Secure Money Storage Safe with Two Combination Locks (Fingerprint + Keypad)

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ABSTRACT

A safe is a tool used to store valuables including money, jewelry, assets or valuable documents. A safe is a storage place that is considered practical but has a high risk. There are several shortcomings in existing safes, including using one key, which makes the safe easy to break into, which can cause losses to the owner. Therefore, it is necessary to innovate or develop by using a combination of several keys by applying fingerprint and keypad technology to add security features to the safe. The solution to this problem can be made by creating a Money Storage Safe Security With Two Key Combinations (Fingerprint + Keypad), this system can open the safe with two combinations of fingerprint and keypad so that it can increase security on the safe. This study aims to design a safe security system using fingerprint and keypad. This system is a prototype that will open the safe door based on the user's fingerprint that has been recognized and uses the keypad to enter a previously created password. Based on the results of research and testing of tools and fingerprints, an accuracy of 100% was obtained for tool testing and 53.33% for fingerprint testing, so it can be concluded that the design of the tool has worked well.

I. Introduction

A safe is a device used to store valuables, including money, jewelry, assets, or valuable documents. A safe is considered a practical storage device, but it carries a high risk [1]. There are several shortcomings with existing safes, including the use of a single key, which makes them easily broken into, potentially causing losses to the owner. Therefore, innovation or development is needed, including the use of a combination of multiple keys, using fingerprint and keypad technology, to enhance the security features of safes.

Previous research has conducted research on Safe Security, namely the Design and Construction of a Safe Security Device Using an Arduino-Based Fingerprint Sensor [2]. This system uses an Arduino UNO microcontroller, fingerprint sensors, buzzers, door solenoids, and LCDs, all of which are used in home safes. Further research is on designing a safe security system using the SMS Gateway-based fingerprint method [3]. This system uses fingerprint, Arduino UNO microcontroller, LCD, relay, solenoid door lock and SMS Gateway to send email notification to the owner who opens the safe access. The difference with the author's research is that the author's research does not use SMS gateway as notification via email. In further research, the Safe Security Lock Uses PIN and RFID [4]. The safe security lock control device was created using a PIN, RFID, keypad, LCD, and solenoid. The difference with the author's research is that this research uses RFID as an identifier to open the safe, while the author's research uses a fingerprint sensor to open the safe. The next research is a prototype of a safe security and tracking system using fingerprints and GPS based on the Internet of Things [5]. This study uses fingerprints, Arduino Mega, limit switches, LCDs, keypads, and Internet of Things-based GPS technology to detect the location of the safe. The next step is to design a safe door security system using fingerprints and an Arduino-based keypad [6]. This study used fingerprint and keypad technology, along with a buzzer that sounds when the door is successfully opened. The author's previous study only used a fingerprint sensor and keypad.

Based on the problem and previous research, further research is needed to implement this on a safe measuring 40 cm x 30 cm x 20 cm. This device is designed using a fingerprint scanner, LCD, relay, solenoid, and keypad as a password combination. The author's reason for using a password combination is to increase the level of security of the safe by using fingerprint verification along with a registered password combination, so that opening the safe requires more than just a fingerprint. This system is expected to maintain the security of the safe and prevent the loss of valuables such as money, assets, and securities.

II. Method

1. Arduino Uno (Mikrokontroler Atmega328)

Arduino Uno is a microcontroller board based on ATmega328 (datasheet). It has 14 input pins from digital output where 6 input pins can be used as PWM outputs and 6 analog input pins, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. To support the microcontroller to be used, simply connect the Arduino Uno Board to a computer using a USB cable or power with an AC-to-DC adapter or battery to run it [7]. The following is a table of Arduino Uno specifications as in table 1.

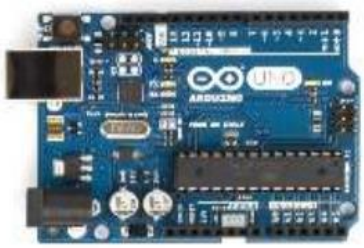

Figure 1. Arduino Uno

Table 1. Arduino Uno Components

Components	ArduinoUNO
Microcontroller	Atmega328
Operating voltage	5 V
Recommended voltage	7V-12V
Digital I/O pin	14
Analog input pin	6
Digital pin current	40 mA
Current on pins 3.3	50 mA
Flash memory	32 KB
SRAM	2 KB
EEPROM	1 KB
Clock speed	16 MHz
Dimensions	685,8 mm ×533,4 mm

On the Arduino Uno board there are important parts to know as follows:[8]

1. Digital input/output pins (labeled ‘0 to 13’)
   In general, this I/O pin is a digital pin, namely a pin that works at a digital voltage level (0V to 5V) for both input and output. However, on some analog output pins, which can output an analog voltage of 0V to 5V, these pins are pins 3, 5, 6, 9, 10 and 11, besides that, pins 0 and 1 also have a special function as serial communication pins.
2. Analog input pins (labeled ‘A0 to A5’).
   This pin can receive analog voltage input between 0V to 5V, this voltage will be represented as the number 0 – 1023 in the program.
3. Pins for voltage source
   This pin group is a collection of pins related to the power source, for example 5V output, 3.3V output, GND (2 pins) and Vref (reference voltage for internal ADC reading).

4. IC ATMega328
   As explained, this IC acts as a data processing control center.
5. IC ATMega16U
   This IC is programmed to handle data communication with the PC via the USB port.
6. Jack USB
   It is a USB type B socket as a serial data connector with a PC.
7. Jack Power
   It is a socket for external power supply between 9V to 12V DC.
8. Port ICSP (In-Circuit Serial Programing)
   This port is used to program Arduino without a bootloader.
9. Reset Button
   Used to reset the Arduino microcontroller board to start the program from the beginning.

2. Relay

A relay is a switch that is electrically operated and is an electromechanical component that consists of 2 main parts, namely an electromagnet (coil) and a mechanical (a set of switch contacts). The relay uses the electromagnetic principle to move the switch contacts so that with a small electric current (low power) it can conduct electricity with a higher voltage. For example, with a relay that uses a 5V and 50 mA electromagnet, it can move the relay armature (which functions as a switch) to conduct 220V 2A electricity [9].

Figure 2. Relay

3. Fingerprint Scanner

A fingerprint is a device used to recognize a person's fingerprints, which are their identity, using a computing system. This system includes a scanner hardware and software that records specific fingerprint characteristics and stores each user's data in a database. When the user attempts to access the system again, the software compares the data stored in the database with the fingerprint reading from the scanner. There are several fingerprint scanning techniques, such as optical, ultrasonic, capacitance, and thermal [10]. The input limit for this fingerprint is only 225 fingerprints that can be input.

Figure 3. Fingerprint Scanner

4. Keypad

A keypad is a matrix of pushbutton switches used for data input. The 4x4 keypad is used to determine the text data the user will select. The input data is then processed by a microcontroller [11].

Figure 4. Keypad

5. Fingerprint Measurement Accuracy

This system will store the fingerprint data of the occupants of the house and then match it when a user will open the safe. If it matches, the door will automatically open. From the requirements obtained, there is a main controller in the form of a microcontroller, two devices that will be used as input devices, namely a fingerprint scanner and a keypad, then processed by the Arduino fingerprint that has been entered. While for the output device there is one device, namely an LCD that will display information when successfully opening the safe. Input testing was carried out with 10 trials involving 5 people and testing fingerprints with 5 trials and keypad with 5 trials. This test was carried out to test the fingerprint system that has been detected with the undetected fingerprint along with the password entered into the keypad. Then the combination of fingerprint and keypad features will be tested when applied in double. When still wrong in 5 trials, an additional 30 seconds will be given to correct the input errors entered. The measurements to measure the success of the safe are: [12] :

$$error = |\, X - Xi \,| \quad (1)$$

$$\%error = |((X - Xi)/\, Xi\,) * 100\% \quad (2)$$

$$accuracy = (100 - \%error) \quad (3)$$

Description:

X : successful test

Xi : total tests

III. Results and Discussion

A. Research Results

The following is the design result of a Safe Security for Money Storage with Two Combination Locks (Fingerprint + Keypad). This tool was created to help improve the security of the safe so that it is not easily broken into by applying two key combinations (fingerprint + keypad) to open the safe. The detected fingerprint is then matched with the fingerprint that has been registered in the database then input the password on the appropriate keypad to open the safe. For more details, please see Figure 5 below.

Figure 5. Tool Design Results

B. Discussion

1. Implementation of Design Results

Once the system has been thoroughly analyzed and designed, the next step is implementation, which means the tool is ready for use. The goal of implementation is to strengthen the design module so users can contribute to its development.

a. Implementation of Arduino Uno Design Results

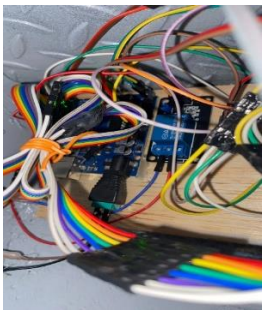

Figure 6. Arduino and Relay Design Results

In Figure 6 is the result of the Arduino design, the pins on the Arduino UNO are connected to the fingerprint, relay, and solenoid.

b. Implementation of Fingerprint and LCD Design Results

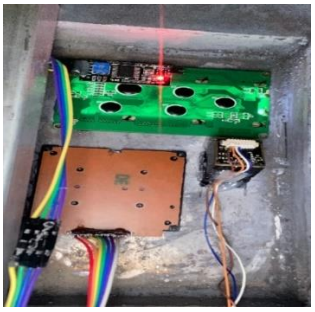

Figure 7. Fingerprint and LCD Design Results

Based on Figure 7, it can be seen that the fingerprint and LCD are connected to the Arduino and the relay processes each fingerprint and pin inputted by the user.

2. Overall Tool Testing

a. LCD Initial Display

This is the initial screen when accessing the safe. The LCD displays a message asking you to enter your PIN and fingerprint.

Figure 8. LCD Initial Display

a. Fingerprint display

Figure 9. Fingerprint Scan View

In Figure 9, it shows when the user scans his fingerprint to the fingerprint sensor. If the fingerprint matches, the LCD will display "Fingerprint received and being processed." If it does not match, the LCD will display the message "Wrong fingerprint, please try again."

b. Display inputting password on keypad

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Figure 10. Enter Pin View

Figure 10 shows the display when a user enters a PIN on the keypad. The initial LCD screen displays "Please enter your PIN." After the user enters the correct PIN, the vault is unlocked.

c. Safe view successfully opened

Figure 11. Safe Display Successfully Opened

Figure 11 shows a display of a safe that has been successfully opened. When the PIN access has been received, the safe can then be opened.

3. Overall Test Results

The following are the results of testing the entire tool that has been designed as shown in the table below.

Table 2. Tool Test Results

No	Testing	Test Figure	Test Results	Description
1	Entering fingerprints			Successfully detected fingerprint

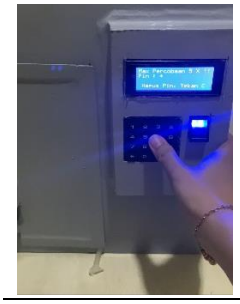
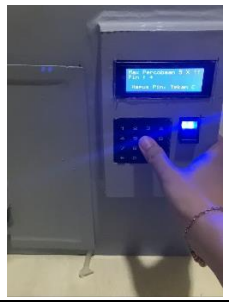
No	Testing	Test Figure	Test Results	Description
				
				Failed to detect fingerprint
2	Entering the PIN			Successfully entered the PIN and access was granted.
				Have tried entering the PIN 5 times
3	Open safe			Successfully open the safe when access has been granted

Table 3. Fingerprint Test Results Clean

Test	Results	
	Success	**Failure**
Experiment 1	✓	×
Experiment 2	✓	×
Experiment 3	✓	×
Experiment 4	✓	×

Test	Results	
	Success	Failure
Experiment 5	✓	×
Experiment 6	✓	×
Experiment 7	✓	×
Experiment 8	✓	×
Experiment 9	✓	×
Experiment 10	✓	×

$$\%error = |((Xi - X)/\ Xi)| * 100\%$$
$$\%error = |((10 - 10)/\ 10)| * 100\% = \frac{0}{10} * 100\% = 0\%$$
$$accuracy = (100\% - \%error)$$
$$accuracy = (100\% - 0\%) = 100\%$$

Where:
Xi = Total Tests
X = Successful Tests
Table 4 shows the fingerprint test with clean fingerprints. From 10 trials, the results showed that clean fingerprints could open the safe with a 100% success rate.

Table 4. Sweat Fingerprint Test Results

Test	Results	
	Success	Failure
Experiment 1	✓	×
Experiment 2	×	✓
Experiment 3	✓	×
Experiment 4	×	✓
Experiment 5	×	✓
Experiment 6	×	✓
Experiment 7	✓	×
Experiment 8	×	✓
Experiment 9	×	✓
Experiment 10	×	✓

$$\%error = |((Xi - X)/\ Xi)| * 100\%$$
$$\%error = |((10 - 3)/\ 10) * 100\% = \frac{7}{10} * 100\% = 70\%$$
$$accuracy = (100\% - 70\%) = 30\%$$

Table 5 shows a test of fingerprints with sweaty fingerprints. From 10 experiments carried out, the results showed that sweaty fingerprints could open the safe with a 30% success rate.

Table 5. Dirty Fingerprint Test Results

Test	Hasil	
	Success	Failure
Experiment 1	×	✓
Experiment 2	×	✓
Experiment 3	×	✓
Experiment 4	✓	×
Experiment 5	×	✓
Experiment 6	✓	×
Experiment 7	×	✓
Experiment 8	×	✓

Test	Hasil	
	Success	Failure
Experiment 9	✓	×
Experiment 10	×	✓

$$\%error = |((Xi - X)/\ Xi)| * 100\%$$
$$\%error = |((10 - 3)/\ 10) * 100\% = \frac{7}{10} * 100\% = 70\%$$
$$accuracy = (100\% - 70\%) = 30\%$$

Table 6 shows a fingerprint test with dirty fingerprints. From 10 experiments, the results showed that sweaty fingerprints could open the safe with a 30% success rate.

$$\text{Total} = \frac{\mathbf{100 + 30 + 30}}{\mathbf{3}} = \frac{\mathbf{160}}{\mathbf{3}} = 53{,}33\%$$

Based on the overall test results, the fingerprint test accuracy results under various conditions were 53.33% in opening the safe. The most common cause of the fingerprint sensor not detecting fingerprints is wet conditions or dirty hands.

IV. Conclusion

The conclusion of this study is:

1. Based on the research results, fingerprint testing with normal finger conditions obtained 100% accuracy and sweaty hand testing obtained 30% accuracy and dirty hand testing obtained 30% accuracy.
2. This tool has been tested by conducting a combination experiment with the keypad and fingerprint, based on the test results the safe door was successfully opened.

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