

# The Design and User Acceptance of IoT-based Access and Entrance Control System Using Voice Recognition

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## ABSTRACT

Despite the usability of the conventional security measure to identify user's identity and gain access approach, biometric security devices-based Internet-of-Things (IoT) are to be trusted more due to its significant and enhanced security features. This paper aims in designing an IoT-based smart voice activation access control system. The proposed Voice-Activation Entrance System (VAES) is developed based on information gathered through a field-testing approach. The system has been evaluated through usability field testing methodology. Eventually, this can be considered as a reference model for developers and researchers in the area to develop similar apps-based IoT.

**Keywords:** Voice recognition, Internet of Things, biometric, security system

## I INTRODUCTION

IoT is now an important topic from various aspects of human life whether technical, social or economic. Various types of products whether small or large are connected to the Internet. With the ability to analyze powerful data, it promises to change the way people work, live, and play. The projections for the impact of IoT on the Internet and the economy are impressive with some expecting as many as 100 billion IoT devices connected to the Internet that will impact the global economy by more than USD11 trillion by 2025 (Rouse, 2019). Even though there is no single definition has been done for the term Internet of Things, The Internet Society defines IoT as "scenarios where network connectivity and computing capability extends to objects, sensors and everyday items not normally considered computers, allowing these devices to generate, exchange and consume data with minimal human intervention" (Internet Society, 2015). An example of IoT implementation is in the security field such as to control the entry of people to certain place such as building, room or even car.

The physical security to enter and gain access to a facility especially to a sensitive area such as data center should be a top priority for any organization. Since the threats to these facilities continue to increase, the term entrance control and access control

must be properly understood so that a proper security measure can be taken to control them. The access control confirms authorized users using their credentials such as face, fingerprint, voice, number, proximity card, etc. Then the system will decide whether they are allowed to enter or not. On the other hand, the entrance control is the system that enforces the decision whether by allowing the user to enter the facility or not (Internet Society, 2019). An electronic access control systems restrict entrance to secure areas of a property, building, room, file cabinet, drawer, or other area containing sensitive or proprietary information, assets, or data with round the clock protection and access. (Senseon Secure Access, 2020).

The entrance to a building should be secured to ensure the assets and people's belonging is safe (Wahyudi, 2007). Many types of security systems still use the conventional authentic approach such as password, smartcard, and key (physical). Password is one of the security methods widely used for user authentication (Strassmann, 2002). It helps to secure building and facilities by preventing unauthorized users from accessing private places. However, most organization institutes' policies that requires a complex password that is built upon an alphanumeric upper and lower case, digital, symbol, and the least character to secure the password. This causes certain users to be doubtful in using the password as they are afraid that may be unable to memorize the long and complex password. This may result to deniable access if the designated password is not correctly remembered. Another approach is the use of smartcard and keys in order to replaced password. However, there is a chance that users forget to bring their smartcard and key. Furthermore, the cards or keys may be stolen or misplaced. Hence, there is a need for an alternative solution in ensuring the security of buildings or facilities. The biometric technology that uses people's body features like voice, eyes, face, and fingerprint for user authentication seems to be a promising solution. Biometric is more convenient to be used as compared to using a smartcard or a physical key. But the user are required to follow strict measure so that biometric fingerprints can function effectively. The registered user's finger must be in an acceptable condition else the system cannot authenticate it (Thakkar, 2020).

The fingerprint will be inaccurate if the user has a skin disease (Thakkar, 2020) The other available biometric measure is the 2D face recognition. This may be insecure because it is easy to be recreated by somebody else. The face is also difficult to be recognized by the system if the system uses low quality imaging technology. In addition, face recognition may cause privacy issues as it cannot be recognized from a distance. The cost of iris and retina recognition is relatively high compare to other biometric. There are too expensive if the system is installed at each door. Hence, a small income organization cannot afford the cost. Due to this problem, there is a need for a biometric measure that is based on user's voice. The emergence of IoT technology in human life creates an opportunity towards controlling security (i.e user authentication) by using people's voice. As the IoT system becomes pervasive and integrated into human daily lives, this study investigates the potential of IoT as a tool to electronically control door access using people's voice. The proposed Voice-Activation Entrance System (VAES), a prototype of an IoT for managing door access using people's voice was developed and evaluated. The study contributes towards an understanding of the system requirements for such apps and could be a reference model for developers and researchers to improve an electronic process for user authentication based on voice recognition. The upcoming section describes related studies and it is followed by the design and development of VAES. The subsequent section explains the evaluation of VAES. And, finally the conclusion and future work is presented in the last section of the article.

## II RELATED WORK

This section describes the background of using people's voice to open the door. It also includes the significance, objective, and scope of the project. In phonetics and phonology, voice refers to the speech sounds produced by the vocal folds (also known as the vocal cords). Also known as voicing. Each human has a unique tone, rhythm, frequency, and pitch (show in figure 1 express including where they stop in phrases and how quickly they speak depending on where they are in a phrase and it cannot simulate by other people easily. Obviously, the average male has a lower voice than the average female but the average range of each person's voice is unique. (Voice and Speech Recognition, n.d.) This system use voice to recognize the user. It also calls a voice recognition system. This paper's aim is to design a voiceactivated entrance system. Voice recognition system can use in security system.

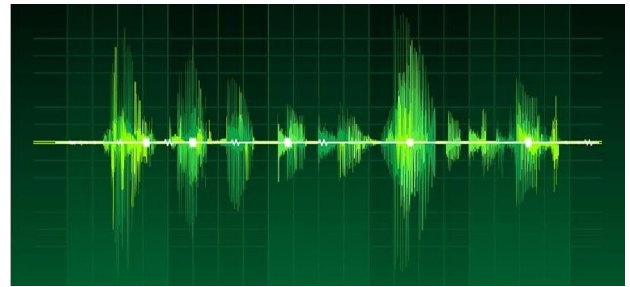


Figure 1. Pitch of Human Sound

A Voice recognition system is one of the biometric methods. Biometric is biological measurements or physical characteristics that use in computer science as a form to identify and access control. Biometrics are directly linked to an individual. They are unique and are very difficult to recreate. The term behavioral biometrics may be used to describe another class of biometrics (Alzubaidi and Kalita , 2016).

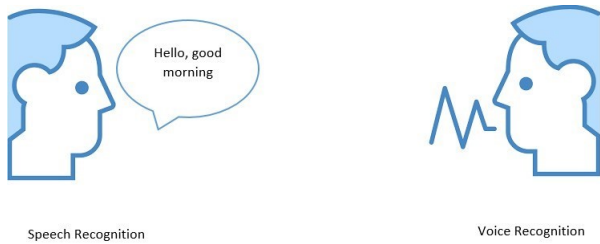
For the user, it does not require him/her to remember a unique digital passcode. Biometric authentication is convenient to use compared to other security methods like smartcard and password. Smartcard and password maybe will be stolen or lost.

Other examples of biometric are face recognition, DNA, palm print, hand geometry, iris recognition, and retina. Each method has its own advantages and disadvantages based on its usability and security. Among the biometrics methods, voice has high usability characteristics which include the simplicity for the user, feeling of resistance, speed of authentication, and level of false-rejection rate.

There have two different types of methodologies in voice recognition technology. One methodology is speech recognition. Speech recognition also calls text dependent which requires a user to remember a sentence, phrase, and keywords. (Wood, 2020) This means the speaker cannot say anything he or she likes to authenticate. In static text-dependent voice authentication, each authentication uses the same password. In voice authentication relying on dynamic text, a random passphrase, such as a sequence of numbers, will be generated for the user. This content must also be registered.

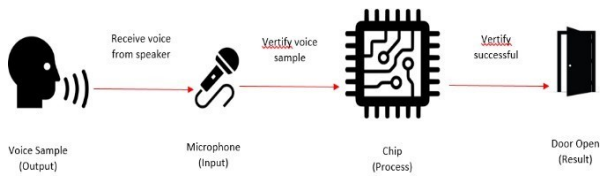
Another methodology is voice recognition. Voice recognition also call text-independent which requires no specific passphrases. This means the speaker can say anything he or she like to authenticate because it referred to as a voiceprint, which is the identification and authentication arm of the vocal modalities (Wood, 2020). A Voice recognition system can measure the unique biological sound of each individual when speaking.

Figure 2 show the difference between speech recognition and voice recognition.



**Figure 2. Speech Recognition VS Voice Recognition**

Voice recognition system have three main component i.e. voice sensor, speaker verification system and door access control. Voice sensor like mic as an input will receive the voice from person. Then, voice sample will send in speaker verification system to verify the authenticity of the person based on his/her voice. Finally, the door will open if the voice is match with sample voice in database. Figure 3 show the process of Voice Activated Entrance System. Figure 4 show the hardware that use in Voice Activated Entrance System.



**Figure 3. The Process of Voice Activated Entrance System**



**Figure 4. Hardware Use in Voice Activated Entrance System**

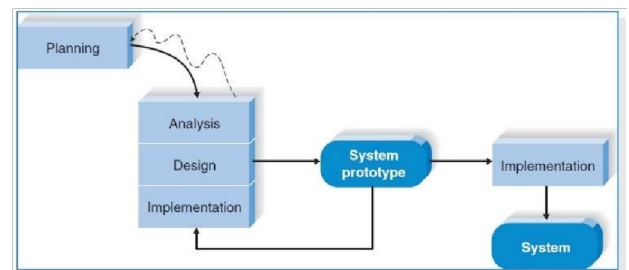
This system is important because it can help the user to save the cost. (Find Bio Metrics , 2020) The price of acquiring a voice recognition system is usually quite reasonable, especially when compared to the price of another biometric system like fingerprints and iris biometrics. This system relatively low cost to implement and maintain. Because of little equipment is needed, so making the cost-effective. This can help users to save a lot of costs in the security system. Next, this project can help the user enhance the security of a building or house. Some of the buildings use smartcard or passwords as an

entrance system. This maybe will affect the safety levels of a building because the smartcard and password will be stolen, lost, forgotten, guessed by other people. By using a voice recognition system as a security system can help users to solve the problem that might occur in using smartcard and passwords as the security system. In addition, this project can help to improve the performance of an organization and customer satisfaction. Since voice recognition systems require little equipment, so it can usually be implemented without the addition of new equipment and system. So, it is so easy to use for everyone. This can let the organization improve performance and customer satisfaction by reducing their personnel and make use of them elsewhere in the company.

This paper's main objective is presenting the development of a Voice-Activation Entrance System to ensure the security of a building. The VAES is then evaluated by users of different background. However, the study is limited to authenticate registered users and must be used in a quiet environment. This is because of the quality of the microphone deployed in the experiment is not very good. Having background noise can affect the quality of the voice sample and, in return, fail to authenticate users. This system can be deployed in residential house as well as industrial buildings, as long as they have door access. The registered users may include from different age and level such as children, adults, and the elderly. As of now, VAES only supports English language. For the speech recognition system, the user must say aloud a passphrase or word in the English language to open a door.

### III METHODOLOGY

The development of VAES was realized by adapting System Prototyping. There are four basic processes of system prototyping as illustrated in Figure 5.



**Figure 5. The System Prototyping Methodology**

#### • Planning

Identify the problem in the current security system were difficult to fulfill customer requirements. At this stage, a plan is proposed to develop a system which is voice-activated entrance system helps security system at building more effectively and meet customer requirement. A project proposal is drafted explaining the problem that happens in the

current security system, the objective of the project, the significance of the project, the scope of the project, and the schedule of the project.

- **Analysis**

The requirement of the voice-activated entrance system will be analyzed by conducting a requirement analysis process. The activities involved in this phase are identifying the functional and non-functional requirements for the voice-activated entrance security system. The requirement will be gathered by analyzing the current voice recognition system, analyzing a similar system implemented in previous, and find detailed information in an online article to improve the voice-activated entrance system. A use case analysis, process modeling, and data modeling will be produced at this stage. The design or the sketches of the user interface will be also produced at this stage.

- **Design**

In designing the Voice Activated Entrance System, Visual Studio Code will be used to design the interface. Dart is the programming language that will be used in the Visual Studio Code. The database of the system is SQL. The Voice-Activated Entrance System will be hosted on a cloud webserver. At this stage, a low-fidelity prototype will be developed to refine the functional and non-functional requirements. The prototype will be shown to the selected users for suggestions or improvement. If a requirement is identified, then the analysis phase and design phase will be repeated. A usability or user acceptance study will be conducted to evaluate the functionality of the Voice Activated Entrance System. A group of random customers who interest in the system will be recruited to evaluate the system.

- **Implementation**

In this stage, the system will be fully implemented by hosting the Voice Activated Entrance System at a cloud service provider. A user training will be conducted to have a smooth transition of the old security system to the new one, Voice Activated Entrance System. The system will be observed and monitored regularly, and customer feedback will be received after the training.

#### IV DESIGN AND DEVELOPMENT

This section describes the design and development of a mobile app for register people’s information and voice and an IoT system for activating the door using people’s voices following the first three phases of prototyping. The section is divided into two subsections; (1) the requirements of a mobile app for register people’s information and voice and an IoT system for activate door using people’s voice and (2)

the prototype development of VAES; a mobile app and IOT system developed to demonstrate the gathered requirements. The requirements of a mobile app for register people’s information and voice and an IoT system for activating the door using people’s voices. A requirement gathering process was carried by analyzing documents and related IoT system that using voice to control things like LED from the Internet.

For the secondary requirements gathering process, the documents were searched using Google searching engine by providing keywords primarily “Voice recognition,” “Internet of Things,” “biometric” and “security system.” The documents were analyzed to elicit the requirements for an IoT and mobile app that can use people’s voices to open doors. Table 1 lists five significant requirements with their priority produced from the requirements gathering process. The requirements include register account, login account, select room, view history record, and manage door.

**Table 1. List of requirements for voice activated entrance system (vaes)**

ID	Requirement Description	Priority
<b>VAE_1</b>	<b>Register Account</b>	
VAE 1_1	The system allows first time user to register a new account.	M
VAE 1_2	The system must save all information of user such as email, phone number and password in database.	M
VAE 1_3	The system can record the voice of user.	M
VAE 1_4	The system allow user to do verification by using email.	M
<b>VAE_2</b>	<b>Login Account</b>	
VAE 2_1	The system allows user login using email and password.	M
<b>VAE_3</b>	<b>Select Room</b>	
VAE 3_1	The system allow user to select the room.	M
<b>VAE_4</b>	<b>View Entrance Record</b>	
VAE 4_1	The system allow user to view the entrance history for a room.	M
<b>VAE_5</b>	<b>Manage Door</b>	
VAE 5_1	The system allow user to open the door using speech recognition.	M
VAE 5_2	The system will do the verification of user’s voice.	M
VAE 5_3	The system will make a sound “Welcome” to user.	M

The requirements presented in Table 1 were translated into the computer system functionality.

The next process is visualizing and modeling the requirements of the app using the appropriate modeling method and tools. In this work, the Unified

Modelling Language (UML) was used to visualize and model the requirements. The models used in this work are two behavioral diagrams namely use case and sequence diagrams, and a class diagram that represents the structural components of the system. The diagrams were drawn using StarUML. Figure 6 illustrates the use case diagram and the communications between the use cases and the actor for an IoT and mobile app that can be used to voice activated entrance system. Five major use cases are register, login, select room, view entrance record, and manage the door. The use case of register, login, select room, view entrance record is the function on the mobile app and manage door are the function for IoT system.



Figure 6. Use case diagram of Voice Activated Entrance System

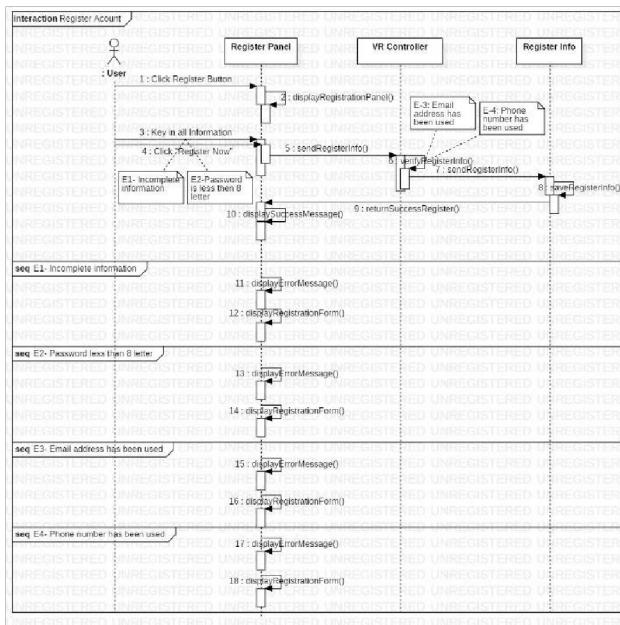


Figure 7. Sequence diagram of Voice Register Account

The use case diagram is detailed out to show the dynamic behavior of an IOT and the app. Hence, the operations involved in using a mobile app for register people's information and voice are illustrated in a sequence diagram from Figure 7, 8, 9 and 10. An IOT for activate door using people's voice are illustrated in an activity diagram of Figure 11. Both diagram shows the alternative flow for each function in each sequence diagram.

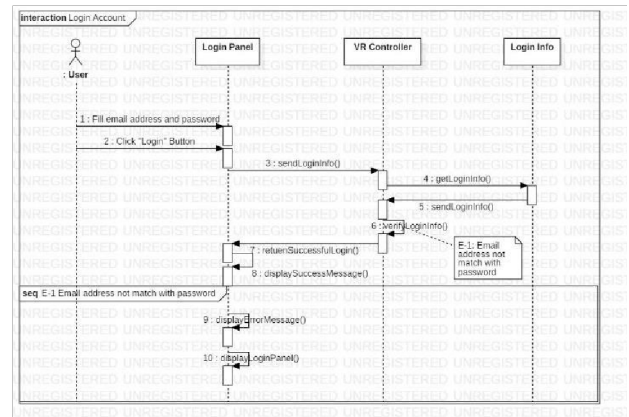


Figure 8. Sequence diagram of Login Account

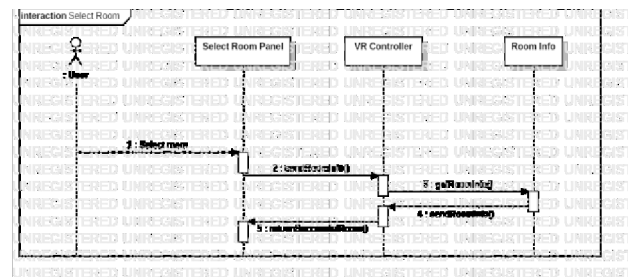


Figure 9. Sequence diagram of Select Room

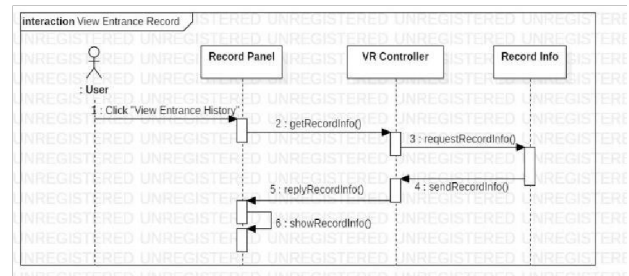


Figure 10. Sequence diagram of View Entrance Record

The structural components of a mobile app for register people's information and voice are represented in a class diagram as illustrated in Figure 12. The class diagram in Figure 12 shows the attributes and operations of an IoT and the app. The interactions between the classes are illustrated clearly in the diagram.

## V PROTOTYPE DEVELOPMENT

A prototype of a mobile app for register people's information and voice and an IoT for activate door using people's voice was developed. It represents the requirements explained in the previous subsection. Software prototyping is a standard way of demonstrating the software requirements so that further comments and suggestions could be obtained from the users based on their experience in interacting with the prototype. The Flutter was used as the main integrated development environment (IDE) tool. Further, the MySQL development platform was used to facilitate crucial functions like user authentication, and database for data storage. Screenshots in Figures 13, 14, and 15 show the

selected interfaces of the software of VAES. Figure 16 show the interface design of hardware of VAES.

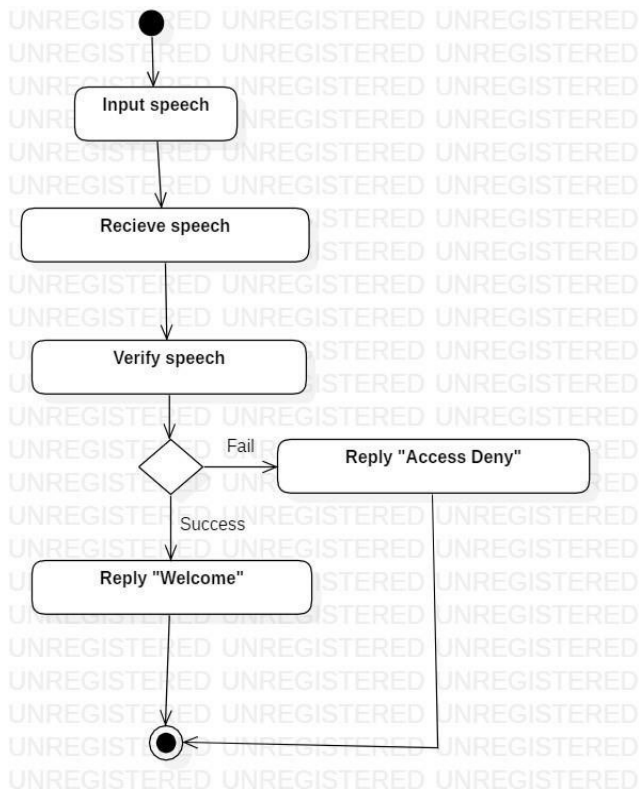


Figure 11. Activity diagram of Manage Door

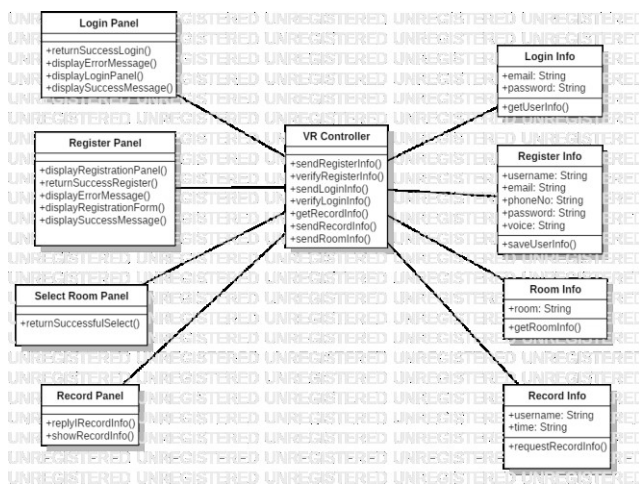


Figure 12. Class diagram of Voice Activated Entrance System

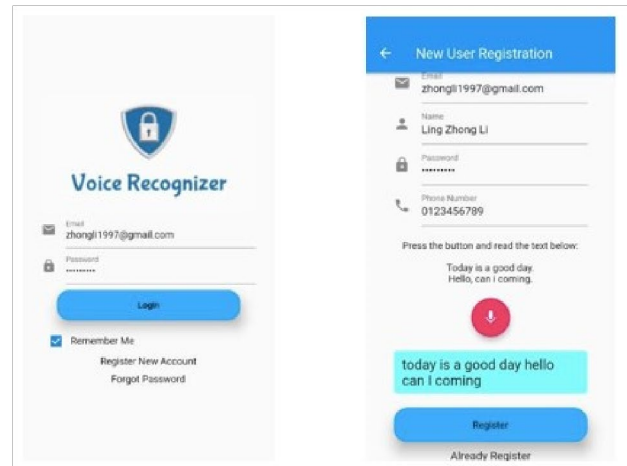


Figure 13. Login Screen (Left) and Register Screen (Right)

## VI EVALUATION OF VAES

### A. The Evaluation Setting

A usability evaluation was conducted on 5 respondents, consist of different gender and different age group. The respondents were approached randomly online. The instruments used for the evaluation of the VAES are questionnaires online. The questionnaire was consisting of 32 items in two sections. Section A asked the respondents' demographic information and background research in yes, no, or not sure while Section B asked the respondent's opinion about VAES in a five-point Likert scale where one represents strongly disagree, and five represents strongly agree. The respondents performed the following step-by-step procedure for the evaluation: (1) download the VAES (software) by clicking the link at google form description, (2) register the VAES (software) and test all the function of the VAES (software) (3), test the VAES (hardware) by using speech to open the door and (4) after the test the VAES (software and hardware), respondents start to evaluate the system by filling the questionnaire at google form.

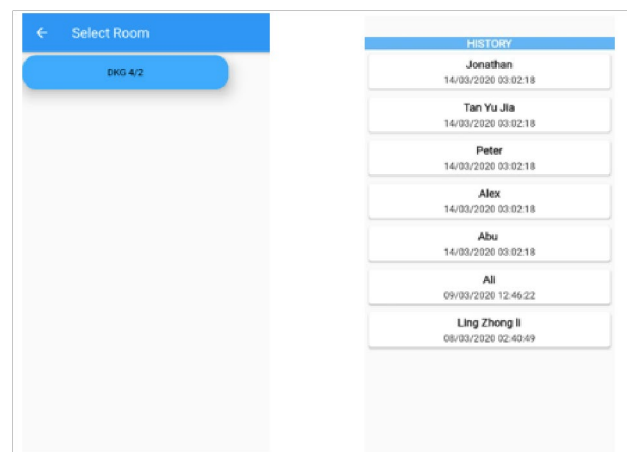


Figure 14. Select Room Screen (Left) and View Entrance Record Screen (Right)

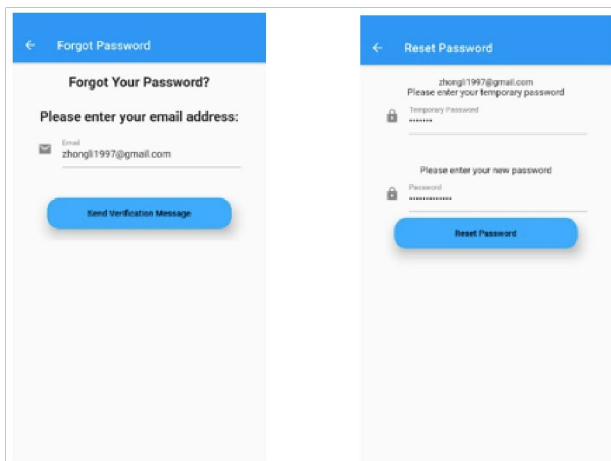


Figure 15. Forgot Password Screen (Left) and Reset Password Screen (Right)

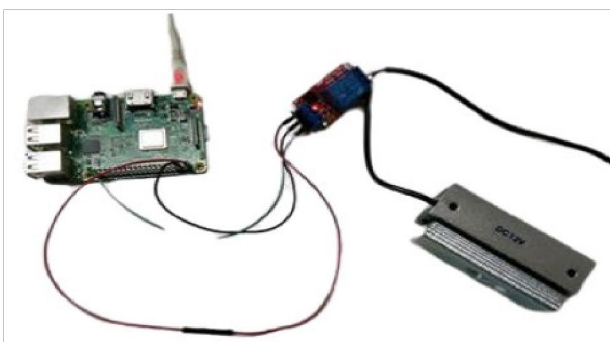


Figure 16. Manage Door in Hardware Design

## B. The Respondents' Demographic Information and Background Research

Analysis of the respondents' demographic information revealed that 40% of respondents are male and another 60% are female. Next, all respondents are between 21-25 years old. Based on the feedback obtained from the respondents, it is learned that as high as 80% of respondents feel that VAES is necessary nowadays. In addition, all respondents wanted to have the VAES in their office. The study also reveals that 80% of respondents feel that VAES is very helpful in reducing the security threats in buildings.

## C. Usability of VAES

An analysis was conducted on the respondents' responses in Section B of the questionnaire. This section is measuring the respondents' perception towards VAES usefulness, ease of use, satisfaction, and security which contains 25 question Tables 2, 3, 4, and 5 reported the frequency of the responses.

The outcomes of the evaluation suggested that respondents are satisfied with the feature of the mobile app and IOT that facilitates them in VAES.

More than half of the respondents are very satisfied with the system and wanted to recommend it to their friends. All of the respondents also feel the system is

useful and easy to use. The respondent can use the system without too many instructions. However, there are still some functions that can be improved to make the system more usable. The look and feel of the system can improved to ensure a good user experience.

## VII CONCLUSION

This paper described the design and development of a mobile app for the purpose of user authentication. Only authenticated users (based on voice recognition) are allowed to access/open the door. There are many aspects to activate the door using people's voices like voice recognition and speech recognition. Under speech recognition, it also can divide into two, static speech or dynamic speech. In this study, we are using dynamic speech recognition. In the future, we plan to use voice recognition that using people's voice patterns in the system. This method can increase the security of the buildings because everyone has a unique voice pattern and voice patterns are hard to recreate. Hence, will help to tighten the security.

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