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Design of Arduino-Based Fingerprint Security System in the Financial Archive Room Dinas Pariwisata, Kabupaten Maluku Tengah

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Abstract

This research aims to develop an effective security system in managing access to sensitive financial records. The method used is Research and Development (R&D), which includes steps to identify problems, collect data through observation, unstructured interviews, and documentation, system design, system creation, and prototype testing. The designed system utilizes key components, including an Arduino Uno R3 as a microcontroller, an FPM10A fingerprint sensor for user authentication, a 4x4 keypad as an authentication alternative, a relay module to control the solenoid lock mechanism, and a blue LED to indicate the system status. The result of this research is a prototype of a system capable of securing financial archive doors with an adequate level of accuracy and speed in the fingerprint authentication process. Through a series of tests, the system has been proven to improve the security and efficiency of access to financial archives, as well as offer innovative solutions for the management of a more modern security system at Dinas Pariwisata. It is hoped that this research can contribute to the development of security technology and improve the quality of archive management in government agencies.

Keywords: *Security Systems, Fingerprints, Arduino Uno, Archive Management, Research and Development.*

1. Introduction

In today's era of increasingly rapid digitalization, technology has become a crucial element in human life. Digital transformation is an important step in the evolution of technology that affects various aspects of people's lives, including in terms of information security. One of the growing applications of technology is biometric-based security systems, specifically using fingerprints as an authentication method. The use of digital technology not only improves efficiency, but it also brings significant changes in the way people interact and manage information [1].

Technological advances bring many benefits, such as improving access to information and facilitating communication. However, its unwise use can have a negative impact. In this digital era, it is very important to preserve culture through technology, especially to the younger generation. With digital platforms, we can introduce cultural values and strengthen national identity, so that culture can be recognized and preserved. Through these efforts, it is hoped that the character of a good citizen can be formed, and our culture will continue to live in the midst of the development of the times [2].

Dinas Pariwisata, Kabupaten Maluku Tengah, as an institution responsible for tourism and sports development. The Tourism Office needs to focus on information security in the management of financial archives. The implementation of a fingerprint-based security system aims to protect financial data and improve transparency and efficiency of public services. There are 3 (three) main aspects related to the security system that will be focused on in this research. First, the manual lock system currently used is less effective and efficient in maintaining the security of financial records. Second, it is necessary to design a system that integrates components such as Arduino Uno R3, FPM10A Fingerprint Sensor Module, 12V LED, 1Ch 5V Relay Module, Wires Jumper, 4x4 Keypad, 12V Door Lock Solenoid, and 12V 2A Adapter so that it can function synergistically. Third, integration challenges need to be identified to ensure that all components can work well together, so that the system can operate optimally in protecting sensitive data. The objectives of this study are: (1) Designing a fingerprint-based security system on the door of the financial archive of the Central Maluku Masohi Regency Tourism Office which is safer and more efficient than the manual lock system currently used. (2) Designing the integration of components such as Arduino Uno R3, FPM10A Fingerprint Sensor Module, 12V LED, 1Ch 5V Relay Module, Wires Jumper, 4x4 Keypad, Buzzer, Solenoid Door Lock 12, and 12V 2A Adapter so that it can work synergistically and effectively in maintaining the security of financial records. (3) Identify and evaluate challenges in the selection and integration of all components to ensure the system functions optimally and meets security needs. This research is expected to be able to offer more efficient and modern security solutions for the protection of financial records, as well as improve internal security with the application of cutting-edge technology that can replace less effective manual lock systems and provide

insight and skills in designing security systems based on fingerprint technology, as well as deepen understanding of the integration of electronic components such as Arduino and sensors.

2. Literature Review

This section discusses previous research on the Arduino Uno and fingerprint security systems. The findings provide a scientific basis for the development of a door security system with Arduino Uno. Research conducted by Ardian Sumantri, La Ode Ahmad Barata, Salimin about "Sistem Pengunci Pintu Otomatis Menggunakan Sensor Fingerprint Berbasis Arduino", resulting in an automatic door locking system that is safer than conventional locks. The fingerprint and ultrasonic sensors are effective, with few reading problems. Requires a power source and a heatsink to prevent heat [3]. The research was also conducted by Siti Nasiroh with the title "Penerapan Internet Of Things (Iot) Pada Sistem Pengaman Pintu Dengan Sidik Jari Berbasis Arduino". The results of this study show that door security systems using fingerprints can function with an average sensor reading time of 1.4 seconds [4]. Research conducted by Okta Rea Arsyad and Kurnia P. Kartika about "Rancang Bangun Alat Pengaman Brankas Menggunakan Sensor Sidik Jari Berbasis Arduino" has produced a security control system on the safe door that is equipped with an alarm as a marker when the fingerprint sensor is accessed by someone other than the owner, this alarm will sound [5]. It differs from previous research that integrates the Internet of Things (IoT) or additional sensors in security systems. This research only uses fingerprint technology without internet connectivity. With the Research and Development (R&D) method, it is focused on designing, developing, and testing effective and efficient systems, so that they can function optimally without the need for internet access.

2.1. Theoretical Foundations

1. Microcontroller
   A microcontroller is a computer system that is packaged in a single IC (Integrated Circuit) chip and is designed to perform specific tasks, such as controlling electronic devices. In recent years, microcontrollers have been widely used in a variety of applications, especially in automation and system control. Microcontrollers have several important components, including the CPU (Central Processing Unit), memory (RAM and ROM), and I/O (Input/Output) ports, which allow interaction with other devices. With the advancement of technology, microcontrollers are now available in different types and architectures, such as AVR, PIC, and ARM [6].
2. Arduino
   Arduino is an open-source platform used to build electronic projects, consisting of a programmable circuit board and Integrated Development Environment (IDE) software to write and upload code to the board. Arduino allows users, both beginners and professionals, to easily create a variety of interactive applications, such as robotics, automation systems, and Internet of Things (IoT) devices.[7].
3. Adruino Uno R3
   Arduino Uno is an ATmega328P-based microcontroller board designed to facilitate the development of interactive electronic devices, with specifications such as 5V operating voltage, 14 digital I/O pins, and 6 analog input pins [7].
4. Biometry
   Biometry is a technology used to identify or verify an individual's identity based on their unique physical and behavioral characteristics. Common biometries include fingerprint scanning, facial recognition, voice recognition, and iris scanning. The technology works by collecting data from biometric features and comparing it with data stored in a database to determine a match [8].
5. Fingerprints
   Fingerprints are the result of a reproduction of a pattern found on the skin of a human finger, which is formed from fine lines called ridges. Each individual has a unique and irreversible fingerprint pattern, making it one of the most reliable biometric identification methods. Fingerprints can be taken in a variety of ways, either directly with the sensor or through printing techniques [8].
6. Fingerprint Sensor
   A fingerprint sensor is a biometric device used to identify individuals based on the unique patterns on their fingerprints. One of the popular sensors is the FPM10A, which has the ability to store up to 1000 fingerprints and offers a recognition time of less than 1 second. The sensor uses a Universal Asynchronous Receiver/Transmitter (UART) interface for communication with microcontrollers such as Arduino, allowing for easy integration in a wide range of applications, including security systems and access control. The FPM10A operates at voltages between 3.6 to 6.0 V and has a False Accept Rate of below 0.001%, making it a highly accurate and reliable solution for biometric identification [8].
7. Optical Fingerprint Sensors
   Optical fingerprint sensors are the earliest type of sensor used in fingerprint recognition technology. This sensor works by taking images from fingerprints using light. When the finger is placed on top of the sensor, the light will be reflected off the surface of the finger and captured by the digital camera inside the sensor. The resulting image is then analyzed to detect unique patterns of the fingerprint, including the light and dark parts of the image [8].
8. FPM10A Fingerprint Sensor Module
   FMP10A Fingerprint Sensor Module is an optical sensor designed for high-accuracy fingerprint recognition. The sensor has the ability to store up to 162 fingerprint templates and is equipped with a communication interface that is easy to integrate with various microcontrollers. The FPM10A offers fast scan speeds and the ability to perform identification with good accuracy, making it a good choice for access control and security applications [9].
9. Relay Module
   Relay module is a device that functions as an electronic switch that can be controlled electrically. This module allows users to control external electrical devices, such as motors, lights, and household appliances, using signals from microcontrollers such as Arduino [9].

10. Jumper Wires
    Jumper wires is a flexible cable with connectors at both ends, used to connect electronic components in circuits, especially on prototyping boards. They are available in different types and lengths, allowing for easy splicing and disconnection without soldering. Jumper wires are important in microcontroller projects such as Arduino for fast and efficient circuit testing and modification [10].
11. Solenoid Door Lock
    Solenoid Door Lock is a device that functions as an electronic door lock, which works in two ways, namely Normally Closed (NC) and Normally Open (NO). During the NC system, the solenoid will extend and lock the door when it is stressed, while during the NO system, the solenoid will open the door when it is tensioned [9]
12. Adapter
    An adapter is a device that converts voltage and current from AC (alternating current) to DC (direct current) electricity for electronic devices. The adapter ensures that devices such as computers and smartphones get stable power according to specifications. Equipped with transformers, diodes and capacitors, the adapter stabilizes and stabilizes the voltage [9].
13. Arduino IDE
    Arduino IDE (Integrated Development Environment) is an open-source software used to write code and upload it to an Arduino board. The IDE supports a wide range of operating systems such as Windows, macOS, and Linux [11].
14. Cirkit Designer
    Cirkit Designer is created to make electronic design more accessible, with the goal of helping users from initial ideas to real prototypes. The platform is equipped with an AI assistant that guides users in selecting components, understanding wiring, and writing code [12].

3. Research Methodology

This study applies the Research and Development (R&D) method shown in Figure 1.

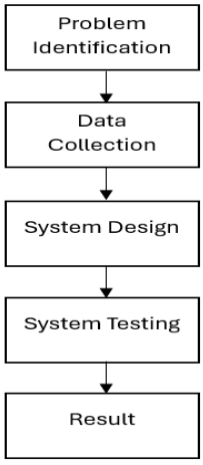

Fig. 1: Research and Development (R&D) Method

1. Problem Identification: Observing the conditions and security systems at the Tourism Office to understand the needs and challenges faced.
2. Data Collection: Conducting observations, unstructured interviews, and collecting relevant documentation to support this research.
3. System Design: Design a system prototype based on the collected data and technical specifications.
4. System Testing: Testing a prototype of the system to ensure all functions are running as planned.
5. Result: This research ended with the development of the desired system prototype, without further implementation.

3.1. Research Instruments

The research instruments featured several devices used in this study, such as:

1. Apple MacBook Air (M1, 2020): To upload code to the Arduino UNO R3 using the Arduino IDE, as well as configure and adjust the system settings.
2. Apple iPhone 11, (2019): To retrieve documentation.
3. Arduino UNO R3: As the main microcontroller that controls the entire system.
4. FPM10A Fingerprint Sensor: As user authentication by reading fingerprints.
5. Relay Module 1Ch 5V : To control the solenoid lock that opens and closes the door.
6. Blue LED 12V: For system status information to users.
7. Solenoid Door Lock: As a door locking mechanism that is activated by a signal from Arduino.
8. Adaptor 12V: As a resource of the system.
9. Buzzer : As a system notification sound.
10. Jumper Wires: As a connecting cable of the system.
11. Tool Kit Jakemy JM-8183 145in1: Tools for assembling systems.
12. Arduino IDE version 2.3.3 for macOS.
13. Cirkit Desginer website based.

4. Results and Discussion

4.1. System Design

Researchers designed the system using the Cirkit Designer website, which integrates a fingerprint sensor and a 4x4 keypad as an alternative door opening method other than fingerprints. The system design is shown in Figure 2.

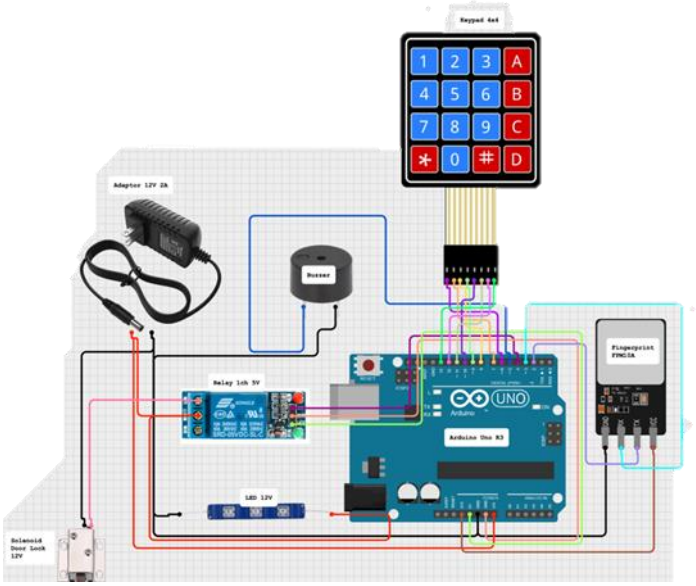

Fig. 2: System Design

4.2. System Pin Connection

The following schematic shows the relationships between components in a system. Accurate connections are essential to ensure all components operate optimally. The schema is shown in Table 1.

Table 1: System Pin Connections

No	Component Name	Pin	Pin	Component Name
1	*LED Strip blue 12V*	(+)	NO	*Relay* 1Ch 5V
		(-)	(-)	
2	Arduino (Uno R3)	D0	-	-
		D1		
		D2	TX	FPM10A Fingerprint
		D3	RX	
		D4	IN	*Relay* 1Ch 5V
		D5	(+)	*Buzzer*
		D6	R1	*Keypad 4x4*
		D7	R2	
		D8	R3	
		D9	R4	
		D10	C1	
		D11	C2	
		D12	C3	
		D13	C4	
		A0	-	-
		A1		
		A2		
		A3		
		A4		
		A5		
		AREF		
		GND	GND	FPM10A Fingerprint
				Buzzer
				Relay 1Ch 5V
		RST	-	-
		3V3	VCC	FPM10A Fingerprint
		5V		*Relay* 1Ch 5V

		VIN	-	-
3	*Relay* 1Ch 5V	IN	4	Arduino (Uno R3)
		GND	GND	
		VCC	5V	
		NO	VCC	Solenoid *Door Lock* 12V
			(+)	LED 12V
		COM	(+)	Adapter 12V 2A
		NC	-	-
4	Adapter 12V 2A	(+)	COM	*Relay* 1Ch 5V
			DC *Power* Jack (+)	Arduino (Uno R3)
		(-)	(-)	LED *Strip Blue* 12V
				Solenoid *Door Lock* 12V
			DC *Power* Jack (-)	Arduino (Uno R3)
5	*Keypad 4x4*	R1	D6	Arduino (Uno R3)
		R2	D7	
		R3	D8	
		R4	D9	
		C1	D10	
		C2	D11	
		C3	D12	
		C3	D13	
6	*Buzzer*	(+)	D5	Arduino (Uno R3)
		GND	GND	
7	FPM10A Fingerprint	GND	GND	Arduino (Uno R3)
		RX	D3	
		TX	D2	
		3V3	3V3	
8	Solenoid *Door Lock* 12V	VCC	NO	*Relay* 1Ch 5V
		GND	(-)	Adapter 12V 2A

4.3. Door Security Operational Process

1. Start:
   System activation is turned on by plugging into a power source, and is in a standby state.
2. Fingerprint Paste:
   User attaches fingerprint to FPM10A fingerprint sensor.
3. Enter your PIN:
   Users can enter PIN combinations using the 4x4 keypad.
4. Fingerprint Validation:
   The FPM10A fingerprint sensor processes and checks if the fingerprint is registered.
5. PIN Validation:
   The Arduino checks the compatibility of the PIN combination entered with the stored data.
6. Not Suitable:
   6a. FPM10A Fingerprint Sensor:
   6a.1 Chance 1: Difficulty identifying due to oily, sweaty, or improper fingers.
   6a.2 Chance 2: Fingerprint not registered.
   6b. Keypad 4x4: If the PIN doesn't match, Arduino Uno R3 reset automatically and this process repeats until the correct PIN is entered.
7. Suitable:
   7a. FPM10A Fingerprint Sensor: Fingerprints are successfully matched.
   7b. Keypad 4x4: The PIN combination entered is correct.
8. Open Door:
   Once matched, Arduino Uno R3 sends a signal to the Relay and buzzer: The buzzer sounds ("tit") once. The relay opens the flow from the 12V. 2A adapter to the 12V door lock solenoid and turns on the blue 12V LED, indicating the door is open for 10 seconds.
9. Finish:
   After 10 seconds, Arduino Uno R3 sends a signal to the buzzer to sound twice ("1x TIT and 1x TUT"). The Arduino stops the signal to the Relay, cutting off the flow to the 12V door lock solenoid and the 12V LED. The door will be closed, and this process will be repeated from the standby stage. The system will stop if it is disabled or shut down by unplugging the power source.

4.4. Prototype Results

The prototype result consists of several parts as follows.

1. Prototype Top
   At the top of the prototype there is a main access consisting of several important components, namely:
   A. Fingerprint sensor: It serves to read and verify the user's fingerprint.

B. Keypad 4x4: Used to enter PIN combinations as an alternative door opening method.
C. Solenoid Door Lock: Components that lock and open doors based on signals from the system.

The top of the prototype is shown in Figure 3.

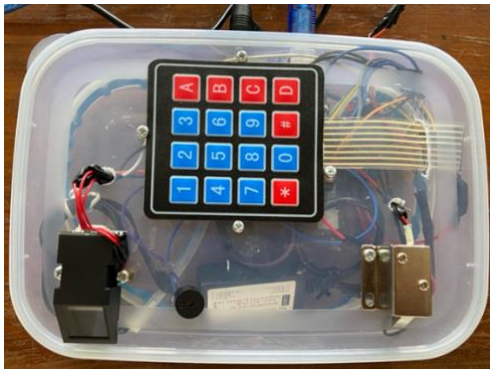

Fig. 3: Prototype Top

2. Inside the Prototype

Inside the system, there are components that support the operation and control of the system, namely:

A. Arduino Uno R3: The main microcontroller that regulates all processes and system logic.
B. LED Lamp (Blue): Lights up to indicate that the door is open.
C. Adapter: Providing power for LED.
D. Relay: Controlling the flow of current to the solenoid door lock and LED lamp.

The Inside of the Prototype is shown in Figure 4.

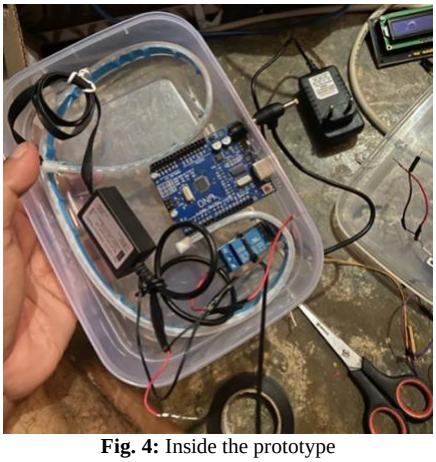

Fig. 4: Inside the prototype

3. Prototype Back Side

On the back side, there are ports that connect the Arduino Uno R3 with other power sources and components, such as:

A. USB B Port: Used to connect Arduino to MacBook for programming and testing.
B. DC Power Jack (7-12V): Connecting external power sources to the system.
C. Cable (+) and (-) : Connecting the door lock solenoid and blue LED lamp to the COM of the Relay, ensuring the proper flow of current for system operation.

The rear side is shown in Figure 5.

Fig. 5: Rear Side

4.5. System Preparation and Arduino IDE

Arduino IDE versi 2.3.3 used by researchers on the 2020 MacBook Air M1 laptop. The system is connected to the MacBook using a USB cable, with the USB Male-B end connected to the Arduino, the A Male end to the A Female converter, and the Male type C to the MacBook port. Once the connection is successful, the system will turn on, while the 12V 2A adapter does not need to be plugged in yet. Next, open the Arduino IDE to proceed with the setup.

4.6. Arduino IDE Preparation Stage

The first step is to make sure that the Arduino UNO R3 can connect properly to the computer device. The connection verification process is carried out by selecting the appropriate board, namely Arduino AVR Boards with the Arduino Uno type, and checking the connected ports, namely: **/dev/cu.wchusbserial10**, via the Tools menu on the Arduino IDE. The selection of these boards and ports is crucial to ensure that the Arduino can communicate with the software optimally.
Once the Arduino is connected, the next stage is to install the libraries needed to operate the fingerprint-based security system. This library plays an important role in integrating the fingerprint sensor with the Arduino. Researchers install **Adafruit Fingerprint Sensor Library**, developed by Adafruit, via the Library Manager at Arduino IDE. Once the library is found through the search feature, the installation is carried out to ensure that the fingerprint sensor can function properly in reading and recognizing the user's fingerprint data.
In addition to the library, the researcher also installed **Library Keypad** developed by Mark Stanley and Alexander Brevig to support the use of Keypad 4x4 as an additional input to the security system. By installing these two libraries, researchers ensure that the hardware and software are effectively integrated, so that the system runs according to the set goals.

4.7. Coding Stages

At this stage, researchers utilize codebases written in C++ dhas been modified to accommodate fingerprint data registration, recognition, and deletion functions. These features are crucial in ensuring that the system is able to manage user data efficiently, especially for the needs of securing financial records. Modifications are also made to ensure smooth communication between the fingerprint sensor, keypad 4x4 and Arduino Uno R3, as well as good integration with other components such as LED, Buzzer, Solenoid Door Lock, dan Relay Module. For more details regarding the encoding results, including screenshots and explanations of the functionality tables of each piece of code, can be seen in the appendix included in this study.

4.8. Stages of Uploading Code to Arduino

Once the coding is complete, the researcher uploads the code to the Arduino Uno R3 via the Arduino IDE. Previously, the connection between the Arduino and the MacBook was checked. This process is important for the instructions in the code to be executed by the hardware. After the upload was successful, the researcher ensured that there were no errors and the program ran as planned.

1. First Way: Using Menus in Arduino IDE
   A. Connect the Arduino Uno R3 to the MacBook via USB cable and Type C Converter.
   B. On the Arduino IDE, open the Sketch menu.
   C. Click Upload.
   D. Wait until the message "Done uploading" appears as a sign that the process is complete.
2. Aa Second Way: Using the Upload Icon
   A. Connect Arduino Uno R3 to MacBook via USB cable and Type C Converter.
   B. Click the right arrow icon (Upload icon) in Arduino IDE.
   C. Wait until the notification "Done uploading" appears.
3. Third Way: Using Keyboard Combinations
   A. Press Cmd + U (macOS) or Ctrl + U (Windows).
   B. Wait for the order "Done uploading" appears, indicating that the upload process is complete.

4.9. Fingerprint Test Arduino IDE

It's time to run the program by opening the Serial Monitor located at the top right corner or it can be with shortcut Command (⌘) + Shift + M. When the monitor serial is opened, the initial display will display the text "Fingerprint found", which indicates that the program is successfully connected with the FPM10A fingerprint sensor. Next, enter the number 1 in the search field that says "Message (Enter to send message to 'Arduino Uno' on '/dev/cu.wchusbserial10')" the gray one. Also make sure that the baud rate is set at 9600 baud. After entering the number 1 (one), the display will appear with the text:

1. "Register ID #1"
2. "Waiting for a valid fingerprint to register as ID #1". The initial display of the Serial Monitor when entering the number 1 is shown in Figure 6.

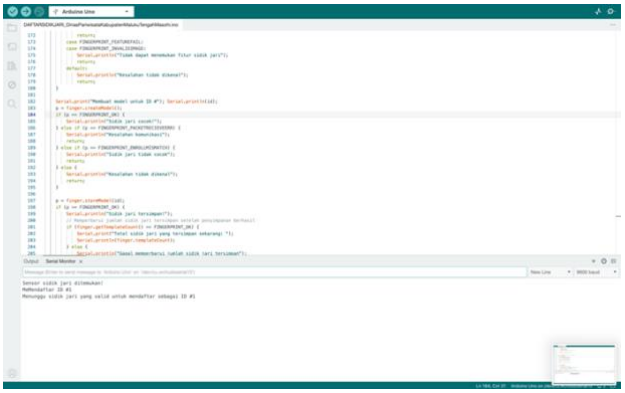

Fig. 6: Serial Monitor Arduino IDE

After that, please attach the finger you want to register to the FPM10A fingerprint sensor. For ID #1, the researcher used the right Thumb Finger. Stick your finger to the FPM10A fingerprint sensor so that it covers all the sensors, not just the fingertips, because if only the tip is attached, the system will have difficulty or even not be able to read the fingerprint properly. Then, after the fingerprint is detected on the FPM10A fingerprint sensor, the following text will appear:

1. Image taken
2. Image converted
3. Release your fingers
4. Place the same finger again. The fingerprint list is shown in Figure 7.

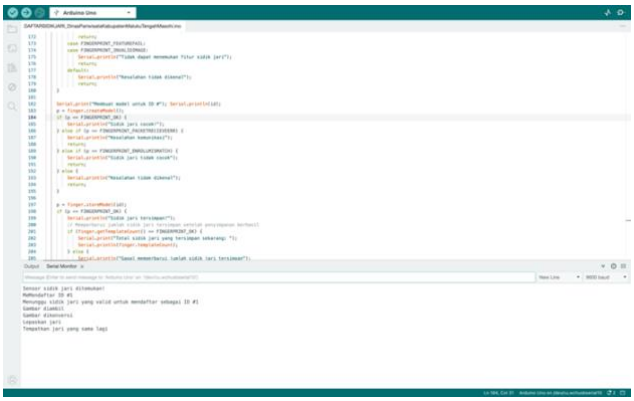

Fig. 7: Arduino IDE Fingerprint List

After that, remove your finger and stick it once again to complete the registration process. If so, the following text will appear:

1. Image taken
2. Image converted
3. Creating a model for ID #1
4. Fingerprint match
5. Fingerprints are stored. The fingerprint successfully registered on the Arduino IDE is shown in Figure 8.

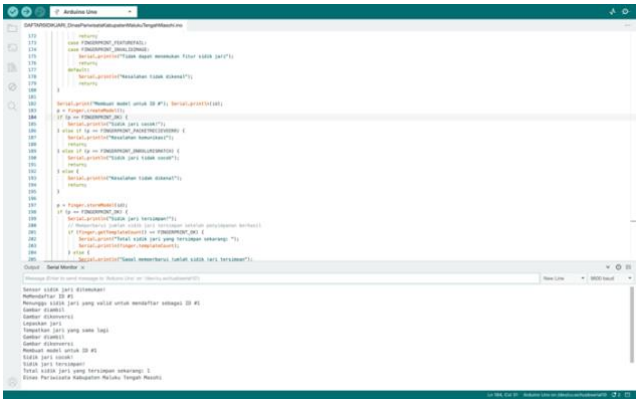

Fig. 8: Fingerprint successfully registered Arduino IDE

The registration process for the left Thumb fingerprint registered in ID #1 has been successful. After that, the program will display the total number of saved fingerprints, which now number 1, along with the text "Dinas Pariwisata Kabupaten Maluku Tengah Masohi." Furthermore, the researcher registered the other fingers, namely the thumb of the left hand in ID #2 and the index finger of the right hand in ID #3. A list of registered fingerprints is shown in Figure 9.

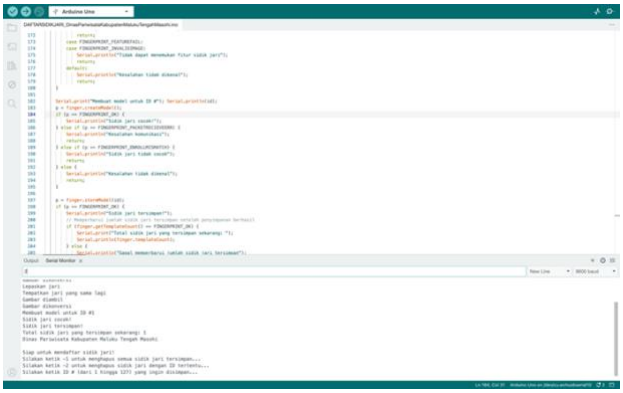

Fig. 9: Fingerprint list ID #2 Arduino IDE

Once the process is complete, Serial Monitor will display the total of the saved fingerprints. The -1 function is used to delete all stored fingerprints, while the -2 function works to delete the fingerprint based on a specific ID. In this experiment, the researchers performed the removal of the right index finger registered on ID #3 by entering the number -2, followed by the number 3, indicating the ID to be deleted.

4.10. Testing

This section displays the tests of the system that has been created. Divided into 2 (two) tests, namely:

1. Fingerprint Testing
   Fingerprint testing is shown in Table 2.

Table 2: Fingerprint Testing

Fingerprint ID	Information	Status	Succeed	Fail
1	Thumb, Right Hand	Registered	Succeed	-
2	Thumb, Left Hand	Registered	Succeed	-
3	Index Finger, Right Hand	Erased *Wearing the Wear Function -2 (ID 3)	Succeed	-
Total 3	Succeed		3	
	Fail			0

   Deletion is done by using the -2 function (ID 3).
   Total Registration: 3 Successful Fingerprints
   Total Failures: 0
   From the above results, it can be concluded that the entire fingerprint registration process was successfully carried out, except for ID #3 which was successfully deleted according to the instructions given.

2. Keypad Testing
   If you try a security system to ensure that the keypad function is operating properly. The following are the results of the PIN combination test shown in Table 3.

Table 3: Keypad Testing

Keypad	PIN Combinations	Information	Succeed	Fail
Side 1	123A456B789C*0#D	Pressing the PIN from scratch with the correct combination	Succeed	-
Side 2	1112131415 123A456B789C*0#D	Pressing a random PIN from the beginning and then proceeding with the correct combination	Succeed	-
Total	Succeed		2	
	Fail			0

   Of the two experiments carried out, the two PIN combinations were successfully inputted correctly, resulting in a total of two successful experiments and no one failed.

5. Conclusion

The designed system has functioned according to the original purpose and meets the security needs of the archive Dinas Pariwisata Kabupaten Maluku Tengah. The fingerprint and PIN methods are separated from each other to ensure that access remains secure even if one of the methods encounters problems, such as forgetting the PIN or incorrect fingerprint reading. Based on the validation results, the additional control application has not been considered necessary because the system is already effective enough without the additional application. A mechanism is needed to automatically turn the system on and off, in order to maintain the durability of components and reduce the risk of damage due to continuous use. The future suggestion is that the system uses a more advanced fingerprint sensor than the FPM10A, which will speed up the identification process and improve the accuracy of the system. iiiiiiiiIn addition to fingerprint and PIN methods, it is recommended to add other authentication methods such as Face ID or voice recognition to improve the flexibility and security of the system. This corresponds to the conclusion about the separation of methods to prevent access issues. Although control applications are not needed now, developers can consider creating more advanced control applications in the future to make the system easier to use.

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