RFID and Voice Recognition Based Dual Security System: A Robust Secured Control to Access Through Door Lock Operation

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Abstract
There are numerous automated access control systems available, but they are relatively expensive and difficult to use. The goal of this research is to create a security system that combines voice recognition and Radio Frequency Identification (RFID) to reduce costs while providing optimal security. This system is based on the Raspberry PI, and it uses RFID reading to scan and identify the user, as well as voice recognition to grant entry by opening the door. The microcontroller also provides access via a visual display in the form of a liquid crystal display for easy identification of the server room access control. Identity information and voice recognition are saved in a database, which can be accessed at any time. The RFID reader can scan a tag within 20 cm in two seconds and perform voice recognition in one second. The data is stored in the database after the two types of access control are identified and recognized. To open the door, the motor will move. This system is designed for ten users and has a 1% error rate.

Keywords: *Access Control, Door Lock, RFID, Voice Recognition*.

Abstrak
Solusi sistem keamanan untuk fasilitas strategis penting diterapkan untuk mencegah akses dari orang yang tidak berwenang. Sistem akses kontrol otomatis relatif mahal dan rumit untuk digunakan. Tujuan penelitian ini adalah mengembangkan sistem keamanan menggabungkan voice recognition dan Radio Frequency Identification (RFID) untuk meminimalkan biaya dengan keamanan optimal. Sistem ini dibangun di atas Raspberry PI yang mengarahkan RFID membaca untuk memindai dan mengidentifikasi pengguna serta pengenalan suara selanjutnya sistem memberikan akses masuk dengan mengizinkan membuka pintu. Mikrokontroler juga menampil-kan akses melalui visual display dalam bentuk liquid crystal display untuk memudahkan identifikasi terhadap akses kontrol ruangan server. Data tanda pengenal dan voice recognition disimpan dalam database untuk dapat di akses. Pembaca RFID dapat memindai tag dalam jarak 20 cm dalam dua detik, pengenalan suara dapat dilakukan dalam satu detik.

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Setelah kedua jenis akses kontrol tersebut diidentifikasi dan dan dikenali, data-data disimpan ke dalam database. Selanjutnya, motor akan bergerak untuk membuka pintu. Sistem ini diterapkan untuk 10 pengguna dengan tingkat kesalahan sebesar 1%.

Keywords**:** *Access Control, Door Lock, RFID, Voice Recognition*.

1. Introduction

Each room has important access controls to prevent unauthorized people from entering the room or accessing the room's devices (Morerwa et al., 2020). The room's vitality will be directly proportional to the level of security required. The better the access control provided, the higher the vitality level of the room that must be protected (Olagoke & Agbolade, 2017). In the last few decades, tools with advanced methods for providing security have been developed and used. Military bases, research centers, laboratories, and other critical facilities are among the important areas that require security systems for strategic applications. Because such sophisticated security systems are complex and costly to implement, they can only be done at a high cost (Adekolaolubukola & Somefunolawale, 2019). However, as a result of recent technological advancements and the growing need for increased security in civil and other applications, a slew of low-cost security solutions with varying degrees of sophistication and high complexity have emerged(Mostafizur Rahman Komol, 2018).

Different access control automation systems are available to reduce system complexity and lower costs. This system does not incorporate complex and expensive components. A gateway is implemented to facilitate interoperability between heterogeneous networks and provide a consistent interface, regardless of the access device (Lee, 2021).

The magnetic stripe, Optical Character Recognition (OCR), barcodes, biometrics, smart cards, and Radio Frequency Identification (RFID) are all examples of Automatic Identification (Auto-ID) systems used for access control (RFID). However, each of these technologies has its own set of benefits and drawbacks. The OCR system allows both manual and automatic identification to be used at the same time, but the reader's high cost prevents it from being widely used (Okafor et al., 2022).

Barcodes are a cost-effective way to manage inventory, but they have some drawbacks, including limited data storage capacity, strict distance requirements between the scanner and the barcode, which effectively prevents multiple barcodes from being processed at the same time, limited data redundancy, and error correction, and a lack of built-in data security standards. Biometrics, such as fingerprints, retinal scans, iris scans, and voice recognition, are effective identification solutions for automated access control, but they are costly and compromise privacy (Gałka et al., 2014).

Smart cards and their derivatives, such as memory cards or microprocessor card solutions, use standard credit card-sized with an integral data storage system to make financial transactions safe and fast, but at the expense of high reader maintenance costs (Hamad et al., 2019). RFID tries to overcome the weaknesses of the previous system by increasing the speed and accuracy of data collection and dissemination and reducing overall costs. RFID systems rely on radio frequencies to transmit a unique, tag-specific serial number to a reader or interrogator (Abdallah et al., 2016).

This technology is based on RFID tags for storing data into their memory, and RFID antennas to read data from the tag or write data to the tag (Mladineo et al., 2019). RFID technology is already well-known technology, therefore it could be implemented into door lock security system, thus creating RFID-enabled Security System (Rohei et al., 2021).

Biometric technology is a technology that uses user feature parameters as passwords. Each person's feature parameter is unique, even if the two users are twins (Shah et al., 2014). Therefore, the voice recognition system is safe for administrator users. Sound is the most natural way to communicate for humans. Voice biometric technology for user authentication is more convenient and accurate. This is due to the biometric characteristics of an individual which is unique and private property until the user dies. It is very convenient for users because there is nothing to carry or remember and will not make ID cards afraid of being stolen or passwords being hacked (Hsiao et al., 2017). This research combines the advantages of RFID and voice recognition to build a computer room access control system.

2. Method

The system development methodology was used to control and manage the software and hardware design processes and to structure and integrate the entire system development process. This method also helped to standardize the development and production processes by indicating the activities to be performed and the techniques to be used.

In this study, the Sequential Linear Model (Sulistyowati et al., 2023), known as the Waterfall Model (Jardim et al., 2020) was used. This method started with requirements engineering which embodies all the activities carried out in development to understand, analyze, validate, and replicate the model using the system correctly and precisely. Activities in the requirements engineering stage include qualitative analysis of the existing system, requirements elicitation, needs analysis, validation, verification, and requirements specification. Thus, requirements for documentation and management have emerged. Interview studies, questionnaires, social analysis, evaluation, and document checks were used to obtain user and system requirements to meet the system requirements.

2.1 RFID Reader

In the RFID Reader system, a reader or scanning device is needed that can read the tag correctly. RFID has several antennas that function to send and receive data to the tag and from the tag (Istiqomah, 2015).

2.2 RFID Tags

Parallax key fob passive RFID tag was used in this research because of its low price, lightweight, and ease of obtain. Twelve (12) units of RFID tags were used; each tag has a unique Electronic Product Code (EPC) for each student which is programmed into the microcontroller database to enable its identification when scanned by the student.

2.3 Software and Software Needs

Testing a web-based access control system using RFID and voice recognition consists of software tools that include: Python programming language, Google Platform MIT App Inventor 2, Notepad ++, XAMPP Emulator, and server-side scripting PHP. The specifications for the hardware requirements used are shown in Table 1.

Table 1. Hardware Requirements Specification

No	Component	Total	Description
1	Raspberry pi 3	1	System Control Center
2	RFID Reader RC 552	1	Card ID Detector using Frequency Signal
3	Buzzer 5V	1	Alarm Notifications when RFID does ID Card Detection
4	Speaker 4 Ohm	1	The output of voice notification from the system
5	*Door Lock Solenoid*	1	The lock tool of Room Door
6	Adaptor 5V/3A	1	The Source of Series Voltage
7	Adaptor 12V/3A	1	The Voltage Source of Door Lock Solenoid Component
8	*Smartphone* Android	1	The Application for Voice Recognition

2.4 RFID Module with Raspberry Pi

This design used SPI serial communication as an interface between the Raspberry pi and the RFID Sensor Type RC552 with a working voltage of 5V DC via the VCC pin, and GND, where this design serves to detect the ID Number on the RFID Card.

2.5 Block Diagram

The block diagram depicts an end-to-end solution, including the components required to construct the access control security system depicted in Figure 1. Physical hardware components include smartphones, Raspberry Pi3, RFID readers, RFID tags, speakers, relays, and door lock solenoids. These components are assembled to form a computer room entry access prototype. A Web Server is used, as well as a MySQL database. Physical and software components communicate with one another via wired and wireless Internet access.

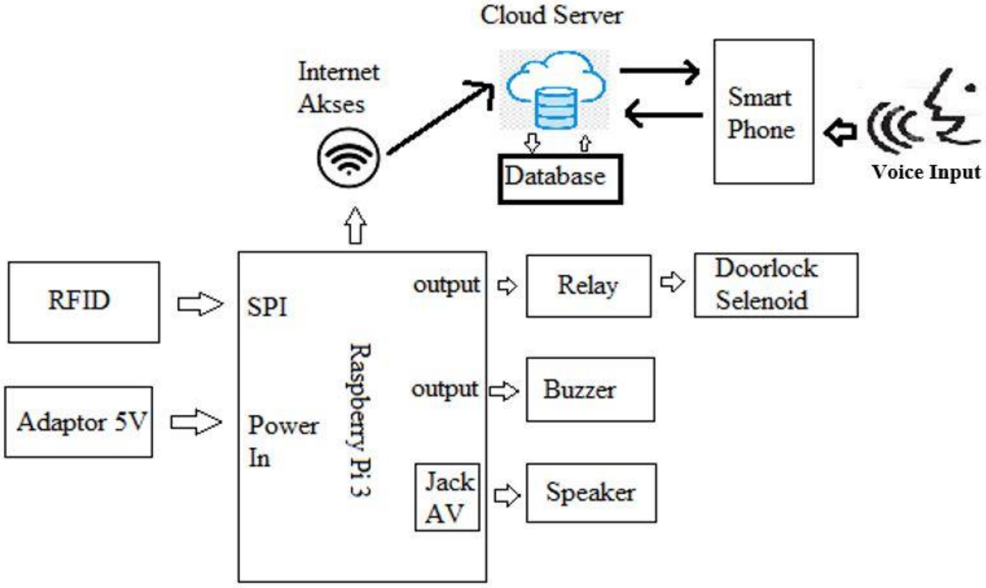


Figure 1. System Block Diagram

2.6 Buzzer Design with Raspberry Pi

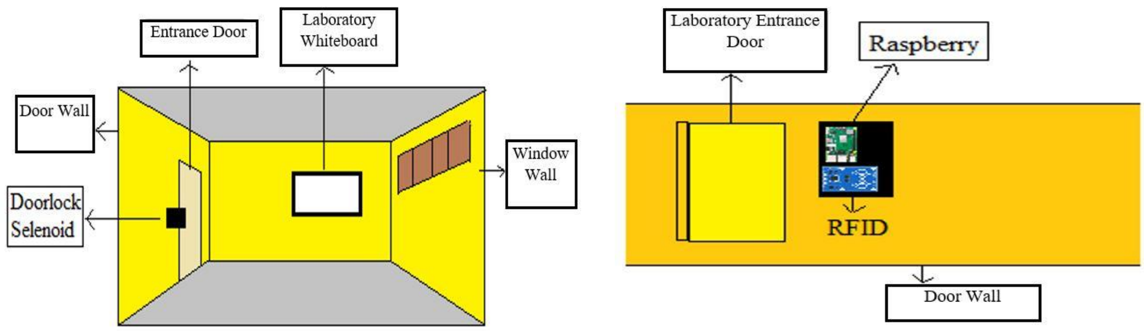
This design use a 5V Buzzer with a 5V input voltage to produce a "Beep" sound as an alarm or device notification. This circuit is connected to the output pin of GPIO 21 to get a HIGH or LOW signal. Meanwhile, the 1815 transistor is used as a voltage amplifier generated by the GPIO pin 21 to control the buzzer.

2.7 Solenoid Door Lock Design with Raspberry Pi

The voltage on the door lock solenoid is connected and disconnected using a relay as a switch in this circuit. To get a HIGH and LOW signal, the relay is connected to the GPIO 20 pin. The relay will actively connect the door lock solenoid to a voltage source when the GPIO 20 pin issues a HIGH signal. The relay will turn off and disconnect the voltage to the door lock solenoid if GPIO 20 issues a LOW signal. This circuit's working voltage is 5V DC, which comes from the External Adapter Voltage Source 5V.

2.8 Building Prototype

In this stage, the author made an overview of the prototype to be built, and a block diagram of the working system of the tool was carried out. Circuit design, application design, and database design were also performed. Figure 2 shows the description of the prototype that will be built in this study.



(a) Overall View (b) Door View

Figure 2. Media Prototype Tool

Figure 2 is a prototype tool designed made of 8mm plywood with a media size of Length = 72 Cm, Width = 51 Cm, and Height = 25 Cm, where the toolbox is placed on the outer part of the door wall as shown in Figure 2 (a) The door lock solenoid as an electronic door lock is placed on the side of the laboratory entrance, the following is picture 2 (b) prototype external appearance as a toolbox placement.

3. Result and Discussion

3.1 Software

The implementation of this software is divided into several parts, namely Raspberry pi 3B programming using Python software to process data, RFID sensors to detect ID Cards and identify detected IDs, and control output in the form of door lock solenoid as door lock and activate buzzer for alarm notification also sound notification through a speaker.

3.2 Hardware

The implementation of this hardware is divided into 2 parts, namely the design of the circuit and the construction of the whole tool, and then proceed with testing the tool to observe the results of the implementation of the hardware that has been made. Below is Figure 3 which shows the hardware implementation results.

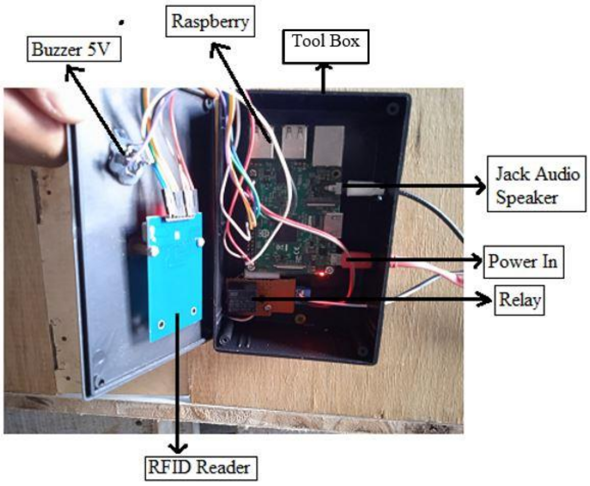


Figure 3. Circuit Implementation Results

Figure 3 above is the result of the implementation of the whole circuit which is placed in a black box with sizes P=15 Cm, L=9.9 Cm, and T=5.2 Cm. In the box. there is a Raspberry pi with an MRC552 RFID Sensor Circuit, a Relay Circuit, as well as a 5V Buzzer. The results of the overall Prototype implementation are presented in Figure 4.

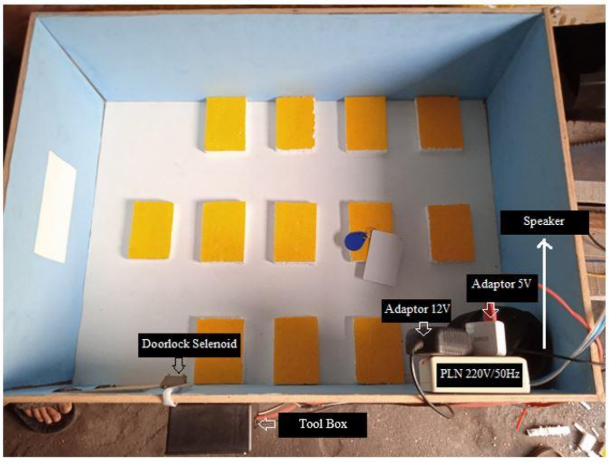


Figure 4. Results of Overall Tool Construction Implementation

3.3 RaspberryPi 3 B Testing

This test is carried out by connecting the raspberry pike to a 5V voltage source and accessing the internet network so that the IP Address of the Raspberry pi can be known and then accessed via the VNC Viewer. This test aims to make sure the Raspberry pi is functioning properly and has the OS installed.

3.4 RFID Reader Sensor Test

This test is done by activating the Raspberry pi and running the command "python3 RFID_TES.py. The next stage is Scanning the RFID Card and E-KTP on the RFID Reader Sensor. Sensor reading results are observed via the python terminal. The purpose of this test is to ensure that the RFID sensor can function properly.

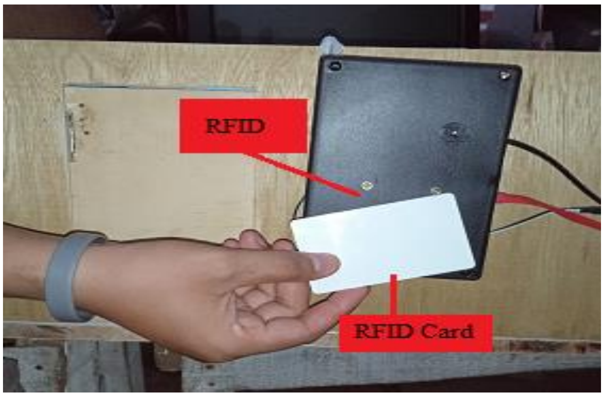


Figure 5. RFID Sensor Testing

The results of testing the RFID Sensor on the Raspberry Pi Python Terminal are presented in Figure 6.

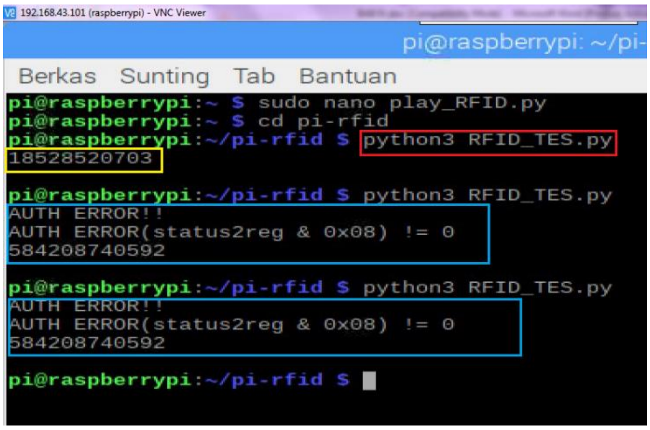


Figure 6. RFID Sensor Test Results

From Figure 6, it can be seen that the RFID sensor can function properly. The red box is a command to run the RFID Sensor, while the yellow box is the ID Result detected by the Sensor. The blue box is the test result of the E-KTP Card. From this test, it will be known Error information when using the E-KTP Card by displaying the ID Results from the E-KTP. Thus, it can be concluded that the RFID Sensor can also read the ID Card on the E-KTP.

3.5 Door Lock Solenoid Testing

This test is done by giving HIGH and LOW logic to the GPIO output pin which is connected to the Door Lock solenoid. When the output is HIGH logic, the Relay will connect the Voltage to the Door Lock solenoid to unlock the door. Conversely, when the output is LOW logic, the relay will disconnect the Voltage to the Door Lock solenoid to lock the door.

Figure 7. Test Results of Doorlock Solenoid Unlock

Figure 7 above shows that the door lock solenoid pulls the lock lever on the door when it gets a logic HIGH from the Raspberry pi output pin so that the door can be opened. The results of the door lock solenoid test when locking the door are presented in Figure 8.

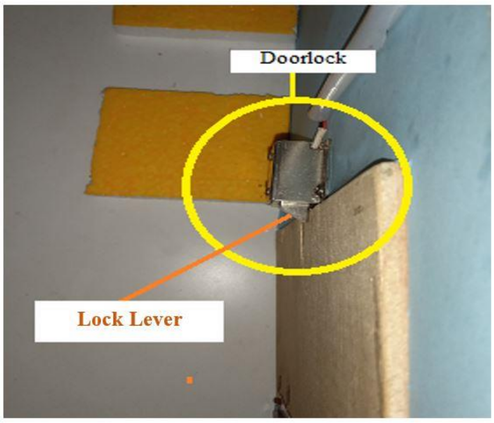


Figure 8. Doorlock Solenoid Locking Door

3.6 ID Card List Testing

This test is done by typing the command in the python terminal "python3 List_RFID.py" and directing the RFID Card at the Sensor. After the ID is detected, the system will display the ID registration input form where the admin fills the input form and presses the enter button to save the data into the database. The purpose of this test is to ensure the system can run the ID registration form and save the data into the database.

Table 2. Test Results for the ID List in the Database

No	ID Number	Result
1	932980700072	Successful ID registration is marked with a notification "Registration is successful". The inputted data is stored in the database under the name of Sandi with Assistant status

No	ID Number	Result
2	584189904484	Successful ID registration is marked with a notification "Registration is successful". The inputted data is stored in the database under the name of Beni with student status
3	584160121139	Successful ID registration is marked with a notification "Registration is successful". The inputted data is stored in the database under the name of Satrio with student status
4	584160121139	ID registration failed because the data was incomplete and the system displayed a notification "You have not entered data related to your cellphone number!

3.7 RFID ID Card Identification Testing

This test is done by running the command "python3 play_RFID.py" on the python terminal then directing the registered and unregistered RFID Cards to the Sensor. ID identification results will be displayed on the python terminal. If the ID identification result is registered with the assistant status in the database, a voice notification will appear with the words "Welcome to the laboratory assistant and good luck on duty" and the system will activate the door lock solenoid to open the lock lever on the door. If the ID identification results are registered with student status, a voice notification will appear with the sentence "Thank you, welcome (name) please sit on seat number (x).

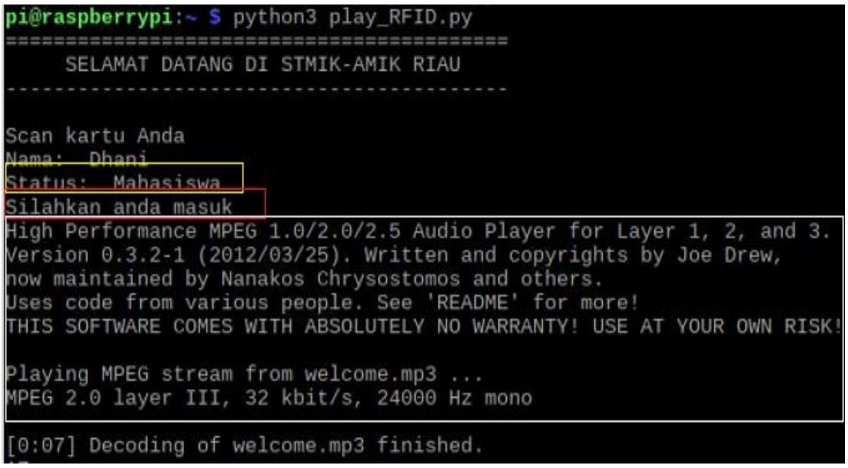


Figure 9. Results of Successful Identification with Student Status

The system will issue a voice notification in the form of "Sorry your ID was not found, please register with the labor assistant" if the ID is not found in the database. Based on the results of the three images above's identification test. The system can distinguish between registered and unregistered ID cards, it can be concluded.

3.8 Sensor Detection Distance Testing

This test is carried out by typing the command "python3 play_RFID.py" to run the system then directing the RFID Card at the sensor and measuring the detection distance using a roller meter, while the purpose of this test is to observe and find out the maximum reading distance of the RFID sensor used.

Table 3. The results of testing the detection distance of the RFID Sensor

No	Detection Distance (cm)	Result
1	1	Detected
2	2	Detected
3	2.5	Detected
4	3	Detected
5	3.5	Not Detected
6	4	Not Detected

Table 3 above shows that the results of testing the detection distance of the RFID sensor at a distance of 1-3 cm sow that the sensors can detect the RFID card well. Meanwhile, at a distance of 3-4 cm, the sensor cannot detect the RFID card, so it can be said that the maximum reading distance of the sensor is 3 cm.

3.9 RFID System Response Time Testing

This test is done by calculating the system time when reading the RFID sensor. The python terminal will display the results of the ID identification using a timer in the form of a stopwatch. The aim is to observe and determine the speed of system response when using RFID sensors. The results of the RFID system response time are calculated when the sensor detects the RFID Card and displays ID Card information on the python terminal and issues a sound notification on the 70 mS speaker. Test results the Response time of reading the RFID sensor until the system identifies and issues a sound notification is 01.32 seconds. The results of testing the response time of the RFID system as a whole start from the sensor detecting the ID Card then the system identifies the ID and displays information data then issues a sound notification and activates the Door Lock solenoid to open the door lock lever. The test results The response time of the RFID system as a whole that is displayed on the time measuring instrument in the form of a stopwatch is 06.19 seconds.

3.10The Keyword List and Voice Characters Testing

This test is done by opening the Speech Code application on a smartphone. The application will then display a notification with the sentence "Welcome to the speech recognition application". The "Registration" button needs to be pressed to enter the registration form and fill in the data input form for the name, minimum voice frequency, maximum voice frequency, and status. The frequency value is obtained by pressing the "Voice test" button on the list form. Data is saved by pressing the "save data" button. Table 4 presents the results of the list form testing that has been carried out.

Table 4. Test Results of the Registration Form

No	Testing	Result
1	Fill in the registration form input by leaving the status input blank	The application issues a notification with the sentence "choose the status first" and the data is not stored in the database
2	Pressing the status input to select the status type	The application displays the status selection form

3	Did not fill in the name input on the registration form	The application displays a notification "Type your name" and the data is not stored in the database
4	Testing of keyword list and voice character was successful	The application will save the data into the database and issue a "saved dataset" notification.

3.11 Speech to Text Testing

Distance testing is done by measuring the distance between the smartphone and the sound source using a meter with a centimeter scale starting from 10-100 cm. The results of speech to text in the application are observed. This test aims to determine the maximum distance of sound that can be detected by a smartphone.

Table 5. The Results of Measuring The Distance of The Sound Input

No	Distance (cm)	Keyword	Description
1	10	Dani	Detected
2	20	Dani	Detected
3	30	Dani	Detected
4	40	Dani	Detected
5	50	Dani	Detected
6	60	Dani	Detected
7	70	Dani	Detected
8	80	Dani	Detected
9	90	Dani	Detected
10	100	Dani	Detected
11	>110	Dani	Detected but not accurate

3.12 Testing on Distance Response and Response Speed of Speech to Text System

This test is carried out by measuring the distance and speed of the speech-to-text system response. The measuring instrument used is a Roller Meter with a centimeter scale to measure distance, and a stopwatch application to calculate the response speed of speech to text reading. This test aims to determine the maximum distance and speed of voice input response to speech to text. The following is the test data that has been done.

Table 6. Test Results of Distance and Speed of Speech to Text Response

No	Distance	Time	Description
1	20	3.06	Detected
2	30	2.91	Detected
3	40	2.90	Detected
4	50	2.91	Detected
5	100	2.97	Detected
6	150	-	Less clear

After the implementation results have been obtained and the testing process has been completed, the next step is to evaluate the test results to determine whether the tools that have been designed and tested are successful in following the plan or not. Evaluation of the test results of the tool and the system as a whole is carried out by distributing questionnaires and videos to several respondents to obtain assessments and suggestions for development as well as evaluation. Respondents consisted of 13 people.

The population is STMIK Amik Riau students where the sample is selected by the sampling method using random simple sampling based on a Likert scale. The percentage value of the questionnaire results that have been answered can be calculated using the following equation formula:

$P=\frac{f}{n} \times 100$

$P=\frac{13}{13} \times 100$

P= 100 %

The results of the calculation of the answers to the questionnaire are presented in Table 7.

Table 7. Percentage Results of Questionnaire Answers

No	Question	Number of Respondents	Answer Percentage (%)		
			S	BS	TS
1	Is RFID fast in responding to input commands?	13	100	0	0
2	Is Voice Recognition fast in responding to input commands?	13	20	80	0
3	Is RFID easy to use?	13	92.30	8	0
4	Is Voice Recognition easy to use?	13	84.61	15.38	0
5	Is RFID accurate in reading the input data?	13	92.30	8	0
6	Is Voice Recognition accurate in reading the inputted data?	13	38.46	46.15	15.38
7	Can a security system using RFID improve the safety of the laboratory?	13	84.61	15.38	0
8	Can a security system using Voice Recognition improve the safety of the laboratory?	13	92.30	15.38	0
9	Are you satisfied with the laboratory room door security system using RFID?	13	100	0	0
10	Are you satisfied with the laboratory room door security system using Voice Recognition?	13	100	0	0

3.13Discussion

The performance comparison between the use of the RFID system and Speech To Text can be analyzed as follows based on the test results and test evaluation results. In the RFID system, the detection distance between the ID Card and the Sensor is a maximum of 3 cm, while the speech To Text system for voice input has a detection distance of < 100 cm with a constant volume level. The RFID system's overall response time is 6.19 seconds, which includes detecting the RFID Card, identifying the registered ID Card owner, unlocking the door for the Assistant, and determining the seat for students. Inputting data on the Speech Text system through the application, the maximum distance for inputting voice between the user and the application is 10-100 cm with a constant volume level. If > 100 cm, then the system cannot detect the voice signal or it is difficult to identify speech sounds and convert the voice signal into text. At a distance of 20 cm, the time required by the Speech Text system to detect and identify voice input is 3.06 seconds. Meanwhile, at a distance of 30 cm-100 cm, the system can detect and identify speech sentences on voice input with a response time of 2.90-2.97 seconds.

At a distance of > 100 cm with a constant volume level, the system is difficult to understand and identify the inputted speech sentences. Based on the questionnaire results table, the percentage of respondents who answered agreed, average, and not based on the level of response, convenience, accuracy, security, and satisfaction in using the RFID System with Speech To Text are as follows:

RFID System:

$$\text{Agree} = \frac{\text{Response+easiness+Accuracy+security+satisfaction}}{5}$$

$$\text{Agree} = \frac{100+92.30+92.30+84.61+100}{5}$$

$$\text{Agree} = 93.84\ \%$$

$$\text{BS} = \frac{\text{Response+easiness+Accuracy+security+satisfaction}}{5}$$

$$\text{BS}= \frac{0+8+8+15.38+0}{5}$$

$$\text{Bs} = 6.27\ \%$$

$$\text{TS} = \frac{\text{Response+easiness+Accuracy+security+satisfaction}}{5}$$

$$\text{TS}= \frac{0+0+0+0+0}{5}$$

$$\text{TS}= 0\%$$

Speech To Text System:

$$\text{Agree} = \frac{\text{Response+easiness+Accuracy+security+satisfaction}}{5}$$

$$\text{Agree} = \frac{20+84.61+38.46+92.30+100}{5}$$

$$\text{Agree} = 67.04\ \%$$

$$\text{BS} = \frac{\text{Response+easiness+Accuracy+security+satisfaction}}{5}$$

$$\text{BS}= \frac{80+15.38+46.15+15.38+0}{5}$$

$$\text{Bs} = 31.38\ \%$$

$$\text{TS} = \frac{\text{Response+easiness+Accuracy+security+satisfaction}}{5}$$

$$\text{TS}= \frac{0+0+15.38+0+0}{5}$$

$$\text{TS}=3.07\%$$

4. Conclusion

With a detection response time of 70ms-1.32 seconds, the RFID sensor can detect RFID cards at a maximum distance of 3 cm. The application's Speech To Text system can detect and convert voice signals into text data at a distance of up to 100 cm. Based on the frequency value in decibels, the Speech To Text system can recognize the character of the input voice (dB). On the python terminal and application, the designed system can store data entered by the user through the list form. The level of response, convenience, accuracy, security, and satisfaction using the RFID system by answering Agree is 93.84%, and the percentage of those who answer agree using the Speech to Text system is 67.04%, according to the data on the percentage of the questionnaire results. The tool's purpose is to open the room door's lock lever and determine student seating in the laboratory.

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