SEMARAK ILMU PUBLISHING

Journal of Advanced Research in Applied Mechanics

Journal homepage:
https://semarakilmu.com.my/journals/index.php/appl_mech/index
ISSN: 2289-7895

Performance Analysis of RFID-Based Smart Door Lock Controlled by Arduino

Bukhari Kasim[1], Hamdani Nurdin[1,*], Sariyusda[1], Akhyar Ibrahim[1], Muhammad Razi[1], Adi Saputra Ismy[1], Azwar Yunus[1], Mawardi[1], Sumardi[1]

[1] Department of Mechanical Engineering, Lhokseumawe State Polytechnic, Indonesia

ARTICLE INFO

Article history:
Received 6 May 2024
Received in revised form 1 July 2024
Accepted 14 July 2024
Available online 30 July 2024

Keywords:
RFID; Arduino; Solenoid

ABSTRACT

Traditional door lock systems that usually use mechanical locks are now starting to be replaced with electrical and control-based lock systems that have more capabilities than traditional door lock systems. These techniques are an integration of mechanical devices, electronics, and intelligent control devices. One of the important features of this innovative lock system is its simplicity and high efficiency. In this research, an automatic lock system was constructed by combining mechanical and electrical components into a device. A microcontroller Arduino was used to control the whole functions of the system. The input component for this system is an RFID card or RFID Tag. An RFID reader is installed on the device to detect the RFID card used when accessing the door whether a registered card or not. A solenoid door lock is used as an output that will function as a door lock mechanism. The door lock system developed in this study is integrated with the attendance system database. The result of this research shows that the system can recognize the identity of the door accessor and is also able to store data in form of identity and time the door is accessed. The solenoid door lock will retract to unlock the door if the door is accessed with a registered RFID card and vice versa solenoid door lock will continue in the push position to lock the door if the door is accessed with a not registered RFID card. Some of the main performances of this system are that RFID read range from 0 - 20mm, RFID sensor can detect the presence of an RFID card even if it is blocked by objects such as papers, plastics, glass, and cloths. When objects such as aluminum or iron are present in between the RFID sensor and the RFID card, it will interfere with the signal so that the RFID sensor cannot detect the presence of the RFID card.

1. Introduction

The door is an important thing in the security system because the door is the main access to enter and exit a building or room. Aside from being an access point in and out, the door also functions as a barrier to access entry and exit of the room when it is closed [1]. The door access method of a room is very important and is directly related to the security of the room. To secure a room, a lock is usually

* *Corresponding author.*
E-mail address: hamdani_jtm@pnl.ac.id

https://doi.org/10.37934/aram.122.1.163174

installed on the door of the room. The key is needed in a security system as a safety used to open the door [2]. Conventional mechanical keys are used to secure doors that are operated manually. The use of conventional door locks has many drawbacks, especially for rooms that have access for more than one person, such as an office or laboratory room. Because offices or laboratories are often accessed by several people, conventional keys often change hands and sometimes one forgets who has the key, which results in the key having to be regenerated [3]. As technology advances, electronic door locks are starting to be widely used in business circles. This type of door lock has several advantages over traditional locks, including fast and convenient keyless entry [4].

Every door-locking system now in use requires a traditional key or some other type to access the system [5]. As technology develops, various digital door security systems have been developed. The presence of a microcontroller has made it possible to apply a door access system automatically or without having to use a mechanical key. Several devices have started to be used to realize this automatic door access, including using hole cards, NFC (Near Field Communication), and also RFID (Radio Frequency Identification) [6]. NFC technology enables data transfer in just a short touch and only takes less than a tenth of a second.

RFID technology may be used to safeguard not only buildings, houses, or workplaces, but even motorcycles. The RFID-based motorcycle security idea is carried out by developing a motorcycle security system model that controls and improves motorcycle security by utilizing Radio Frequency Identification (RFID) and Global Communication System (GSM) [7]. The technology is designed to identify identification that is based particularly on RFID. The RFID sensor is linked to a mobile phone communication device through the PIC16F877A microcontroller. Every time a motorbike is attempted to be stolen, the alarm will sound. In addition, the system sends brief messages to the motorbike owner's cell phone to warn him of the theft in progress.

Recently, Temperature measurement in the present machining process has begun to use the intelligent measurement idea. The system is designed to measure product temperature as it is being machined [8]. The temperature measuring system is constructed around the MLX90614 Infrared Thermometer sensor, which captures the workpiece temperature during the milling process and compares it to Infrared Fusion from the Fluke Ti400. Integrating the MLX90614 Infrared Thermometer sensor with Arduino and Microsoft Excel allows for real-time readings.

Nowadays, technology is developing so fast. RFID has begun to be used by companies for employee identification purposes. RFID is a fundamental and inexpensive technology that enables remote data transfer [9]. RFID technology provides an efficient and simple method for data identification[10]. Radio frequencies are used to transfer data from the RFID tag to an RFID reader. In theory, RFID technology is similar to bar codes [11].

The identification process is usually carried out for assets, employees, and others. RFID has also started to be used in supermarkets and hospitals to identify employees and identify goods for the sales process. Many types of control systems are made to control the door. The main objective in designing a door control system is should be easy to control, should be durable, and should be secure to provide security. Radiofrequency identification system has proven themselves self-one of the secure, inexpensive, and fast emerging technology [12].

Besides being implemented in companies, supermarkets, and hospitals, RFID technology has also been implemented by educational institutions. This is done not only for security purposes from the rooms in an educational institution but also as an attendance system for both employees and students [13]. The manual attendance method has a high error rate, especially in the process of recapitulating attendance data. The percentage of this error can be reduced by implementing an ICT-based automatic attendance system. This method is quite good in terms of security, dependability, and ease of use [14]. Radiofrequency identification technology in the present system can support the

smooth running of the lecture administration process more easily. With RIFD technology, student attendance data can be identified automatically so that students no longer need to sign the attendance list [15]. The educational institution must have many rooms with different designations and are used by different people. Some rooms are only meant to be accessed by one or two people. Some of these rooms certainly need to be given security so that not just anyone can enter them. However, there are many rooms whose use is intended for the general public such as study classrooms. For room conditions like this, it is very difficult to know exactly who is going in and out of this room in real-time. These problems are very likely to be solved by using Information and communication technologies (ICT). ICT has become a tool that characterizes almost all of today's technological developments which are commonly referred to as digital natives. Many digital tools today can be used to facilitate work, including in the field of education [16]. The integration of RFID technology with smart cards and ICT will make it possible to create a door security system that can detect who is accessing the door in real time. In general, the implementation of smart cards will improve security, the efficiency of a cashless society, data consistency, and functionality of the student card [17].

2. Methodology

RFID technology is made up of 2 parts, namely RFID reader and the RFID tag. The RFID reader is used to receive data emitted from the RFID tag. The use of this RFID system is to send data from the Tag which is then read by the RFID reader which can later be processed using a computer application. Data emitted and sent by RFID tags can contain various information, such as ID, location information, or other information. The data for each RFID account is stored in a system called Active Directory using LDAP (Lightweight Directory Access Protocol) technology.

The device attached to an object to be identified by an RFID reader is called an RFID tag. RFID Tag has two parts, the first part is the microchip which functions to store and process information while the second part is the antenna to receive and transmit signals. Each RFID tag has a specific serial number which is only valid for one object. There are two types of RFID tags, namely active and passive. Passive tags can be used without having to use batteries while active tags require batteries to operate. The RFID tag contains a unique tag that is different from one another. In addition, the information stored on an object or an object connected to the tag is only contained in the system or database that is connected to the RFID reader. An RFID reader is a device that can read RFID tags. The type of RFID used in this research is passive RFID.

To solve a problem stated earlier, this research begins with determining the system specifications and continues with system design. The system design consists of mechanical systems, electronic systems, and software. Furthermore, these three systems designed will be functionally tested to see if it’s working properly. If these three systems can perform the function properly, the integration of these three systems will be carried out to form a smart door system. To ensure that all systems function well, the whole construction is tested to see the performance of the smart door. In detail, all stages of this research are shown in Figure 1.

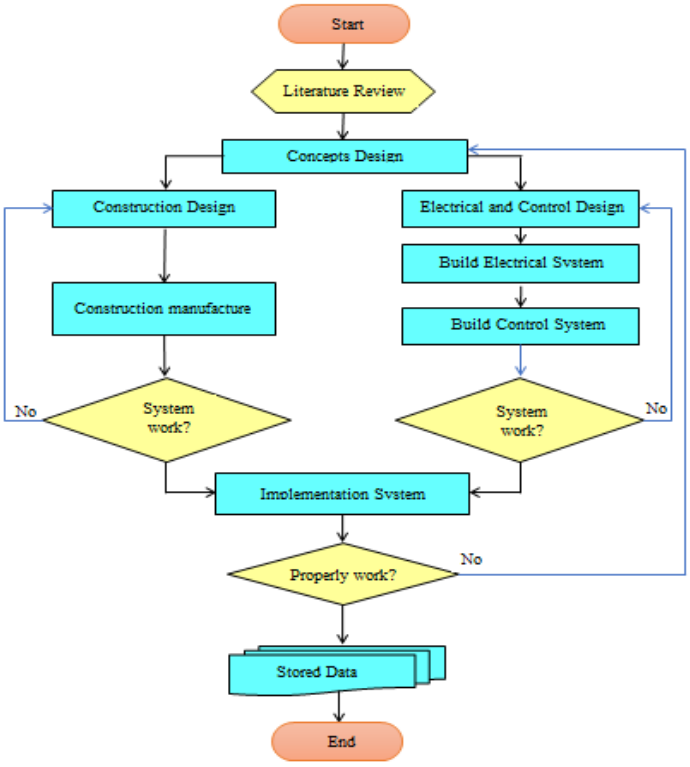

Fig. 1. Research flowchart

The construction of a smart door is built as a prototype in this research. This prototype is classified into two main parts, namely the mechanical part, and the electronic part equipped with the controller. The mechanical part is made to build a prototype room that has a door with a scale of 1:4. The room construction is built with aluminum elbow plates that function as columns of a building. The door frame is also made of an aluminum elbow plate. The walls and doors are made of aluminum composite panels. The door lock used in this room construction is not a door lock commonly used in general doors (manual locks) but it's replaced with a solenoid actuator. The function of this solenoid actuator is the same as the function of a manual lock, to lock or unlock the door.

Besides the mechanical part, this smart door system is also equipped with an electronic part that functions to read and validate RFID tags, control system performance, send alarm signals, shows interactive information on a liquid-crystal display, power on or off indicator light, and also lock or unlock the door. The software that will be used in this research is the Arduino IDE. This software is used to create programming sketches to control the whole electronic part. The electronic part of this research is consist of an RFID tag and an RFID reader in form of an RFID module, Arduino microcontroller, relay, linear solenoid door lock, liquid crystal display, voltage regulator, and also 12-volt power supply. All these electronic components will be arranged into one system as shown in Figure 2.

Arduino microcontroller requires 9 volts of input voltage while activating the solenoid door lock requires 12 volts. The smart door system is designed to be directly connected to a 220-volt AC voltage source. In addition, to convert 220-volt AC into 12-volt DC, a 12-volt power supply is used. This value is suitable for solenoid doorlock input voltage. To power, the Arduino, the 12-volt output from the power supply is then reduced to 9 volts using a voltage regulator. The output from the voltage regulator is then used as voltage input for an Arduino. The voltage regulator used in this research has a specification input voltage range between 4 to 40 volts, an output voltage range is 1.25 volts up to 37 volts, and an output current is 3A. The efficiency of this voltage regulator is 88%.

Arduino used in this research has the main function to control the entire components of the smart door system. The type of controller used is Arduino Uno with chipset Atmega 328P DIP. This Arduino has 32 KB flash memory, with 2 KB SRAM and 16 MHz clock speed. It has 14 digital input/output pins with 6 analog pins and 6 pulses with modulation (PWM) pins. This Arduino will work for input voltage between 7 to 12 volts.

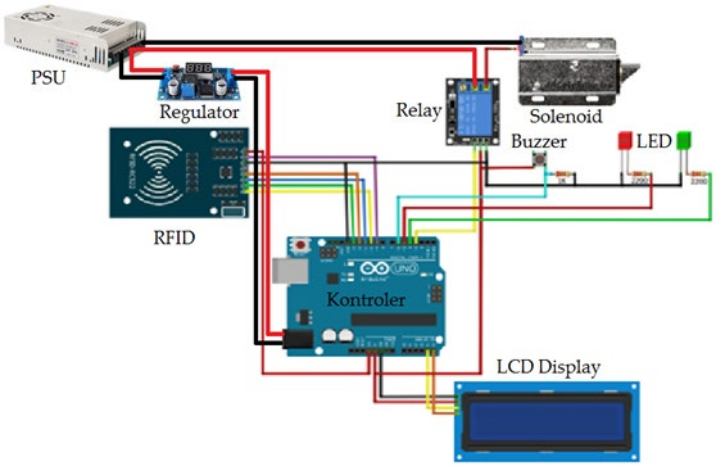

Fig. 2. Smart door electronics circuit

The most important part of this smart door is an RFID reader type MFRC-522 that works at 13.56MHz working frequency and 3.3-volt input voltage. The working temperature of this RFID is between -20^{o}C and 80^{o}C and the maximum data transfer rate is 10Mbit/s. The Selenoid Door Lock used in this study functions as a doorlock component that works with an electromagnetic principle, meaning that the lock will activate when there is a voltage through it. The solenoid door lock needs 12 volt DC input voltage with 600mA current. Power consumption is 7.5Watt and unlock time is less than 1 second

The construction of the smart door built in this research can only be accessed by attaching an RFID card to the RFID reader that was previously installed on the door. If the affixed RFID tag card is registered in the program memory, the solenoid door lock will retract to unlock the door so that the door can be opened, but if the affixed RFID tag card has not been registered in the system memory, the door will not be able to be opened. The flow of user authentication can be seen more clearly in Figure 3.

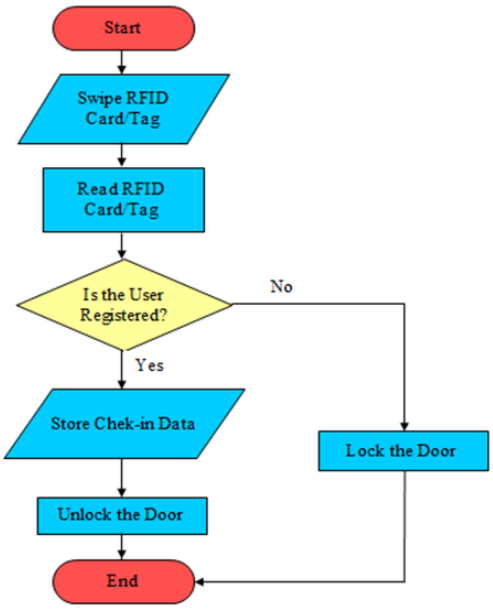

Fig. 3. User identification flowchart

As a default, the smart door will continuously work in standby mode for the whole time. The smart door will be active when the user swipes their RFID tag in front of the RFID reader. At this condition, the RFID tag as a transmitter will send an analog signal to the RFID and it will be received by the microcontroller through the RFID reader that is connected to it. If the RFID tag used is registered, the controller will send a signal to the solenoid to unlock the door. Along with this, the controller will also send a signal to activate the green indicator light as a sign that access is accepted and also display the text “Access Granted” on the LCD screen. But, if the RFID card used to access the door is not registered card, Arduino will send a signal to the buzzer to activate the alarm and turn on the red indicator light and the solenoid door lock will stay in locked mode.

After the prototype is built, the next step is to test the whole function of the smart door system. In this step, functional testing of the smart door will be carried out using samples of RFID tags and RFID cards, both those RFID have been registered and those that have not been registered to see the response from the application to the Arduino. To see the accuracy of the performance of the tool made, testing the tool was carried out using 15 samples of RFID tags (10 samples of RFID tags that had been registered and 5 samples of RFID tags that had not been registered). This test serves to see the ability of the tool to detect or read Card-ID from the RFID tag card. Not only the ability to detect but at this stage, the detection distance and sensitivity of the RFID sensor (RFID reader) will also be tested. This testing process is carried out by comparing the distance reading the card by the RFID reader to the output voltage generated by the RFID reader. Characterization was carried out on 15 RFID cards with different distances. The test was carried out at a distance of 1-10 cm.

3. Results

The main input device used in this system was RFID (Radio frequency identification), the RFID is placed on the front of the door so that it can be seen clearly when the user wants to access the room door. Above the RFID reader, an LCD monitor is installed which serves to provide information about the status of the door access, whether it is accepted or rejected. In addition to the LCD monitor at the front of the room, red and green light indicators are also installed. This light will light up when the user matches the status of the card used to access the door. To control the performance of this smart door prototype, the inside of the room construction is paired with electronic equipment

ranging from controllers, power supplies, voltage regulators, buzzers, relays, and Inter-Integrated Circuits (I2C).

3.1 RFID Function Test

RFID function test is carried out to test the functional ability of the RFID reader for detecting the ID tag card and the performance of its reading distance capability. Testing the detection of ID tag cards is done by bringing the RFID card closer to the reader and the results of reading the RFID card are seen on the Arduino serial monitor display. Figure 4 shows the results of the RFID card reading test. RFID card reading by the system can be done properly. This shows that the hardware and software on the Arduino Uno work well.

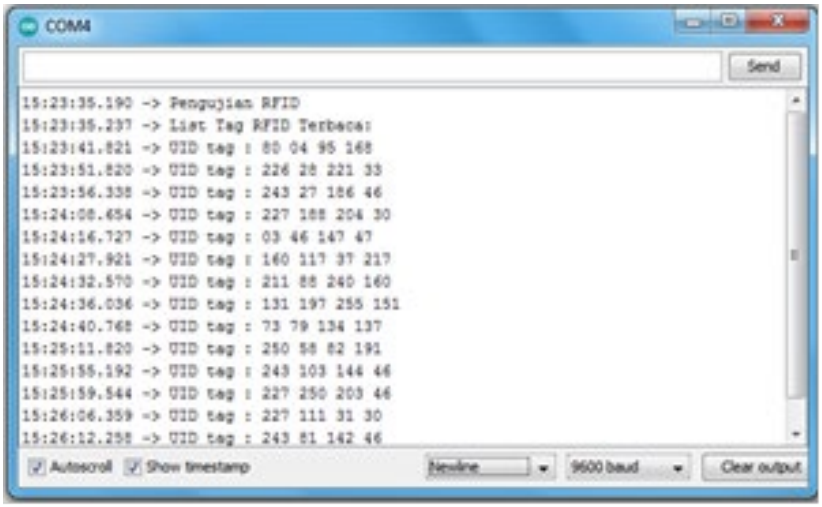

Fig. 4. Test results of reading RFID tags on a serial monitor

3.2 RFID Reading Range Test

The RFID reading distance test is carried out to determine the maximum distance of RFID in detecting RFID cards or RFID tags. The resolution of the readings made in the test is 2mm. The RFID card is placed within a predetermined distance and the Unified Information Devices (UID) of RFID are read by the system that has been built. RFID card testing is done 7 times for each predetermined distance. Table 1 shows the results of the reading distance test. The card is declared detected if the UID appears on the serial monitor is the same as the UID on the card for all tests. The system's readability of the RFID card is a maximum of 20mm. The test results show that the RFID tag card reading range is from 0 to 20mm. Before the testing process is carried out, the RFID tag card is registered in the Arduino program, so that when the RFID tag/transponder is within range of the RFID reader, the system will send an analog signal to the RFID which will be forwarded to the Arduino.

Table 1
The results of testing the RFID reading range

Range of RFID Tag (mm)	Test number						
	1	2	3	4	5	6	7
0	√	√	√	√	√	√	√
2	√	√	√	√	√	√	√
4	√	√	√	√	√	√	√
6	√	√	√	√	√	√	√
8	√	√	√	√	√	√	√
10	√	√	√	√	√	√	√
12	√	√	√	√	√	√	√
14	√	√	√	√	√	√	√
16	√	√	√	√	√	√	√
18	√	√	√	√	√	√	√
20	√	√	√	√	√	√	√
22	x	x	x	x	x	x	x
24	x	x	x	x	x	x	x

"√" = detect, dan "x" = not detect

From the test data shown in Table 1, it can be seen that the RFID reader can read tags well up to a distance of 20mm. While testing at a distance of more than 20mm the RFID reader can no longer detect the presence of RFID tags. From these tests, it can be concluded that the RFID reader has a reading range from 0mm - 20mm with a success rate of 100%.

3.3 RFID Reading in an Angled Position Test

This test is done by placing the RFID tag card in front of the RFID reader with the condition of the RFID card at an angle to the RFID reader. This condition is carried out to determine the ability of RFID to read RFID tags that are not aligned with the RFID Reader. The test is carried out with the position of the RFID Tag from an angle of 0^o to 90^o. The test results are shown in Table 2.

Table 2
Test results of RFID reading in an angled position

Tag RFID Angle (o)	Test Number						
	1	2	3	4	5	6	7
0	√	√	√	√	√	√	√
10	√	√	√	√	√	√	√
30	√	√	√	√	√	√	√
40	√	√	√	√	√	√	√
50	x	x	x	x	x	x	x
60	x	x	x	x	x	x	x
70	x	x	x	x	x	x	x
80	x	x	x	x	x	x	x
90	x	x	x	x	x	x	x

"√" = detect, dan "x" = not detect

The test results show that RFID is only able to read RFID tag cards that are placed in a parallel position (0^o) until the RFID tag forms a 40^o angle to the position of the RFID reader. In this position, the RFID reader can consistently read the presence of the RFID Tag Card. But when the RFID Tag card is placed at an angle greater than 40o, the RFID reader cannot detect the presence of the RFID tag at all.

3.4 RFID Reading Block Test

The test is intended if the card uses a cover or container to make it easier for the card used to store. The reading test is done by sticking the Tag card on several types of goods such as plastic, paper, leather, iron, aluminium foil, and foam heart. Then the goods will be read by the RFID reader simultaneously with the card tag. The position of the item is read before the Tag card, assuming the card is covered with the type of item.

The following are the results of testing the reading of RFID tags on several types of paper, plastic, aluminium foil, and iron goods. The test results are shown in Table 3.

Table 3
Testing of blocked RFID tag readings types of items

Barrier Type	Test number						
	1	2	3	4	5	6	7
Paper	√	√	√	√	√	√	√
Plastics	√	√	√	√	√	√	√
Glass	√	√	√	√	√	√	√
cloth	√	√	√	√	√	√	√
Aluminum	x	x	x	x	x	x	x
Stell	x	x	x	x	x	x	x

“√” = detect, dan “x” = not detect

Based on the test in Table 3, it can be seen that none of the experiments on reading RFID tags with metal items were successful. This problem arises from the fact that metal objects can reflect radar signals to their transmitting sources fairly large, as well as produce significant interference with Tag readings. The next problem is that the card tag antenna is usually made of metal. When the object is attached to a metal object at a low operating frequency of 900MHz, a short circuit occurs if the distance between the top and bottom surfaces of the metal is less than ±1mm. This causes a significant reduction in the quality of RFID.

From these tests, it can be concluded that the RFID reader cannot read the RFID tags affixed to metal. This is because RFID tags affixed to the metal can cause interference and short circuits occur which can cause a decrease in RFID quality. However, the RFID reader can read on objects such as plastic, and paper with a 100% success percentage.

3.5 Comprehensive Smart Door Test

The test is carried out to record user data that has access to the entrance. This process begins with running the door access program that has been created on Arduino as the logical basis for recording card tags. After that, the reading experiment was carried out using an RFID reader. In this test, each card is attached to the RFID reader three times. If the card used to access the door is a registered card, the door will be unlocked when the card is pasted, but if the card used is not registered, the door will not be unlocked.

When a registered card is first used to access the door, the date and time of access will be recorded, in this condition, the door will be in the "unlocked" position. At this time the system will also activate the green LED light and the text "Entrance Door Open" will be displayed on the LCD monitor screen. When the same tag card is affixed a second time, the system will record the time as an exit clock, the door will be "unlocked" which is indicated by the green LED light. Simultaneously with this on the LCD monitor screen will be displayed the words "Exit Door Open". When the tag card is affixed for the third or more time, the system will turn on the red LED light and activate the buzzer

as a sign that door access is not permitted. The result of reading the RFID reader is shown in Figure 5 which is the result of reading 10 card tags sequentially one by one. The result of reading this RFID card will be stored in the system database in excel file format.

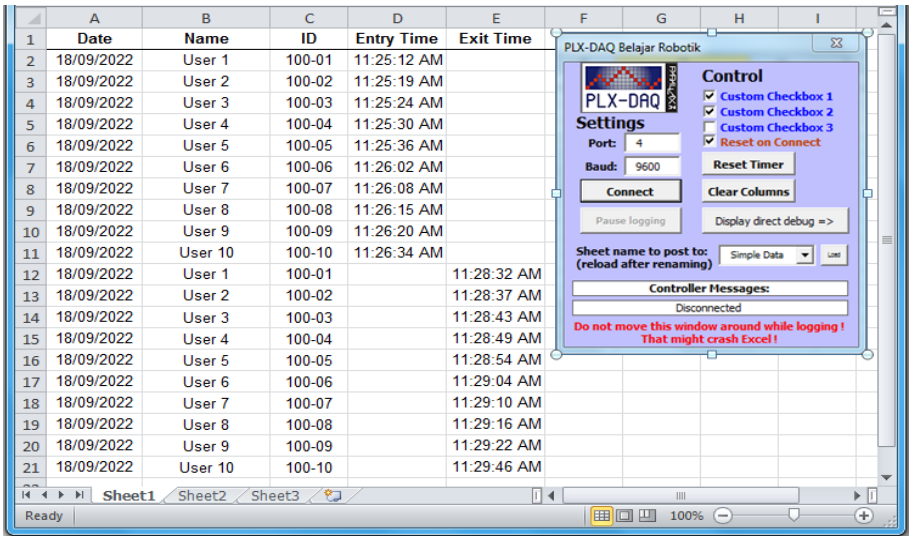

Fig. 5. Door access data display

The door opening process will be carried out if the RFID card that is affixed is a card that has been registered to the Arduino program database system, if the card is not registered then the door will not be able to be opened. The whole system are tested using 15 RFID tag, 10 of them are registered and 5 are not registered. The test results are shown in Table 4.

Table 4
Testing system output

Tag RFID Number	LCD Display	LED Indicator	Solenoid Door	Description
1	Access Granted	Green	Unlock	Register User
2	Access Granted	Green	Unlock	Register User
3	Access Granted	Green	Unlock	Register User
4	Access Granted	Green	Unlock	Register User
5	Access Granted	Green	Unlock	Register User
6	Access Granted	Green	Unlock	Register User
7	Access Granted	Green	Unlock	Register User
8	Access Granted	Green	Unlock	Register User
9	Access Granted	Green	Unlock	Register User
10	Access Granted	Green	Unlock	Register User
11	Access Denied	Red	Locked	Unregister User
12	Access Denied	Red	Locked	Unregister User
13	Access Denied	Red	Locked	Unregister User
14	Access Denied	Red	Locked	Unregister User
15	Access Denied	Red	Locked	Unregister User

Table 4 shows that all registered RFID tags can be used to activate the door lock solenoid so that the prototype door can be opened, after which it will be locked again. Meanwhile, 5 RFID tags that have not been registered cannot be used to activate the door lock solenoid, so the prototype door remains locked and cannot be accessed.

RFID provides several benefits in the security of door lock. RFID technology enables door access without the use of a physical key. Users may unlock the door by swiping the RFID card to the RFID

reader, making entrance faster and eliminating the need to carry a traditional key. RFID also offers more security than traditional door locks. RFID cards include encrypted data that is difficult to copy, lowering the possibility of illegal access. RFID door lock systems enable more precise access control. Different RFID cards can be provided to different persons or organizations, allowing particular doors to be opened exclusively by certain people. This helps to prevent unwanted access and guarantees that only those with the password have access.

The system designed is able to control door opening and is able to detect every user who accesses the door. The system will record all door access activities and store the data in the system database. The data information stored includes username, user ID, date and time the door access was made. The data will become a database for the attendance system based on the authentication and authorization embedded in each RFID card. An LCD screen is installed on the system to display information on the status of door access by the user. In addition, LED lights and speakers are installed as output devices to give an alarm against any door access made by persons who are not registered in the system. Overall, the system created has the ability to detect the presence of an RFID card in the range of 0mm to 20mm in front of an RFID reader, is able to detect the presence of an RFID card that is positioned between 0^o to 40^o to the surface of the RFID reader, is able to detect the presence of an RFID card even though it is blocked by materials. materials such as paper, plastic, glass, except aluminum and iron.

4. Conclusions

RFID based smart door system was implemented in this reseacrh. The systems can detect whether the user enters or leaves the room in real-time and store data in the system database. Even though there are obstacles on the reader when the RFID tag is scanned, the RFID reader can respond unless there are certain obstacles such as iron or aluminium so the reader cannot respond to the scanned tag. The distance between the RFID card and the RFID reader must be between 0mm to 20mm. RFID readers can detect RFID cards that are placed in 0^o up to 40^o in parallel with the RFID reader. The process of scanning the RFID Tag card by RFID reader will store the user's ID tag based on the time of accessing the door and the unregistered RFID card will be not allowed to access the door.

Acknowledgment

The authors thank The Ministry of Education, Culture, Research, and Technology Indonesia for financial support during this research. The authors also thank to Lhokseumawe State Polytechnics Indonesia which has facilitated publication.

References

[1] Afwadi, Ifwal, Bukhari Bukhari, Dailami Dailami, Marzuki Marzuki, and Sumardi Sumardi. "Rancang Bangun Prototipe Pintu Pagar Menggunakan Sensor Ultrasonik Berbasis Mikrokontroler." *Jurnal Mesin Sains Terapan* 5, no. 1 (2021): 22-26. https://doi.org/10.30811/jmst.v5i1.2139

[2] Mintorogo, Dwi Anggadi, and Andi Wiranata. "Sistem Monitoring Dan Keamanan Pintu Berbasis Sms Via Arduino Uno." *SISKOM* 1, no. 2 (2018).

[3] Ekayana, Anak Agung Gde. "Implementasi Sistem Penguncian Pintu Menggunakan RFID Mifare Frekuensi 13.56 Mhz dengan Multi Access." *Jurnal Pendidikan Teknologi Dan Kejuruan* 15, no. 2 (2018). https://doi.org/10.23887/jptk-undiksha.v15i2.14361

[4] Batra, Sarthak, and Amruta Pattnaik. "RFID Smart Card Door Lock." *Int. J. Eng. Res. Technol.* 10, no. 11 (2021): 51-54.

[5] Dabekar, Sujita B., Sandhyarani A. Lahade, Manasi S. Lunge, and P. D. Yewale. "IOT Based Smart Door Locked System Using Node MCU." *International Journal for Research in Applied Science & Engineering Technology* 10, no. 7 (2022). https://doi.org/10.22214/ijraset.2022.45909

[6] Djamar, Ahmad Sadik, Sherwin RUA Sompie, and M. Dwisnanto Putro. "Implementasi teknologi NFC untuk akses pintu masuk dan keluar." *Jurnal Teknik Informatika* 11, no. 1 (2017). https://doi.org/10.35793/jti.11.1.2017.16971
[7] Jusoh, WWI Wan, KA Mohd Annuar, S. H. Johari, M. H. Harun, and I. M. Saadon. "Motorcycle security system using GSM and RFID." *Journal of Advanced Research in Applied Mechanics* 16, no. 1 (2015): 1-9.
[8] Sudianto, Agus, Zamberi Jamaludin, Azrul Azwan Abdul Rahman, Fajar Muharrom, and Sentot Novianto. "Smart temperature measurement system for milling process application based on mlx90614 infrared thermometer sensor with Arduino." *Journal of Advanced Research in Applied Mechanics* 72, no. 1 (2020): 10-24. https://doi.org/10.37934/aram.72.1.1024
[9] Pala, Zeydin, and Nihat Inanc. "Smart parking applications using RFID technology." In *2007 1st Annual RFID Eurasia*, pp. 1-3. IEEE, 2007. https://doi.org/10.1109/RFIDEURASIA.2007.4368108
[10] Mishra, Yashi, Gaganpreet Kaur Marwah, and Shekhar Verma. "Arduino Based Smart RFID Security and Attendance System with Audio Acknowledgement." *International Journal of Engineering Research and Technology* 4, no. 1 (2015): 363-367.
[11] Shields, Andrew, Ultan Mc Carthy, Daniel Riordan, Pat Doody, Joseph Walsh, and Ismail Uysal. "Radio Frequency Identification (RFID)." *Wiley Encyclopedia of Electrical and Electronics Engineering* (2015): 1-14. https://doi.org/10.1002/047134608X.W8155
[12] Al Hajri, Eid, Farrukh Hafeez, and Ameer Azhar NV. "Fully Automated Classroom Attendance System." *Int. J. Interact. Mob. Technol.* 13, no. 8 (2019): 95-106. https://doi.org/10.3991/ijim.v13i08.10100
[13] Fauziah, Helmi Yulianti, and Antonius Irianto Sukowati. "Rancang Bangun Sistem Absensi Mahasiswa Sekolah Tinggi Teknik Cendekia (STTC) Berbasis Radio Frequency Identification (RFID)." *Prosiding Semnastek* (2017).
[14] Chowdary, M. Nitin, V. Sujana, K. Satvika, K. Lakshmi Srinivas, and P. S. Suhasini. "Smart Attendance System Using Machine Learning Algorithms." In *Machine Learning and Autonomous Systems: Proceedings of ICMLAS 2021*, pp. 99-115. Singapore: Springer Nature Singapore, 2022. https://doi.org/10.1007/978-981-16-7996-4_8
[15] Kurniadi, Dede, Yosep Septiana, Asri Mulyani, and Agus Hermawan. "Sistem informasi presensi mahasiswa berbasis radio frequency identification." *AITI* 17, no. 1 (2020): 1-10. https://doi.org/10.24246/aiti.v17i1.1-10
[16] El Mrabet, Hicham, and Abdelaziz Ait Moussa. "IoT-school attendance system using RFID technology." (2020): 95-108. https://doi.org/10.3991/ijim.v14i14.14625
[17] Sreelekshmi, S., T. S. Shabanam, Preethi Presannan Nair, Neema George, and Sajana Saji. "RFID based Smart Card for Campus Automation." *Int. J. Eng. Res. Technol* 9 (2021): 38-40.