommended that for the end-user errors in information security to be managed meritoriously, the university must encourage and raise the security awareness of possible security incidents or attacks, risks, threats, vulnerabilities, and data protection requirements. It must also strengthen its ICT policy to serve as a guideline. In addition, the division in charge needs to use security best practices.

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A LIGHTWEIGHT TWO-LAYER BLOCKCHAIN MECHANISM FOR RELIABLE CROSSING-DOMAIN COMMUNICATION IN SMART CITIES

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ABSTRACT

The smart city is an emerging notion that is leveraging the Internet of Things (IoT) technique to achieve more comfortable, smart and controllable cities. The communications crossing domains between smart cities is indispensable to enhance collaborations. However, crossing-domain communications are more vulnerable since there are in different domains. Moreover, there are huge different devices with different computation capabilities, from sensors to the cloud servers. In this paper, we propose a lightweight two-layer blockchain mechanism for reliable crossing-domain communication in smart cities. Our mechanism provides a reliable communication mechanism for data sharing and communication between smart cities. We defined a two-layer blockchain structure for the communications inner and between smart cities to achieve reliable communications. We present a new block structure for the lightweight IoT devices. Moreover, we present a reputation-based multi-weight consensus protocol in order to achieve efficient communication while resistant to the nodes collusion attack for the proposed blockchain system. We also conduct a secure analysis to demonstrate the security of the proposed scheme. Finally, performance evaluation shows that our scheme is efficient and practical.

KEYWORDS

Smart city, IoT, Lightweight blockchain, Reliable Communication.

1. INTRODUCTION

The development of Internet of Things (IoT) technology gives rise to many urban technologies, scenarios of which are more and more extensive: smart power grid [1, 2] relying on IoT infrastructure implemented intelligent monitoring and dispatching of power resources, simplifying complicated household electricity consumption procedures, and better coordinate supply and demand of urban electricity; With the help of IoT and edge computing, real-time systems such as Internet of vehicles [3], UAV [4, 5] have great potential value in intelligent transportation, intelligent logistics, urban security, agricultural monitoring and other aspects. The development and integration of these technologies enhance the bright future of smart city [6].

However, smart city faces many challenges [7-11]. First, smart city is a huge and complex system, and various devices are mainly not interoperable between them, which limits the collaborative work of the smart city. The above problem also exists in cross-city communication processes. Secondly, many data generated in smart city system are privacy-sensitive, such as user

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identity, purchase records, position information, etc. Therefore, it is challenging to implement a reliable, privacy guaranteed, heterogeneous cross-domain data communication network within and between smart cities. In addition, complex, frequent interaction systems tend to be fragile, which is threatened by plenty attacks, such as sybil attack allowing a malicious user or device to adopt multiple identities to occupy majority resources, Dos/DDoS attack which threats traditional centralized smart city network infrastructure, collusion attack which may control the entire smart city system, etc. These attacks may lead to the collapse of the entire smart city system or the loss of user's profit.

In order to solve these problems, there is a heated discussion in academia, producing many representative views: Rahman et al. proposed a IoT infrastructure based on blockchain and smart contract, which used to guarantee super wisdom city sustainable IoT security requirements in a shared economic [12]. Yu et al. proposed a distributed big data audit scheme based on lightweight blockchain to eliminate dependence of data audit on third-party authorities in traditional smart cities [13]. Sharma et al. proposed a smart urban automotive industry infrastructure based on the blockchain, which can be used to organize the manufacturing, supervision, maintenance and insurance services of self-driving vehicles, suitable for future smart contracts and smart applications [14]. These schemes prove that blockchain, as the infrastructure, can well organize the interactions within the distributed system and ensure the data integrity within the system. In addition, blockchain can credibly organize resource scheduling within a distributed system. These correspond to the dilemma faced by smart cities. Therefore, we could adopt blockchain to solve the problem of cross-domain communication within and between smart cities.

However, the application of blockchain in IoT has many drawbacks. First, as the price of high reliability, the cost of computation associated with traditional PoW based blockchain is so high that it doesn't apply to most IoT devices, because their computing resources are limited. The computing overhead of blockchain is mainly generated by the consensus protocol, but if we simply reduce the complexity of consensus computing, then the reliability of blockchain will decrease. How to balance the reliability and efficiency of blockchain could be a tricky issue. Second, blockchain is a public distributed ledger, and any participant has the right to access all information on the chain. This privacy protection brings challenges, so we need to implement an effective privacy protection mechanism on the basis of the blockchain infrastructure.

Our contribution: In this article, we designed a lightweight blockchain based on a two-layer blockchain to meet the cross-domain communication requirements of smart cities to address the previously mentioned issues of data security, privacy, and efficiency. Our contributions are as follows:

- (1) We adopt a layered network structure to optimize the consumption of computing resources and realize access control. We use sub-chain and global-chain to organize the distributed architecture within the domain and between the domains/cities, so as to reduce the storage and computing pressure of devices.
- (2) We designed a lightweight consensus protocol for the sub-chain, which enables the nodes to reach agreement on pooled data, dynamically manage the credit value of each node, and timely eliminate the Byzantine nodes. The improved PoS consensus protocol is adopted in the global-chain.
- (3) According to the threat model we defined, we proved the security of the scheme.

Organization: The structure of this article are as follows. In section 2, we present some background that is related with our work. Our proposed methodology is illustrated in section 3. In section 4, some related work was presented. Finally, section 5 concludes this paper.

2. BACKGROUND

In this section, we introduce the basic concepts of smart cities and blockchain, and introduce threat models to help readers to understand our solution.

2.1. Smart City

2.1.1. Preliminary

A smart city architecture could be simply abstracted into three levels: terminal equipment, edge devices, cloud server.

- (1) Terminal equipment, such as various sensors, cameras and so on. These terminal devices directly collect data in the city, but their computing and storage resources are limited, so it is difficult to handle the computing tasks with high time complexity.
- (2) Edge devices, such as roadside routers. These edge devices handle several terminal devices, which have a little more computing power, but still can't handle complex calculations. The calculation of edge equipment requires data collected by the terminal equipment in charge of its own or adjacent edge equipment.
- (3) Cloud servers, all data are stored in the cloud server, and complex computing is also carried out in the cloud server.

A number of such smart city systems can be linked together to form smart city clusters. Cross-domain (which includes cross-city) communication is performed through cloud servers to disseminate data, while the edge and terminal equipment inside cities cannot directly interact with equipment outside cities. Here we divide a cloud server and the edge devices and IoT devices it manages into a domain. The construction of smart city cluster introduces cross-domain communication.

2.1.2. Threat model

Due to the existence of malicious users or devices, as well as the unreliable communication channels, the complex network structure of smart cities often faces many security and privacy threats. Based on the smart city architecture and blockchain related preliminary introduced in the previous section, we define the threat models in this system as follows:

- (1) Individual malicious device or user: by manipulating the malicious device, the attacker can release false information, lose packets, choose and forward packets and other attack means, thus damaging the normal operation of the system, or damage the reputation of other devices to gain more benefits in the reputation system.
- (2) Device collusion attacks: in a smart city system, it may be easy to control edge or IoT devices, increasing the likelihood that an attacker will take control of as many devices as possible and make them work together for the same malicious purpose. It is not realistic to control more than half of the devices in the city, so we consider that attackers may interfere with the blockchain by controlling some devices for a period of time.
- (3) DoS/DDoS attacks: considering the possible collusion of devices, we should also be aware that these conspired devices can perform DoS/DDoS attacks by sending large numbers of requests to the target device.

2.2. Blockchain

Blockchain [15] proposed by Satoshi Nakamoto in 2008 is generally regarded as a distributed, decentralized and highly trusted ledger. Blockchain enables accounting participants to reach consensus to transactions in a verifiable and secure way [16]. Its application scope is expanding from the financial field to the non-financial field. The blockchain infrastructure can be abstracted into three levels.

- (1) Block: Participants listen to the broadcast of transactions, summarize them into the block and encapsulate it with hash, which ensures that the data integrity in the block can be verified.
- (2) Blockchain ledger: Transactions are packaged into the block together with the hash of the previous block, which constitutes a chain structure that cannot be tampered with. Blocks are arranged in time sequence, and the order cannot be changed.
- (3) Consensus agreement: In the blockchain network, each accounting node holds a copy of the blockchain, and in order to eliminate the influence of Byzantine nodes (on premise that the total number of nodes n and the number of Byzantine nodes f meet the requirement of $n > 2f + 1$), we need a consensus mechanism to make the accounting participants reach a consensus on the account book. Representative consensus protocols include Proof-of-Work (PoW) and Proof-of-Stake (PoS). PoW consensus protocol binds the workload of the block generation through hash collision calculation, and guarantees the credibility of the account book by assuming that it is difficult to master more than half of the computing resources of the whole network unilaterally. Obviously, PoW is not suitable for IoT devices. However, PoS determines the accounting right of nodes through the amount of equity held and the holding time, and guarantees the credibility of account books by assuming that it is difficult to unilaterally control more than half of the interests of the whole network. PoS avoids a lot of computing overhead and is suitable for IoT devices as well as edge devices.

3. METHODOLOGY

In this section, we will briefly introduce the scheme we designed, including distributed smart city system, intra-city communication based on sub-chain and cross-city communication based on global-chain, as well as the blockchain structure reconstructed based on smart city system.

3.1. Overview

- (1) Sub-chain: The sub-chain is deployed inside the smart city, forming a peer-to-peer network between edge devices and edge devices, edge devices and cloud servers, and edge devices and sensors or actors. We deploy sub-chain on this distributed network. Sub-chain is a private blockchain used to track and record the interactions and reputation information of various nodes within a city, and has a series of policies to constitute internal and external access control management. As the city communication involves the privacy of many users, it is necessary to introduce the password mechanism to encrypt the data. Considering the limited storage resources of terminal devices such as sensors and referring to the Simple Payment Verification (SVP) node in the Bitcoin network, we only store the block header information in the terminal device, but store the complete copy of account book in the edge device. The edge device periodically uploads a copy of the ledger to the cloud server, releasing storage resources. Considering the limited computing resources of terminal and edge devices, we introduce a new consensus protocol based on average reputation value fusion to eliminate the influence of Byzantine nodes on the network.

- (2) **Global-chain:** In order to facilitate the collaborative work between regions within cities and between smart cities, we consider the possibility of constructing smart city clusters. Cloud server/cloud server clusters in their respective cities can form a cross-domain (and cross-city) distributed network on which we try to deploy the parent chain. The parent chain adopts PoS consensus protocol.

3.2. Sub-chain: a reconstructed blockchain

Considering that the terminal and edge devices in the smart city system are resource-limited and low energy consumption, it is unreasonable to deploy the block chain based on PoW protocol on these devices. Therefore, we reconstructed a new blockchain for the sub-chain.

- (1) **Block structure:** A block in sub-chain consists of header and body, whose structure is shown in Table 1, including the current block hash, the previous block hash, reputation root, strategy table, timestamp, and transaction root. The reputation tree is a tree data structure that uses the modified Merkle Patricia Trie structure to record the reputation value of nodes. Such data structure allows the node to record only the modified data in the block without affecting the computation of the reputation value, thus effectively reducing the memory footprint and computational complexity, as shown in the figure. The block body is composed of a reputation tree and a transaction tree, and the reputation value of each sub-chain node is recalculated after suspicious behavior, such as access violating the access control policy, and the creation of invalid blocks or transactions.
- (2) **Transaction structure:** The transaction structure is shown in Table 2, where we define the micro scale transaction data structure in detail, including the initiator device ID and target device ID, initiator signature, and additional data segments. This data structure takes up very little storage space, thus saving the limited storage resources in the sub-chain nodes. Since our reputation evaluation algorithm includes various weighting coefficients, we define a set of operations to describe transactions with different weighting coefficients. We classify transactions into the following five categories:
- a) **QUERY:** the device queries specific information about the specified device by issuing a QUERY.
 - b) **REPLY:** the target device of the QUERY transaction takes advantage of the additional data segment of the REPLY transaction to REPLY.
 - c) **UPDATE:** the device broadcasts an UPDATE transaction to UPDATE the status of the device (such as a new action initiated by the actor, a new state detected by the sensor, a new device found by the edge device, etc.).
 - d) **RATE:** the equipment scores the reputation of a certain device through the reputation evaluation scheme, and announces the score by initiating the RATE.
 - e) **ASSERT:** a device broadcasts its own exception state by initiating the transaction.

Table 1. Composition of a block.

Contents	Size(bit)	Description
CURRENT_HASH	80	Hash of current block
PRE_HASH	80	Hash of previous block
TMP	24	Timestamp
ROOT_REP	80	Root of reputation tree
ROOT_TRANS	80	Root of transaction tree

Table 2. Composition of a block.

Contents	Size(bit)	Description
TYPE	4	Type of transaction
ID_FROM	8	UID of sender service
ID_TARGET	8	UID of target device
SIG	1024	Signature of sender
ADD	1024	Note of transaction

- (3) Data processing: Every new node is assigned a pair of public and private keys before entering the domain. The unique ID of each node comes from its own public key to ensure the anonymity and non-repudiation of the framework. When a node receives a transaction, it must verify the signature of the transaction message to ensure the integrity and authorization of the transaction message, and transactions that are not validated are discarded. In order to minimize the computational overhead of terminal and edge devices, we use Keccak cite lightweight hash digest algorithm compared to the commonly used hash algorithm [17-19], because it is considered to have high performance in both program size and cycle counting. And we truncated the hash digest to 80 bits to save memory.
- (4) Storage release mechanism: The maintenance of blockchain requires the continuous linking of new blocks to the end of the chain, which makes the ledger volume larger and larger. The capacity of terminals and edge equipment is limited, so we can infer the use frequency of equipment from data such as road conditions and people flow, and try to backup the data when the use frequency is low. After data backup is complete, terminal and edge devices need to free up memory in a timely manner.

3.3. Sub-chain: a consensus protocol based on reputation fusion

In this section, we introduce the credibility evaluation mechanism for sub-chain nodes and the consensus mechanism based on this mechanism.

3.3.1. Reputation evaluation mechanism

Our proposed trust evaluation mechanism maintains a credit score for each node in the sub-chain. When a new node joins a domain, other nodes in the network set an initial credit value of 100 for that node. When other nodes consider the node to be a Byzantine node (state exception, access and operation violating policy, etc.), the credit value is appropriately reduced according to the illegal operation of the node. This value can be increased when the node executes the correct command or feedback.

A node's credit is evaluated by other nodes that interact directly with it. Considering that different transactions have different characteristics, we add the weighted factor W of the transactions into the credit evaluation calculation. We should also consider the timeliness of the data when evaluating the reputation of a node, so we specify that the node traverses and evaluates each transaction record at time t . At time t , the evaluation result of node v given by node u is $R_{u,v}(t)$, and we have:

$$R_{u,v}(t) = \frac{\sum_{i=1}^{C(u,v,t)} \sigma(t,i) \cdot Q(v,i) \cdot W(v,i)}{\sum_{i=1}^{C(u,v,t)} W(v,i)}$$

in which $C(u,v,t)$ represents the number of transactions generated between node u and node v before time t , $Q(v,i)$ represents the quality coefficient of i th transaction between u and v , $W(v,i)$

represents the significance coefficient of i th transaction between u and v , and $\sigma(t, i)$ represents the timeliness coefficient of i th transactions. It is not difficult to understand that transactions with lower timeliness have less impact on the current system, so transaction timeliness is inversely proportional to its ability to affect the node's reputation. Let $t(i)$ be the moment when the i th transaction is completed, we define:

$$\sigma(t, i) = 1/(t(i) - t)$$

In this way, the credit value of each node is evaluated by other nodes that interact directly with it and updated dynamically. However, we need to consider that there is often more than one node to judge the reputation of node v , and that the evaluation of v by different nodes may vary according to the transactions with v . We believe that weighted reputation fusion is a good solution to this problem. Let $R(t_0)$ be the weighted credit score set of other nodes at time t_0 , let $R_v(t)$ be the weighted credit score set of the newly calculated node v at time t , let R_v be the credit score set of other nodes on node v . First, we removed the maximum and minimum values in order to reduce the impact of the maximum on the score without negotiation:

$$R_v^* = R_v \setminus \{\max(R_v, \min(R_v))\}$$

After that, we take the reputation of other nodes as the weight, and calculate the weighted average of the reputation score of other nodes to node v as the current weighted reputation score of node v . We have:

$$R_v(t) = \sum_{i=1}^N \frac{R_i(t_0)}{\sum_{j=1}^N R_j(t_0)} \cdot R_{i,v}(t)$$

in which $R_{i,v}(t)$ represents the reputation score of other node i to node v . We take $R_v(t)$ the reputation of node v at time t .

3.3.2. Consensus protocol

In order to eliminate the influence of a small number of Byzantine nodes on the overall global ledger, so that all nodes reach a final agreement on the state of the ledger, we need a consensus agreement. In order to solve the contradiction between security and computing overhead mentioned above, we design a lightweight consensus protocol based on the credibility calculation method introduced above, which can avoid huge computing overhead while ensuring the anti-collusion performance of sub-chains.

Committee election: inspired by the DPoS protocol, we adopted the method of selecting a node delegation to be responsible for bookkeeping and generating new blocks, with the nodes in the delegation taking turns to be responsible for bookkeeping and block production in a specific order. The process of producing blocks does not require complicated mathematical calculations. We propose strategy 1 and strategy 2 for the sub-chain as the basis for delegation elections and mix the two strategies as the consensus agreement for the sub-chain.

- a) Strategy 1: randomly select sub-chain nodes as miners. On the premise that more than half of the sub-chain nodes are trusted, we can randomly select a sub-chain node to be responsible for transaction collection, block packaging and release in the production block. Considering the limited computing resources of the terminal equipment, we can appropriately prefer the edge equipment node when selecting the miner.

- b) Strategy 2: vote for sub-chain nodes as miners. Under the premise of a majority of the chain, we can select first n nodes for candidate nodes according to descent ranking of nodes' reputation, constitute a set S , and choose K online nodes to constitute the final mining executive set E . Nodes in E take turns as the miner, until all nodes in E were travelled, and reselection of E should be triggered. If the ledger is bifurcated, then we can assume that the credit value of nodes within S will change, so we need to re-select S .

The advantage of strategy 1 is that it is difficult to predict the miners' nodes in each round of production block, so the influence of Byzantine nodes in the sub-chain on the whole system is minimized. The advantage of strategy 2 is that there will not be frequent and complex miner election behavior for a period of time, thus achieving optimal sub-chain performance. Strategy combining strategy 1 and strategy 2, we finally designed the consensus protocol as shown in Algorithm 1.

In this way, users can adjust each threshold to adapt to different security needs or security environment, and the sub-chain will adjust the system state timely according to the security threshold set by users, and actively isolate the Byzantine nodes with greater influence, to further reduce the influence of Byzantine nodes.

Algorithm 1: Consensus Protocol

Input:

Counting Threshold T_1 ;
 Duration Threshold T_2, T_3 ;
 Reputation Threshold T_4 ;
 S Election Counter β_1 ;
 Timer β_2 ;

Output:

Global Consensus

1. begin
2. start β_2
3. for $\beta_1 = 0$ to T_1 do
4. exec Strategy 2
5. end for
6. stop β_2
7. if $\beta_1 > T_1$ and $\beta_2 > T_2$ then
8. for v in whole network do
9. $R_v(t) \leftarrow R_v(t)/2$
10. end for
11. clear β_2 and start
12. exec Strategy 1
13. if $\beta_2 > T_3$ then
14. stop β_2
15. isolate v in whole network which $R_v(t) < T_4$
16. end if
17. end if
18. clear β_1, β_2
19. goto 2
20. end

3.3.3. Block Release

Another important issue for leveraging the blockchain technique in the resource constrained IoT network is storage release problem. As in the blockchain technique, each node will store a copy of the whole ledger, the size of the blockchain system will grow with the block increase. However, in the IoT systems, each IoT device is with limited storage. Thus, we need a mechanism to release the past block in the IoT devices without decreasing the security of the blockchain system. In our design, we leverage the constant release method to address this problem. With a constant time, all nodes will agree with the current status of the blockchain systems. All nodes will store a consensus block that stores the hash value of the previous blocks, and this consensus block will act as a new genesis block. The block data will be stored in a server for inspection when it is needed in later.

4. SECURITY ANALYSIS AND PERFORMANCE EVALUATION

4.1. Security Analysis

According to our design of lightweight consensus scheme, if the sub-chain in the frequency range of users receive the blocks bifurcates, then the sub-chain automatically bifurcates into a safer consensus strategy, and isolate the credibility not timely recovery of nodes (we can assume that the nodes have great influence on the system). Therefore, if a Byzantine node wants to survive in a sub-chain for a long time, it must compress the length of its abnormal state to a range acceptable to the user. From the reputation evaluation mechanism, it can be seen that the higher the credibility of the node, the greater the weight of other nodes. Obviously, under the premise that the number of Byzantine nodes is less than 1/2 of the number of summary points, the colluding Byzantine nodes cannot play a decisive role in the credibility of the node. To sum up, the influence of Byzantine nodes on system security is likely to be tolerated by users or external systems.

4.2. Malicious Server

As mentioned before, a malicious server might damage the availability of the whole system in two methods. Broadcasting fake information which might cause usage accidents could be defended by the novel reputation evaluation scheme. It mainly because the activities of each device in the network are being evaluated to build a trust rating scheme and the receiver accepts or drops the message according to the reputation value of the server. Thus, those fake information and unfair reputation report messages could be blocked with high probability.

4.3. Dos/DDos Attacks

In the design of our system architecture, the Dos/DDos attack can be mitigated by evaluating the reputation value of each node in the blockchain. If a malicious node executes the Dos/DDos attack, it is needed to generate amount of blocks to consume other nodes' resource. However, when a new block is broadcasted to the blockchain network, it will consume a predefined amount of reputation of the block holder. When the block holder's reputation decreased to a low bound, all its blocks broadcasted to the blockchain network will be discarded by other nodes. In such a manner, each node in the blockchain network can only issue a limited number of blocks, and thus the Dos/DDos attack is mitigated by our design.

4.4. Performance Evaluation

In this subsection, we conduct an experiment to evaluate the performance of our proposed blockchain system. We implemented the nodes' reputation value in three different manners: all nodes are with the same reputation value and this value is constant, a random reputation is set for each node in the system, and our presented reputation computation method.

As shown in Figure. 1, with the time increase, the reputation of a malicious will go down in our method and the random reputation method. Moreover, the reputation of a malicious in our method is lower than that of the other method. Thus, the attack executed by the malicious node can be protected better in our design.

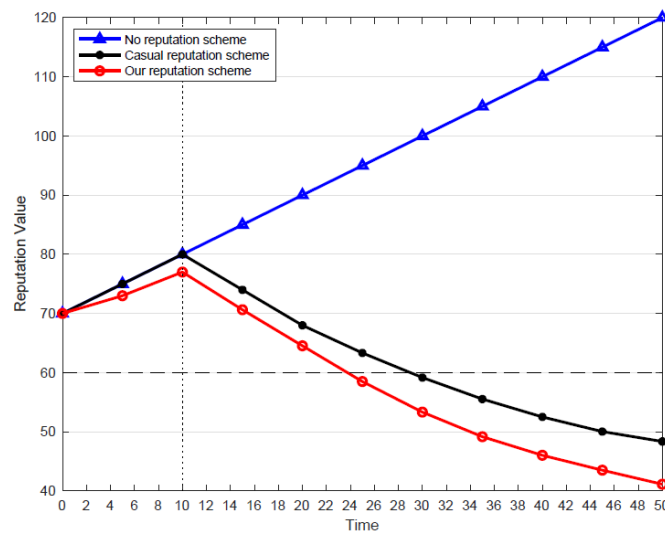


Figure 1. Reputation fluctuation of a malicious node

5. RELATED WORK

For the security and privacy protection of smart cities, the academia has proposed many feasible schemes. Mehdi Gheisari et al. adopted the smart city IoT system based on software custom network (SDN) and proposed an effective privacy protection method [20]. Yin et al. proposed an attack vector assessment model based on vulnerability, path and action, and proposed a formal representation and quantitative assessment method for network security risk assessment of critical information infrastructure in smart cities [21]. Wang et al. ensured information security at the hardware level [22]. Badii et al. proposed an Internet of things and smart city platform that conforms to the GDPR specification, and claimed to have verified the reliability of the scheme in practical application [23]. Some researchers also proposed to use ontology to define an edge computing network to protect privacy [24]. Khatoon et al. proposed an efficient, secure, bilinear pair-based, unlinked, and mutually authenticated key protocol to ensure the privacy security of telecare medicine information system (TMIS) [25]. Duan et al. focused on modelling privacy content from multiple sources, mapping them to the data, information, and knowledge types of resources in the well-known DIKW architecture [26]. Sucasas et al. proposed a protocol based on OAuth 2.0 for privacy protection in smart city mobile applications [27]. Gope et al. proposed a lightweight, private-protected RFID authentication scheme for distributed Internet of things infrastructure based on secure localization services for smart urban environments [28].

On the other hand, the blockchain technique has been leveraged in many other IoT application scenarios due to the development of embedded processors, high speed network technique and artificial intelligence. Adopting the blockchain technique in the Internet of Vehicles (IoV) is an emergence representative. The first decentralized trust management mechanism based on blockchain for IoV which leveraged the proof of stake and proof of work consensus protocol was introduced by Yang et al. [29]. In their scheme, the trust value model was used to evaluate a node pow to write a new block. Ma et al. [30] introduced a novel lightweight blockchain system for the IoV system. In their design, the reputation of a node is viewed as its stake. To ensure real time communication, they designed two separated chains to deal with the outside communication and inside communication for a vehicle. Later, many different blockchain platforms was designed to realize secure, robust and privacy communications in the IoV network.

6. CONCLUSION

In this paper, we investigate the probability of blockchain infrastructure organizing a cross-domain communication in smart city, proving that blockchain is of great future to solve privacy preserving and data integrity issues in smart city. To solve contradiction between computational-sensitivity of blockchain and limited computational resources in smart city, we proposed two-layer blockchain architecture: sub-chain and global-chain. To fit IoT devices, we reconstructed the data structure of blockchain and proposed a reputation-based consensus scheme inspired by DPoS consensus protocol. Security analysis and related experiment are performed to prove the effectiveness of our scheme. We consider our scheme as a new thought that can solve data security issues in smart city.

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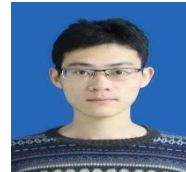
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DATABASE SECURITY IN A DYNAMIC IT WORLD

Sub-Title: Examine Database Security Fundamentals That Help To Make Sure High Levels of Flexibility in Data Use, And Effectiveness in Data Protection

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ABSTRACT

Databases are vulnerable. Public statements by Target, Home Depot, and Anthem following their extremely advertised data breaches are each uniform and succinct on how their breaches unfolded: unauthorized access to those systems that ultimately led to the extraction of sensitive information. A comprehensive strategy to secure a database is over data security. Usually, security events will be related to the later action: illegitimate access to data confidentiality damage, injury to the integrity of knowledge, loss of data accessibility (Discover). Loss of privacy of data, creating them accessible to others without a right of access is not visible within the database and does not need changes deductible database. This paper addresses these events to confirm database security.

KEYWORDS

Data Security, Database, Data Integrity, Data Science, Information Technology.

1. INTRODUCTION

There is a great need for information security due to many factors. Database security refers to the use of a wide range of information security controls to protect databases (possibly including data, database applications or stored functions, database systems, database servers, and associated network connections) from compromising their confidentiality, integrity, and availability, include different types or categories of controls, such as technical, procedural, and physical. The cost of data breaches is increasing while the brand and business impact of a data breach is difficult to separate from other influences, there will be tangible costs to the organizations affected; for example, to protect data subjects from further harm through free credit monitoring and identity protection services. Information Security solutions protect enterprise and government information and aid to discuss the need for compliance with Government and business needs in physical and virtual systems [10] Security technologies that help protect against misuse by external hackers and internal privileged users embrace information Masking, encoding, Identity Management, Degaussing, Firewalls, Auditing, and necessary Access Controls [23].

In this Research Project, I examine database security fundamentals that will help to prove high levels of flexibility in information use, and effectiveness in data protection.

2. DATABASE SECURITY

Definition - What does Database Security mean?

We can define database security as the joint measures adapted to protecting and secure an information or database management software system from unlawful use and malicious threats and attacks. This is also concerned with the utilization of a wide range of data security controls to defend databases against the compromises of their confidentiality, integrity, and accessibility.

It includes different types or categories of controls such as technical, procedural / administrative, and physical. Database security could be a specialty in the broader areas of computer security, data security, and risk management. Security risks for database systems are for example: Illegal or improper use by authorized database users, database administrators or network or system administrators or by hackers (for example unauthorized access to confidential data, metadata or functions in databases or improper changes to programs, structures or database security settings); Malware infections that include incidents such as unauthorized access, loss or disclosure of private or proprietary data, deletion or damage to information or programs, interruption or denial of authorized access to the database, attacks on alternative systems and thus unforeseen failures of the database services Overloads, performance constraints, and capacity issues that result in authorized users not using the databases as intended; Physical damage to database servers from fire or flooding in the computer room, overheating, lightning, accidental spillage, static discharge, electronic failure / device failure, and obsolescence damage or loss of data from entering invalid data or commands, errors in the database or system administrative procedures, sabotage / criminal Damage [25], etc. Ross J. Anderson mentioned above generally that security breaches can never be released through the abuse of massive databases; if it is intended for a large simple access system, it becomes unsafe; If it is made waterproof, it cannot be used. This is often referred to as Anderson's Rule. Many levels and types of information security control apply to databases, including access control, auditing, authentication, encryption, integrity controls, backups, application security, and database security using statistical methods. against hackers through network security measures such as firewalls and network-based intrusion detection systems, while network security controls remain valuable in this regard and the core systems themselves protect data and the programs / functions and data between them have arguably become more critical as networks are increasingly open to broader access System access, program, function and data access controls along with the associated user identification, authentication and rights management functions have always been of crucial importance for restricting and sometimes recording the activities of authorized users. Users and Administrators In other words, these are complementary approaches to database security that works both outside and inside [18].

- Database security encompasses and enforces security in all aspects and elements of databases. This includes:
 - Data stored in the database.
 - Database server
 - Database management system (DBMS)
 - Database workflow applications
- Database security is generally planned, directed, and maintained by a database administrator and/or alternative data security expert. Discusses and implements some of the ways information security can:
 - Limit unauthorized access and use by implementing robust, multifactorial data management and access controls.

- Load/stress tests and capacity tests of a database to ensure that it does not crash during a Distributed
- Denial of Service attack (DDoS) or user overload. Physical security of the database server and backup equipment against theft and natural disasters Verify Existing systems to identify known or unknown vulnerabilities and processes and implement a roadmap/plan to mitigate them (Stephens, Ryan (2011). Databases are vulnerable. Public statements by Target, Home Depot, and Anthem following their highly published at a breach are both uniform and concise on how their breaches unfolded: unauthorized access to those systems that ultimately led to the extraction of sensitive information [8].

2.1. Can a Database really be Secure?



Data breach prices are mounting. Though the impact of data breaches on brand and business is tough to segregate from different influences, what is clear is that there are tangible expenses that the breached firms incur; for instance, in their honesty efforts to protect affected people from more damage with free credit observance and identity protection services. Also, class-action lawsuits represent another expense[10].

2.2. Info Security Best Practices

Info Security Best Practices info security has never been additional vital, given the high-value hackers' place of information. These info security best practices can facilitate defend your knowledge [26]

- Ensure physical database security.
- Use web application and database firewalls.
- Harden your database to the fullest extent possible
- Encrypt your data.
- Minimize value of databases

- Strictly Database Access Management
- Audit and monitor database activity.

2.2.1. Ensure physical database security

Databases contain knowledge, and knowledge corresponding to Mastercard data is effective to criminals. Meaning Information is a sexy target for hackers and its why database security is vital [26]. guarantee physical info Security within the ancient sense, this simply means keeping your info server in very secured surroundings with access controls and far away from the unauthorized individual. However, it means that keeping the database on a separate physical machine, off from the machines running application or net servers [26] An online server is possible to be attacked since it is in an incredibly open place and thus in publicly accessible. And if an online server is compromised and therefore the info server runs on a similar machine, the hacker would have access as a root user to your information [26]

2.2.2. Use net Application and information Firewalls

Your database server ought to be protected against info security threats by a firewall, that denies access to traffic by default. the sole traffic allowed through ought to return from specific applications or net servers that require to access the information [27]. The firewall is supposed to defend your information from initiating an outbound connection except otherwise. Similarly, to protect the info with a firewall, you must deploy an online application firewall that is because of attacks corresponding to SQL injection attacks directed at an online application will be accustomed exfiltrate or delete data from the database [27]. An information firewall will not essentially stop this from happening if the SQL injection attack comes from an associated application that is associate allowed supply of traffic, however, an online application firewall might. For additional on SQL injection attacks, see a way to stop SQL Injection Attacks [27]

2.2.3. Harden Your Database to Fullest Extent Potential Clearly.

It is vital to confirm that the info you abuse continues to be supported by the seller or open supply project to blame for it which you are running the foremost up-to-date version of the info computer code with all info security patches put in to get rid of better-known vulnerabilities. However, that is not enough.

2.2.4. Minimize Value of Databases

It is also vital to uninstall or disable any options or services that you just do not ought to use and make sure that you alter the passwords of any default accounts from their default values - or higher still, delete any default accounts that you just do not need [27].

Finally, make sure that all database security controls provided by the info are enabled (most are enabled by default) unless there is a reason for any to be disabled. Once you have done all this, you must audit the hardened configuration - using an automatic change auditing tool, if necessary, to confirm that you just are instantly responsive to a change to the hardened configuration is created that compromises your database security [27].

2.2.5. Encrypt Your Data

It is a standard operating procedure in several organizations. To encrypt stored data, however, it is important to ensure that backup data is additionally encrypted and stored separately from the decryption keys [29] Not, as an example, stored in encrypted type, however alongside the keys in

plain text.) also as encrypting data at rest, it is also important to ensure that sensitive data is encrypted while in transit on your network to protect against database security threats [10].

2.2.6. Strictly Database Access Management

Database Administrators should only have the minimum permissions they have for their work and only during the periods of time they have access. This may not be practical for smaller organizations, but permissions should at least be managed through teams or roles instead of being assigned directly [10]. If your business is a larger organization, it is important to consider automating access management using an access management software system. This could give authorized users with a temporary password the permissions they need every time they need to access a database, and it records the activity applied during that period and prevents administrators from sharing passwords while administrators have an Alize share Undoing passwords makes database security and accountability nearly impossible [12].

In addition, it is advisable to ensure the following standard account security practices:

- Passwords must be implemented securely
- Password hashes should be encrypted and kept salty.
- Accounts should be locked after three or four attempts to log in.
- A procedure should be put in place to ensure that accounts are disabled when employees leave or change roles entirely.

2.2.7. Audit And Monitor Database Activity

These includes monitoring logins to the operating system and database and reviewing logs frequently to check abnormal activity.

Effective monitoring call allow you to easily detect a compromised account. It allows you to verify if users are sharing accounts and provide you with a warning if accounts are created without your permission (for example, by a hacker).

Database activity monitoring (DAM) software system will help with this by providing monitoring which is independent of native database logging and monitoring functions; it also can help monitor administrator activity [8].

3. TOP DATABASE SECURITY VULNERABILITY

The top database vulnerability by far is SQL injection, Sabo detected. For eight years SQL injection was at the top of the list of top security threats compiled by the Open Web Application Security Project (OWASP). These occurrences occur when untrustworthy information is disseminated as part of a command or query and the system for executing it performs unplanned commands or accesses information without proper authorization. For example, forms used on websites can be filled in with specially crafted code instead of regular text replies (like name and address) so that the website can query the database directly by simply entering the information. [12].

3.1. 10 Tips for Defense against SQL Injection

"Building a robust defense against SQL injection requires a comprehensive defense-in-depth strategy," says Sabo.

There are several facets to this:

3.1.1. Implement Continuous Monitoring

Monitoring and continuously analyze all SQL statements generated by applications connected to databases to identify vulnerabilities and incorrect SQL statements. Qualities like dB Networks DBN-6300 will come in handy here. "Identifying malicious SQL on the core network is the last line of defense before the database is compromised," said Sabo.

3.1.2. Baseline Database Infrastructure

Database Connectivity Insecure and unpatched applications may have unknowingly connected to production databases, providing an easy way for attackers to enforce coding best practices.

3.1.3. Enforce coding best practices

Do not chain dynamic SQL to external input and use parameterized SQL when you need external input need to process. Disable unnecessary database functions. This prevents an attacker from using these skills, which are carefully paid for privileged skills and command shell spawning.

3.1.4. Enforce Least Privileges

Keep application privileges to the minimum.

3.1.5. Apply Patches

SQL injection vulnerabilities are **common** in commercial software **systems**,so patch as **soon** as **possible**.

3.1.6. Perform Penetration Testing

Consider regular penetration tests of database-connected applications to identify infiltrated vulnerabilities Implement perimeter security Firewalls and IDSs are primary line of defense against SQL injection. Keep the signature files until this point in time.

3.1.7. Suppress the Error Messages

Attackers can learn a lot about your architecture and operating environment through error messages. saved as local. If external messages are required, keep them generic.

3.1.8. Enforce Password Policies

Enforce the use of strong passwords and change the passwords for application accounts in the database daily [12].

3.1.9. Calculating The Cost of a Data Breach In 2018, The Age of AI and the IOT

Businesses run on risk; they place their bets on the market and they sometimes get good rewards. But when you consider the cost of a data breach, you will wonder what the value of your business is and what exactly is at stake. Here is one way to look at it: It is more likely that there is a data breach of at least 10,000 records (27.9%) this winter than getting the flu (5-20 percent, online with WebMD). As with the flu, acting quickly and asking for a cure is critical to a speedy

recovery. Since data breaches cost money, it is better to advocate a cost-based approach to get a proper perspective on the problem at hand [8] Implementation of Artificial Intelligence (AI) and the in-depth use of Internet of Things (IoT) devices. The analysis also includes the cost of a so-called mega-break, an event that leads to the loss of a million or more records, and the monetary consequences of a loss of customer trust in the organization [15].

3.1.10. Investigating the Impact of AI and IoT Adoption

This year's study examined for the first time the effects of adopting AI in organizations as part of their security automation strategy and in-depth use of security devices. Artificial intelligence security platforms save an average of \$ 8 per compromised record for companies that also use machine learning, analytics, and orchestration to help human responders and contain violations. However, only 15% of company surveys indicated that they have fully implemented AI. Meanwhile, companies using IoT devices pay an average of an additional \$ 5 per compromised record[8].

Customer Trust Impacts the Total Cost of a Breach



4. THE DEVIOUS EMPLOYEES AND THE MALICIOUS HACKER

Organizations around the world lost customers because of data breaches within the past year. However, businesses that worked to enhance customer trust reduced the number of lost customers — thereby reducing the price of a breach. Once they deployed a senior-level leader, like a chief privacy officer (CPO) or chief information security officer (CISO), to direct client trust initiatives, businesses lost fewer customers and, again, reduced the monetary consequences of a breach [8]

Organizations that offered data-breach victim's identity protection kept additional customers than people who did not [8]

5. 2018 COST OF A DATA BREACH STUDY BY PONEMON

IBM was proud to sponsor the 13th annual Cost of a Data Breach Study, the industry's gold standard benchmark study conducted independently by the Ponemon Institute.

Year's 2018 study reports the world cost of a data breach is up half-dozen.4 % over the previous year to \$3.86 million. the common price for every lost or taken record containing sensitive and guidance conjointly hyperbolic by 4.8% year over year to \$148 [8]

6. COST OF IBM DATA SECURITY SERVICES ESTIMATED

Research has proven that IBM data Security Service is one of the trusted so, I recommended it and should in case I want to propose this to any organization, I will work with the following team Chief financial officer, 3 data Analyst, Project Manager and Chief Information Officer. we got quotes from different information security services providers and we went with IBM [8]

However, I realize most standard organization all have their data on the cloud and the most widely used is Microsoft SQL management server studio which I discovered IBM support. Here is the functionality below:

- Critical data protection program: help protect your most important data from compromise.
- Data loss prevention and encryption: help protect sensitive data and enforce company security policies.
- Managed Cloud data Protection: Secure your cloud data with a managed cloud access security broker (CASB) solution
- End to end Support by IBM Services
- Must execute within ninety days of provisioning
- 20 Virtual Servers

Cost

starting at \$65,000.00 per Virtual Server

6.1. What is a data breach?



I said a breach refers to an event where a person's name and a medical record or financial file or debit card, whether electronic or paper, are likely to be at risk. Data breach - Malicious or criminal attack, system failure, or human error. The cost of a data breach will vary depending on the cause and protective measures at the time of the data breach.

6.2. How can a Compromised Record Be Defined?

We can define this as the data that identifies an individual whose info has been lost or stolen during a data breach. One example may be a retail company's database with an individual's name associated with Mastercard details and the concerns personal details [8].

6.3. How is the Data Collected?

They collected data in-depth qualitative information through more than a pair of 500 separate interviews conducted over a 10-month period at intervals 477 organizations. Recruiting of organizations began in February 2017 and it completed interviews in April 2018. In every of the 477 taking part organizations, we have an intention to speak with an IT compliance and data security analyst who are knowledgeable in their organization's data breach and the costs related to resolving the breach. For privacy functions, we did not collect organization-specific info. solely occurrence directly relevant to the information breach experience is represented during this research [8]

6.4. How Is the Data Breach Price Calculated?

To understand the common fee for a data breach, we aggregate all direct and indirect fees incurred through use by the organization. Direct expenses comprise taking part in forensic specialists, outsourcing hotline support, and providing free credit monitoring subscriptions and discounts for future product and services. Indirect costs include in-house investigations and communication, also because of the extrapolated value of client loss resulting from turnover or diminished client acquisition rates. For consistency with previous years, we use a similar currency translation technique instead of changed accounting costs [8]. This approach solely affects global analysis because of all country-level results are shown in local currencies [8].

Key Findings during this section of the report, we offer a quick outline of the major salient findings from the analysis and how the costs have changed over the past year.

6.5. Percentage Amendment in Data Breaches Measures Over the Past Year

- The global cost of data breaches inflated.
- The average total cost of data breach inflated by 6.4 % and the per capital cost inflated by 4.8 percent.
- The usual size of a data breach (number of records lost or stolen) increased by a further 2.2 percent.

Data breaches are most expensive in the US and the Middle East, and cheapest in Brazil and India. The average total price within u. s. was \$7.91 million and \$5.31 million within the geographical region. the lowest average total price was \$1.24 million in Brazil and \$1.77 million in India. the absolute best average per capita prices were \$233 within U.S and \$202 in Canada.

Notification prices are the highest within United State. These prices comprise the creation of contact databases, determination of all regulative requirements, engagement of outside consultants, postal expenditures, email bounce-backs, and incoming communication set-ups. Notification prices for organizations within U.S was at \$740, 00 whereas India had the lowest at \$20,000. U. S and the geographical region paid the foremost on post data breach response. Post data breach response activities entails help desk activities, incoming communications, special inquiring activities, remedy, legal expenditures, product discounts, identity protection services,

and regulative interventions. Within U.S, these prices were \$1.76 million and \$1.47 million within the geographical region [8].

7. CONCLUSION

Database Security is a broad topic, covering many vulnerabilities. Various malicious people often caused data Security issues to get information and to cause harm [30]. Two types of attacks can be carried out on databases: Physical attacks and logical attacks. Physical attacks can include the forced disclosure of sensitive information such as passwords, the destruction of storage devices in the system, a complete power outage, and the theft of secure information. To prevent such attacks, the usual method is to restrict access to everyone. Storage devices. Backup and recovery procedures. While logical threats are intentional or unauthorized access to sensitive information. This is usually done through software. Logical threats can lead to denial of Service (DOS), disclosure of confidential information and data moderation.

Ensuring data security databases is achieved by following two rules.

- Security requirements, Implying vulnerability management and review.
- Managing access.

The DBCC CHECKDB procedure is used to check the errors in the database as regards data integrity.

Managers of a database often undervalue DBCC CHECKDB procedure; it represents an especially important, often crucial aspect of protecting the business data. I said prevention to be better than cure. We can take precautions; I am sure we can avoid financial consequences that could cause the loss of data. There are several security methods available to protect the database system from external users in the network. In other to protect the database system, IBM's data security service can be considered as well as data governance.

ACKNOWLEDGEMENT

I would like to thank everyone that made contributions in making the work successful.

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AUTHOR

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I am an Efficient Data Analyst professional with expert skills in SQL, Power BI, Tableau, EXCEL, and other data analytics tools. My experience includes generating, manipulating, interpreting, and analyzing data in a fast-paced delivery and operations.

Growing up, I have always enjoyed solving puzzles. So, this is the same way I see Data Set. I see it as a puzzle I want to solve. Finding the patterns nobody sees is a challenge to me.



AN INTELLIGENT MOBILE FLOATING APPLICATION TO AID SENIORS IN USING THE SMARTPHONE USING MACHINE LEARNING

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ABSTRACT

The twenty-first century is a century of rapid technological growth, one significant area being the smartphone [4]. By 2021, more than eight percent of US adults own a smartphone. Smartphones are capable of making phone calls, messaging texts, making purchases, taking pictures, playing games, finding roads, and more. However, not everyone is a beneficiary of this technology. Seniors often fall behind in this technology advancement. They often struggle with finding the right button to press or get confused with the variety of functions. This paper develops a floating application that when launched, checks the opening application and displays a list of its functions. Then, the user can select what they want to do, and the application will begin a tutorial to guide the senior in using their phone. We applied our application to Google Play and conducted a qualitative evaluation of the approach. The results show that this application will be effective in facilitating seniors in using the smartphone.

KEYWORDS

Machine Learning, Big Data, Mobile Application.

1. INTRODUCTION

The twenty-first century saw a rapid growth of technology in transportation, aerospace, scientific research, recreation, home utilities and communication [5]. Since tech giant IBM's development of the world's first smartphone---Simon---smartphones and mobile devices have undergone a series of revolutions and changes. From sending messages to searching online forums, from taking pictures to editing videos, the function of the smartphone has extended to all parts of our lives [6]. However, the reliance on technologies has resulted in a series of problems. Whilst appreciating technology's great power, the term "technical difficulties" is common without professionals. Even the national television makes errors with technology sometimes. This phenomenon is especially common among the older generation, or rather, any generation other than Generation Z. In 2021, the digital divide is not only between the rich and the poor, but has also emerged between the young and the old [7].

In the world of COVID-19, the reliance on technology has created a series of issues for those who are unfamiliar with it. In the beginning of the pandemic, many stores and restaurants were shut down, most of which shifted their service online [8]. Many schools and workplaces require online qualtrics or surveys to enter. Even vaccine centers rely on online appointments. However, these interfaces are usually filled with information too complicated for seniors, because it is hard for older people. While some elder-lies may ask young people for help, this may not be the case all the time. Also, this is merely shifting the reliance on technology to the reliance on

youngsters and does not solve the problem. Should technology wait for the people? But there are people benefiting from it. The implementation of technology during COVID-19 has encouraged social distance, reduced face-to-face contacts, and facilitated contact tracing [15]. Thus, we came to the conclusion that assistance is needed to seniors and those who struggle with technology.

There have been some proposals to facilitate seniors in using their smartphones. Some phones and applications have incorporated an Easy Mode into their program. For example, the Easy Mode on Samsung Galaxy Smartphones alters the UI to a version with a simpler layout, larger icons, and larger texts. The Bald Phone is another interface designed for senior citizens. It replaces the phone's original interface into a bigger and simpler one. However, this approach has many limitations. First, this approach makes some settings and functions unavailable, which may be more counterproductive in some circumstances. Because the algorithm does not apply on browsers and websites, users will still struggle on the internet. If the easy mode or interface is not up to date, they will still be struggling with technology when they want to use a new function that just came out. Additionally, this approach does not teach the user how to perform a certain function. While it helps with some functions on the smartphone, the user will still be left in confusion when they need to use technology on other devices. The fundamental problem, seniors' struggle to understand the necessary workflow in using an interface, is neglected [9].

Our proposed method is a floating application that provides tutorials to functions on a variety of APPs. When the user needs help, they can simply click on the floating icon and the app will display a list of available tutorials in the form of questions. The user can then select a question they have, and a corresponding tutorial will display by drawing indicators and notes on the screen. Our goal is not only to facilitate senior usage in the mobile phone with our application, but also to teach seniors how to perform a function in the normal interface. This approach will teach seniors the processes of normal APPs with guidance and help them understand the fundamental logic behind APP layouts [10]. Ideally, the seniors will eventually be able use APPs without any additional help.

In two application scenarios, we demonstrate how the above combination of techniques increases. First, we show the usefulness of our approach by a comprehensive case study on the evolution of the Easy Mode application. Second, we analyze the evolution of our floating app. To show our solution actually solves the problem, we design two different experiments. Experiments 1 test AI prediction results with test cases, Experiments 2 shows user surveys which can help us know if the app is useful or not.

The rest of the paper is organized as follows: Section 2 outlines the details on the challenges we encountered while designing the sample; Section 3 describes our methodology and algorithm in detail; Section 4 presents the experiments and evaluations process of designing our APP; Section 5 discusses works relating to our research; finally, Section 6 ends the paper with a conclusion and remarks on future works.

2. CHALLENGES

In order to build the tracking system, a few challenges have been identified as follows.

2.1. Identify the type of the APP the user is on

The first challenge we encountered was how to identify the type of the APP the user is on in order to provide the correct list of tutorials. We don't want to have the user tell us and want our algorithm to be able to detect it. Our solution was to take a screenshot of the screen, and identify

it with machine learning using our database, which consists of screenshots from a variety of APPs [12]. Another challenge embedded in taking the screenshots is the timing. When the user clicks on the icon, the APP takes a screenshot of the screen and displays a set of functions in the form of questions. However, if the timing is incorrect, the list might display after the screenshot, and the algorithm will not be able to evaluate the correct APP.

2.2. Overlaying the instructions on screen real-time

Another challenge we faced was how to overlay the instructions on screen real-time. We want to put our tutorials directly above the user's screen instead of displaying a marked up screenshot. This is because we need to work with other APPs to draw tutorials over it. It is a struggle to have third-party APPs cooperate with us. Also, this function requires the APP to be constantly aware of what the current screen is displaying. If the display changed, we can't have the drawn tutorials still be in their original places.

2.3. Choose the right tip and rendering strategy

Another challenge we faced was how to accurately choose the right tip and rendering strategy [11]. To display our tutorial, we will draw boxes and add notes to let the user know where to press. However, we can't manually draw out all tutorials for all screen sizes, so we calculate it through keywords. It is very difficult because different phones have buttons of different shapes and sizes. Although we can find the general area at which the rectangles should be drawn, it is very difficult to get the box right around the button. We also faced the risk of the screen changing after we determined where to draw the box and write the notes.

3. SOLUTION

Tutorial4Senior is an intelligent mobile floating application to aid seniors in using the smartphone using machine learning. When first launched, the APP will ask for permission to float over other APPs and permission to take screenshots. The APP will then appear on the screen as a floating icon. When a user needs help, the APP will take a screenshot of the current screen and identify what APP the user is using, using machine-learned data from our screenshot database. Then, the APP will display a list of questions that asks how to perform a function on the APP such as: How to write a message? The user can then select a question that matches their needs. The APP will then draw boxes and display notes on the screen to indicate what the user should do to achieve their purpose.



Figure 1. Screenshot of Tutorial4Senior

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@Override
protected void onCreate(@Nullable Bundle savedInstanceState) {
    super.onCreate(savedInstanceState);

    setContentView(R.layout.splash); // set the UI to be activity_magic_8_ball

    new Handler().postDelayed(() -> {
        Intent intent = new Intent(getApplicationContext(), Magic8BallActivity.class);
        startActivity(intent);
        finish();
    }, delayMillis: 2000);

```

Figure 2. SplashActivitiy.java

When the APP is first launched, the user will first see a splash screen, giving the APP a few seconds to load completely. The implementation of the splash screen is done using a very standard Android activity. It is based on a standard layout with a logo in the center. The Android intent is used to delay and trigger the start of the next screen. The default delay is 2 second but we can customize the delay time with any given number.

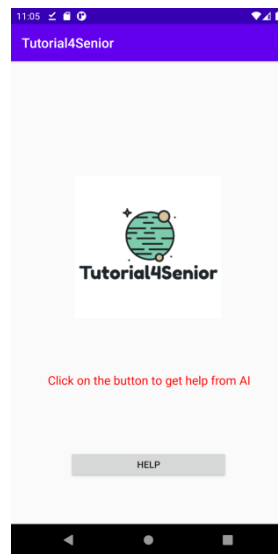


Figure 3. Screenshot of getting help

```

40      setContentView(R.layout.activity_magic_8_ball); // set the UI to be activity_magic_8_ball
41
42      requestPermission();
43      checkDrawOverlayPermission(getApplicationContext());
44
45      final MediaProjectionManager mgr =(MediaProjectionManager) getSystemService(MEDIA_PROJECTION_SERVICE);
46
47      DisplayMetrics displayMetrics = new DisplayMetrics();
48      getWindowManager().getDefaultDisplay().getMetrics(displayMetrics);
49      int height = displayMetrics.heightPixels;
50      int width = displayMetrics.widthPixels;
51      Log.i( tag: "test", msg: height + "," + width);
52
53      getAnswerButton = findViewById(R.id.button);
54      helpButton = findViewById(R.id.button4);
55
56      getAnswerButton.setOnClickListener((view) -> {
57
58          System.out.println("The button is clicked!");
59
60          Intent startIntent = new Intent(getApplicationContext(), ClassifierActivity.class);
61          startActivity(startIntent);
62
63      });
64
65
66
67
68      helpButton.setOnClickListener((view) -> {
69          startActivityForResult(mgr.createScreenCaptureIntent(),
70                              REQUEST_SCREENSHOT);
71      });
72
73

```

Figure 4. Magic8BallActivity.java

This is the home screen of Tutorial4Senior. The code sets up a button that listens for the user to press. This is a very critical screen for the whole application [13]. Once the user presses the button the app will first check the permissions required to run this app. This app runs at the system level because it needs to check the status of the app as well as putting overlays and getting screenshots at the system level [14]. These types of functionality require system permissions such as recording the screen, rendering content as overlays on the other apps, and setting the floating icon as a launcher app on the top of the screen. If any of these permissions were not given by the user when we run this app, the app will pop up the dialogue to ask the user to enable these permissions before we can move on to the next screen. A specific 3rd party library is used to simplify the permission checking and permission requesting process, as a standard Android way of getting these permissions requires more code. Once all the permissions are given and set, this screen will be stopped and the app will move on to the launcher app mode.

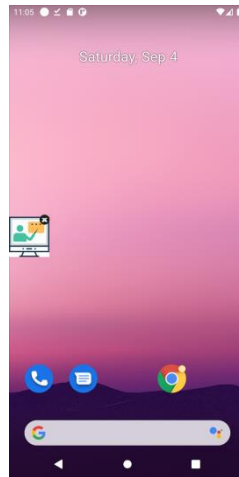


Figure 5. Screenshot of the button

```

150  @Override
151  public boolean onTouch(View v, MotionEvent event) {
152      switch (event.getAction()) {
153          case MotionEvent.ACTION_DOWN:
154              initialX = params.x;
155              initialY = params.y;
156              initialTouchX = event.getRawX();
157              initialTouchY = event.getRawY();
158              return true;
159
160          case MotionEvent.ACTION_UP:
161              //when the drag is ended switching the state of the widget
162              collapsedView.setVisibility(View.GONE);
163              startCapture( imagePurpose: 1);
164
165              new Handler().postDelayed(() -> {
166                  expandedView.setVisibility(View.VISIBLE);
167              }, delayMillis: 2000);
168
169              canvasLayout = expandedView.findViewById(R.id.tutorialCanvas);
170              canvasLayout.removeAllViews();
171
172              final ListView tutorialListView = expandedView.findViewById(R.id.tutorialListView);
173              tutorialListView.setVisibility(View.VISIBLE);
174              adapter = new ArrayAdapter<String>(getApplicationContext(),
175                  android.R.layout.simple_list_item_1, android.R.id.text1, TutorialDB.getTutorialNameList());
176
177              tutorialListView.setBackgroundColor(Color.WHITE);
178
179              tutorialListView.setAdapter(adapter);
180
181
182

```

Figure 6. FloatingViewService.java (1)

An `OnTouch` method is set up for the float. The widget can be moved around the screen at the system level. When it's clicked on, it captures a screenshot of the screen. This is the core part of the code of the whole application. It mainly does the following tasks: first of all, it allows the app to run as a launcher in mode and display an icon on the top of the screen. Secondly the app can trigger getting and capturing a screenshot of the whole app whenever that user creates a contact button, and the screenshot will be sent to the machine learning engine for further analysis. Next the machine learning engine which is built-in into the app will read the image and run a deep learning classification to try to figure out what type of app is. Lastly, once we figure out the type of the app, the relevant tips and tutorials about this app will be shown up on the top of the screen. The user can select one of the tips from the screen and figure out the tutorial mode to see all the help information. More details about the tips and tutorial rendering will be discussed in the next section.

In order to differentiate the different types of app based on a given screenshot, we have applied deep learning and neural networks to do the prediction and classification. Tensorflow Lite has been applied in this case, because of its advantage of a small-sized and well-trained image classification model that is applicable on mobile devices. Running deep learning analysis on

mobile devices is really important as it provides an almost real time prediction without the costs of sending images to the cloud and waiting for the result to be sent back. In our experiments which will be discussed in section 4, we have trained over 500 screenshot images for 10 different Android apps in the Android operating system. It turns out that the result of image classification in this case is very accurate. Even though some of the apps share very similar UI, the TensorFlow based machine learning model can precisely differentiate the different types of app if sufficient images are given in the training data-set. This is a key differentiator of our app compared with most other tutorial apps available in the store, since most other apps require users to identify manually what the type of app is. However, a lot of users, particularly the senior users do not even know the name of the app, and that is when these kinds of apps cannot be used as effectively as designed. Thus, we believe that the AI-based image classification can close this gap and greatly improve the user experience.

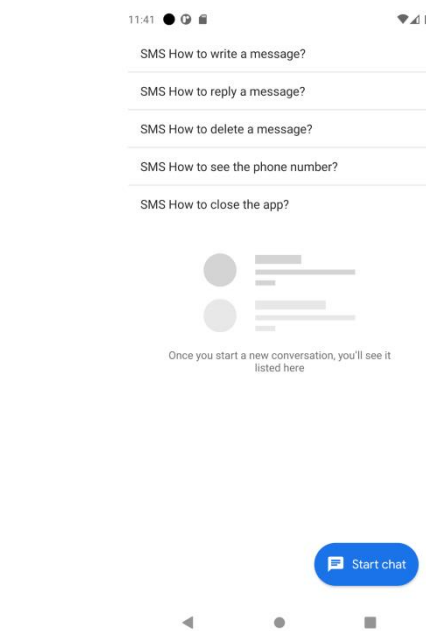


Figure 7. Screenshot of general questions

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case MotionEvent.ACTION_UP:
    //when the drag is ended switching the state of the widget
    collapsedView.setVisibility(View.GONE);
    startCapture( ImagePurpose: 1);
164
    new Handler().postDelayed(() - {
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        expandedView.setVisibility(View.VISIBLE);
    }, delayMillis: 2000);

    canvasLayout = expandedView.findViewById(R.id.tutorialCanvas);
    canvasLayout.removeAllViews();

    final ListView tutorialListView = expandedView.findViewById(R.id.tutorialListView);
    tutorialListView.setVisibility(View.VISIBLE);
    adapter = new ArrayAdapter<String>(getApplicationContext(),
        android.R.layout.simple_list_item_1, android.R.id.text1, TutorialDB.getTutorialNameList());

    tutorialListView.setBackgroundColor(Color.WHITE);

    tutorialListView.setAdapter(adapter);

    tutorialListView.setOnItemClickListener((parent, view, position, id) - {
        // position
        Log.i( tag: "TEST", msg: "Click item: " + position);
        tutorialListView.setVisibility(View.GONE);
        keyword = TutorialDB.getTutorialKeyword(adapter.getItem(position));
        startCapture( imagePurpose: 2);
        //TutorialStep ts = TutorialDB.tutorialList.get(position);
        //((LinearLayout)canvasLayout).addView(new TutorialDrawingView(getApplicationContext(), ts));
    });

    ((LinearLayout)expandedView).addView(new TutorialDrawingView(getApplicationContext(), ts));

    return true;

```

Figure 8. FloatingViewService.java (2)

Based on the result obtained from the deep learning model, we can decide the type of the app. A list of tips and tutorials have been stored in our local database for different kinds of apps. The relevant app tips will be filtered out in this case so that the users will only see the useful tips in tutorials based on the current context.

The database of storing all the tips in tutorials has been structured in such a way that it is very easy to extend it with more types of apps or tips. We have implemented a very efficient search engine to quickly match the tips in tutorial space on the name, tags, keywords, so that as long as we know the name of the app, all the relevant tutorials will be organized and displayed on top of the screen. One special UI implementation we have done here is to make sure the background color of the ListView is transparent. This is very important because it provides and allows users to see the actual app running which we believe will make the users easier to choose the right tips and tutorials. Clicking on a tutorial will trigger the next step of the tutorial help.



Figure 9. Screenshot of messages

```

18  @
19
20  public TutorialDrawingView(Context context, TutorialStep tutorialStep) {
21      super(context);
22      this.tutorialStep = tutorialStep;
23
24      int x = tutorialStep.x;
25      int y = tutorialStep.y;
26      int sideLength = tutorialStep.height;
27      int sideWidth = tutorialStep.width;
28
29      // create a rectangle to draw later
30      rectangle = new Rect( left: tutorialStep.x - 20, top: tutorialStep.y - 80, right: tutorialStep.x + tutorialStep.width - 20,
31                          bottom: tutorialStep.y + tutorialStep.height - 80);
32
33      // create the Paint and set its color
34      paint = new Paint();
35      paint.setStyle(Paint.Style.STROKE);
36      paint.setStrokeWidth(10);
37
38      textPaint = new Paint();
39      textPaint.setStrokeWidth(5);
40      textPaint.setTextSize(50);
41      textPaint.setColor(Color.BLUE);
42  }
43
44  @Override
45  protected void onDraw(Canvas canvas) {
46      canvas.drawColor(Color.TRANSPARENT);
47      canvas.drawRect(rectangle, paint);
48      canvas.drawText(tutorialStep.hint, x: tutorialStep.x - 20, y: tutorialStep.y - 130, textPaint);
49  }

```

Figure 10. TutorialDrawingView.java

As you can see in the figure shown above, the displayed tips and tutorials are purely based on the current setting of the screen. It is not a hard-coded content or image like most other apps have been providing. Instead, the app tries to identify and locate the important UI widgets such as buttons and text boxes, and draw the overlay and highlight the position for users to interact directly on top of the screen. Even if the screen size changes or the app updates the UI, as long as the label on this UI widget remains the same, the algorithm will be capable of identifying the UI widgets and displaying overlay the tutorial content in the precise position.

The main technique we use to identify the UI widget is based on text recognition. Every tip or tutorial has a bunch of keywords that we used in searching. We will send the screenshot of the app to the machine learning engine which will trigger the text recognition algorithm and extract all the text on that image. We will run a quick search algorithm to match all the text with the relevant keywords in each of the tips. If we find that any of the tapes is matched based on these keywords, we will compare all the match tips with their confidence about us. The highest confidence battle will determine which is the final tip and the rendering content to use. Every tip and the tutorial has specific overlay content information to display. We have developed a simple content rendering engine in the app so that it can briefly and clearly draw most of the commonly used highlights such as rectangles, boxes, text and labels, using different colors.

4. EXPERIMENT

4.1. Experiment 1

In experiment 1, We want to test the accuracy of the Deep Learning Image Classification Model. To evaluate the Precision, recall rate, accuracy and F1score of our deep learning model, we have collected 200 real dataset from 5 different users. Every user tries 40 different times and records if the deep learning model predicts the operation correctly. In order to compare the approaches, we conducted experiments to verify three different aspects: the accuracy of using different deep learning networks, and the result table of the network with the best accuracy performance.

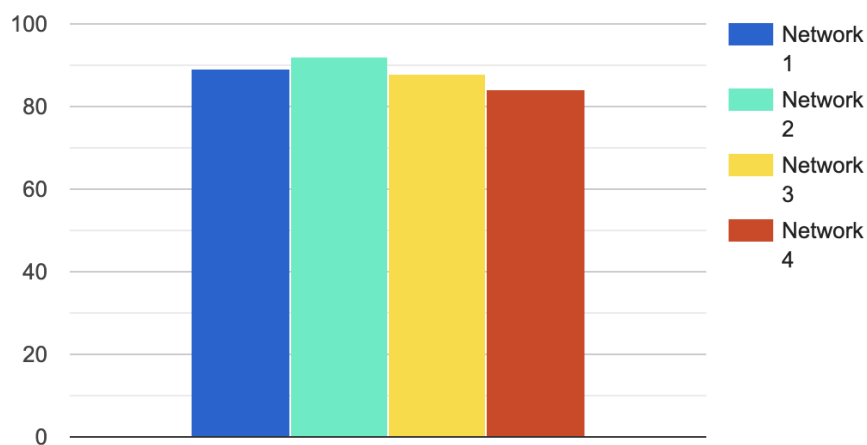


Figure 11. Experiment result

The result shows the second network has the best performance with the accuracy at 94%. It shows it can successfully predict the senior user's next operation on the mobile phones most of the time. We test the network to find the Confusion Matrix and the result shows below: Accuracy = 94%, precision = 80%

4.2. Experiment 2

In experiment 2, we designed a user review survey to test if the app actually helps senior people and check if they have any reviews and suggestions. We found 300 seniors from LA county, the test group numbers are big enough for a user survey test. We divide them into 3 different groups. Senior ages from 60 - 65 as group one, Senior ages from 65- 70 as group two, Senior ages above 70 as group three, the score table from the survey shows below:

Group	4	3	2	1	0
age 60 - 65	88	5	1	3	3
age 65 - 70	71	15	5	6	3
age above 70	66	24	3	5	2

Figure 12. Table of result

The graph below shows the rate of score 4 from different group:

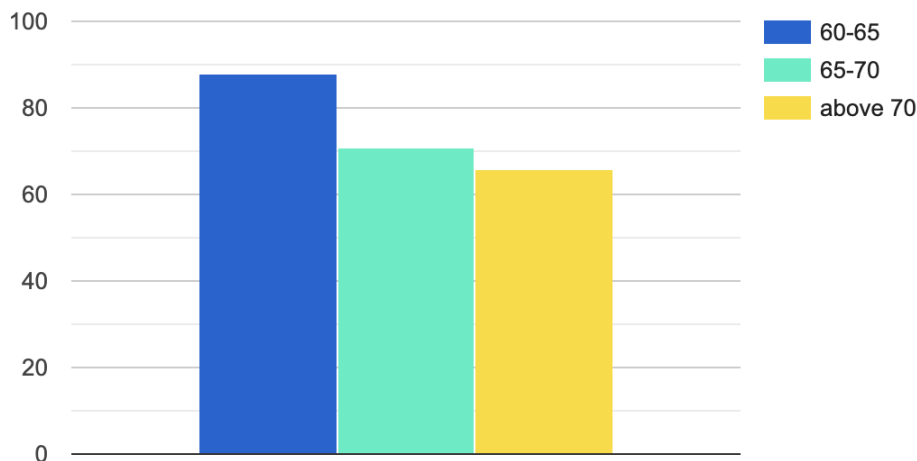


Figure 13. The rate of score 4 from different group

As elaborated above, we designed two Experiments to prove our effective solution has a high accuracy of prediction results. Experiments 1 test AI prediction results with test cases, Experiments 2 shows user surveys which can help us know if the app is useful or not. Both of the two Experiments have enough test cases with reasonable testing group and stable diversity, which can be used to prove our floating app can actually help senior people learn how to use smart iPhone.

5. RELATED WORK

Peacock and Kunemund theorized that senior citizens' lack of participation in internet technology is primarily due to "prive access possibilities, motivational indifference, and deficient knowledge." They state that efforts to close the digital age gap are crucial [1]. This paper was written in 2007 when smartphones and the internet did not have as much impact as now. By 2021, however, more than 85 percent of adult Americans will use a smartphone. While the financial-caused digital divide can be lessened with a growing economy and advancing technology, the age-caused digital divide is much harder to resolve. The older generation tends to have less experience with technology and lower education, making it harder for them to comprehend the logistics behind

APPs on mobile phones. This makes our proposal significant because not only does our APP provide tutorials, it can also teach seniors where and how to perform functions on a display like everyone else's.

Hsiao, S. et al proposed a user interface that uses the Kinect sensor [2]. The interface can be operated by hand gestures. This method will make it very easy for seniors to perform basic functions like close, swipe, return, etc, while our proposed method will make it easier to navigate more complicated functions. The method will also make it easier for seniors with neural disorders, because they will be able to perform a function without looking for that one tiny button on the small screen. On the other hand, our proposed method has an advantage to help seniors understand technology on a cognitive level.

Werner et al. suggests an iPad model designed for seniors [3]. While our proposed method provides tutorials to regular APPs, this model suggests developments of tablet based applications. The advantage of this method is that seniors will be able to use their mobile devices without any external aid. Using a tablet will also make it easier for seniors with presbyopia or other eye problems. In contrast, our proposed method helps seniors learn and adapt to APPs, which could potentially help them use their normal APPs without any aid.

6. CONCLUSIONS

Tutorial4Seniors is an intelligent mobile floating application that aids seniors in using the smartphone.

This application is primarily limited by its database. The functions users wish to perform would have to be included in our database for us to provide tutorials. As a result, we might not be able to provide for all the functions a user needs, or stay up to date with all APPs. We also do not have perfect accuracy in detecting which APP the user is on, for some APPs look alike and are hard to distinguish from one another. We were only able to design our APP for android devices because of iOS restrictions.

For future works, we hope to develop tutorials with artificial intelligence. We also wish to come up with better ways to identify the APP the user is on, either through adding more screenshots to our APP database, or initiating communications with the phone. In addition, we would like to figure out ways to implement our program on iOS.

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AN INTELLIGENT SYSTEM TO ASSIST PIANO COMPOSITION AND CHORDS GENERATION USING AI AND MACHINE LEARNING

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ABSTRACT

As a musician and producer, I've always struggled with finding chords when I first started writing music [5]. It sometimes goes to the extent of me forgetting my melody because I take so long trying to figure out the chords. So I came up with an idea for this app, that will help amateur and beginner musicians save time and provide chord suggestions to them as a booster to start writing songs [6]. It features a recording or a midi input feature, then the app will carefully analyze the given melody and give a selection of the best chord progressions using intelligent AI. As an output, it is able to present it as guitar chords, piano chords, and ukulele chords, enabling more different musicians to use this app.

KEYWORDS

Music, Chords, Melody, Chord Generation.

1. INTRODUCTION

There are many beginner musicians all around the globe, and many of them are aspiring songwriters and producers. With a proper tool, many musicians will have the benefit of saving time and getting a jump start on their passion. By using our app, the musician can simply just record or upload a file into the app, and it will automatically present a set of the best chord progression that matches their melody perfectly. After the app outputs the chord progressions, it will also provide a chord chart for three instruments, piano, guitar, and ukulele, enabling for the musicians to learn the chords along the way as well.

There isn't a tool that fits so perfectly into the needs of the musicians. There are apps that transcribe existing music into chord progressions, but there has not been an app that transcribes a brand new melody into a chord progression. The existing apps are very simple since an existing song already includes a chord progression within, so it is very easy to identify. But using a melody to determine its chords, then it is a way harder thing to achieve. Luckily, with knowledge in songwriting and coding, we are able to create a very intelligent app that will do just that, enabling musicians to easily create chord progression inspirations.

Our goal with Melodyfi is to create an algorithm that thoroughly examines the user's melody, taking the first note of each measure and matching it to a chord that perfectly fits the melody. Then the many chords will create a perfect chord progression that fits the melody and also stays within a good key. The app includes a feature that enables musicians to record their melody idea, then the algorithm takes in the melody to produce the final chord progression suggestions. Other

features that are coming with future updates, are a bank of guitar, piano, and ukulele chords that lets the user learn any chords on the instrument of their choice.

In two application scenarios, we demonstrate how the above features are of use. In experiment 1, firstly, we show the usefulness of our approach by testing the accuracy of the melody and chord progression. Second, we will compare the chord output to a real human approach in finding the chords to the same exact set of melody. In experiment 2, we create a survey and send it to a group of the users to collect the review score.

The rest of the paper is organized as follows: Section 2 gives the details on the challenges that we met during the experiment and designing the sample; Section 3 focuses on the details of our solutions corresponding to the challenges that we mentioned in Section 2; Section 4 presents the relevant details about the experiment we did, following by presenting the related work in Section 5. Finally, Section 6 gives the conclusion remarks, as well as pointing out the future work of this project.

2. CHALLENGES

In order to build the tracking system, a few challenges have been identified as follows.

2.1. Choosing chords from a melody

Whether because they do not have sufficient knowledge in music theory or if they just don't know how to compose chords, beginner musicians all around the world suffer from unable to identify chords to songs to a melody they've come up with [7]. In order to quickly come up with chords, a musician must have sufficient knowledge in at least the basics of music theory, which a lot of beginner musicians lack.

2.2. Forgetting melodies

As a Beginner musician, they forget their catchy melodies easily while in the process of songwriting due to the lack of experience. A lot of time goes into figuring out the technical side of the song instead of them focusing on the important creating part, so a lot of the time goes wasted on figuring out chord progressions or other technical music processes.

2.3. Wrong chord usage

Beginner musicians tend to create chord progressions that match the melody's notes but it is not correct by musical definition due to the lack of experience. They would write chords that "fits" technically, but does not necessarily sound good and/or is not musically correct, whether if it doesn't fit the key or many other reasons [15].

3. SOLUTION

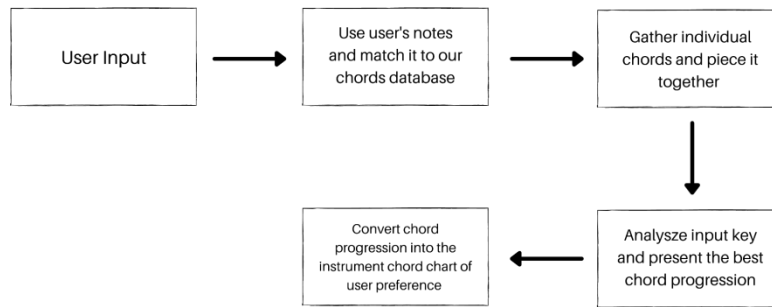


Figure 1. Overview of the system

Figure 1 shows a high-level overview of the system. The system is implemented as a web service application as the backend, and a frontend mobile UI for users to interact [8]. All the requests are coming from the mobile component, and those requests will be sent to the backend server for generating the recommended chords. The backend server runs in the cloud and it uses algorithms to process the input melody file and generate the recommended chords based on that melody. The result will be sent back to the mobile devices and the mobile screen will render the results in a user-friendly way [1]. Figure 2 shows the basic mobile design and the user experience of the app. More details about each functionality and the implementation will be discussed in sections 3.1.

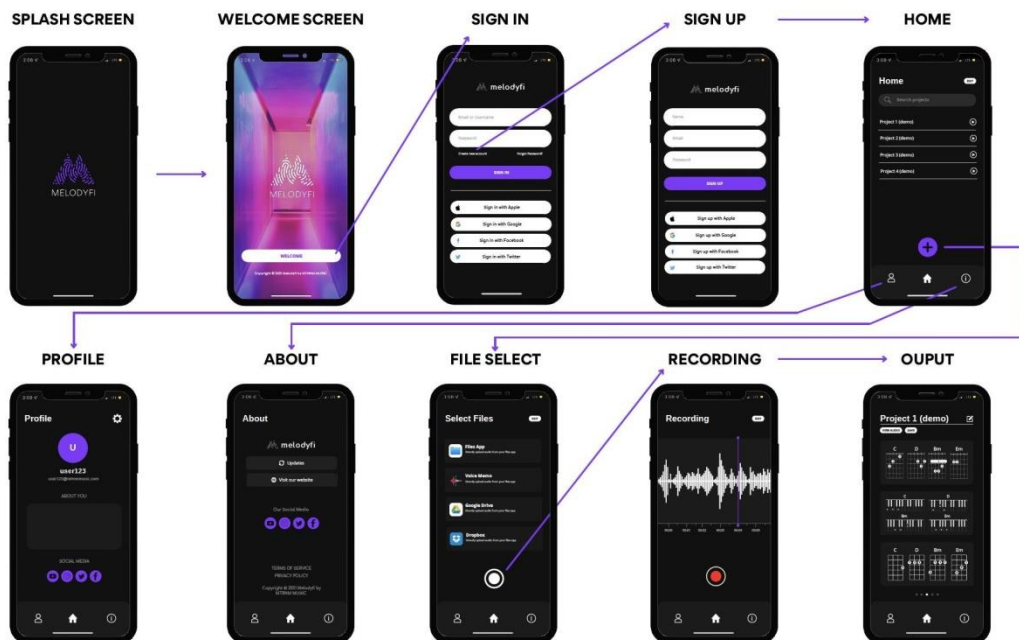


Figure 2. The UI design of the application

3.1. Mobile Development

We have decided to use Flutter to develop this mobile application. Flutter is a popular and advanced mobile development framework. It supports both Android and iOS systems, so that you only need to write the code once and the app will be generated for both platforms. Flutter uses the language Dart which is very similar to Java. Dart has a lot of new features that simplify the logic and algorithms, including a strong support from the 3rd party libraries.

```
1  import 'package:flutter/material.dart';
2  import 'splash.dart';
3
4  void main() {
5    runApp(MyApp());
6  }
7
8  class MyApp extends StatelessWidget {
9    // This widget is the root of your application.
10   @override
11   Widget build(BuildContext context) {
12     return MaterialApp(
13       title: 'Melodify',
14       debugShowCheckedModeBanner: false,
15       theme: ThemeData(
16         primaryColor: Colors.black,
17         accentColor: Colors.cyan[600],
18         backgroundColor: Colors.black,
19         canvasColor: Colors.black,
20         textTheme: const TextTheme(
21           ) // TextTheme
22       ), // ThemeData
23       home: Splash(),
24     ); // MaterialApp
25   }
26 }
```

Figure 3. The code excerpt of the app starter main method

The entrance to the app is specified in the MyApp class. Our app uses material design. As we can see from the code above, we specify the color theme used for the app. The color theme includes the primary color, accent color, background color, canvas color and text theme. Flutter uses a lot of Json style specifications for different kinds of configurations [9]. This code also specifies the very first screen to start with when people run the app.


```

26 Widget build(BuildContext context) {
27   return Scaffold(
28     body: Center(
29       child: Container(
30         width: double.infinity,
31         decoration: BoxDecoration(
32           image: DecorationImage(
33             image: AssetImage("asset/bg_app.png"),
34             fit: BoxFit.cover,
35           ), // DecorationImage
36         ), // BoxDecoration
37         child: Column(
38           // mainAxisAlignment: MainAxisAlignment.center,
39           children: [
40             Expanded(
41               child: Image(image: AssetImage("asset/white_icon.png"))
42             ), // Expanded
43             Container(
44               margin: EdgeInsets.only(bottom: 20),
45               child: Text(
46                 "Copyright @ 2021 Melodyfyfi by MTRNM MUSIC",
47                 style: TextStyle(
48                   fontSize: 12,
49                   color: Colors.white
50                 ), // TextStyle
51               ), // Text
52             ) // Container
53           ],
54         ), // Column
55       ), // Center
56     ), // Scaffold
57   );

```

Figure 4. The code excerpt of the app splash screen

The code above shows how we implemented the splash screen [10]. All of the UI layout and components are specified in the build method. In this case, a center layout is used that includes a container with the image inside. A line of text is displayed at the bottom of the screen for the copyright information. All the images used in the app must be specified in the yaml configuration file first before being referred to in the UI code such as AssetImage [11].

```

37   child: ListView.separated(
38     padding: const EdgeInsets.all(8),
39     itemCount: entries.length,
40     itemBuilder: (BuildContext context, int index) {
41       return Center(
42         child: SizedBox(
43           width: double.infinity,
44           child: ListTile(
45             title: Text('${entries[index]}',
46               style: TextStyle(fontSize: 20,
47                 color: Colors.white
48               ), // TextStyle, Text
49             subtitle: Text(
50               criteria[index]['description'],
51               style: TextStyle(
52                 color: Colors.white
53               ), // TextStyle
54             ), // Text
55           ), // ListTile
56         ); // SizedBox, Center
57       },
58       separatorBuilder: (BuildContext context, int index) =>
59         const Divider(),
60     ), // ListView.separated

```

Figure 5. The code excerpt of the about screen

The app uses a bottom navigation bar to navigate between different screens. The first item in the bottom navigation bar is called “learn”. This table shows all the information about the app including how to use the app, the purpose of the app, and the user tips. The screen contains most of the text information. In order to make the screen more extensible and customizable, we have stored all the text information in the list of strings. As we can see from the code above, the UI of this screen uses a ListView to display the list of strings. All the text information is not hard-coded, so that whenever we need to make a change, the only change to make is the list of strings.

```

67 void _onVideoButtonPressed(BuildContext context) async {
68   FilePickerResult result = await FilePicker.platform.pickFiles(
69     withData: true
70   );
71   Navigator.push(
72     context,
73     MaterialPageRoute(
74       builder: (context) => ResultPage(
75         fileBytes: result.files[0].bytes, startValue: keyMap[dropdownValue]
76       )); // ResultPage, MaterialPageRoute
77 }

```

Figure 6. The code excerpt of the file upload library

The middle tab is the major functionality of the app. Users choose the base key and upload a file of the melody, so that all these inputs will be sent to the backend server for processing. This UI is implemented with a couple of UI input widgets including the drop-down menu, and the file upload button. File upload on a mobile device requires interaction with the operating system [12]. In our app, we have applied a 3rd party library to facilitate the file uploading process. This library automatically interacts with both Android and iOS file systems so that whenever a user presses the button, it triggers the external file picker used by the operating system which enables users to easily pick the files from different folders and different categories. The code shown above shows how the file picker library works. It is a very simple and straightforward API to call that will return all the file information being selected. The selected default information will be sent to the next crane where the results green will process all the requests and render the result.

```

44 void uploadFileToServer() async {
45   print("uploading ... " + widget.startValue);
46   var url = 'https://justin-zhang-server.sunyu912.repl.co/uploader/' + widget.startValue;
47
48   http.MultipartRequest request = http.MultipartRequest('POST', Uri.parse('$url'));
49   await request.files.add(
50     http.MultipartFile.fromBytes(
51       'file',
52       widget.fileBytes,
53       filename: 'test.midi',
54       contentType: MediaType('audio', 'midi'),
55     ), // http.MultipartFile.fromBytes
56   );
57
58   request.send().then((r) async {
59     print(r.statusCode);
60     if (r.statusCode == 200) {
61       results = json.decode(await r.stream.transform(utf8.decoder).join());
62       if (results.isNotEmpty) {
63         print(results);
64         _saveScores();
65         updateResult();
66       }
67       print(results);
68     } else {
69       setState(() {});
70       print('error + $r.statusCode');
71     }
72   });
73 }

```

Figure 7. The code excerpt of sending the midi file to the backend for processing

When the next screen receives the selected file, it will send all the chosen file together with the chosen base key to the back-end server. We have applied the HTTP library in Dart to send all the requests. The back-end server has been hosted in replit.com with the HTTPS configured. Sending the HTTP from Dart in Flutter is very straightforward by specifying the base URL, the input parameters, and the file input. The library takes care of converting the chosen file on the mobile device to an array of bytes which will be sent together in the HTTP request. A callback is used here to check the response. If the status code is 200, and if the content is returned correctly, we will save the results on the local device with the local database, followed by rendering all the generated results on the screen.

```

75 void updateResult() {
76   for (var gen in results) {
77     print(gen);
78     var r = Row(
79       children: [],
80     );
81     for (var key in gen) {
82       print(key);
83       r.children.add(Expanded(
84         child: Image(
85           fit: BoxFit.cover,
86           image: AssetImage("asset/keys/" + key.toString() + "_key.png"),
87         ), // Image
88       )); // Expanded
89     }
90     rows.add(Divider(
91       color: Colors.white
92     ));
93     rows.add(r);
94   }
95   setState(() {
96   });
97 }
98 }

```

Figure 8. The code excerpt of converting the generated chord result to images

The updateResult method handles rendering the final result on the screen. The generated chord is saved in the list as integers. The updateResult method reads the list and chooses the corresponding images to use in the display. In order to improve the performance of the rendering, we have stored all the images on the device since there are a certain number of keys being used in the generation process. Loading these images directly on a device is a lot faster compared with loading those from servers. We simply use a file name schema to automatically map the key number to the image.

```

34 _loadScores() async {
35   SharedPreferences prefs = await SharedPreferences.getInstance();
36   List dates = [];
37   if (prefs.containsKey('date')) {
38     dates = prefs.getStringList('date');
39     for (var date in dates){
40
41       scores[date] = json.decode(prefs.getString(date));
42       print(scores);
43     }
44     setState(() {
45     });
46   });
47 }
48 }

```

Figure 9. The code excerpt of loading the persisted generated results

In order for the users to view the past generated chords, we have implemented a local database to store and persist all the generated results. Every time a generation request was handled successfully, the result will be saved as a Json string in the SharedPreferences. SharedPreferences is a simple mechanism supported by most mobile operating systems to store the information as key-value pairs [13]. Instead of setting a professional relational or non-relational database, the SharedPreferences provides a very simple and rapid way to handle the local information storage efficiently.

4. EXPERIMENT

4.1. Experiment 1

For experiment 1, we check for the AI's accuracy on the chord progression output. I asked 10 participants to try inputting 5 different files with different keys into the apps. The results they received are all very accurate since the AI targets the specific notes and produces the chords based on the notes. The data table shows below:

tester	chords1	chords2	chords3	chords4	chords5
1	correct	correct	correct	correct	correct
2	correct	correct	correct	correct	correct
3	correct	error	correct	correct	error
4	correct	correct	correct	correct	correct
5	correct	correct	correct	correct	correct
6	correct	correct	correct	correct	correct
7	correct	correct	error	correct	correct
8	correct	correct	correct	correct	correct
9	correct	correct	correct	correct	correct
10	correct	correct	correct	correct	correct

Figure 10. Table of chords

In the table we can see that the AI's accuracy on the chord progression output is 94%. Based on the test cases and performance we can consider that the AI has a high accuracy rate.

4.2. Experiment 2

For experiment 2, we compare the AI's output to humanistic output β if the musician produces the chords with his own thinking. We ask 5 musician produce to do the test and the result turns like this:

	Total patterns	Chords Maches With AI
musician 1	6	3
musician 2	8	3
musician 3	15	6
musician 4	18	7
musician 5	5	3

Figure 11. Table of result

After comparing some results, we can conclude that the list of chords contains at least one of the chord patterns produced by a human.

4.3. Experiment 3

For experiment 3, we create a review survey provided to users. We collected all the data from the 50 different users to check the review score, the result shows below:

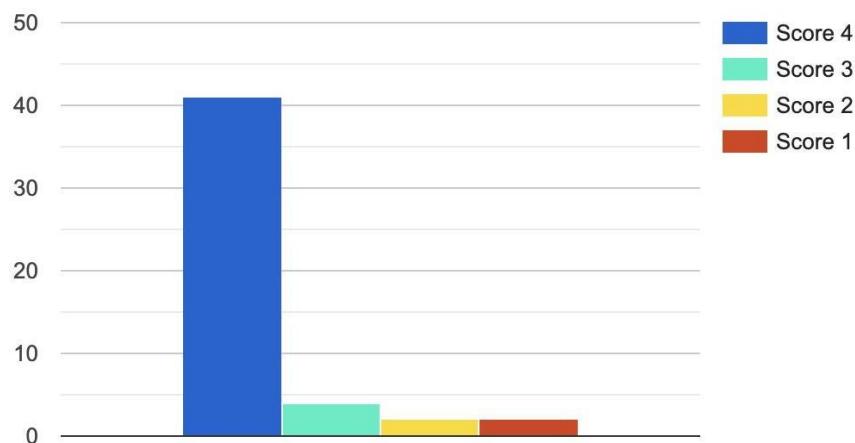


Figure 12. Result of Experiment 3

We can tell most of the users have a score as 4, which can prove the app works effectively.

To summarize, in the first experiment, we checked AI's accuracy rate asking 10 participants to try inputting 5 different files. The results they received with an accurate rate 94%. For the second experiment,

We compared the AI's outputs to humanistic outputs, which turns out at least one of the chord pattern matches for every tester. For the third experiment, we create a review survey to collect the review scores from users. 92% of the users score as the best score.

5. RELATED WORK

This research is very similar to mine, but this specially focuses on the input of a produced vocal, and it produces a superficial accompaniment [2]. Whereas my research and app inputs using any recorded melody line as well as any midi file, and it produces a unique chord progression that has not been superficially produced beforehand as a default output.

This research is based on using the user's humming to produce a ringtone [3]. But again, this research is based on pre-produced and superficial made output. It might give the same output to many different users since the ringtone has been pre-made from before. Whereas my research and app is based on a unique input and unique chord progression output system.

This research is based on the user inputting an existing song as “inspiration” and the system will produce a set of chord progressions that shares a similar vibe or characteristics as the chords in the existing song [4]. This app is also made to aid beginner musicians but all it does is to give inspiration for the musicians to write a similar song to the ones they’ve input into the system. Whereas my research and system does a similar thing, but it is designed for the musician to have their own freedom and allows them to express music the way they want to; by setting the input into the user’s melodic idea and producing a set of unique chords that would perfectly match the melody.

6. CONCLUSIONS

To summarize, the app Melodyfi, is a new innovative way to the future of songwriting [14]. It is efficient yet accurate in generating chord progression. As we have seen from the experiments, the app is very accurate and can be worked closely with the musicians.

The current limitations to the algorithm is that we currently only have the basic major and minor chords. We have yet to implement more advanced chords such as the 7th chords, augmented, diminished chords, inversions, and etc.

We will continue to advance and update our app with the more advanced chords. In the next update we will for sure implement a better UI with more functions such as profile, chord bank, and more options for users to input and record audio.

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AN INTELLIGENT AND DATA DRIVEN MOBILE PLATFORM FOR EARLY CHILDHOOD DEVELOPMENT USING MACHINE LEARNING AND DATA MINING

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ABSTRACT

In China almost 96 million children live in rural areas. Some of these children suffer from malnutrition since parents or guardians do not have knowledge of nutritional plans or how to calculate nutritional values. However, most of the Chinese population has access to a mobile device. This paper proposes a mobile application, which runs on the IOS and Android platforms, to calculate nutritional values and recommend a nutritional menu. EZ Nutrition and Education is a mobile app that targets millions of parents and caregivers in rural China and provides a solution to the regions' early childhood underdevelopment problems. It provides recommendations for healthy meals and age-appropriate educational activities, measures children's daily intake of calories and macro-nutrients (protein, carbs, and fats), and provides a way to have fun through activities that teach skills and values so as to prevent the underdevelopment of rural children's physical, intellectual and mental growth. We applied our application to a group of participants (ages 6-12) and conducted a qualitative evaluation of the approach. The results show that the nutritional calculator feature can help parents improve the nutritional health of their children. Though two of the underweight participants lost weight and two of the overweight participants gained weight while using the recommended nutritional plan, we believe that the recommended nutritional menu could be an excellent feature for this application after we adjust some of the parameters since some parents claimed they could not follow the recommended menus.

KEYWORDS

Computer Science, Game, Art Design.

1. INTRODUCTION

In China, 40% of the 238 million children under the age of 14 live in rural areas. What happens to them matters deeply to China and the rest of the world. According to a Stanford study, one in three rural Chinese children are cognitively delayed and over half suffer from a lack of nutrition. [7] Of the 1,808 children in rural counties of the Shaanxi province (northwestern China) aged 12 to 30 months who were surveyed, 57% scored below a certain threshold on an international infant mental development scale. "Research consistently shows that developmental and growth delays in this critical period before age 3 are irreversible, and can have serious implications even into adulthood." [8] Early childhood underdevelopment is dramatically changing the landscape of rural China, where almost 54% of rural children live with some degree of language impairment. Many of these will go on to have difficulties learning at school.

There are two major issues with early childhood development (ECD) in rural China. First, studies show that “misinformation over childhood nutrition abounds in rural China. Parents do not know what kinds of food to feed their children at what age.” [8] Proper food consumption is necessary to boost brain and body growth during pre-adolescence. Without healthy amounts of the right nutrients, the body and brain are unable to function as they should, leading to chronic illnesses and cognitive impairment. Secondly, researchers find rural caregivers, particularly grandparents, do not interact with their children enough. They do not know the benefits of early childhood activities. [9] They do not understand the importance of stimulating baby talk, and they do not respond to them and engage them in communication. They do not understand that the number of words babies are exposed to early on will determine the number of words they will be able to produce before age two. Also, caregivers do not know the importance of reading to babies. They do not understand that reading to babies opens up more learning opportunities. The fact that only 10% of rural children have more than five books means most rural children have reduced chances of developing an early, simulative imagination and may lack essential interpretive and communication skills. [10] Thirdly, caregivers do not play with their babies and they do not understand that babies learn important life skills through playing games.

Research has found “a troubling generational disconnect between the information-seeking behaviors and parenting practices of rural caregivers.” [13] Millions of rural Chinese children suffer from misinformation about both education and nutrition during early childhood.

Parents in China care about child education. The problem is that there are not enough service providers in rural areas. However, state and private-sponsored early childhood development (ECD) centers are becoming more plentiful in urban areas. [14, 15] There are some ECD centers in rural areas, but they are often for children between the ages of three and six. ECD centers for children before age three are rare, and if there are any, they are usually too distant for rural families to take advantage of them. Living in sparse villages where families are busy and may be dependent on the economy makes wide-spread usage of ECD centers hard to achieve. Researchers have compared ECD centers to home-based intervention and found that the average impact of the center-based intervention was half that of home-visiting intervention. Although children benefit the most from ECD centers, rural children and their caregivers are less likely to participate in the programs. With this being the situation, it is hard to reach and educate rural parents or caregivers about nutrition and children's activities.

While apps and websites focusing on early childhood nutrition and education have been developed in China, they mostly target urban areas because they are more profitable. In rural areas, however, such as apps are unheard of.

We have developed an app that we believe will provide a solution to this growing problem. Mobile phones and apps are widely used in China. By November 2019, the number of mobile phone subscribers in China had skyrocketed to 1.6 billion. Close to 900 million people in China have accessed the internet via a mobile device, and our mobile app can be easily downloaded and accessed daily within rural homes.

To solve this nutrition deficiency problem, our app provides suggested food menus based on the user's profile, and the parent/caregiver is able to select these menus to use as references for what their children should eat throughout the week. Then the caregiver is able to record the amount and types of food their child or children consumes during the day. The system can calculate their daily intake of calories and macronutrients (protein, carbs, and fats). Users will then receive a rating for the day's meals, from bad to good, and recommendations to adjust the nutritional and/or caloric intake based on the data. The app updates these recommended menus as more

meals are recorded, and users are able to navigate to any day or meal to see the specific information and rating for each item consumed.

To solve the issue of lack of interaction, the app also focuses on cognitive and mental development. The app offers a multitude of activities, such as playing hide-and-seek, listening to lullabies, and reading stories, which are all designed to engage children's minds. [11, 12] It also contains a built-in calendar, which not only gives caregivers foresight into the days ahead, but also allows them to become more organized in their daily activities.

Caregivers can easily navigate the system and find potential nutrients their children may lack or have too much of, as well as provide their children an alternative way to have fun through handpicked activities that teach them skills and values along the way.

To solve the early childhood underdevelopment problem, direct intervention through ECD centers, which is costly and less effective, is also limited. Our solution is unique—not only does it target the underprivileged, but it is also scalable. In addition to parents/caregivers, young kids and teenagers who have access to mobile phones can also use the app to monitor their own nutrition levels and participate in age-appropriate activities.

Compared to other well-known apps such as boohee.com, which aims to help adults control their weight, our app targets rural caregivers to help them learn to provide younger kids with a balance of nutrition and activities based on specific government guidance.

In this paper, we present an approach for parents, guardians, and teenagers to obtain access to recommended nutritional plans and calculate the total intake of calories, proteins, carbs and fat for themselves and their children. Since some Chinese parents, guardians, and teenagers do not have access to free nutritional plans and nutritional calculators, we propose a mobile application that runs on IOS or Android platforms to retrieve nutritional menus and calculate nutritional values. In two application scenarios, we demonstrate how the above combination of techniques improve children's health by calculating their daily calories and macronutrients (protein, carbs, and fats) and allow them to follow recommended nutritional menu plans. First, we demonstrated the usefulness of our approach via a comprehensive case study of the children's weight changes two weeks after their guardians recorded their daily body weight. Second, we analyzed the evolution of the children's weight during the two-week period in which they were using the recommended nutritional plan.

The rest of the paper is organized as follows: Section 2 provides details on the challenges that we met during the development period as well as some of the challenges faced by China's rural parents and their children; Section 3 focuses on the details of our solutions corresponding to the challenges mentioned in Section 2; Section 4 presents the relevant details of our experiment, followed by the related work in Section 5. Finally, Section 6 provides concluding remarks and points out future work for the project.

2. CHALLENGES

In order to design a mobile application that provides recommendations for healthy meals and age-appropriate educational activities, measures children's daily intake of calories and macronutrients (protein, carbs, and fats), and provides a way to have fun through activities that teach skills and values, a few challenges have been identified as follows.

2.1. Challenge 1: Learning how to develop a nutritional mobile app for multiple platforms

One challenge in developing this application was the cost in terms of time and knowledge. We wanted to make a nutritional app that could be available for both Android and Apple users. Because writing the app for both platforms would be time-consuming and require knowledge of at least two different languages, we had to consider software development that is suitable for both Android and Apple systems.

2.2. Challenge 2: Chinese rural parents' access to tools

How do China's rural parents get access to a tool that calculates daily calories, proteins, carbohydrates, and fats, as well as if their child is under, over, or of ideal weight and nutrition?

Chinese rural parents do not have access to tools that provide personal records of their children's diet or guidelines for a healthy diet. Rural parents might not have enough time or education to know if their children suffer from early childhood development problems. As a result, rural parents need a way to learn if their child suffers from malnutrition early so the child does not suffer other diseases in the future.

2.3. Challenge 2: Chinese rural parents' access to nutritional plans and physical activities

How do China's rural parents get access to nutritional plans and physical activities to improve their children's health?

In order to improve children's health and boost their immune systems, parents need to have adequate nutrition plans and have their children engage physical activities. However, many parents do not have access to free resources or the time to obtain nutritional plans or do healthy activities. We plan to provide a mobile application with which guardians can access nutritional menus and healthy activities that can boost their children's health.

3. SOLUTION

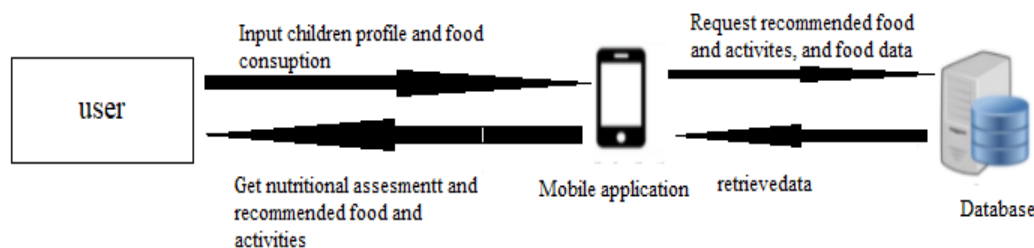


Figure 1. Overview of EZ Nutritional Education

To develop our mobile application (see Figure 1), we decided to use the Flutter software. [3] Flutter is an open-source UI software development kit developed by Google. This open-source UI provides the ability to develop applications for Android, IOS, Linux, Mac, Windows and web from a single codebase. The programming language that is used to code the Flutter app is Dart. Dart is a programming language developed by Google and is used to build servers and desktop

applications. [5] By using Flutter we solved the issues mentioned in Challenge 1, so we could develop both IOS and Android apps using a single codebase.

For calories and macronutrient data (protein, carbs, and fats), we used information from the National Health Commission of the People's Republic of China to make the app suitable for all children. In order to calculate daily caloric intake as well as macronutrients (protein, carbs, and fats) and customize the information according to the user's requirements, we grouped users according to age, gender, and physical measurements such as height and weight.

For the total calories and macronutrients (protein, carbs, and fats) of each food, we used data provided by WebMD [6] and saved the data in our database. Similarly, we saved recommended food and activities in our database.

In order to use the mobile application, a user must enter his/her child's information, such as name, weight, height, age and gender. Then the system redirects to the home page. To get the recommended food, the system sends a request to the database, which retrieves the information. On the home page, the user can then see the recommended nutritional plans for breakfast, lunch and dinner or create his/her own nutritional plan. If the user decides to create a nutritional plan, they would select the meal time and add the food. After the user selects the food, the screen displays the calories and macronutrients (protein, carbs, and fats). Another functionality of the mobile app is that users can get personalized recommendations for activities according to their inputted data. Finally, the mobile app also allows users to edit their children's profile after it is created.

```

void initState() {
  super.initState();
  widget.recommendation.get_recommended_food().then((rec_map) {
    setState() {
      breakfastList = rec_map['breakfast'];
      lunchList = rec_map['lunch'];
      dinnerList = rec_map['dinner'];
    };
    calculateNutrition(breakfastList);
    calculateNutrition(lunchList);
    calculateNutrition(dinnerList);
  }).catchError((e) {
    print("Failed to load the data." + e.toString());
  });
}
void calculateNutrition(list) {
  calculateCalories(list);
  calculateProtein(list);
  calculateFat(list);
  calculateCarbohydrate(list);
}
void calculateCalories(list) {
  var temp = 0.0;
  for (int i = 0; i < list.length; i++) {
    temp += double.parse(widget.recommendation.food_map[list[i]]['calories']);
  }
  setState() {
    calories += temp;
  }
}

```

```

    });
    print('calories' + calories.toString());
}
void calculateProtein(list) {
    var temp = 0.0;
    for (int i = 0; i < list.length; i++) {
        temp += double.parse(widget.recommendation.food_map[list[i]]['protein']);
    }
    setState() {
        protein += temp;
    });
    //print('calories' + calories.toString());
}
void calculateFat(list) {
    var temp = 0.0;
    for (int i = 0; i < list.length; i++) {
        temp += double.parse(widget.recommendation.food_map[list[i]]['fat']);
    }
    setState() {
        fat += temp;
    });
    //print('calories' + calories.toString());
}
void calculateCarbohydrate(list) {
    var temp = 0.0;
    for (int i = 0; i < list.length; i++) {
        temp += double.parse(
            widget.recommendation.food_map[list[i]]['carbohydrates']);
    }
    setState() {
        carbohydrate += temp;
    });
    print('carbohydrate' + temp.toString());
}

```

This page recommends food for users based on their personal data (see Figure 2). It also displays calories, proteins, fats, and carbohydrates in the recommended menu for users to see. We input the recommended data from the database. The database includes all data for the food. We coded to summarize data for users.



Figure 2. Recommending food

```

Expanded(
  flex: 7,
  child: Container(
    margin: EdgeInsets.only(top: 15),
    child: ListView.separated(
      padding: const EdgeInsets.all(8),
      itemCount: food_details.length,
      itemBuilder: (BuildContext context, int index) {
        return Container(
          margin: EdgeInsets.only(left: 30, right: 30),
          height: 50,
          color: Color.fromRGBO(255, 223, 191, 100),
          child: Text(
            food_details[index].toUpperCase() +
            '      : ' +
            widget.recommendation.food_map[widget.foodId]
              [food_details[index]],
            textAlign: TextAlign.left,
            style: TextStyle(fontSize: 20),
          ),
        );
      },
      separatorBuilder: (BuildContext context, int index) =>
        const Divider(),
    ),
  ),
)

```

This page provides the details for each food (see Figure 3). It gets the data from another file and presents it.



Figure 3. Details for each food

```

getHealthRating() {
  var height = double.parse(_height);
  var weight = double.parse(_weight);
  if (_gender == 'Female') {
    if (double.parse(_head) <= 2 &&
        double.parse(_height) <= 20 &&
        double.parse(_age) <= 2 &&
        double.parse(_weight) <= 30) {
      healthRating = 'hum';
    }
    if (height <= 106) {
      if (weight < 14) {
        healthRating = '偏轻';
      } else if (weight > 17) {
        healthRating = '偏重';
      } else {
        healthRating = '正常';
      }
    }
    else if (height <= 108) {
      if (weight < 14.4) {
        healthRating = '偏轻';
      } else if (weight > 17.6) {

```



```

healthRating = '偏重';
} else {
healthRating = '正常';
}
}
else if (height <= 112) {
if (weight < 16) {
healthRating = '偏轻';
} else if (weight > 19.2) {
healthRating = '偏重';
} else {
healthRating = '正常';
}
}
else if (height <= 116) {
if (weight < 17.4) {
healthRating = '偏轻';
} else if (weight > 21.1) {
healthRating = '偏重';
} else {
healthRating = '正常';
}
}
}
}

```

This page shows the user's data (see Figure 4). It also gives a rank for their body condition based on the data. We used an "if else" statement for this.

Figure 4. User's data and body condition

```

Widget build(BuildContext context) {

```

```

return Scaffold(
  appBar: AppBar(
    title: Text(widget.title),
    leading: Container(),
    backgroundColor: Color.fromRGBO(255, 180, 105, 100),
    elevation: 0.0,
  ),
  body: Center(
    child: Container(
      decoration: BoxDecoration(
        color: Color.fromRGBO(255, 235, 222, 100),
      ),
      child: Column(
        children: <Widget>[
          Expanded(
            flex: 2,
            child: Row(
              mainAxisAlignment: MainAxisAlignment.center,
              crossAxisAlignment: CrossAxisAlignment.center,
              children: <Widget>[
                Expanded(
                  flex: 1,
                  child: Container(
                    margin: EdgeInsets.only(right: 30),
                    child: Text(
                      "ID",
                      textAlign: TextAlign.right,
                    ),
                  ),
                ),
                Expanded(
                  flex: 2,
                  child: Container(
                    margin: EdgeInsets.only(
                      right: 30, left: 30, top: 15, bottom: 15),
                    child: TextField(
                      controller: idTextFieldController,
                      obscureText: false,
                      decoration: InputDecoration(
                        border: OutlineInputBorder(),
                        labelText: 'ID',
                      ),
                    ),
                  ),
                ),
              ],
            ),
          ),
        ],
      ),
    ),
  ),
)

```

This page makes the user input their data for the app to use (see Figure 5).

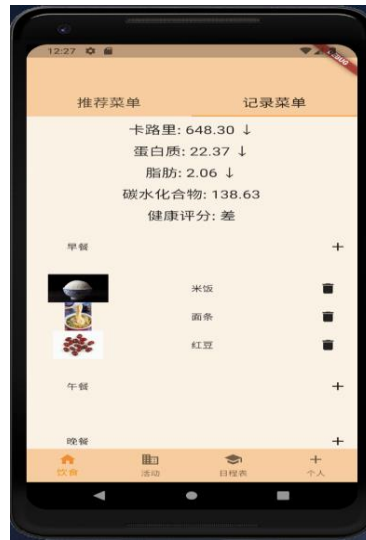


Figure 5. User inputting data

```

getRate(){
  var count = 0;
  setState() {
    proteinRate = '';
    caloriesRate = '';
    fatRate = '';
    carbohydrateRate = '';
    if(dailyprotein < protein - 10){
      proteinRate = ' ↑';
      count += 1;
    }else if(dailyprotein > protein + 10){
      proteinRate = ' ↓';
      count += 1;
    }
    if(dailycalories < calories - 100){
      caloriesRate = ' ↑';
      count += 1;
    }else if(dailycalories > calories + 100){
      caloriesRate = ' ↓';
      count += 1;
    }
    if(dailyfat < fat - 10){
      fatRate = ' ↑';
      count += 1;
    }else if(dailyfat > fat + 10){
      fatRate = ' ↓';
      count += 1;
    }
    if(dailycarbohydrate < carbohydrate - 10){
      carbohydrateRate = ' ↑';
      count += 1;
    }else if(dailycarbohydrate > carbohydrate + 10){
      carbohydrateRate = ' ↓';
    }
  }
}

```

```

        count += 1;
    }
});
setState() {
    if (count >= 3){
        healthRate = '差';
    }else if (count == 2){
        healthRate = '良';
    }else{
        healthRate = '优';
    }
});
void calculateProtein(list) {
    var temp = 0.0;
    for (int i = 0; i < list.length; i++) {
        temp += double.parse(
            widget.foodRecommendation.food_map[list[i]['name']]['protein']);
    }
    setState() {
        protein += temp;
    });
    //print('calories' + calories.toString());
}
void calculateFat(list) {
    var temp = 0.0;
    for (int i = 0; i < list.length; i++) {
        temp += double.parse(
            widget.foodRecommendation.food_map[list[i]['name']]['fat']);
    }
    setState() {
        fat += temp;
    });
    //print('calories' + calories.toString());
}
void calculateCarbohydrate(list) {
    var temp = 0.0;
    for (int i = 0; i < list.length; i++) {
        temp += double.parse(
            widget.foodRecommendation.food_map[list[i]['name']]['carbohydrates']);
    }
    setState() {
        carbohydrate += temp;
    });
    print('carbohydrate' + temp.toString());
}

```

This page allows users to record their food and the app will give a rank based on their data. The program first gives a score for the recorded food based on the food and user data, then it gives a rank for the users based on the score.

活动：

```
class _RecommendedActivityPageState extends State<RecommendedActivityPage> {
  void initState() {
    super.initState();
    widget.recommendation.get_recommended_activities().then((rec_map) {
      setState(() {
        activityList = rec_map;
        //print(activityList);
      });
    }).catchError((e) {
      //print("Failed to load the data." + e.toString());
    });
  }
  var activityList = [];

```

This provides recommended activities for the users.

活动detail：

```
Row(
  children: <Widget>[
    Expanded(
      flex: 1,
      child: Container(
        margin: EdgeInsets.only(right: 30),
        child: Text(
          RecommendationActivity.activity_map[widget.activityid]
            ['description'],
          textAlign: TextAlign.center,
        ),
      ),
    ),
  ],
),
```

This provides the detailed description of the recommended activities for the users.

```
Expanded(
  flex: 2,
  child: Container(
    color: index % 2 == 0
      ? Color.fromRGBO(255, 223, 191, 100)
      : Color.fromRGBO(255, 243, 231, 100),
    height: height,
    alignment: Alignment.center,
    child: Text(
      activityList[index]['time'],
      textAlign: TextAlign.left,
    ),
  ),
),
Expanded(
  flex: 1,
  child: Container(
    color: index % 2 == 1
      ? Color.fromRGBO(255, 223, 191, 100)

```

```

: Color.fromRGBO(255, 243, 231, 100),
height: height,
width: 80,
alignment: Alignment.center,
child: Container(
height: height -30.0,
child: Image.network(
RecommendationActivity.activity_map[
activityList[index]['name']]['image']),
),
),
Expanded(
flex: 2,
child: Container(
color: index % 2 == 1
? Color.fromRGBO(255, 223, 191, 100)
: Color.fromRGBO(255, 243, 231, 100),
margin: EdgeInsets.only(right: 30),
height: height,
alignment: Alignment.center,
child: Text(
RecommendationActivity.activity_map[
activityList[index]['name']]['name'],
textAlign: TextAlign.left,
),
),
),

```

This provides the recommended schedule for users.

4. EXPERIMENT

To evaluate our approaches, we collected body weight fluctuation data for 16 participants for two weeks. These participants were from 6 to 12 years of age. Some participants suffered from being underweight or overweight, while others had a healthy weight. We conducted two different analyses to verify the two aspects of our approach: 8 participants that calculated their intake of calories, macronutrients (protein, carbs, and fats) and observed their weight changes, and 8 participants who used the recommendation nutritional plan and observed their weight after two weeks.

In this experiment, we used eight participants (6-12 years of age): four children who were overweight, two children who were underweight, and two children who had a healthy weight. We utilized the weight data of these participants, which was recorded by their guardians every day. First, the guardians inputted the information for their child into the EZ Nutrition and Education app. Then they included the food that they consumed in the corresponding mealtime every day. After two weeks, we collected the data and observed the weight of the first and last day of the child while using the mobile app.

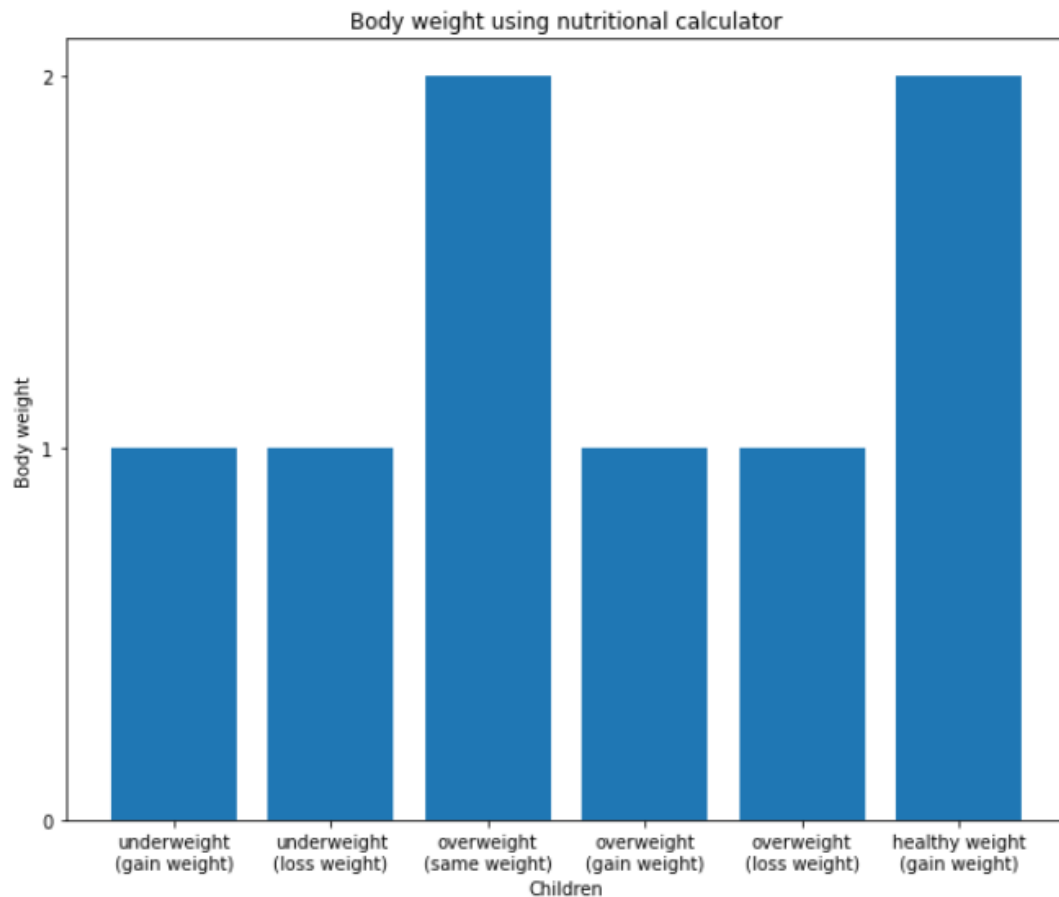


Figure 6. Bodyweights

As seen in Figure 6, some children lost weight, while others gained or maintained the same weight after two weeks. Some gained or lost 2-5 ounces of their bodyweight. We observed that one of the underweight children gained weight, while the other underweight child lost weight. For the four overweight children, we observed that two maintained the same weight, while one lost weight and the other gained weight. For the two children with healthy weight, both had gained weight after two weeks.

In the second experiment, similar to the previous one, we used eight participants (6-12 years of age): two overweight children, three underweight children, and three children with a healthy weight. We utilized the weight data that was recorded by their guardians. The guardians created their child's profile and followed the recommended nutritional menus for each corresponding meal time. After two weeks, we collected the data and noted the weight of children on the first and last days of using the recommended nutritional menus recommended by the app.

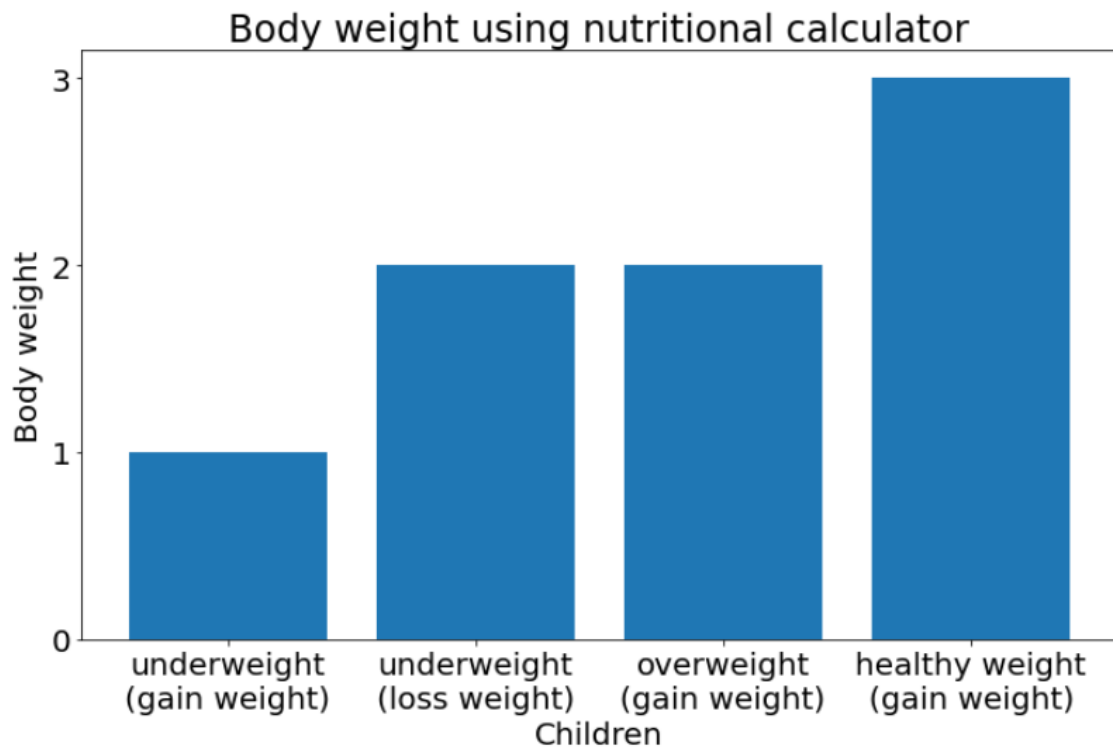


Figure 7. Bodyweights

Similar to the previous experiment, the results of this experiment were that some children lost weight while others gained after using the recommended nutritional menus (see Figure 7). Some gained or lost 2-8 ounces of their bodyweight. We observed that one child who was underweight gained weight, while the others lost weight. For the overweight children, we observed that both gained weight. For the children who had a healthy weight, we observed that all gained weight after two weeks.

Experiment 1 shows that the nutritional calculator feature can help parents to improve the nutritional health of their children. Even though we observed that one of the underweight participants lost weight and one of the overweight participants gained weight, we can claim that calculating the daily intake of calories and macronutrients (protein, carbs, and fats) can improve a child's nutritional health, overall. We do not know if parents followed the indicators that were displayed for their children since they did not record the daily intake of calories or macronutrients (protein, carbs, and fats) during the experiment.

Experiment 2 shows that some children gained or lost weight. Though two of the underweight participants lost weight and two of the overweight participants gained weight, we believe that the recommended nutritional menus might be an excellent feature for this application after we adjust some of the parameters, since some parents claimed that they could not follow the recommended menus. The reason was because some participants had food allergies or did not like the recommended foods.

5. RELATED WORK

Tine, F. et al. developed a mobile health application called Mhealth to manage acute malnutrition in five different countries: Afghanistan, Chad, Kenya, Mali and Niger. [1] Mhealth is a step-by-

step guideline that helps health workers perform assessments and/or provide treatment for children that visit the CMAM program. It is built on the open-source Open Data Kit (ODK) platform, which provides feedback, saves medical history, and calculates z-scores. Unlike Mhealth, the objective of the EZ Nutrition and Education application is for parents to prevent malnutrition in their children, since they can build healthy diet plans according to their children's age and weight.

Dr. Aniruddha Vidwans, MD, a neonatologist, developed an iPhone app called NICU Nutrition Calculator. [2] The NICU Nutrition Calculator is a mobile app that assists health workers when they need to provide an adequate diet for premature infants, especially those weighing less than 1000g. It analyzes diverse resources for both enteral nutrition (EN) and parenteral nutrition (PN) to calculate the total calories/kilogram/day (kcal/kg/d) and glucose infusion rates based on the diet prescription entered. The NICU Nutrition Calculator and our EZ Nutritional and Education app both calculate the daily intake of calories, however, our EZ Nutritional and Education app also calculates the daily intake of macronutrients (protein, carbs, and fats). The NICU Nutrition Calculator is developed only for the IOS platform, while our EZ Nutrition and Education app is developed for both Android and IOS devices. Another difference is that our EZ Nutritional Education app was developed for young children and teenagers, while the NICU Nutrition Calculator was developed for premature infants.

Lerena, L. et al. proposed an adaptive food recommendation system based on the user's profile and requirements. [3] The goals for their study and ours are similar since we also wish to develop software that can recommend nutritional plans depending on a user's IBM. However, we are focused on children and teenagers who might suffer from malnutrition.

6. CONCLUSION AND FUTURE WORK

In China, almost half of the population's children live in rural areas. Some of these children suffer from malnutrition since they do not have access to nutritional tools. In this paper, we proposed a mobile application that runs on IOS and Android platforms and can calculate the daily intake of calories, proteins, carbs and fats, as well as recommend nutritional menus. We developed the EZ Nutritional and Education app, which is a personal app for children according to their height, weight, gender, and age. The app can also recommend a nutritional plan and calculate the total calories, protein, carbs and fats that children consume each day. For our approach, we performed two experiments to observe and analyze the performance of the mobile features. We selected 16 participants (6-12 years of age), who used two different features of our mobile app, and recorded their bodyweights before and after a two-week period of using the app. Through our experiments, we observed that some children maintained the same weight, while others lost or gained weight after using the recommended nutritional menus and calculating their nutritional values. Some gained or lost 2-8 ounces of their bodyweight. Even though we observed that some of the underweight participants lost weight, and some of the overweight participants gained weight, we can claim that calculating the daily intake of calories, macronutrients (protein, carbs, and fats) can still improve children's nutritional health, overall. We believe that the recommended nutritional menu will still be an excellent feature for this mobile application after adjusting some of its parameters.

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FENCINGESTIMATE: A 3D GAME-BASED INTERACTIVE DRIVING SIMULATION TRAINING SYSTEM USING ARTIFICIAL INTELLIGENCE AND COMPUTER VISION

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ABSTRACT

Training for fencing during the pandemic has changed from what it was beforehand. Students have been taking lessons online, and instead of fencing with peers, students now train by watching and analyzing fencing videos. Learning fencing from watching videos of world class fencers is an effective way of learning. However, sabre fencing is so fast that many inexperienced fencers are unable to capture the important information by watching short clips. Therefore, they are unable to learn techniques such as sabre fencing just from watching videos. This paper traces the development of an application that can utilize computer vision and pose estimation to analyze fencing video clips and output accurate scored points as well as the techniques used within the given clips. We applied our application to help less experienced fencers improve their ability to recognize points and conduct qualitative evaluations of different fencing techniques.

KEYWORDS

3D simulation, Computer vision, Artificial intelligence, Fencing lessons.

1. INTRODUCTION

Fencing, like most sports, relies on in-person experience and training. [2, 3, 4] During the pandemic, online learning has been recognized by the vast majority as a more viable option. [1] However, fencing is hard to understand without a solid foundation, and this is one of the reasons why it has had limited access for the vast majority of people. [11] This is especially true for sabre, which is the fastest of the three disciplines of fencing. Even less experienced fencers who fence using sabre themselves struggle to understand clips of world-class fencers, due to its high speed. However, there are many valuable things fencers can learn from such videos, especially during the pandemic, since this type of learning is not as restricted as in-person learning in many places. Learning from videos of world class fencers is useful when fencers have to train at home for whatever reason. This application aims to aid less experienced fencers to learn from fencing videos, and to also make it easier for them to understand the sport through watching fencing tournaments.

Some of the techniques and systems that have been proposed are neural network deep learning. [5, 6] Deep learning is effective when it comes to identifying a point, however, this assumes that the techniques and strategies used by the fencers are not important, which is exactly the purpose

of this program. Other techniques, such as using a box to go around the fencers to decide whether the fencers hit each other are also used. This is not ideal because it often results in wrong judgements regarding hitting. This method considers the distance between the fencers as a sign of the end of a point instead of identifying the blade and actual hit. Other proposals include background removal where fencers can be represented by a two-dimensional array. However, a practical problem with this method is that as long as there are any changes in the camera, such as zooming in and out, or changes in the video such as lighting or set up, the background becomes difficult to analyze. [12]

This program uses python as its coding language, and Google colab as IDE in order to use GPUs provided by Google to analyze the video. [7, 8] In order to judge fencing points, this program first processes videos by splitting them using CV2 to get frames from the video feed. These frames are then passed into the pose estimation algorithm in jpeg format to capture the fencers' motions while the machine learning algorithm researches a series of json files containing the positions of the key points of the people detected in the video. Key points include major joints such as shoulders, elbows, and knees, and also important body parts such as the head, hands, and feet. [9, 10] The positions of these key points are checked to confirm if the people detected are the two fencers since many times the algorithm detects people passing in the background or the judge. Frames with people other than the two fencers detected, or with less than two fencers detected are discarded. To analyze the fencers' techniques and points, the positions of the key points are processed with the algorithm we developed, which detects the distance between the fencers, the speed of the fencers, and the slope of the arms of the fencers. With this data, the program returns the technique used, as well as the result of the point, with either the fencer on the left or right earning the point.

In two application scenarios, we demonstrate how the above combination of techniques. First, we show the usefulness of our approach for pose estimation by running all fifteen test cases, which includes fifteen videos with the correct points and tactics being used in the videos. Out of the fifteen videos, all resulted in too much background noise when background removal was applied, and all fifteen worked with pose estimation, with some frames having errors. This can be solved and the solutions are discussed later in this paper. Second, we analyzed the usefulness of the approach of the two main algorithms used in this application: one involving the angle between the lower arm and the straight line from wrist to shoulder, the other utilizing the slope of upper arm and lower arm, when processing the tactics and points in a video. The result revealed a 60% accuracy in judging a point when the method involving the angle between the lower arm and the straight line from wrist to shoulder was used, and an 87% accuracy with the method using the slope of the upper arm and lower arm. Therefore the method utilizing the slopes of the upper and lower arms was deemed the best algorithm when judging points and tactics. This method proved to have an 80% accuracy rate when judging tactics in the given videos.

The rest of this paper is organized as follows: Section 2 provides details on the challenges that we encountered as we designed the program; Section 3 focuses on the details of our solutions corresponding to the challenges mentioned in Section 2; Section 4 provides details about the effectiveness of our solutions in Section 3, followed by related work in Section 5. Finally, Section 6 provides concluding remarks and points out suggestions for future work for this project.

2. CHALLENGES

In order to develop an application that can utilize computer vision and pose estimation to analyze fencing video clips and output accurate scored points as well as the techniques used within the given clips, a few challenges were identified as follows.

2.1. Challenge 1: Gaining inspiration from related works

The first challenge was to find inspiration for ways to approach the development of the app from related works. Most related works that were researched utilize deep learning and train neural networks to recognize a point in fencing. However, all related works that were discovered did not focus on the tactics being used in a point, but rather the result of a point. This was not useful for the development of this app since its primary purpose is to educate beginners or those who are interested in sabre fencing to help them understand and learn from sabre fencing videos. The related works focusing on machine learning to act as a judge could not provide much valuable data or insight for us, so we had to develop our own methods to recognize tactics used by fencers within fencing video clips.

2.2. Challenge 2: Finding the right method

Another challenge was finding the right method. Initially, we focused on the algorithm of background removal, which uses machine learning to differentiate the background from moving objects in a video. The algorithm outputs a two-dimensional array, with the background being 0s and the object being 1s for each frame. However, as we developed the program, it did not work as intended because in many fencing videos, the cameras used aren't stable enough for background removal since they sometimes zoom in and out. Also, the lighting used in the video can affect background removal. All of these factors make the results of background removal noisy, so we had to switch from background removal to pose estimation, which is an algorithm that identifies the key points, mainly joints, of people in a video such as elbows, wrists, hips, knees, as well as the head. Using pose estimation allowed us to capture the movements of the fencers more accurately.

2.3. Challenge 3: Processing data captured by pose estimation

Another challenge came from processing data captured by pose estimation. Before actually processing the data, we needed to remove frames that did not work with the following algorithm that processes the data. An example of this is the pose estimation capturing people other than the fencers, such as the judge or others passing in front of the camera. Having the wrong people detected creates conflict with the following algorithm, which is designed for only two people standing behind the *en garde* lines, which are the starting lines in fencing. The general solution was to limit the number of people that could be detected in the videos, as well as the frames that don't have fencers detected correctly, whether from missing key points or pose estimation error.

3. SOLUTION

The machine learning program takes in user input in video format and processes it by using computer vision to split the video up into frames. With the frames ready, the program passes them to the pose estimation algorithm. This is a machine learning algorithm that can recognize body positions in videos by pinpointing the positions of key points. Key Points include important joints such as elbows, shoulders, wrists, and also the head. The positions of every body part in each frame is stored in json files. All later algorithms are based on these json files. The json files are then passed into later algorithms for further analysis about fencers' movements. Before that, files are processed so that frames that will be used later all correctly recognize the fencers and their body parts. Therefore, frames with people other than the two fencers as well as those with any important body parts left unrecognized are eliminated. Any frames with swapped body parts (left and right) will be swapped back. The left and right of the fencers should always match the first correct frame. Then the json files will be processed with an algorithm developed in order to

judge the point and the technique being used to make the point. The algorithm includes judging the right of way of the fencers, checking which fencer is the first to move, movement speeds of each fencer, as well as the extension of each fencer's arms. With the right of way, the computer checks the movement of the fencers right before and after the touch, which is decided when two fencers are close together. If there is no change in right of way, meaning no valid or successful defense effort, the point goes to the fencer with right of way originally. Otherwise, the point is rewarded to the defender. The frontend of this application was built in the IntelliJ integrated development environment (IDE) using Google's open-source UI software development kit Flutter. Flutter uses the object-oriented programming language Dart. See Figure 1 for a schematic of FencingEstimate's functioning.

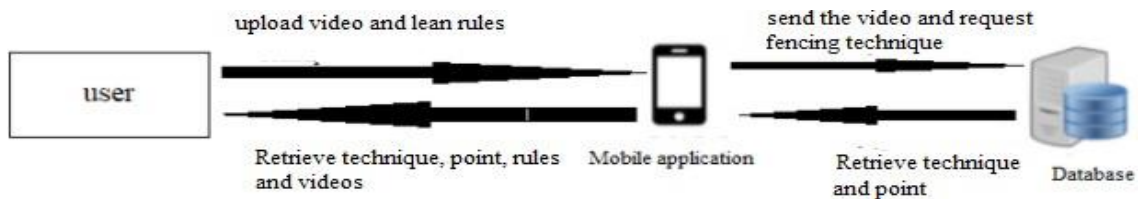


Figure 1. FencingEstimate UI schematic

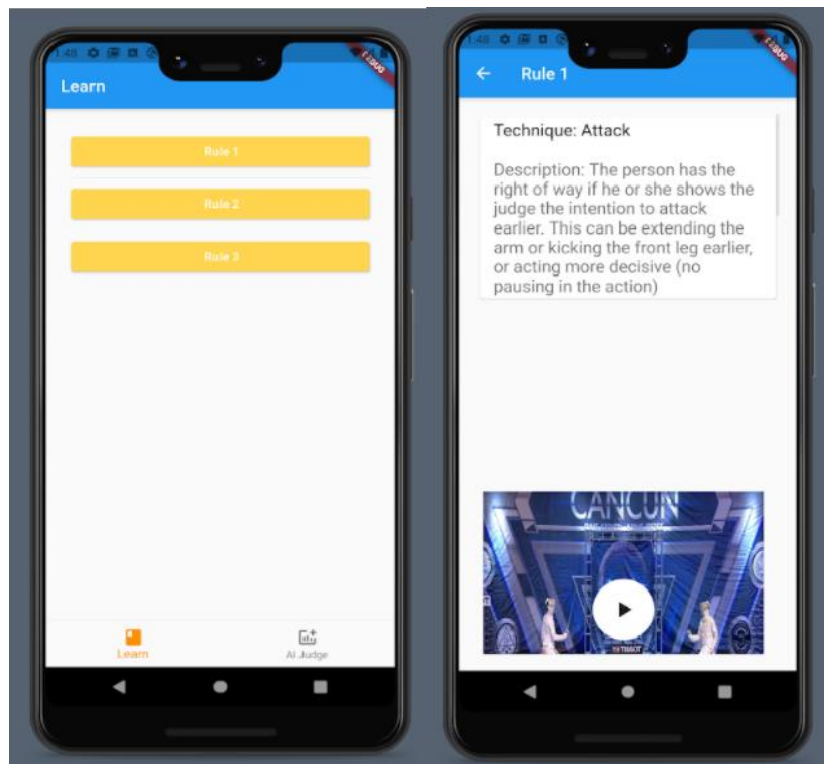


Figure 2. FencingEstimate Learning page and AI judge page (screenshots)

The AI judge page allows users to upload fencing videos, and the application sends them to the server. From there, the server passes them through computer vision and pose estimation to gain movement information about the fencers in json files. The program first checks which fencer gets the right of way by seeing which one moved their leg and arm first. Then, the program continuously checks the distance between the fencers, and only starts to evaluate the score and tactics when the distance between them is within the distance equivalent to the length of a sabre. In order to get the length of a sabre in pixels, and adjust to different resolutions, we take into

consideration the fact that the ratio of the distance between the fencers' front feet is set by the distance protocol, which is 4 meters, and the blade of the sabre, which is 0.88 meters long. Using these perimeters, we are able to calculate the distance between the fencers in pixels, then multiply that number by 0.22, the ratio of the distance between the fencers to the length of the sabre blade. In our application, since we are only given monocular information, it is difficult for the program to identify the position of the blades. Therefore, we set the default to read that as long as the fencers are closer together than the length of their blades, a hit should occur. See screenshots of FencingEstimate's Learning page and AI judge page in Figure 2 and AI Judge screenshots in Figure 3.

Then, the slopes of the fencers' arms are measured. If the slopes of both upper and lower arms are close to 0, it means that the fencer has extended his arm, and hence is currently attacking. If the other fencer is also attacking, then whoever has the right of way, or who attacks more aggressively gets the point. The program checks the decisiveness of the fencers by checking the landing of the front leg, as well as how stretched out their legs are, which is checked by the ratio between a fencers' height and the distance between their front and back legs as they attack; we use this ratio instead of distance because different fencers differ in height. The fencer is considered to be defending if the slopes of the upper and lower arm are closer to 1 and -1 than 0 and the ratio between the fencers' height and the distance between the front and back foot is greater than the other fencer, meaning the fencer is standing more upright and not having their legs more separated than the attacker. In this case, the system checks to see if the parry happens at the same time as the attack, if yes, then the defender gets the point if they extend their arm again for the riposte, otherwise it is considered a failed parry and the attacker still gets the point.

The program will then output the results of the score, and either the fencer on the left or right will get the point, with tactics output given alongside.

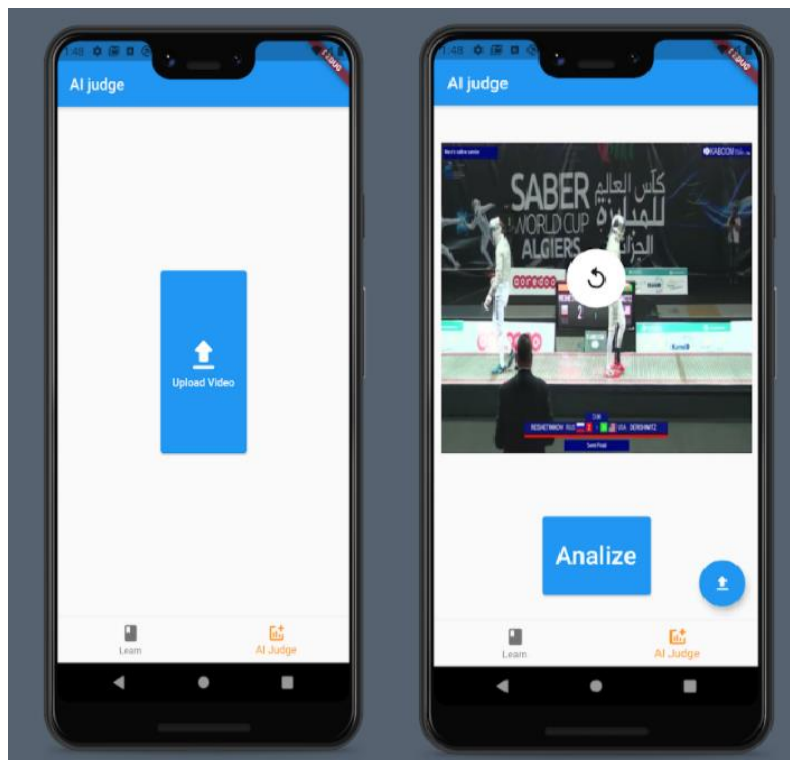


Figure 3. FencingEstimate AI Judge (screenshots)

4. EXPERIMENT

The two approaches compared here are the angle method, which utilizes the angle between the lower arm and the line drawn from wrist to shoulder, and the slope method, which utilizes slopes of the upper and lower arm (see Figure 4).

The results demonstrated a 60% accuracy in evaluating the point using the angle method, which does not include tactics, while the slope method had a rate of 87% accuracy. Therefore, the slope method was considered the best approach for this application. This method demonstrated an 80% rate of accuracy in correctly identifying tactics such as parry riposte, attack in preposition, attack no attack, and simultaneous within twelve video clips.

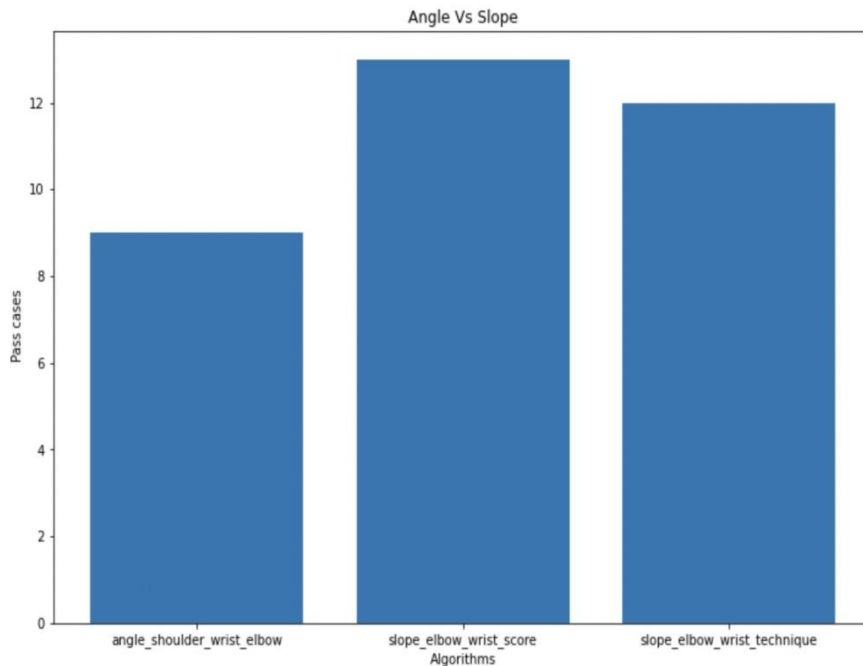


Figure 4. Pass cases: Angle vs. Slope

To evaluate the approach of the app, we use the fifteen test cases that include tactics such as parry riposte, attack in preposition, and attack no attack. All test cases include a short clip that only includes one point in sabre fencing to improve efficiency, as well as the correct score given and the tactics used in the clip. The two approaches of the algorithm were first used to decide the final algorithm of the application, and the one that generates a result with a higher accuracy is the approach for this application.

Out of the fifteen test cases, with the slope method, we sorted the data by technique, separating the test cases into Parry Riposte, Simultaneous, and Attack. As seen in Table 1, out of the seven parry riposte cases, six of them pass. All four of the simultaneous cases passed, and three out of four of the Attack cases passed.

Table 1. Test cases using the slope method

Technique	Parry Riposte	Simultaneous	Attack
Pass	6	4	3
Fail	1	0	1

The result of the experiment proved that our approach as a whole, including computer vision, pose estimation, as well as the later algorithms, works. With an accuracy rate of 87% for judging points, and 80% for judging techniques, the program still has room for improvement, but is a solid solution to the proposed problem.

5. RELATED WORK

Bridgeman, L., et al. presented a machine learning approach to apply multi-person pose estimation to sports. [13] Their methodology involves use of cameras from different angles to enable the detection of 3D skeletons from 2D information. In our application, we only have one camera angle, since most fencing competitions only have one camera in the center for the judge to review. In this case, our application was not intended to make 3D skeletons, since they are not needed for our algorithm to judge fencing points.

Fastovets, M., et al. presented another machine learning approach to estimate human posing from 2D, monocular camera views. [14] This work deals with moving camera angles with a trained model, while our work is designed for a stable camera angle. In both works, pose estimation is used to detect key points of bodies, which are the major joints including shoulders, elbows, hips, and important body parts such as the head, hands, or feet. The movement of a human body is captured via the recording of these key points, and most body parts can be represented by drawing lines connecting the key points.

Madelena, L., et al. presented a methodology for background subtraction on tracking moving objects. [15] This work involves the use of computer vision and other machine learning algorithms to achieve the detection of moving objects. This paper mentions some of the weaknesses of background subtraction, including the fact that it can be affected by certain lighting environments or colors. When we first developed our application, we tried background subtraction instead of pose estimation, and encountered the same issues mentioned in this paper.

6. CONCLUSION AND FUTURE WORK

In designing this application, we applied computer vision and pose estimation to judge fencing scores and tactics used by fencers in a given video, and used these algorithms on mobile applications, so that the upload of videos can be done in a convenient way. The mobile application features the instruction of basic rules, judging scoring via sample fencing videos, and the uploading of videos for analysis.

A limitation of this application is its limited number of cases. The current application was not designed to handle edge cases, such as when the right of way changes before blade contact, as the attacker purposely moves back to set up a defense position, or when the attacker makes a mistake and the right of way shifts to the defender. The current application also does not apply to situations where the camera is moving, and only applies to cases in which the points end in the middle.

We plan to continue to add more features to the application to identify edge cases. We also plan to improve the limiting error output by pose estimation when the camera is in motion, add more features, and apply deep learning to detect a point and tactics when the camera is in motion.

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DRIVE2PASS: A 3D GAME-BASED INTERACTIVE DRIVING SIMULATION SYSTEM FOR IMPROVING THE YOUTH DRIVING LEARNING AND TRAINING USING MACHINE LEARNING

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ABSTRACT

Youths have a higher car accident rate, so to decrease the percentage, I developed a game that will teach players to practice safer driving behaviors [5]. It is meant to simulate real driving, and teaches the players key individual concepts about road safety. This game puts an emphasis on properly executing blinking, hill parking, and headlights. This addresses the problem in other games where they solely focus on steering and acceleration, as this game also includes other driving elements to promote defensive driving. The intended goal of this game was to teach beginner drivers proper driving etiquette in a safe, risk-free environment and become a potential alternative to the traditional method of driving on real roads.

KEYWORDS

Youth Driving, Machine Learning, 3D Modeling.

1. INTRODUCTION

Nowadays, youth drivers have a higher rate of getting into car accidents. According to Driver Knowledge in 2018: “6.7 million cars involved in traffic crashes”, the main factors to keep driving safe is to manual in keeping your hands on the steering wheel; visual in watching the roadway and traffic around you; and cognitive in keeping your mind on driving safely [1]. “Four common driver behaviors are reported to have caused about 70 percent of those 2016 fatalities. Those are drunk driving, not wearing a seat belt, speeding and distracted driving” [2]. According to InjuryFacts 2021 graph: Average rate of 11.9 deaths per 100,000 population “Peaked among persons age 18-25; high of 18.9 at age 21” [3]. According to Statista 2020: the age at which auto-insurance is most expensive in the U.S. is 18 years old [4]. According to Hedges Company 2019: “The lowest percentage of total licensed drivers is among 16- to 19-year-olds, where just 34.8% of the population has a driver’s license” [5].

I wanted to create a game of my own, and driving seemed like an interesting genre to me. I could develop a game while at the same time introducing a more educational component to give it a practical application, in that it can teach others how to drive. This will accordingly help in reducing injury and fatality rates in car accidents.

The problem is that youth drivers have a higher rate of getting into car accidents. Right now, there are no established solutions for this problem, so I aim to develop an application that can

promote safer driving behavior by having youths engage in a driving simulator that teaches them safe driving.

Popular video games like Grand Auto Theft 5 and Mario Kart excludes typical vehicle functions like the turn signal, headlights; also does not educate on proper driving behavior [6].

In this paper, we follow the same line of research by developing a driving simulator composed of levels that feature different driving concepts. Our goal is to teach young drivers proper driving etiquette without having to put themselves in danger on the road. Our method is inspired by a drunk driving simulator in a museum; that simulator allowed the player to experience driving under the influence of alcohol without actually having to drink alcohol [8]. As programmed in the drunk simulator, the player could not accurately control the car [7]. A game that provides a more complex, nuanced driving experience.

This game allows the player to activate the other important vehicle features like the blinker.

The rest of the paper is organized as follows: Section 2 describes the challenges that we encountered during the game development process and experimental design; Section 3 provides the details of the game, including the game structure, level design, and educational reinforcement; Section 4 presents the relevant details about the experiment we did, following by the mentioning related works in Section 5. Finally, Section 6 gives the conclusion remarks, as well as discussing the future work of this project.

2. CHALLENGES

In order to build the tracking system, a few challenges have been identified as follows.

2.1. People are discouraged from investing extraneous resources into driving

As of now, most people learn to drive via the traditional method, which is enrolling into a driving school and practicing to drive as a student driver. Consequently, few people will consider learning virtually as it is not a viable option [9]. I will make my application accessible for anyone learning to drive by making it free to download on PC and iOS. As this application acts as an alternative to the traditional method, users will not have to worry about taking a supplement course and further use up their financial and temporal resources. In addition, this application should be effective enough to the point where people can use this as a substitute to the traditional method. As this application is virtual, it lacks the feeling of realism, so the goal of this app would have to teach users how to follow proper driving etiquette without them actually driving. This can be done by showing them how to follow etiquette so that the users can replicate the behavior in real life.

2.2. How to effectively educate people on appropriate driving etiquette

This application will educate people about driving concepts in a unit format, where each unit focuses on a particular driving concept. A diagnostic test will be conducted at the beginning of each unit to gauge the student's level of familiarity with the tested concept. One way to teach people to drive safely is to communicate to people the risks of not practicing appropriate driving

etiquette. This application aims to allow the students to freely experiment with different actions in the driver's seat that result in different outcomes. This way, the students can digitally experience the consequences and recognize the risks, encouraging them to practice safer driving behaviors to avoid these risks.

2.3. How to gather useful and relevant results from this application

The third challenge is that the application needs to collect data from the users that can be used to generate useful and relevant results for the study. The manner in which the data will be collected is by asking the users to fill out a survey outside of the application. This survey will ask for the user's age, gender, time spent driving, rating on the effectiveness of each unit, and the way that they heard of the app. The compiled data will be used by me to generate a data table listing all of these categories, and I will analyze and interpret the data [10]. In order to produce useful and relevant results, I need to record how many people downloaded my application and how effective the app was. I also need to see which age demographic and amount of driving experience is most prevalent in the user base as this app is meant for teenagers and young adults learning to drive.

3. SOLUTION

I developed a single-player game called Safe Drive Test. The game was developed using the Unity game engine, and the code was written using C#. It plays out as a driving sim split into levels that teach individual driving concepts. Each level starts out with the level title screen, followed by an introductory prompt that provides the player a preface to the driving concept that the level is focused on. The player then plays through a pretest that offers them a chance to implement the concept they were taught [11]. After the player completes the pretest, the player is shown a scorecard that details their results. Based on certain conditions unique to each level that the player fulfills, the points associated with the conditions are added to the total score. Therefore, from the scorecard, the player can learn what they did and did not do correctly. Regardless of the player's performance, the player is asked a multiple-choice question that tests their knowledge of the concept. The player is unable to proceed until they correctly answer the question; this was done to reinforce the player's knowledge of the tested concept. The player then plays through the practical test, which builds upon the previous test by providing a different and more complicated scenario. Finally, the player is given a final score based on their performance in the practical test, where their score determines whether or not they can progress to the next level.

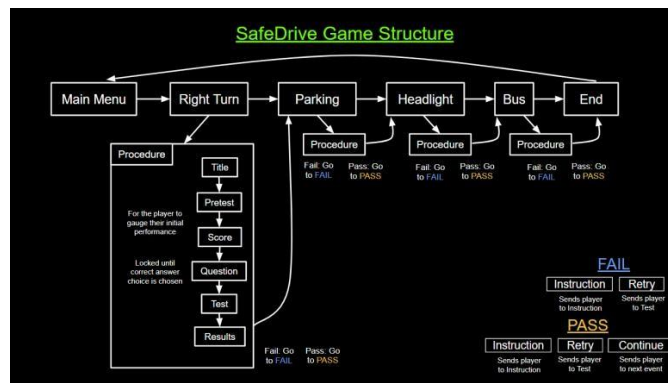


Figure 1. Overview of the game

```

1 using System.Collections;
2 using System.Collections.Generic;
3 using UnityEngine;
4 using UnityEngine.SceneManagement;
5
6 [CreateAssetMenu(fileName = "MasterControl", menuName = "ScriptableObjects/MasterControl")]
7 public class MasterControl : ScriptableObject
8 {
9     public static MasterControl MC;
10
11     public bool TouchControls;
12     public Units[] Units;
13     public string Credits = "Credits";
14
15     private int unitIndex = 0;
16     public enum UnitStages
17     {
18         Start,
19         PretestPrompt,
20         Pretest,
21         PretestPause,
22         Question,
23         QuestionScore,
24         PracticalTest,
25         Score,
26         Debug
27     }
28
29     public UnitStages CurrentStage = UnitStages.Start;
30
31     public float PassingScore { get { return Units[unitIndex].PassingScore; } }
32     public bool Paused
33     {
34         get { return unitIndex < Units.Length & Units[unitIndex].GetPaused(CurrentStage); } //return (if this is true) ; (then return this) ; (else return this);
35         // set ( )
36     }
37
38     private void OnDisable()
39     {
40         MC = this;
41         Debug.Log("MC setup");
42     }
43 }

```

Figure 2. Code 1

To establish a proper level progression system, I created an enumeration listing each of the different stages of a level in a specific order. The order is as follows: Start, PretestPrompt, Pretest, PretestPause, Question, QuestionScore, PracticalTest, and Score (the Debug stage was used during game development to find and fix bugs, does not appear in the final version).



Figure 3. Screenshot of the game 1



Figure 4. Screenshot of the game 2

```

File Edit View Project Debug Test Analyze Tools Extensions Window Help Full Screen
QuestionHandler.cs ScorePanelHandler.cs AICarRaycastInitializ.cs NavMeshAgentTest.cs MasterControls
Miscellaneous Files MasterControl
34 // set {}
35 }
36
37 private void OnEnable()
38 {
39     MC = this;
40     Debug.Log("MC setup");
41 }
42
43 public bool SceneLoading;
44 public void StartUnits() //resets units back to start
45 {
46     unitIndex = 0;
47     CurrentStage = 0;
48     SceneManager.LoadScene(Units[0].GetScene(0));
49 }
50 public int unlockedUnit = 0;
51
52 public void UnlockNextUnit() //sets currently unlocked units in the main menu
53 {
54     //unlockedUnit = Mathf.Max(unlockedUnit, unitIndex);
55     if (unlockedUnit < unitIndex)
56     {
57         unlockedUnit = unitIndex;
58     }
59 }
60
61 public void StartNextUnit() //moves on to next unit or credits depending on the current unit
62 {
63     unitIndex ++;
64     if (unitIndex < Units.Length)
65     {
66         UnlockNextUnit();
67         LoadUnit(unitIndex);
68     }
69     else
70     {
71         SceneManager.LoadScene(Credits);
72     }
73 }
74
75 public void LoadUnit(int unitIndex)
76 {

```

Figure 5. Code 2

In the first main menu screen, only the first level “Right Turn” is not shaded out, indicating that “Right Turn” is the only currently accessible level. The game features a level selection system where the player progresses through the levels chronologically. After the player finishes a level, he/she is able to play the level, and the new level will be permanently unlocked, which is indicated by the change in color. As shown in the second menu screen, all the levels have been unlocked.



Figure 6. Screenshot of the game 3



Figure 7. Screenshot of the game 4

This is one of the starting screens that appears at the beginning of each level. The starting screen displays the unit number and level title, e.g. “Unit 3: Headlights.” Each level is categorized into scenes in Unity. When the player finishes a level and continues onto the next, the MasterControl script incrementally adds to the unitIndex int variable to move to the correct level map. If the player selects a level from the level selection, the unitIndex variable will be set to equal the level scene index.



Figure 8. Screenshot of the game 5

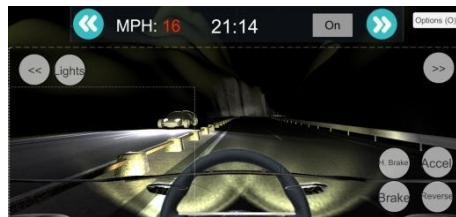
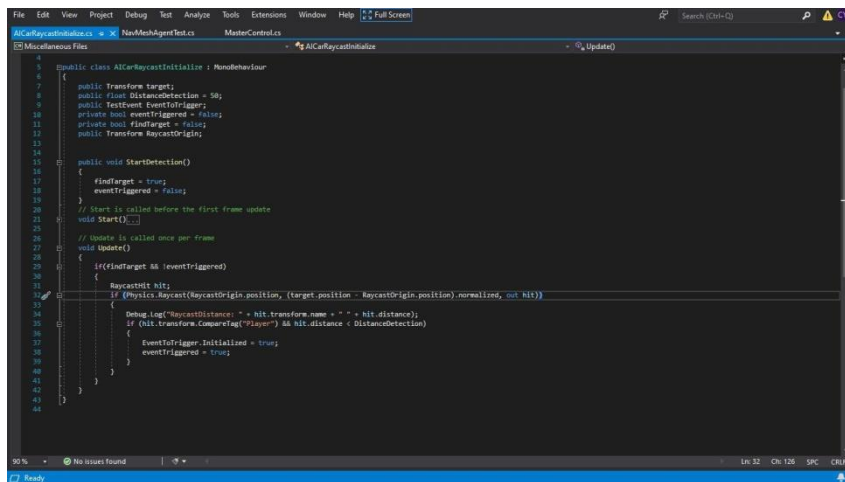


Figure 9. Screenshot of the game 6



```

1  public class AICarRaycastInitializer : MonoBehaviour
2  {
3      public Transform target;
4      public float distanceDetection = 50;
5      public bool eventTriggered;
6      private bool eventTriggered = false;
7      private bool findTarget = false;
8      public Transform RaycastOrigin;
9
10     public void StartDetection()
11     {
12         findTarget = true;
13         eventTriggered = false;
14     }
15     // Start is called before the first frame update
16     void Start()
17     {
18     }
19     // Update is called once per frame
20     void Update()
21     {
22         if (findTarget && !eventTriggered)
23         {
24             RaycastHit hit;
25             if (Physics.Raycast(RaycastOrigin.position, (target.position - RaycastOrigin.position).normalized, out hit))
26             {
27                 Debug.Log("RaycastHit: " + hit.transform.name + " = hit distance);
28                 if (hit.transform.CompareTag("Player") && hit.distance < distanceDetection)
29                 {
30                     EventTrigger.Initialized = true;
31                     eventTriggered = true;
32                 }
33             }
34         }
35     }
36 }

```

Figure 10. Code 3

The AI car is able to locate its position relative to the player using raycasting. Both the player and the AI car have a RaycastOrigin object attached that allows the Raycast to calculate the distance between the two. Within the distance, the AI car is able to detect the light state of the player's car. This is important because the score for this unit is calculated based on the player's light state when approaching the AI cars.



Figure 11. Screenshot of the game 7



Figure 12. Screenshot of the game 8

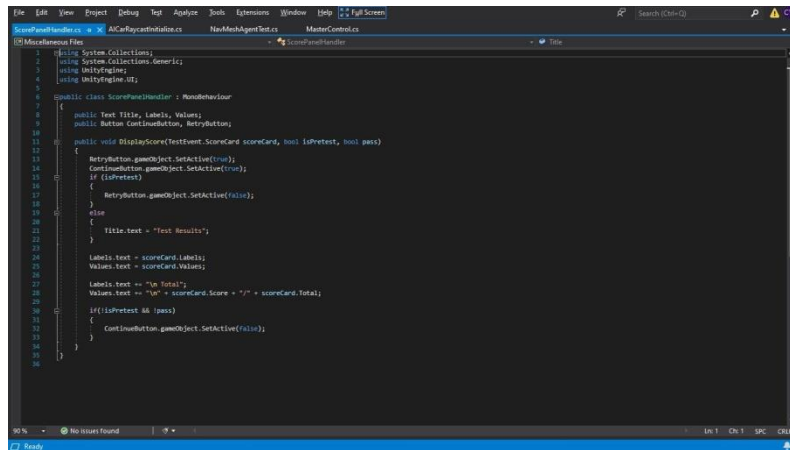


Figure 13. Code 3

Test results are displayed on a scorecard when the player finishes the level. The criteria listed on the scorecard changes depending on the level. The two variants of the scorecard are the pretest and the test variants. Because the pretest is only meant as a self-diagnostics for the player, the retry button is taken out of the pretest scorecard, which is done by setting it to inactive when the bool variable isPretest is true. The kind of criteria shown is determined by Unity objects outside of the script, meaning that each level has its own dedicated objects for listing criteria.

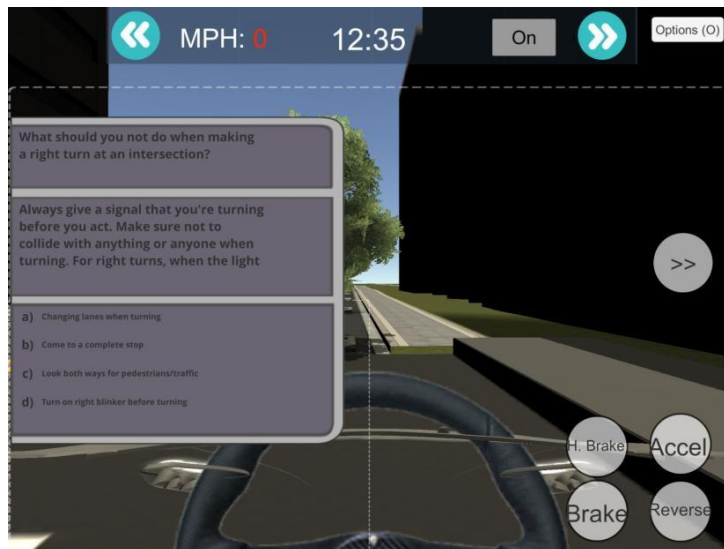


Figure 14. Screenshot of the game 9

```

16 // Start is called before the first frame update
17 void Start()
18 {
19     //DisplayQuestion();
20     CurrentQuestion = Questions[0];
21     QuestionResults = new bool[Questions.Length];
22 }
23
24 public void DisplayQuestion() //displays question number from QuestionCanvas
25 {
26     QuestionUI.GetComponent<QuestionCanvas>().DisplayQuestion(CurrentQuestion, this);
27 }
28
29 public void HideQuestion()
30 {
31 }
32
33 public void InputAnswer(int answer)
34 {
35     //Debug.Log(answer == CurrentQuestion.Answer ? "Correct" : "Incorrect");
36     //string response = answer == CurrentQuestion.Answer ? "Correct" : "Incorrect";
37     QuestionResults[index] = answer == CurrentQuestion.Answer;
38     if (answer == CurrentQuestion.Answer)
39     {
40         index ++;
41         if (index > Questions.Length - 1)
42         {
43             FindObjectOfType<Handler>().MC_NextStage();
44         }
45         else
46         {
47             CurrentQuestion = Questions[index];
48             DisplayQuestion();
49         }
50     }
51     else
52     {
53         //display "incorrect answer"
54         QuestionUI.GetComponent<QuestionCanvas>().DisplayIncorrectMessage();
55     }
56 }
57
58
59
60

```

Figure 15. Code 4

Within each level, the player is asked a question to test his/her knowledge. The way in which the question is changed for every unit is similar in concept to the score criteria.

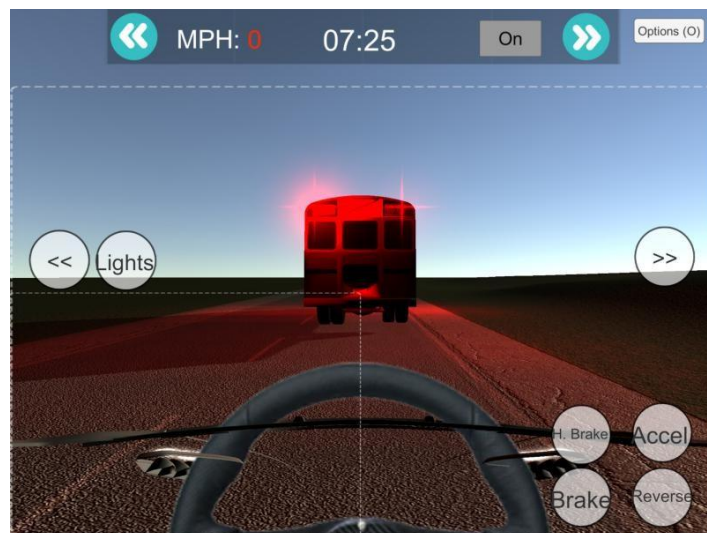


Figure 16. Screenshot of the game 10

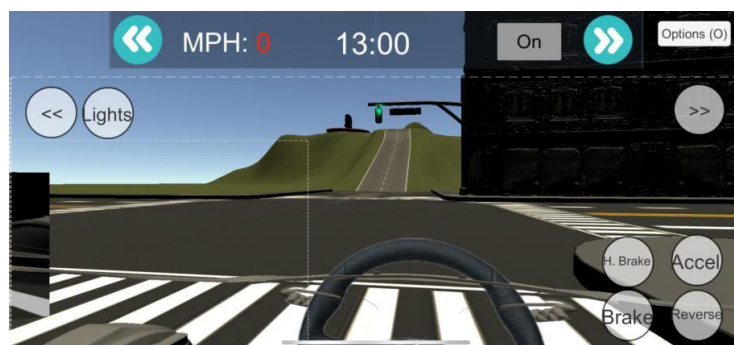


Figure 17. Screenshot of the game 11

Many methods were used to detect and judge the score criteria. For example, area detection, blinker detection, velocity detection, and head turn detection are the detector scripts used in the above two images. The area detection can be used for checking if the car either entered the area designated by the object hit-box or did not enter. blinker detection is used to determine which blinker the car turned on, and when. Velocity detection can be used to detect if the car has stopped or if it's under a certain speed limit. Head turn detection is used to check if the player turned their head by tracking the camera angle.

4. EXPERIMENT

4.1. Experiment

In experiment, We want to test how effective is SafeDrive at teaching players how to drive. To evaluate the effectiveness, We need to collect number of attempts, amount of time played, and helpfulness rating on the game tests. Evaluating the relationship between the number of attempts vs amount of time played and number of attempts vs helpfulness rating on tests will help me determine the effectiveness of SafeDrive in teaching people to drive. In general, the higher the number of helpful ratings, the more effective the game is, and the higher the amount of time played, the higher the level of engagement. I published the app on the app store in February, and as of March 18, out of 731 people who saw the app, 13 people installed it. 100 people 's responses were randomly chosen from the player base, meaning sample data comes from simple random sampling

Table 1. Result of experiment

	Passed tests with 1 attempt	Passed tests with 2-5 attempts	Passed tests with 6+ attempts	Not pass all tests	
play >24h	0	0	1	3	4
play 6-24h	1	6	15	2	24
play 1-6h	7	13	20	6	46
play <1h	6	10	8	2	26
	14	29	44	13	100

Table 2. Result of survey

	Very Helpful	Helpful	No help
Passed tests with 1 attempt	2	9	3
Passed tests with 2-5 attempts	4	19	6
Passed tests with 6+ attempts	5	27	12
Not pass all tests	0	5	8

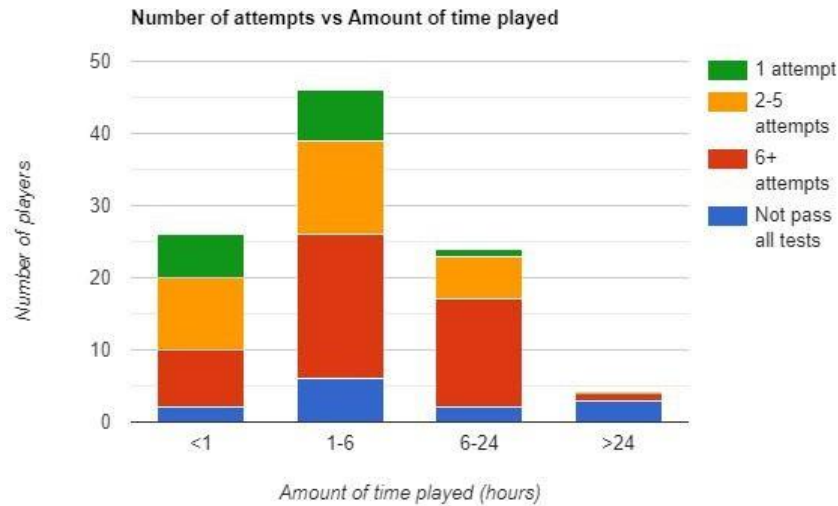


Figure 18. Number of attempts vs Amount of time played

5. RELATED WORK

This research paper is about predicting the potential benefits and the challenges that come with implementing driving simulator training in Norwegian driver education [12]. Although this study did not develop an actual simulator, it did anticipate the potential benefits of sim training based on other countries' results and discussed future challenges in implementing such a system. My study is not directly comparable with this study as the objectives of the two studies differ. My study involves developing the simulation while this study is more oriented towards "investigating the use of simulator training in driver education in Norway, discussing the potential gains and challenges and looking at the possibility of increasing the availability and use of driving simulators" (Taylor & Francis Group 2018). However, unlike this study, my experiment does not rely on results generated from other studies as my own simulation was able to produce concrete results.

Hirsch, Pierro, and François Bellavance did a study on the impacts of driving simulator-based training (DSBT) in driving programs in Canada [13]. This illustrates that the situation is happening around the world.

Similar to my study, Öztel, İsmail, and Ö. Z. Cemil's study also developed a driving simulator game [14].

6. CONCLUSIONS

To address the problem of youths more frequently getting into car accidents, I created a gamethat can teach beginner drivers how to drive safely. The game aims at teaching beginner drivers proper driving in a safe, risk-free environment, which has no solution to solve the problem perfectly on the market yet based on our study [15]. So I used the Unity game engine and C# to finish the whole project. The game plays out as a driving sim split into levels that teach individual driving concepts. Each level has its own individual driving concepts to teach and train. After development work is completed we publish the game on the ios platform, which is very easy to get more downloads and test people. After the experiment, we proved the app actually helps users improve their test score and learn faster.

Driving simulations on a flat screen can never substitute for actual driving. The controls in the sim vs real life are simply too different to compare. However, players will be able to learn concepts that they can apply in real-life driving. They will still have to learn how to drive using a steering wheel.

Although the game is free, the game contains relatively few levels -- too few to encapsulate all driving concepts. In order to include all content from the DMV test, the game development period would have to be greatly extended as it took half a year to create the 4 levels currently in the game.

It takes significantly less time to complete this game than in a traditional driving course. However, based on the results, most players have learned very little from this simulation.

I will have this game support gyro controls so that this can more accurately imitate real-life driving in terms of the steering wheel and head movements. I also plan to develop more levels so that more driving concepts can be added.

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