DEVELOPMENT OF AN IMPROVED MONEY BOX WITH COUNTER AND FINGERPRINT LOCK USING MICROCONTROLLER

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Computer Engineering Technology (Computer Systems) with Honours

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Tajuk Projek : Development of an improved money box with counter and fingerprint lock using microcontroller

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DEDICATION

This project is dedicated to the unwavering support and love of my parents, whose sacrifices and encouragement have been the foundation of my academic journey. Your financial assistance has enabled me to pursue my dreams, and for that, I am deeply grateful.

I extend my heartfelt gratitude to my dedicated supervisor, Ts. Imran Bin Hindustan. Your guidance, patience, and steadfast support from the start to the completion of this project have been vital to its success. Your mentorship has been a guiding light, and I am sincerely thankful for the knowledge and skills I have gained under your direction.

To my friends, thank you for being pillars of strength and for the camaraderie that made the challenges easier to bear. Your moral support has been a source of inspiration, making this semester at Universiti Teknikal Malaysia Melaka truly memorable.

This achievement is not mine alone but a collective effort, and I am grateful for the invaluable contributions of everyone who played a part in this endeavour.

ABSTRACT

The development of an improved money box with a counter and fingerprint lock using a microcontroller addresses the limitations of traditional savings methods. Conventional money boxes lack advanced features such as money detection, automatic counting, and robust security measures, often resulting in inefficiency, inaccuracy, and vulnerability to theft. This project aims to overcome these challenges by integrating a TCS3200 color sensor for banknote detection, an automatic counter for real-time tracking of savings, and an AS608 fingerprint scanner for secure access. At the core of the system is the Arduino Uno R3 microcontroller, which coordinates the operation of these components along with a solenoid lock to ensure seamless functionality. The project methodology included designing both hardware and software systems and conducting extensive testing to ensure precision and reliability. Results revealed that the system accurately detected and counted RM1, RM5, and RM10 notes but encountered difficulties with RM20, RM50, and RM100 due to sensor calibration limitations. Fingerprint authentication demonstrated high reliability, with successful detections in most cases. To enhance the system, future improvements include refining sensor calibration to support a wider range of banknotes, improving the user interface for better usability, and integrating IoT capabilities for real-time tracking and remote management. This project demonstrates how microcontroller-based systems can modernize personal savings by providing a secure, efficient, and user-friendly solution, encouraging better financial management habits.

ABSTRAK

Pembangunan tabung wang yang ditambah baik dengan kaunter dan kunci cap jari menggunakan mikropengawal bertujuan menangani kekurangan kaedah menabung tradisional, yang tidak mempunyai ciri canggih seperti pengesanan wang, pengiraan automatik, dan langkah keselamatan yang kukuh, menyebabkan ketidakcekapan, ketidaktepatan, dan terdedah kepada kecurian. Projek ini mengintegrasikan sensor warna TCS3200 untuk mengesan wang kertas, kaunter automatik untuk mengesan jumlah simpanan secara masa nyata, dan pengimbas cap jari AS608 untuk akses yang selamat, dengan mikropengawal Arduino Uno R3 sebagai penghubung operasi komponen ini bersama kunci solenoid. Metodologi projek merangkumi reka bentuk sistem perkakasan dan perisian serta ujian menyeluruh bagi memastikan ketepatan dan kebolehpercayaan, dan hasil ujian menunjukkan sistem ini mampu mengesan dan mengira wang kertas RM1, RM5, dan RM10 dengan tepat, tetapi menghadapi kesukaran dengan RM20, RM50, dan RM100 disebabkan oleh batasan kalibrasi sensor, sementara pengesahan cap jari menunjukkan kebolehpercayaan yang tinggi. Untuk meningkatkan sistem ini, cadangan masa hadapan termasuk memperbaiki kalibrasi sensor untuk menyokong lebih banyak jenis wang kertas, meningkatkan antara muka pengguna untuk kegunaan yang lebih mesra pengguna, dan mengintegrasikan keupayaan IoT untuk pengesanan dan pengurusan jarak jauh secara masa nyata, membuktikan bagaimana sistem berasaskan mikropengawal boleh memodenkan tabungan peribadi dengan menyediakan penyelesaian yang selamat, cekap, dan mesra pengguna, serta menggalakkan tabiat pengurusan kewangan yang lebih baik.

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My deepest appreciation goes to my parents, family members, and friends for their love and prayers during my studies. Special thanks to Puan Rozitah Binti Abdul Ghani and Encik Amil Bin Razali for their motivation, understanding, and financial support. Additionally, I am thankful to my housemates for always accompanying me through thick and thin.

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%	-	Percentage

LIST OF ABBREVIATIONS

V	-	Voltage
RM	-	Ringgit Malaysia
+	-	Positive
-	-	Negetive
X	-	Multiplication
=	-	Equal to
≈	-	Approximately equal to

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CHAPTER 1

INTRODUCTION

1.1 Background

In this modern era, saving money is still very important, but traditional ways of saving, need to be updated to meet modern needs. The project titled "Development of an Improved Money Box with Counter and Fingerprint Lock Using Microcontroller" aims to create a new and better way to save money by using advanced technology for better security and convenience.

This updated money box uses a fingerprint scanner to make sure only the right person can open it, adding a strong layer of safety. It also has an color sensor that can tell what type of money is being put in, helping to count the money accurately. This automatic counting makes saving easier and helps people keep track of their money better.

At the centre of this improved money box is a microcontroller, which controls everything, including the fingerprint scanner, color sensor, and a solenoid lock that locks and unlocks the box. By combining these technologies, the money box not only keeps money safe but also makes saving money simpler and more fun. This project shows how modern technology can make everyday tasks easier and encourage good money-saving habits.

1.2 Problem Statement

The conventional money box has no features to detect money notes and count the total amount saved. Normally, user has to manually count the total, which is time consuming and prone to human error. Furthermore, it is difficult to retrieve the money saved in the box. Especially, for money box that made of ceramic, glass and that are made to be open once only by breaking tempered the box. Moreover, it does not have security features. If the money box is stolen, anybody can break the box and take the money. Therefore, there is a need to create and implement a reliable system that can benefits the user in many ways, such as easy to use, save time, accurate counting and more secure.

1.3 Project Objective

The main aim of this project is to propose a systematic and effective methodology to create an automatic counting money box with reasonable accuracy and security. Specifically, the objectives are as follows:

1. To design a system that can detect the value of money note that is being inserted into the box and automatically count the total amount.
2. To construct a money box system circuit consisting of microcontroller, solenoid lock, color sensor and fingerprint sensor.
3. To validate the accuracy of the money notes detector, counter, and fingerprint.

1.4 Scope of Project

The scope of this project are as follows:

a) The system will automatically recognize the value of money notes entered by using color sensors.

b) The system will only be unlocking the money box when it detects the fingerprint of the authorized users.

c) Solenoid lock will be used to control the lock and unlocking of the money box.

d) By using the microcontroller, we can control input sensor and manage the output device.

e) Allowing users to get real-time updates on savings activity through the LCD screen.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Today, the habit of saving money is increasingly forgotten and rarely practiced, leading to financial insecurity and poor money management. The traditional money box no longer meets the needs of modern users who require security and ease of use. Consequently, an improved money box with a counter and fingerprint lock using a microcontroller has been developed to address these issues. This literature review involves reviewing and analyzing previous studies on similar technologies and methodologies to enhance the design. By exploring existing literature, a deeper understanding of the advancements in security and sensor technologies can be gained. This knowledge will help refine the money box design, making it more effective and reliable. Through this review, researchers and developers can improve financial saving devices, promoting better money management practices and financial security for users.

2.2 Previous related projects

2.2.1 SecureTouch: Fingerprint-Enabled Automated Locker System

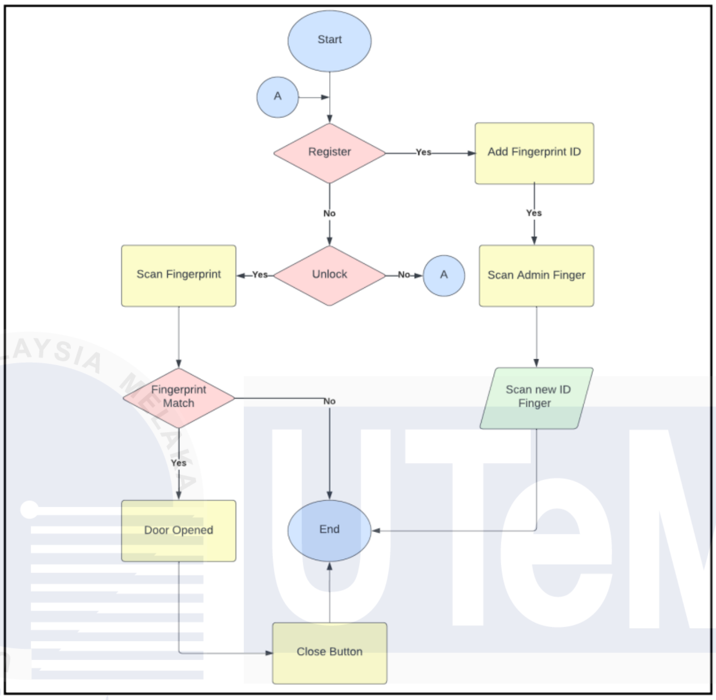


Figure 2.1 Flowchart of the prototype [1]

According to [1], we rely a lot on passwords and keys, but they often get lost or stolen, causing security problems. Biometrics, which uses things like fingerprints or eye patterns, offers a solution to this. Figure 2.1 illustrates the sequence of operations in the fingerprint-enabled automated locker system. First, users sign up by scanning their fingerprint, which gets linked to a specific locker. To open their locker later, they press "Scan" and place their finger on the sensor. The system checks if the fingerprint matches the stored data. If it does, the locker unlocks. If not, an error shows on the screen. Users can also add new fingerprints by pressing "Add fingerprint," but they need to verify with an admin fingerprint first. The flowchart covers both successful and unsuccessful scans, making sure locker access is clear and safe.

2.2.2 Fingerprint Door Lock Using Arduino

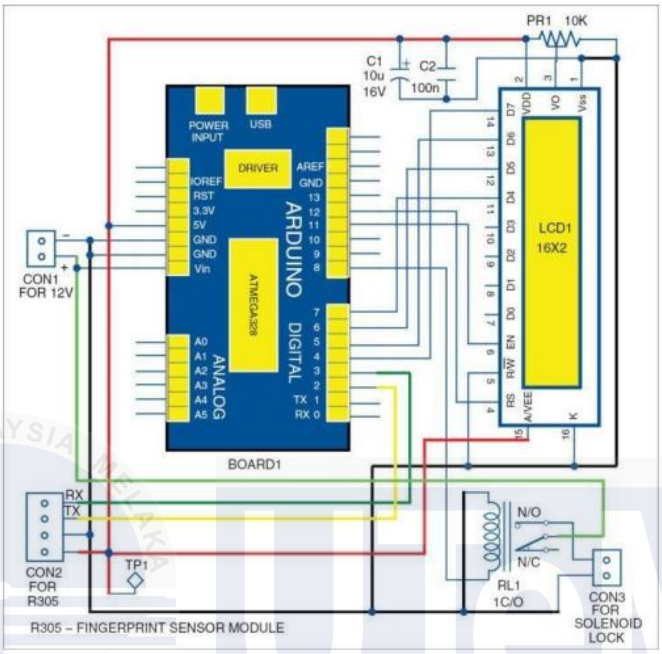


Figure 2.2 Circuit diagram of the fingerprint door unlock system [2]

Based on Figure 2.2, the circuit uses a 12V power supply to power both the 5V Arduino microcontroller (MCU) and the 12V solenoid lock. The Arduino Uno has 14 digital I/O pins, six analog inputs, a fingerprint sensor, USB connection, power jack, battery, and charger. It is programmable with Arduino IDE software. The R305 fingerprint sensor module connects via UART, allowing direct connections to the MCU or a PC with a max232/USB adapter. It can store and identify fingerprints in 1:1 or 1:N modes, with TX and RX pins linked to Arduino pins 2 and 3. A 16×2 LCD display shows messages, with control lines connected to PR1 output, pin 12 (Arduino), GND, and pin 11 (Arduino), and data pins connected to Arduino pins 7, 6, 5, and 4. PR1 adjusts the LCD contrast. Fingerprint door lock system addresses the common problems of getting locked out, losing keys or smart cards, and relying on caretakers by providing secure, keyless access for authorized users, eliminating delays and the need for passwords [2].

2.2.3 Development of Multi-Purpose Donation Box based on the Internet of Things

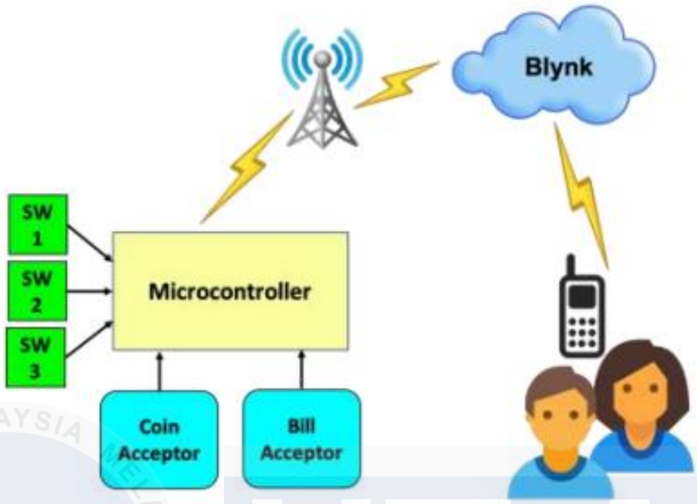


Figure 2.3 The overview of the system [3]

Based on Figure 2.1, the project titled "Development of Multi-Purpose Donation Box based on the Internet of Things" presents the development of an intelligent donation box that offers multiple donation options, informs the owner of the amount donated for each purpose, and tracks the total amount of money collected in the box. Then, this project demonstrates the overview of the system that are user-friendly and provide a real time monitoring for the owner by sending notification to their phone. The author states that the system consists of three main parts which is hardware, software, and service. The coin and bill acceptors are connected to the microcontroller, which detects and calculates the total donated amount, then sends this data to the Blynk server to forward to the user's smartphone. The donation box is designed for ease of use with two main steps, selecting the donation type by pressing a button on the front of the box, and then placing the money in the box [3].

2.2.4 Design and Implementation of Automatic Money Counting and Sorting System

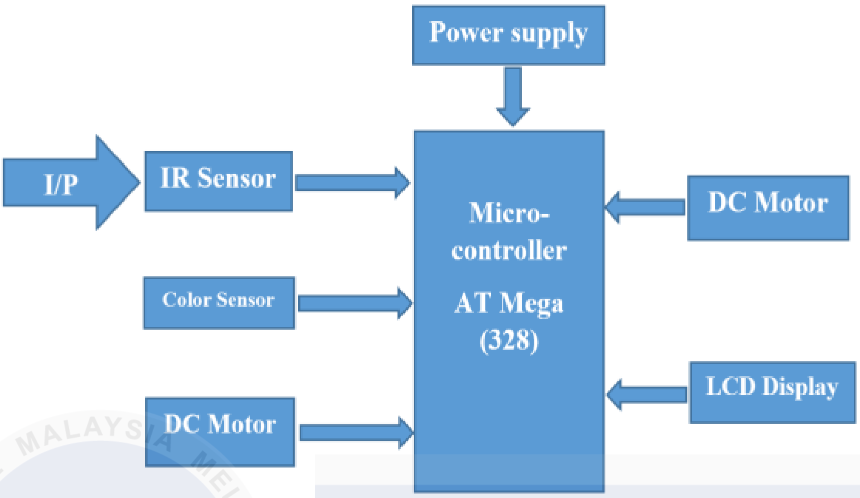


Figure 2.4 System block diagram [4]

In 2018, research titled "Design and Implementation of Automatic Money Counting and Sorting System" was conducted in India to design an automatic money counting and sorting system that will be used in donation box at a temple [4]. Figure 2.4. shows that the block diagram includes an Arduino Uno controller connected to various devices like an IR sensor, a color sensor, a 16x2 LCD display, a UV sensor, a DC motor and power supply. An IR sensor detects notes in the insertion section, while a color sensor identifies the notes' colors. A second IR sensor manages the sorting mechanism. The first motor accepts the note and passes it to the sorting mechanism. An LCD display monitor provides real-time information in a clear format. This project aims to simplify the donation process in temples [4].

2.2.5 Development of Biometric Based Door Security System

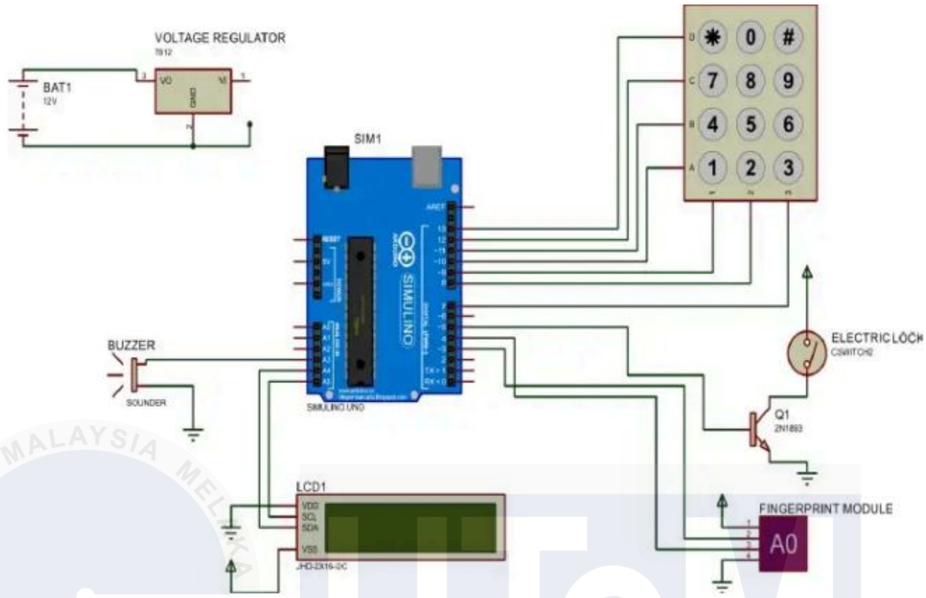


Figure 2.5 Circuit diagram of the developed system [5]

Figure 2.5 illustrates the circuit diagram of the developed system of the biometric based door security using an Arduino Uno microcontroller. A 12V battery powers the system, with a voltage regulator stepping down the voltage to 5V for the Arduino and peripherals. The setup includes a 4x4 matrix keypad for password input, a fingerprint sensor for biometric authentication connected via the A0 analog pin, a 16x2 LCD display for user prompts and feedback, a buzzer for alerts, and a solenoid electric lock controlled by a transistor (2N2903). The Arduino stores fingerprint data and uses it, along with the keypad input, to authenticate users and control the door lock, providing secure and efficient access. According to [5], to save a fingerprint, users need to scan their finger twice in a row to ensure a clear image. If the placement of the finger is even slightly different between the scans, it might not be saved properly. This explains why some attempts to save fingerprints fail, as they require consistent and complete placement of the finger each time.

2.2.6 Design of a Prototype of Paper money Detector for The View

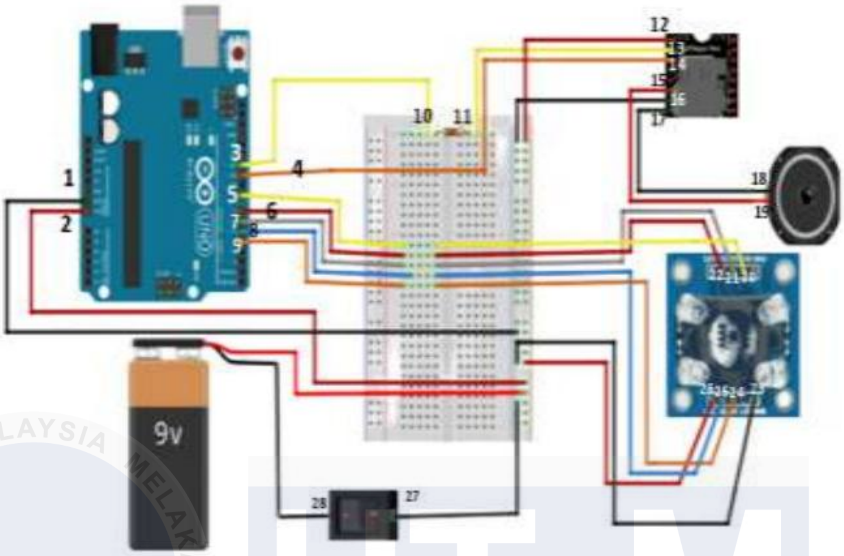


Figure 2.6 Overall system circuit [6]

According to [6], this system innovatively integrates speakers into the device, enabling it to produce sound outputs for detected currency values. It is designed to assist the blind in their daily activities, such as buying and selling goods and services. By referring to Figure 2.6, the system uses the TCS3200 color sensor, MicroSD card module, 9V battery, speaker/buzzer, toggle Switch, and an Arduino UNO R3 microprocessor, which are the main parts that control the input and output. The microcontroller processes the input data received from the color sensor, which reads the light intensity emitted by the super-bright LED onto the object. When a banknote is placed over the color sensor, it determines the RGB value of the currency. The microcontroller then converts this data into a sound output through the speakers, indicating the currency's nominal value [6].

2.2.7 Nominal of Money and Colour Detector for the Blind People

The author stated that blind people often have difficulty identifying colors and money. They usually fold their banknotes or ask others for help, but this method isn't always reliable. To solve this, a device that detects the color and value of money is needed. This paper explains how such a device can be made using a sensor and microcontroller [7]. So, the research aims to provide a system that can help to make a blind people life more convenience.

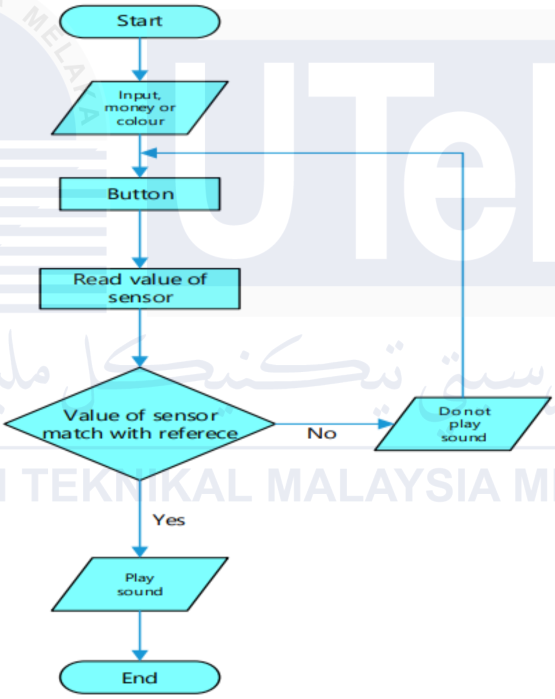


Figure 2.7 Flowchart of Proposed System [7]

According to figure 2.7, the flowchart outlines a straightforward process starting with user input, either money or a color, followed by a button press to proceed. The system then reads a value from a sensor and checks if it matches a predefined reference value. If there's a match, the system plays a sound. Otherwise, it remains silent.

2.2.8 Simple Smart Glasses Based on Microcontrollers as Money Detector of Nominal and Authenticity

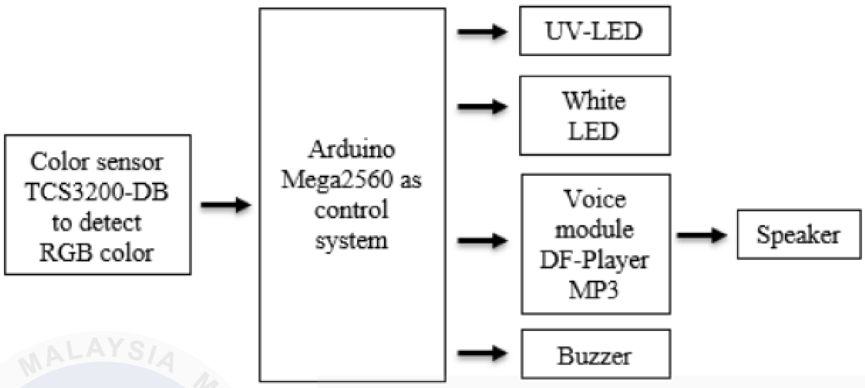


Figure 2.8 Block Diagram of the system [8]

Figure 2.8 illustrates the operational process of the nominal detection glasses system for verifying banknote authenticity. The system comprises input, processing, and output stages. It utilizes a TCS3200-DB color sensor to receive RGB colors, which are then processed by an Arduino Mega 2560 control system. UV LED emits light onto the banknotes to discern their authenticity, while RGB data from the sensor is processed by the Arduino Mega 2560. Additionally, LED illumination helps in identifying the denomination of the banknotes. The DF-Player MP3 sound module plays pre-recorded sounds stored on an SD-Card, with a speaker for audio output. A buzzer serves as an indicator of the device's operational status, signaling proper functionality [8].

2.2.9 Design and Implementation of a Fingerprint Based Lock System for Shared Access

In the proposed model in [9], the author has suggested fingerprint lock system that provides secure and convenient access for homes, offices, and universities with accurate fingerprint scanning and password authentication.

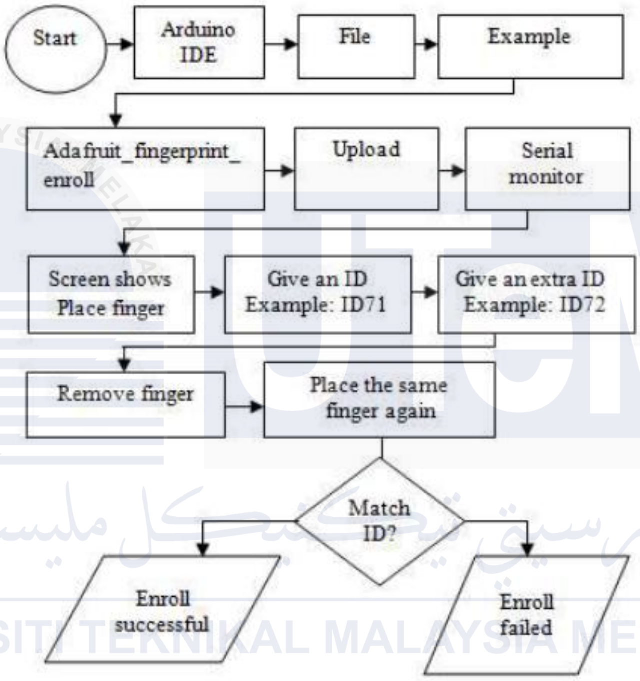


Figure 2.9 Flowchart fingerprint enrollment steps [9]

Based on the flowchart shown in Figure 2.9, it outlines the process for enrolling a fingerprint using the Arduino IDE and an Adafruit fingerprint sensor. It begins by opening the Arduino IDE and selecting a file from the examples. After uploading the code and opening the serial monitor, the Adafruit_fingerprint_enroll function is initiated. The screen prompts the user to place their finger on the sensor, assigns an ID to the fingerprint and then prompts for the same finger to be placed again to confirm the ID. If the fingerprints match, the enrollment is successful, otherwise, it fails. If successful, the process concludes with the fingerprint being stored in the system.

2.2.10 Development and Experimentation of a Security Door Lock System Using Biometric Fingerprint Architecture

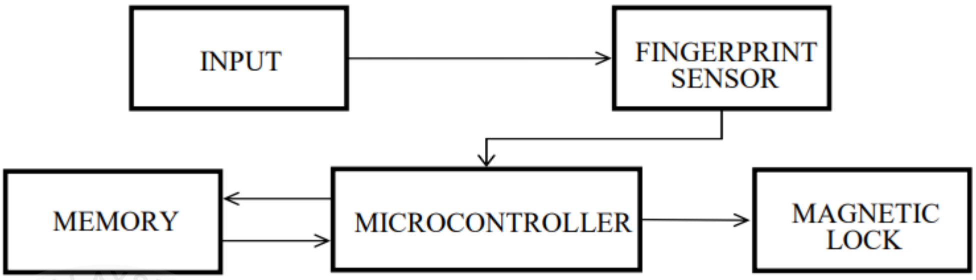


Figure 2.10 Block diagram of the design [10]

Figure 2.10 represents a fingerprint-based lock system. The "INPUT" block indicates where user input which is fingerprint is provided. This input is sent to the "FINGERPRINT SENSOR," which scans and reads the fingerprint data. The scanned data is then forwarded to the "MICROCONTROLLER," which serves as the central processing unit of the system. The microcontroller retrieves stored fingerprint data from "MEMORY" to compare and verify the input. If the input matches the stored data, the microcontroller activates the "MAGNETIC LOCK," unlocking the door. This process ensures secure access control using fingerprint recognition. Fingerprint recognition is a common method to identify people by analyzing unique features in their fingerprints. With crime rates rising globally, there's a growing need for effective security systems [10].

2.3 Comparison of Previous Related Projects

Table 2.1 Comparison of previous related projects

No	Reference	Similarity	Difference	Remark/Comment
1	SecureTouch: Fingerprint-Enabled Automated Locker System [1]	Use fingerprint scanner as a lock.	1.One fingerprint scanner is used to lock three lockers. When one user placed his/her finger onto the fingerprint scanner and if it is match then its corresponding locker will automatically open. 2.Use Arduino Mega 2560	1.One fingerprint scanner is shared between three lockers is a good idea because it can minimize the surface used, but it is not convenient for the user because they have to que and wait for their turn to access the fingerprint scanner and use their locker. 2.Arduino Mega 2560 size is bigger than other Arduino and has high power consumption.
2	Fingerprint Door Lock Using Arduino [2]	Use fingerprint scanner as a lock.	This project implemented to door while my project is used on money box.	The overall cost for this project is high.

3	Development of Multi-Purpose Donation Box based on the Internet of Things [3]	Use microcontroller.	Use coin acceptor, bill acceptor and IoT.	The cost is high because it uses high accuracy component like coin acceptor and bill acceptor.
4	Design and Implementation of Automatic Money Counting and Sorting System [4]	Use IR sensor to detect and count the money inserted and colour sensor to detect the value of money.	Each money note is divided into different section.	It is complicated and require a lot of space to create different section for every money notes.
5	Nominal of Money and Colour Detector for the Blind People [7]	Use color sensor to detect the money.	Use speaker to produce an output.	Speaker has high power consumption and low-quality speakers may produce distorted or unclear sound, affecting effectiveness of auditory feedback.

2.4 Summary

The literature review offers valuable insights for creating a " Development of an improved money box with counter and fingerprint lock using microcontroller." This project can utilize fingerprint scanning for secure access and advanced money detection and counting for efficient cash management.

Firstly, integrating a fingerprint lock system into the money box ensures that only authorized users can open it, thereby improving security. Using Arduino microcontrollers, as demonstrated in the SecureTouch locker and biometric door lock systems, can enable dependable fingerprint authentication. Users can register their fingerprints, and the system will allow access only if the scanned fingerprint matches the stored data, eliminating the issues of lost keys or forgotten passwords.

Secondly, incorporating money detection and counting features will simplify the process of handling donations or cash. By employing sensors and microcontrollers similar to those used in automatic money counting systems for temples, the money box can accurately detect and count money notes.

In summary, combining fingerprint authentication for secure access with automated money detection and counting will result in a secure and user-friendly money box. This project will leverage the effective technologies discussed, providing high security, accurate financial management, and improved user convenience.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The strategy that was taken to create the project and accomplish the goals is explained in this chapter. Extensive research was conducted on the selected hardware to determine its functionality and select the most appropriate models for the project. In this procedure, the effectiveness and sustainability of the system are confirmed, the hardware and software are assessed, and the accuracy and consistency of the sensors are verified. It is also crucial to ensure that the system is user-friendly, cost-effective, and designed for easy maintenance to cater to a wide range of users. The process flow section will provide a detailed explanation of the system workflow. Furthermore, the integration of the components was meticulously planned to ensure seamless operation and minimize potential errors. Specific design choices and configurations are discussed to illustrate how challenges were addressed during development. Lastly, this chapter emphasizes the importance of testing and iteration to achieve optimal system performance.

3.2 Methodology

This thesis presents an innovative analytical method for estimating the functionality of a microcontroller-based improved money box with a counter and fingerprint lock. Understanding the needs of the user is crucial to the creation of this system, which includes choosing an Arduino Uno R3 microcontroller, a solenoid lock, a colour sensor, and a fingerprint scanner, building and testing the circuit, combining these parts, and programming the system to detect money, count automatically, and authenticate fingerprints. The operation and compatibility of every piece of hardware are guaranteed by thorough investigation. In order to assure accuracy and dependability, the procedure entails gathering and processing all data pertaining to money detection and counting as well as testing, validating, and improving the system. This methodical approach guarantees the functionality and dependability of the money box in securely detecting and counting money, providing accurate total savings, and ensuring secure access.

3.2.1 Elaboration of system flow

The flow of data and the order of processes inside a system are shown graphically in a system flowchart. Its main purpose is to give a clear and comprehensive diagram that shows all the procedures, decision points, and information flow of a system. Using a system flowchart has the benefit of simplifying complicated processes, which makes them easier to comprehend, evaluate, and explain to others. It assists in locating inefficiencies, possible problems, and areas that require repair. All things considered, system flowcharts are quite helpful for creating, recording, debugging, and optimising systems.

3.2.1.1 Flowchart of the overall procedure

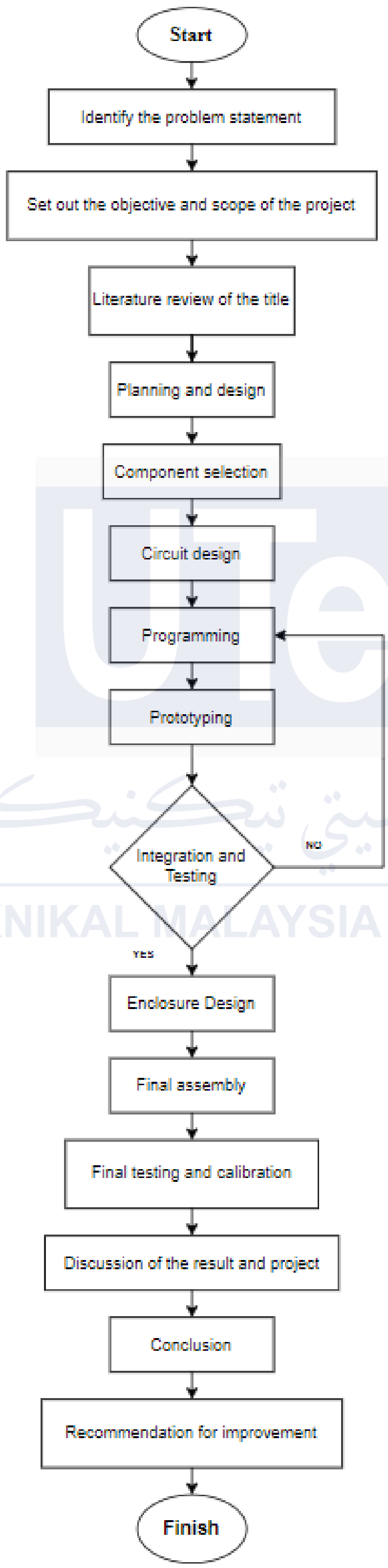


Figure 3.1 Flowchart of the overall procedure

The flowchart on Figure 3.1 describes a methodical process for creating an improved money box with a microprocessor, color sensor, and fingerprint lock. The first steps in the process involve determining the issue and establishing the goals and parameters of the project. After that, a comprehensive analysis of the literature is done in order to comprehend current solutions and obtain pertinent data. This provides information for the planning and design stage, which creates the overall system design and chooses the appropriate components.

Following the planning stage, circuit design and programming are the first steps in the project's actual implementation. For early testing, a prototype is put together, and any problems are fixed through iterative revisions. After the prototype works as intended, attention turns to creating the final container that will safely house all of the components.

The project draws to a conclusion with a results analysis that covers the obstacles and achievements. The project's results are summed up and suggestions for next improvements are given. This methodical methodology guarantees a comprehensive development process that covers all required steps from inception to completion.

3.2.1.2 Flowchart of the Fingerprint system

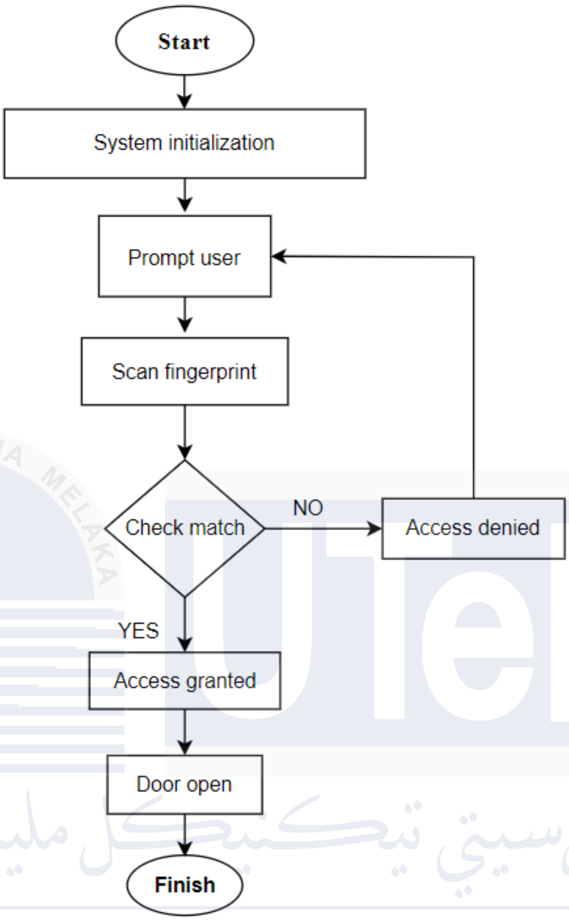


Figure 3.2 Flowchart of the fingerprint system

The flowchart in Figure 3.2 illustrates how a fingerprint authentication system works, beginning with system initialization and asking the user to scan their fingerprint. The fingerprint is scanned by the system, which then creates a digital template based on it. The system's database is then used to compare this template with previously saved templates. Access is refused and the user is asked to try again if there isn't a match. This guarantees that people who are not authorised can't access the system.

The user can access the secured money if a match is detected, at which point the system triggers a mechanism to unlock or open the door. After the procedure is finished, the system returns to its initial configuration, prepared for the subsequent authentication attempt.

This flowchart efficiently describes a safe technique for restricting access using fingerprint recognition, making sure that the system can only be used by those who are authorised.

3.2.1.3 Flowchart of the money detection system

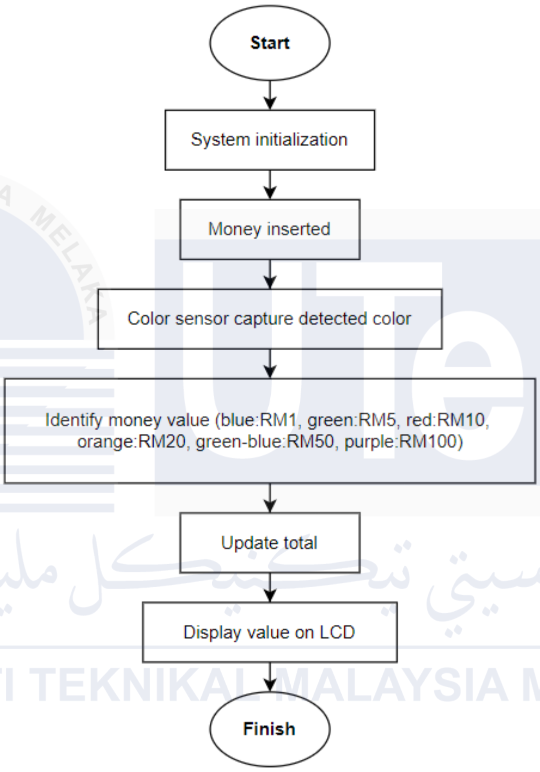


Figure 3.3 Flowchart of the money detection system

Figure 3.3 shows the flowchart of the money detection system. This flowchart shows how the system determines the value of inserted money notes using a colour sensor and shows the total amount on an LCD. During setup, the system sets up the colour sensor and LCD display and resets the total amount to zero. The colour sensor uses the colour of the money note that has been inserted to calculate its value based on predetermined colour mappings, blue for RM1, green for RM5, red for RM10, orange for RM20, green-blue for RM50, and purple for RM100.

The system changes the total amount of money collected after determining the value of the entered note. Next, the value of the most recent note that was inserted and the updated total are shown on the LCD panel. Until the user chooses to end the procedure, more money notes can be entered and their values added to the total. At that time, the system can be reset or turned off. Accuracy and user-friendliness are ensured by this flowchart, which offers a concise, step-by-step summary of the money identification and totaling procedure.

3.3 Requirement of equipment

3.3.1 Hardware equipment

The hardware setup for this project integrates essential components to ensure the efficient functioning of an improved money box with a counter and fingerprint lock. The TCS3200 color sensor is employed to detect the denomination of banknotes based on color analysis, ensuring accurate counting. An AS608 fingerprint sensor enhances security by providing biometric authentication for access to the money box. The Arduino Uno R3 microcontroller serves as the primary processing unit, managing sensor operations, peripherals, and executing control logic for the system. A 16x2 LCD display with an I2C module is used to present real-time information, such as what value of money being inserted and the total amount stored, offering a user-friendly interface. The 12V solenoid lock, controlled via a 2-channel relay module, provides secure and automated locking mechanisms. These components collectively enable reliable operation, combining advanced security, precise counting, and intuitive user interaction to create an effective and innovative money management solution.

Table 3.1 Component use in this project

No	Component	Description	Quantity	Price (Rm)
1	AS608 Fingerprint scanner 	The AS608 fingerprint scanner is a key component in the security system of the improved money box. It captures and stores unique fingerprint patterns, which are used to authenticate users. This scanner communicates with the Arduino Uno R3 using the UART protocol, a serial communication standard that ensures reliable data transmission between the scanner and the microcontroller. The AS608 can store multiple fingerprint templates, making it suitable for systems that require access by several authorized users. Its importance lies in its ability to provide a secure and convenient method of access, eliminating the need for traditional keys or PIN codes, which can be easily lost or stolen. By integrating biometric authentication, the project ensures that only registered users can access the contents of the money box, significantly enhancing its security.	1	49.99
2	12V Solenoid lock	The 12V solenoid lock serves as the primary physical security mechanism of the money box. It is an electromechanical device that	1	21.80

		operates by using the magnetic field generated by the solenoid to control a locking mechanism. The solenoid lock is activated or deactivated based on commands from the microcontroller, which triggers the lock through a relay module. Its robust design ensures that the money box remains securely locked when not in use, and its ability to respond to electronic signals allows it to integrate seamlessly with the fingerprint authentication system. This component is crucial for preventing unauthorized access, as it physically secures the box while allowing convenient unlocking for authorized users. Its automation also eliminates the need for manual keys, which can be inconvenient or pose a security risk.		
3	Jumper 	Jumper wires are indispensable in the hardware setup, providing temporary electrical connections between components. Available in male-to-male, male-to-female, and female-to-female types, these wires allow for flexible and modular connections. They are used to link the Arduino, sensors, display, relay module, and other components, forming the electrical	1	4.99

		pathways needed for the system to function. The importance of jumper wires lies in their ease of use during prototyping, as they allow for quick assembly and reconfiguration of circuits. Their role in establishing secure and reliable connections ensures the smooth operation of the project and facilitates troubleshooting and maintenance.		
4	TCS3200 Color sensor 	The TCS3200 color sensor plays a critical role in the money box by identifying and categorizing banknotes based on their color. This sensor operates by detecting the intensity of red, green, and blue light reflected from the surface of the banknotes. It converts this data into digital signals that are processed by the microcontroller. The sensor typically communicates with the Arduino using I2C or SPI protocols, which ensure fast and reliable data transfer. By accurately distinguishing between different denominations of currency, the TCS3200 enables the system to count and tally the total amount stored in the money box. This feature enhances the functionality of the project by automating the counting process and	1	24.99

		reducing the likelihood of errors, making it both efficient and user-friendly.		
5	Arduino UNO R3 	The Arduino Uno R3 is the central processing unit of the project, coordinating all hardware components and managing the overall functionality of the money box. Built around the ATmega328P microcontroller, it features 14 digital I/O pins, 6 analog inputs, and a 16 MHz quartz crystal, providing the flexibility and reliability needed for the project. The Arduino is responsible for processing data from the fingerprint scanner and color sensor, controlling the solenoid lock, and driving the LCD display. Its USB port facilitates programming and debugging, while its compatibility with a wide range of sensors and modules makes it ideal for prototyping. The Arduino Uno R3 is critical to the project as it acts as the "brain," executing commands, managing peripherals, and ensuring seamless integration of all components.	1	25.99
6	I2C LCD Display 16x2	The 16x2 LCD display with an I2C module provides a user-friendly interface for the money box system. This display is capable of showing alphanumeric characters and symbols	1	13.90

		across 16 columns and 2 rows, making it suitable for displaying real-time information such as the total amount stored, system status, or error messages. The I2C module simplifies the connection by reducing the number of required pins to just two (SDA and SCL), freeing up pins on the Arduino for other components. This component is important for ensuring transparency and usability, as it allows users to interact with the system and monitor its operation. The display's role in providing clear and immediate feedback enhances the user experience and makes the system more intuitive to operate.		
7	Battery 9V 	The 9V battery serves as a portable and reliable power source for the money box system. It is commonly used in low-current applications and provides a convenient solution for powering the Arduino and its connected components. The portability of the 9V battery ensures that the system can operate in locations where a fixed power supply is unavailable, making the money box versatile and practical. Its importance lies in its ability to provide consistent power, ensuring that the system	1	7.80

		remains operational even in the absence of an external power source. This feature enhances the reliability of the project and ensures uninterrupted functionality.		
8	2 channel relay 	The 2-channel relay module is a crucial component that enables the Arduino to control high-power devices, such as the 12V solenoid lock, by providing electrically isolated switching for external circuits. Each relay in the module can independently switch devices on or off, ensuring precise control. This module is essential for the project because the Arduino's output pins cannot directly supply the voltage or current needed to operate the solenoid lock. By acting as an intermediary, the relay module ensures the solenoid lock operates reliably while protecting the Arduino from potential damage caused by high-current loads. Its importance lies in its ability to integrate high-power devices into low-power systems, making it a key enabler of the project's functionality.	1	5.50
Total (Rm)				154.96

Table 3.1 shows the list of the components required for the project, along with their descriptions, quantities, and an estimated price. The functions of each component, such as the Fingerprint Scanner for authentication, the Solenoid Lock for secure access, and the Color Sensor for detecting RGB light, are clearly described in the table. Other components include the Arduino Uno R3 as the central microcontroller, a 16x2 I2C LCD Display for visual output, a 9V Battery for portable power, Jumper Wires for electrical connections, and a 2-Channel Relay Module for controlling high-power devices.

All the functionalities of the components, as stated in the table, are designed to work together seamlessly in the project. The Arduino Uno R3 serves as the system’s core, interfacing with the input sensors and output devices, while the relay module and battery enable reliable control and power management. The estimated total cost for all of the components is RM 154.96, making it an affordable and effective solution for building a money box project with features like secure access and color-based detection.

3.3.2 Software equipment

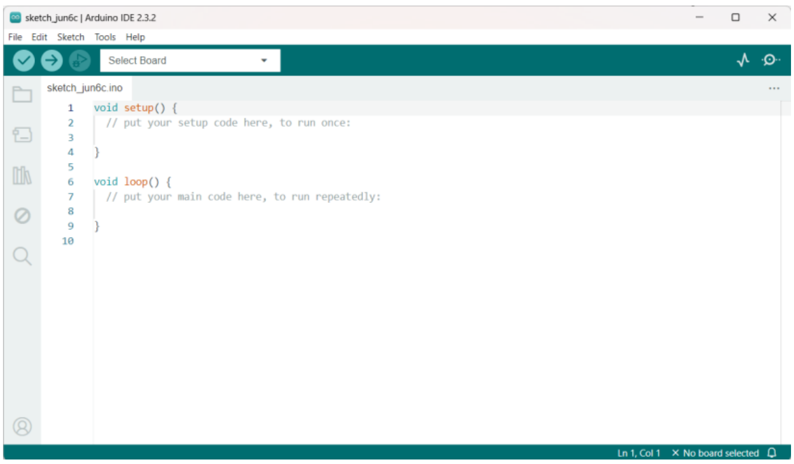


Figure 3.4 Arduino IDE Interface

The Arduino IDE is a software application that makes it easier to programme Arduino microcontroller boards. Enabling the uploading of all Arduino projects and streamlining code simplicity are its main goals. With features designed specifically for Arduino applications, the Arduino programming language is essentially a simplified version of C++. The IDE is well-known for its user-friendly interface, which makes it suitable for programmers of all experience levels to write, compile, and submit code.

When the Arduino IDE is launched, users are presented with an interface for writing code that is a text editor like shown in Figure 3.4. The setup() and loop() procedures are usually the main features of this interface. When the board is activated or reset, the setup() function sets pin modes, initializes variables, and configures settings. Subsequently, the loop() function allows users to define various behaviors for their Arduino projects, executing specified commands repetitively.

After writing the code, the Arduino IDE checks it carefully for errors and converts it into a machine-readable format that the Arduino board can use. It finds and indicates any coding errors quickly so they may be fixed. After compilation is complete, the code is uploaded to the Arduino board. Enabling smooth communication between the computer and the Arduino board, the IDE effectively manages the upload procedure.

In summary, the Arduino IDE proves highly practical for developing both simple and complex projects, boasting a straightforward user interface, robust code editing capabilities, seamless compilation and uploading functionalities, and additional features facilitating serial connections. Whether novice or seasoned, programmers find the Arduino IDE to be an invaluable tool, fostering the success of Arduino projects with its user-friendly and efficient environment.

3.4 Study design

3.4.1 System design

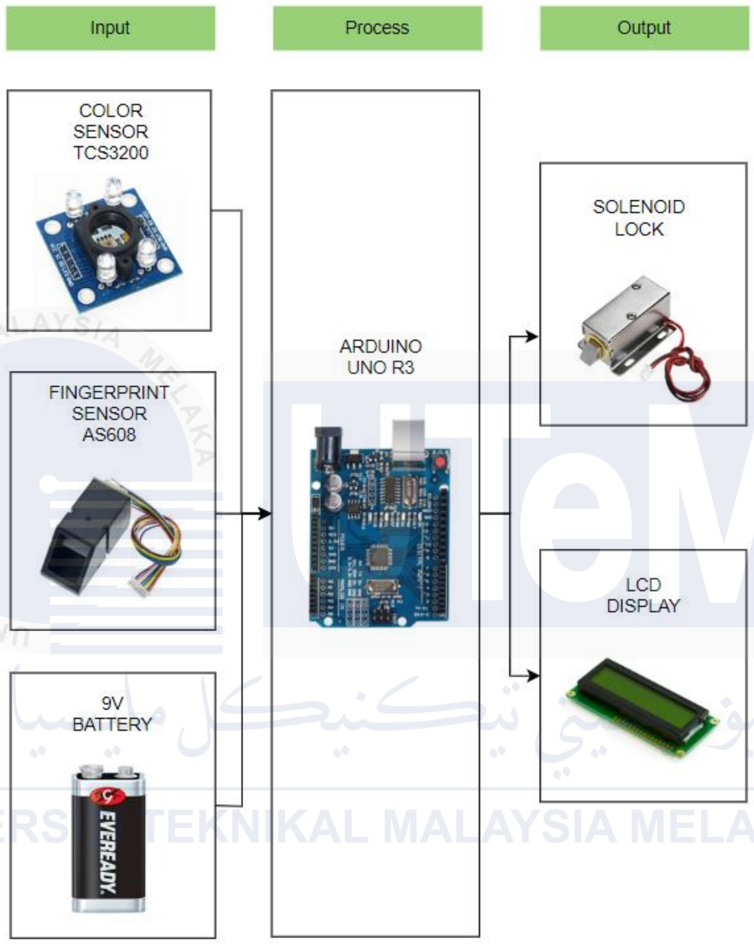


Figure 3.5 Block diagram of the system

Figure 3.5 represents the block diagram of the money box system. The system is divided into three sections which are input, processing, and output. The system has three input sensors which is a TCS3200 color sensor for detecting money note colors, an AS608 fingerprint scanner for biometric authentication and 9V battery as a power supply. It has two outputs, a 16x2 LCD display for user feedback and a solenoid lock for secure access control.

The Arduino UNO R3 processes the sensor inputs to display relevant information and control the lock based on the programmed conditions.

3.4.2 Prototype design

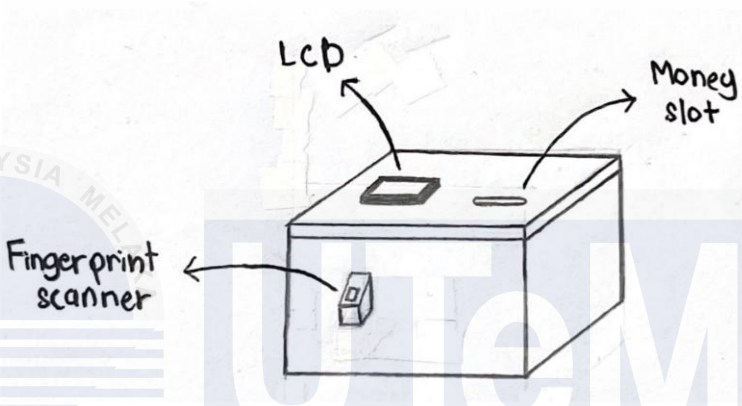


Figure 3.6 Prototype concept

The prototype illustrated in Figure 3.6 is a secure money box designed to differentiate money notes using a color sensor and restrict access through a fingerprint scanner. The box features a money slot on the top, where users insert money notes. The system identifies the denomination of each note by detecting its color. Access to the box is controlled via a fingerprint scanner located on the front side, which ensures that only authorized users can open it. An LCD display on the top surface provides a user interface, likely showing messages or instructions such as the status of the fingerprint authentication and the results of the money note identification. This setup ensures secure and automated management of money, combining biometric authentication with advanced sensor technology.

3.4.3 Circuit design

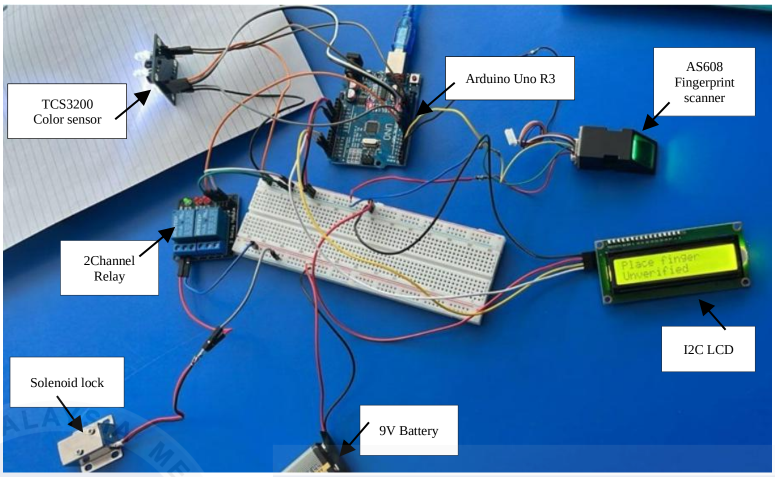


Figure 3.7 Circuit of the system.

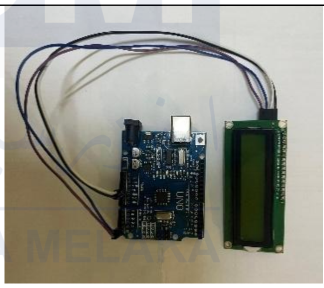
The Figure 3.7 illustrates the hardware implementation of a money box project utilizing an Arduino Uno R3 and several components connected through a breadboard. The system showcases the integration of inputs and outputs to enable functionalities like biometric authentication and secure locking.

The Arduino UNO R3 serves as the central controller, managing sensor inputs and controlling outputs. It is connected to the breadboard for power distribution and signal management. The Fingerprint Scanner is interfaced with the Arduino through UART communication, allowing it to verify fingerprints and send results to the Arduino. Additionally, a Color Sensor communicates with the Arduino via I2C or SPI to detect object colors. A 16x2 I2C LCD Display is also connected to the Arduino, providing visual output such as messages like "Place Finger" and "Unverified" during the fingerprint verification process, and it communicates with the Arduino using the I2C protocol via SDA and SCL pins.

For locking functionality, the Solenoid Lock is wired to a relay module, which controls the lock's operation. The relay receives low-power signals from the Arduino and powers the solenoid lock to lock or unlock it. The Relay Module itself is connected to both the Arduino and the solenoid lock, acting as a switch to control the high-power solenoid based on low-power signals. Power is supplied by a 9V battery, with the breadboard distributing the power to the Arduino, relay module, solenoid lock, and sensors.

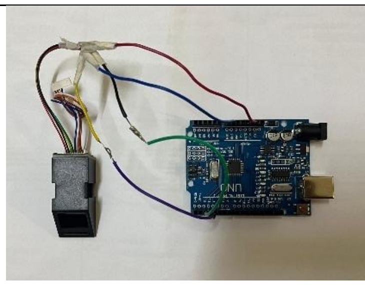
3.4.3.1 Circuit connection

Table 3.2 Connection between LCD and Arduino

I2C LCD	**Arduino Uno R3**	**Picture**
GND	GND	
VCC	VCC	
SDA	A4	
SCL	A5	

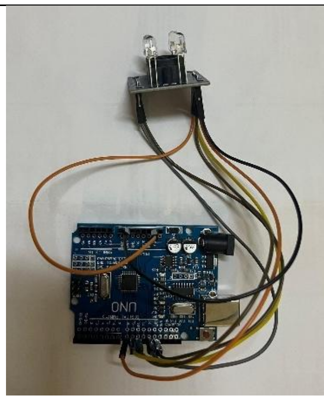
The I2C LCD is connected to the Arduino Uno R3 using four wires as shown in Table 3.2. The GND of the LCD is connected to the GND of the Arduino for a common ground. The VCC of the LCD is connected to the VCC of the Arduino to supply power. The SDA pin of the LCD is connected to pin A4 of the Arduino, which is used for data communication. The SCL pin of the LCD is connected to pin A5 of the Arduino, which is used for clock signals in the I2C communication.

Table 3.3 Connection between fingerprint and Arduino

Fingerprint sensor AS608	**Arduino Uno R3**	**Picture**
GND	GND	
RX	Pin 3	
TX	Pin 2	
VCC	VCC	

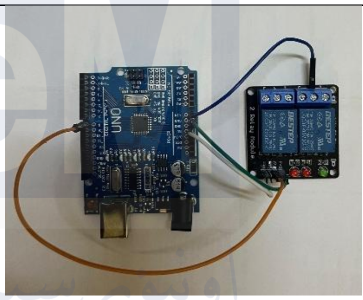
The fingerprint sensor is connected to the Arduino using three wires as described in Table 3.3. The GND of the sensor is connected to the GND of the Arduino for ground reference. The RX pin of the sensor, which receives data, is connected to Pin 3 of the Arduino. The TX pin of the sensor, which transmits data, is connected to Pin 2 of the Arduino. Finally, the VCC of the fingerprint sensor is connected to the VCC of the Arduino to provide power.

Table 3.4 Connection between TCS3200 and Arduino

Color sensor TCS3200	**Arduino Uno R3**	**Picture**
GND	GND	
S0	Pin 12	
S1	Pin 13	
S2	Pin 10	
S3	Pin 9	
OUT	Pin 8	
VCC	VCC	

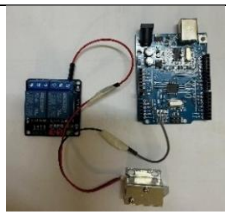
The color sensor is connected to the Arduino using six pins, as shown in Table 3.4. The GND of the sensor is connected to the GND of the Arduino. The sensor has four control pins: S0, S1, S2, and S3, which are connected to Pin 12, Pin 13, Pin 10, and Pin 9 on the Arduino, respectively. The OUT pin of the color sensor is connected to Pin 8 on the Arduino for data output. The VCC pin of the color sensor is connected to the VCC of the Arduino for power.

Table 3.5 Connection between 2 Channel Relay and Arduino

2 Channel Relay	**Arduino Uno R3**	**Picture**
DC+	VCC	
DC-	GND	
IN2	Pin 8	
COM2	GND	

The 2-channel relay is connected to the Arduino with four pins as detailed in Table 3.5. The DC+ pin of the relay is connected to the VCC pin of the Arduino to supply power to the relay. The DC- pin of the relay is connected to the GND of the Arduino for the common ground. The IN2 pin of the relay is connected to Pin 8 of the Arduino to control the second relay channel. The COM2 pin of the relay is connected to GND, which serves as the common ground for the second relay channel.

Table 3.6 Connection between Solenoid Lock, 2 Channel Relay and Arduino

Solenoid Lock	**2 Channel Relay**	**Arduino Uno R3**	**Picture**
Positive	N02		
Negetive		GND	

The solenoid lock is connected to the 2-channel relay and the Arduino for locking and unlocking functionality as shown in Table 3.6. The Positive terminal of the solenoid lock is connected to NO2 (Normally Open terminal) of the relay, which is controlled by the Arduino. The Negative terminal of the solenoid lock is connected to the GND pin of the Arduino. This setup allows the relay to control the solenoid lock, locking or unlocking it based on signals from the Arduino.

3.5 Experiment Testing

3.5.1 Color Detection Testing

Color detection testing is conducted to evaluate the accuracy and reliability of a sensor in identifying specific colours under predefined conditions. The process involves exposing the sensor to multiple attempts to detect different money note colours which are Blue for RM1, Green for RM5, Red for RM10, Orange for RM20, Green-blue for RM50, and Purple for RM100. For each attempt, the sensor's response either "Detect" or "Not Detect" is recorded in a table.

Table 3.7 shown the color detection testing for RM1, RM5 and RM10. When the sensor successfully detects a colour, the corresponding value is displayed on an LCD screen; for instance, if the sensor detects Blue, the LCD shows RM1, Green displays RM5, and Red shows RM10. This immediate feedback ensures accurate recognition of the currency note and real-time verification of the sensor's performance. Additionally, the auto-counting feature is tested, where the correct amount of money is added to a total displayed on the second row of the LCD. If the sensor detects a blue note (RM1), the total increases by RM1. This helps confirm the sensor detects the right colour and adds the correct amount to the total, ensuring the system can keep track of the money accurately throughout the test.

Table 3.7 Color detection testing

NO	DETAILS	PICTURE
1	The LCD display RM1 on the first row and updated the total value saved on the second when money note RM1 is inserted.	
2	The LCD display RM5 on the first row and updated the total value saved on the second when money note RM5 is inserted.	

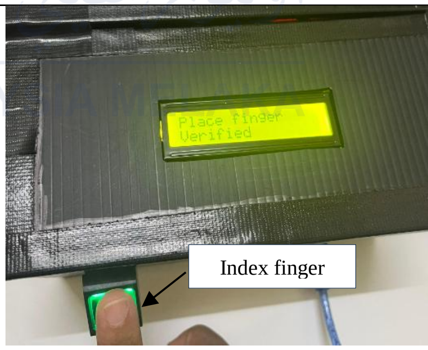
3	The LCD display RM10 on the first row and updated the total value saved on the second when money note RM10 is inserted.	

3.5.2 Fingerprint Detection Testing

To evaluate the precision and dependability of fingerprint scanners used for identification and authentication, fingerprint detection testing is carried out. The primary objective of this testing is to evaluate the accuracy of the fingerprint scanner in detecting the thumb and index finger under a variety of real-world conditions, such as variations in finger placement, skin conditions, and environmental factors. Through testing, we may find any obstacles and constraints to reaching high accuracy rates, guaranteeing the system's performance in practical applications.

Table 3.8 illustrate the fingerprint detection result . When the fingerprint scanner recognizes the fingerprint, the LCD will display "Verified" and this will be counted as "DETECT". If the fingerprint is not recognized, the LCD will display "Unverified" and this will be counted as "NOT DETECT". All the results observed are recorded in a table for detailed analysis and comparison.

Table 3.8 Fingerprint detection testing

NO	DETAILS	PICTURE
1	The LCD displays “Verified” when the user scans their thumb while the thumb is clean and matches a registered fingerprint in the scanner. This indicates successful authentication and grants access to the system.	
2	The LCD displays “Unverified” when the user scans their thumb, but the thumb is wet or dirty, causing the fingerprint scanner to fail in identifying the fingerprint, even if it is registered.	
3	The LCD displays “Verified” when the user scans their index finger, and the finger is in a good position, allowing the fingerprint scanner to successfully identify the fingerprint.	
4	The LCD displays “Unverified” when the user scans their index finger, but the finger is positioned slightly tilted to the left, causing the fingerprint scanner to fail in identifying the fingerprint, even if it is registered.	

3.6 Summary

This chapter outlines the methodology employed in the Development of an Improved Money Box with Counter and Fingerprint Lock Using Microcontroller project, emphasizing the systematic approach taken to ensure its successful completion. The methodology serves as a roadmap, detailing the sequence of methods followed to achieve the project objectives effectively. A comprehensive list of hardware components used in the project is provided in this chapter, enabling easy identification of their functions and roles within the system. This systematic documentation not only clarifies the purpose of each component but also ensures a clear understanding of their integration into the project. Additionally, the analysis and identification of all critical components and control elements are key aspects of this stage, ensuring that the design and implementation processes are accurate and efficient. Ultimately, this chapter establishes a structured foundation for understanding the project's development process, facilitating replication, troubleshooting, and potential future enhancements.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

The results and discussions on creating a microcontroller-based improved money box with a counter and fingerprint lock are presented in this chapter. The system's performance is the focus of the review, which highlights its accuracy, efficiency, and usefulness.

A prototype is a working model or version of a product that is intended to test and validate an idea or procedure. This technique is essential for evaluating and improving new concepts in a variety of industries, such as software development, electronics, and design. During this stage, input from users and system analysts greatly improves the accuracy and general functioning of the product.

In the field of electronics, prototyping involves constructing a physical circuit based on a theoretical design to test its functionality and address any potential issues. Techniques such as wire wrapping or breadboarding are commonly used to create these prototypes, ensuring they are electrically consistent with the final design, despite possible physical differences. Platforms such as Arduino simplify the programming and interfacing with microcontrollers, enabling developers to efficiently bring their ideas to fruition.

4.2 Results and Analysis

4.2.1 Hardware

4.2.1.1 Prototype

Figure 4.1 Prototype of the money box

Figure 4.1 shows the final prototype of the money box system, designed for secure and user-friendly operation. The prototype features a money note slot for deposits and an integrated digital display to show real-time updates of the total savings. The system is powered by an Arduino R3, which manages key functions such as tracking deposits, controlling the fingerprint lock for secure access, and updating the digital display. Powered by a 9V battery, the money box is portable and energy-efficient. Its compact and durable design makes it an ideal solution for personal savings management, combining advanced technology with convenience and security.

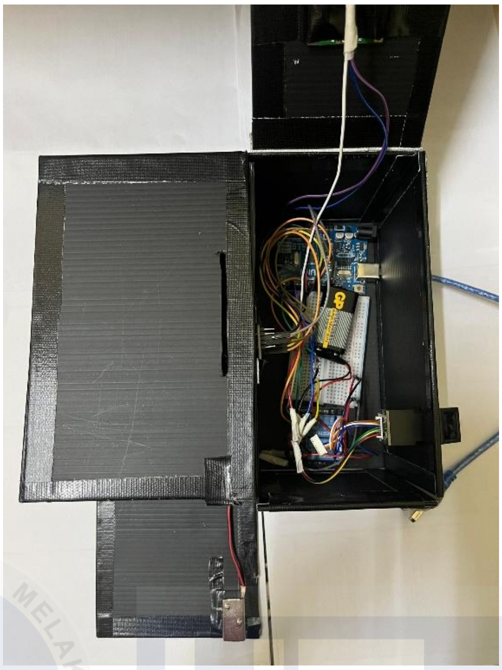


Figure 4.2 Right side compartment of the money box

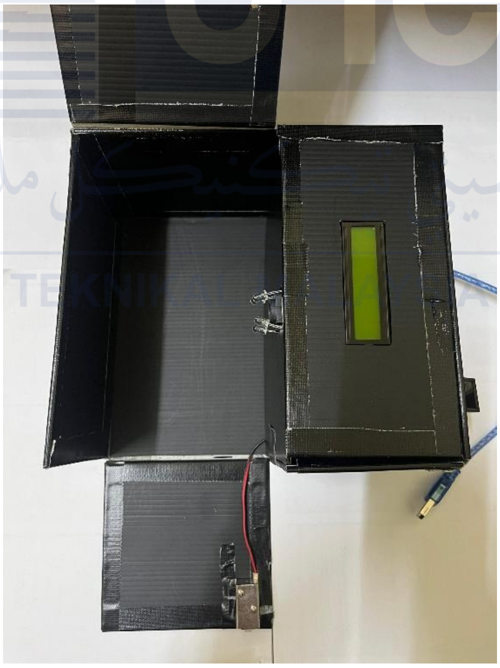


Figure 4.3 Left side compartment of the money box

Figure 4.2 and Figure 4.3 illustrate the two-compartment design of the money box. The right-side compartment securely encloses all the electronic components, ensuring they are protected from tampering or accidental damage. The left-side compartment is specifically designed for storing money and is only accessible when the user's fingerprint is successfully verified. This strategic separation between the components and the storage area enhances the system's security and durability by safeguarding the internal mechanisms while providing secure and convenient access to the money for authorized users.

4.2.1.2 Money detection by using TCS3200

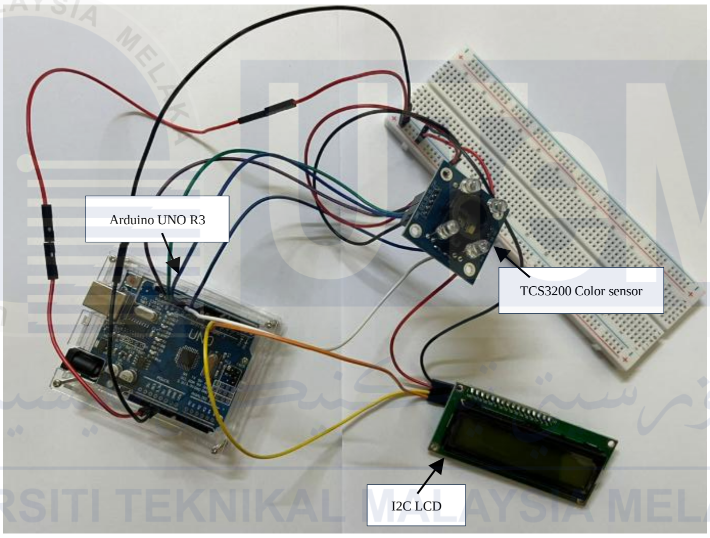


Figure 4.4 TCS3200 circuit connection use to detect color

Figure 4.4 shows the circuit setup for the color detection system. The LCD and TCS3200 color sensor are connected to the Arduino to detect colors and display the money value and total savings. The LCD's VCC and GND pins are connected to the Arduino's 5V and GND for power, while its RS, E, and data pins (D4-D7) are connected to digital pins D12, D11, D5-D2 on the Arduino. The TCS3200 sensor's VCC and GND pins are also connected to the Arduino's 5V and GND. Its S0 and S1 pins, for frequency scaling, are connected to digital pins D8 and D9, and its S2 and S3 pins, for color detection, are connected to D6 and D7. The OUT pin, which sends color signals, is linked to digital pin D10.

When a user inserts a money note into the box, the TCS3200 sensor detects the reflected light using a photodiode and converts it into a square wave signal via its current-to-frequency converter. The Arduino reads this signal, identifies the color based on the frequency, and determines the banknote's predefined value. As specified by Bank Negara Malaysia, blue represents RM1, green RM5, red RM10, orange RM20, green-blue RM50, and purple RM100, as shown in Figure 4.2. The detected value and total savings are then updated and displayed on the LCD, providing real-time feedback for accurate and user-friendly tracking of both individual note values and cumulative savings.

Denomination	Substrate	Denomination	Predominant Colour
RM100	Paper	150mm X 69mm	Purple
RM50	Paper	145mm X 69mm	Green-blue
RM20	Paper	145mm X 65mm	Orange
RM10	Paper	140mm X 65mm	Red
RM5	Polymer	135mm X 65mm	Green
RM1	Polymer	120mm X 65mm	Blue

Figure 4.5 Malaysian Currency Banknote Specifications [21]

The Table 4.5 summarizes the performance of the color detection system across 10 attempts for six banknote colors. The sensor consistently detects Blue (RM1) and Red (RM10) with high accuracy, missing detection only once each. Green (RM5) shows moderate reliability, failing to detect on two attempts. However, the system fails entirely to detect Orange (RM20), Green-blue (RM50), and Purple (RM100) in all 10 attempts, suggesting significant limitations. This inconsistency indicates that factors such as lighting conditions, sensor calibration, or the reflective properties of certain colors may affect the sensor's performance and should be investigated further.

Table 4.1 Color Detection Attempt Results

COLOR	**ATTEMPT**	**OUTPUT (Detect / Not Detect)**
Blue : RM1 	1	Detect
	2	Detect
	3	Detect
	4	Detect
	5	Detect
	6	Detect
	7	Detect
	8	Not Detect
	9	Detect
	10	Detect
Green : RM5 	1	Detect
	2	Detect
	3	Detect
	4	Detect
	5	Detect
	6	Detect
	7	Not Detect

	8	Detect
	9	Not Detect
	10	Detect
Red : RM10 	1	Detect
	2	Detect
	3	Detect
	4	Detect
	5	Detect
	6	Detect
	7	Detect
	8	Detect
	9	Detect
	10	Detect
Orange : RM20 	1	Not Detect
	2	Not Detect
	3	Not Detect
	4	Not Detect
	5	Not Detect
	6	Not Detect
	7	Not Detect
	8	Not Detect
	9	Not Detect
	10	Not Detect
Green-blue : RM50	1	Not Detect

	2	Not Detect
	3	Not Detect
	4	Not Detect
	5	Not Detect
	6	Not Detect
	7	Not Detect
	8	Not Detect
	9	Not Detect
	10	Not Detect
Purple : RM100 	1	Not Detect
	2	Not Detect
	3	Not Detect
	4	Not Detect
	5	Not Detect
	6	Not Detect
	7	Not Detect
	8	Not Detect
	9	Not Detect
	10	Not Detect

Visualizing this data in a chart makes it faster and clearer to understand compared to raw numerical tables. It helps to quickly compare the performance of the three colours across multiple attempts, identify patterns, and analyze trends, such as which colour is the most reliable and when failures occur.

The stacked bar chart illustrates in Figure 4.6 shows the detection results for six banknote colors: Blue (RM1), Green (RM5), Red (RM10), Orange (RM20), Green-blue (RM50), and Purple (RM100) over 10 attempts. Each bar represents the total number of successful and failed detections for each banknote color. The green bars in the chart represent successful detections, while the red bars indicate failed detections. Blue (RM1) demonstrates high reliability, with successful detection in 9 out of 10 attempts, missing only in attempt 8. Green (RM5) shows moderate reliability, with successful detection in 8 attempts but failing in attempts 7 and 9. Red (RM10) exhibits perfect detection performance, with all 10 attempts successful. In contrast, Orange (RM20), Green-blue (RM50), and Purple (RM100) consistently fail to be detected, indicating significant limitations in the sensor's ability to identify these colors.

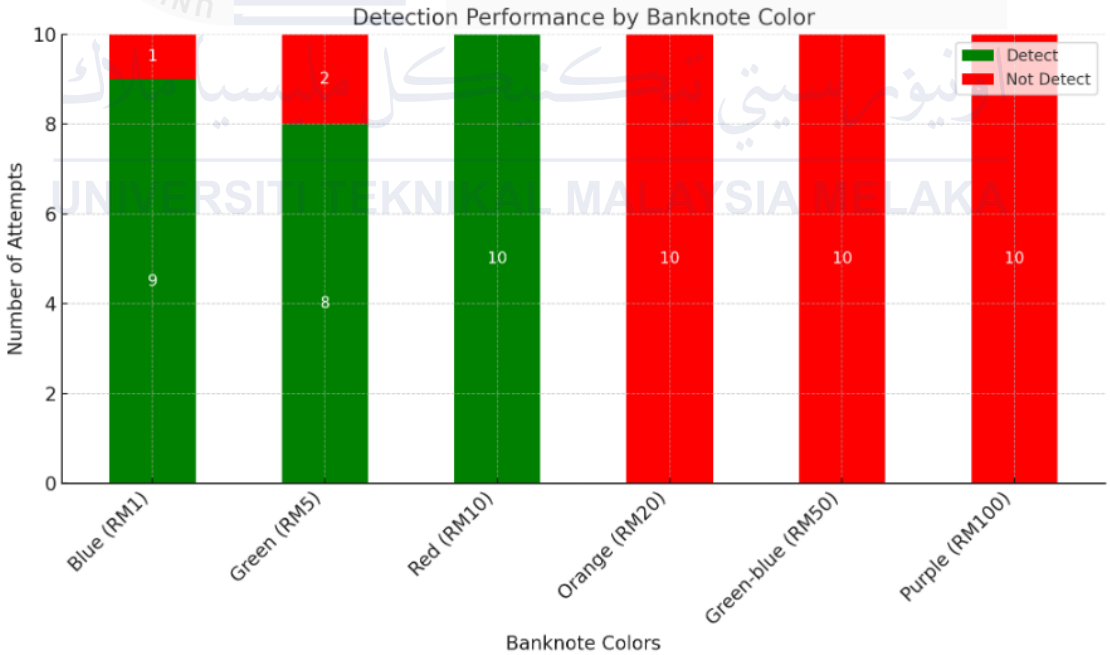


Figure 4.6 Stacked Bar Chart of Detection Performance Results

Calculation: Percentage of Successful Detections

The formula to calculate the percentage of successful detection is:

Percentage of Successful Detection = $\left(\frac{Number\ of\ "Detect"}{Total\ Number\ of\ Attempt}\right)\ X\ 100$

Blue : RM1

- Total attempts: 10
- Successful Detection (Detect): 9
- Percentage of Successful Detections:

$$\left(\frac{9}{10}\right)\ X\ 100 = 90\%$$

Green : RM5

- Total attempts: 10
- Successful Detection (Detect): 8
- Percentage of Successful Detections:

$$\left(\frac{8}{10}\right)\ X\ 100 = 80\%$$

Red : RM10

- Total attempts: 10
- Successful Detection (Detect): 10
- Percentage of Successful Detections:

$$\left(\frac{10}{10}\right)\ X\ 100 = 100\%$$

Orange : RM20

- Total attempts: 10
- Successful Detection (Detect): 0

- Percentage of Successful Detections:

$$\left(\frac{0}{10}\right) X\ 100 = 0\%$$

Green-blue : RM50

- Total attempts: 10
- Successful Detection (Detect): 0
- Percentage of Successful Detections:

$$\left(\frac{0}{10}\right) X\ 100 = 0\%$$

Purple : RM100

- Total attempts: 10
- Successful Detection (Detect): 0
- Percentage of Successful Detections:

$$\left(\frac{0}{10}\right) X\ 100 = 0\%$$

The number of times the sensor properly detected the color over a series of attempts for each type of currency note is used to determine successful detection. Nine out of ten attempts were successfully identified by the sensor for the blue note (RM1), yielding a 90% success rate. For the green note (RM5), the sensor achieved an 80% success rate, detecting 8 out of 10 tries. The red note (RM10) achieved a perfect 100% success rate, successfully detecting all 10 attempts. In contrast, the orange note (RM20), green-blue note (RM50), and purple note (RM100) were completely undetected in all 10 attempts, resulting in a 0% success rate for these colors.

These results highlight a direct relationship between the percentage of successful detections and the accuracy of the sensor in identifying the currency note. The higher the success percentage, the greater the accuracy of the sensor. The red note's flawless success rate indicates that its characteristics, such as color intensity and material properties, align perfectly with the sensor's optimal detection range. The blue note's high success rate suggests good compatibility with the sensor, while the green note's slightly lower success rate may indicate some properties that are less compatible with the sensor's detection parameters, resulting in occasional missed detections. Conversely, the complete failure to detect orange, green-blue, and purple notes suggests that their colors or material properties fall entirely outside the sensor's effective detection range.

Colour Detection Analysis

Based on the collected data, there are two possible reasons why the color sensor cannot detect every money notes with 100% accuracy:

1) Material properties

Material properties play a significant role in the detection of currency notes by sensors. In the case of Malaysian money notes, two primary materials are used: polymer for RM1 (blue) and RM5 (green) notes, and paper for RM10 (red), RM20 (orange), RM50 (green-blue), and RM100 (purple) notes. Each material has unique characteristics that influence how the sensor detects the notes.

- Polymer Notes (RM1, RM5)

These notes are made from synthetic materials like biaxially oriented polypropylene (BOPP), which is known for its durability, water resistance, and smooth surface. The smooth surface of polymer notes creates a reflective property, which can either enhance or reduce detection accuracy depending on the lighting and calibration of the sensor. When light reflects off the note evenly, the sensor can detect its features more accurately. However, if the light reflection is uneven or too intense, it may cause noise or false readings, which can reduce the detection accuracy. The shiny finish of polymer notes, such as RM1 (blue) and RM5 (green), can scatter light, making detection more difficult in certain areas, especially where colours transition or patterns overlap. Sensors may struggle to handle these variations if their sensitivity is not properly tuned.

- Paper Notes (RM10, RM20, RM50, RM100)

Paper notes, such as RM10 (red), RM20 (orange), RM50 (green-blue), and RM100 (purple), are made from a blend of cotton and linen, which provides flexibility and durability. The rough texture of paper notes scatters light in multiple directions, reducing reflectivity and making the surface appear matte. While the matte finish of paper notes enhances light absorption, the rough texture can obscure features or create inconsistencies in light absorption if the note is worn, folded, or dirty. Paper is more porous than polymer, meaning it absorbs ink differently, and over time, this can cause fading or wear of printed features, reducing the sensor's ability to detect those areas. However, paper notes tend to be less prone to light-induced detection errors, provided the notes are in good condition.

The material properties of each note type, polymer versus paper affect how sensors interact with them. Polymer notes, with their reflective surfaces and bright colours, can be tricky for sensors if they are not calibrated to account for their properties. On the other hand, paper notes, though easier to detect initially due to their matte finish, degrade over time, impacting the sensor's ability to detect them accurately. As a summary, blue and green (polymer) and red (paper) notes can be detected easily by the sensor. However, notes with purple, orange, and green-blue colours are more challenging to detect. This may be influenced by factors other than the material, such as the complexity of these colours and their interaction with light.

2) Colour properties

Colour properties significantly impact the ability of sensors to accurately detect Malaysian money notes. Different colour schemes are used for each note, ranging from light and dark tones combined in a single note to vivid primary colours. Because sensors rely on light reflection, absorption, and contrast to differentiate between different sections of the note, these differences may affect detection rates.

- Primary Colours

The RM1 (blue), RM5 (green), and RM10 (red) notes use distinct primary colours, which are generally easier for sensors to identify due to their specific wavelengths. Blue, as found on the RM1 note, offers a strong and easily identifiable wavelength, making it effective for detection. Green, used on the RM5 note, may pose challenges if it appears in lighter or less vibrant shades, as this can reduce detection accuracy. Similarly, red, present on the RM10 note, is bold but may absorb more light in darker shades, decreasing its reflectivity and reliability in detection.

- Secondary Colours

Other Malaysian currency notes feature secondary and mixed colours that present unique detection challenges. The RM20 note is orange, a vibrant and warm tone that is generally easy to detect, but variations in intensity can affect its visibility to sensors. The RM50 note has a green-blue hue, which combines the properties of both green and blue, making it complex for sensors to differentiate if the balance of shades shifts. Lastly, the RM100 note is purple, a blend of red and blue wavelengths, which can be harder to detect as it depends on the dominance of either colour and the overall tone. Sensors must be finely tuned to identify these mixed and secondary colours accurately.

- Multi-Tonal Designs

Malaysian currency notes feature multi-tonal designs that incorporate gradients and detailed patterns to enhance security. However, these elements also introduce challenges for sensor detection. Lighter shades reflect more light, which can aid detection but may lead to overexposure and obscure finer details. Darker areas, on the other hand, absorb more light and may be harder for sensors to detect, especially in the absence of sufficient contrast. Gradients and intricate transitions between tones can further complicate detection by confusing sensors that are not finely calibrated.

- Brightness and Intensity of Colours

The brightness and intensity of colours on currency notes are critical for sensor accuracy. Bright, saturated colours are easier to detect as they consistently reflect light and stand out clearly. In contrast, faded or less vibrant colours, often found on older or heavily used notes, appear duller and are harder for sensors to identify. For example, a worn RM10 note with reduced colour intensity may be more challenging to detect compared to a fresh note.

The colour sensor works best with primary colours like blue, green, and red, as these are easy to detect. Secondary and tertiary colours like orange, green-blue, and purple can be more challenging to detect, as these colours tend to have more complex tonal characteristics and are influenced by factors such as fading or material reflectivity. Achieving high detection accuracy for Malaysian currency notes requires precise sensor calibration. Sensors must effectively distinguish between primary, secondary, and mixed colours, adapt to changes in colour intensity, and account for complex patterns. Proper calibration ensures that sensors can overcome the challenges posed by varying tones, reflectivity, and environmental conditions.

4.2.1.3 Fingerprint scanner to access the box

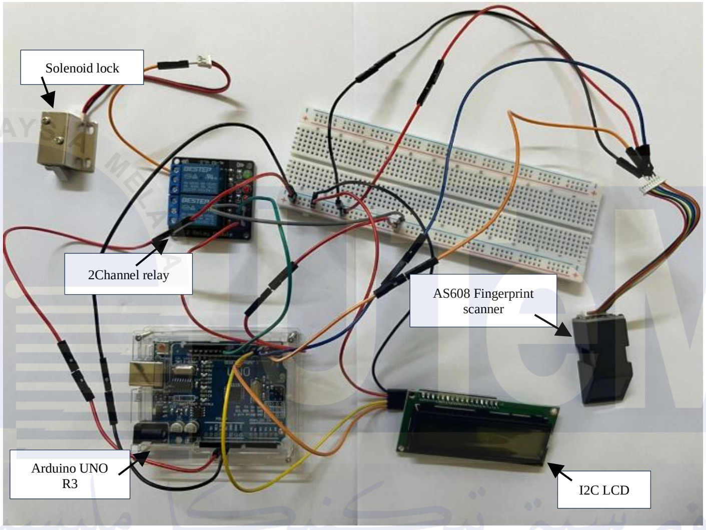


Figure 4.7 Hardware circuit of the fingerprint lock

Based on Figure 4.7, the components used are the fingerprint scanner AS608, Arduino UNO R3, solenoid lock, LCD, and a relay module. The fingerprint scanner AS608 is connected to the Arduino UNO via pins D2 (TX) and D3 (RX) for serial communication. The solenoid lock is powered through the relay module, which is controlled by pin D7 of the Arduino. The LCD is connected to the Arduino using pins D8 to D13 for data and control signals.

The expected result for the fingerprint scanner lock system is that it will reliably secure the contents by allowing access only to authorized users whose fingerprints are registered in the system. Upon scanning, the fingerprint scanner will send data to the Arduino for verification. If the fingerprint matches an authorized user, the Arduino will activate the relay module to unlock the solenoid lock and display "Verified" on the LCD. If the fingerprint does not match, the system will remain securely locked, and the LCD will display "Unverified".

Figure 4.8 Names of the fingers [22]

Figure 4.8 highlights the names of each finger which are, thumb, index finger, middle finger, ring finger and little finger. Human fingers are ideal for biometric identification due to their unique patterns of ridges and furrows, which differ for every individual. These patterns remain consistent over time, making fingerprints a reliable identification method. With modern technology, collecting and storing fingerprints is simple, making the thumb and index finger especially useful for biometric systems. If the thumb is unavailable, such as due to injury, the index finger is the best substitute. It has a clear fingerprint pattern and is easy to position, making it a practical alternative for fingerprinting tasks.

Table 4.2 Fingerprint Testing Attempt Results

TYPE OF FINGER	ATTEMPT	OUTPUT (DETECT/NOT DETECT)
THUMB	1	DETECT
	2	DETECT
	3	DETECT
	4	DETECT
	5	DETECT
	6	DETECT
	7	DETECT
	8	NOT DETECT
	9	DETECT
	10	DETECT
INDEX FINGER	1	DETECT
	2	DETECT
	3	NOT DETECT
	4	NOT DETECT
	5	DETECT
	6	DETECT
	7	DETECT
	8	DETECT
	9	NOT DETECT
	10	DETECT

The fingerprint scanner's performance in identifying the thumb and index finger fingerprints over 10 tries each is displayed in the result Table 4.2. In the case of the thumb, the fingerprint was successfully identified by the scanner nine times out of ten, with only one failure. The identification rate was lower for the index finger, which was identified in seven out of ten tries. This implies that the index finger was harder for the fingerprint scanner to detect than the thumb. In general, these findings indicate that fingerprints on the thumb were more successfully detected than those on the index finger.

Calculation: Percentage of Successful Detections

The formula to calculate the percentage of successful detection is:

Percentage of Successful Detection = $\left(\frac{Number\ of\ "Detect"}{Total\ Number\ of\ Attempt}\right)\ X\ 100$

Thumb

- Total Detect (Thumb + Index): 16
- Successful Detection (Detect): 9
- Percentage of Successful Detections:

$$\left(\frac{9}{16}\right)\ X\ 100 = 56.25\% \ \approx 56.2\%$$

Index finger

- Total Detect (Thumb + Index): 16
- Successful Detection (Detect): 7
- Percentage of Successful Detections:

$$\left(\frac{7}{16}\right)\ X\ 100 = 43.75\% \ \approx 43.8\%$$

Based on the calculations shown above, it is evident that the thumb is more precise and accurate compared to the index finger in terms of successful detections. With a success rate of 56.2%, the thumb demonstrates higher reliability and consistency in detection performance, while the index finger, with a 43.8% success rate, shows comparatively lower accuracy.

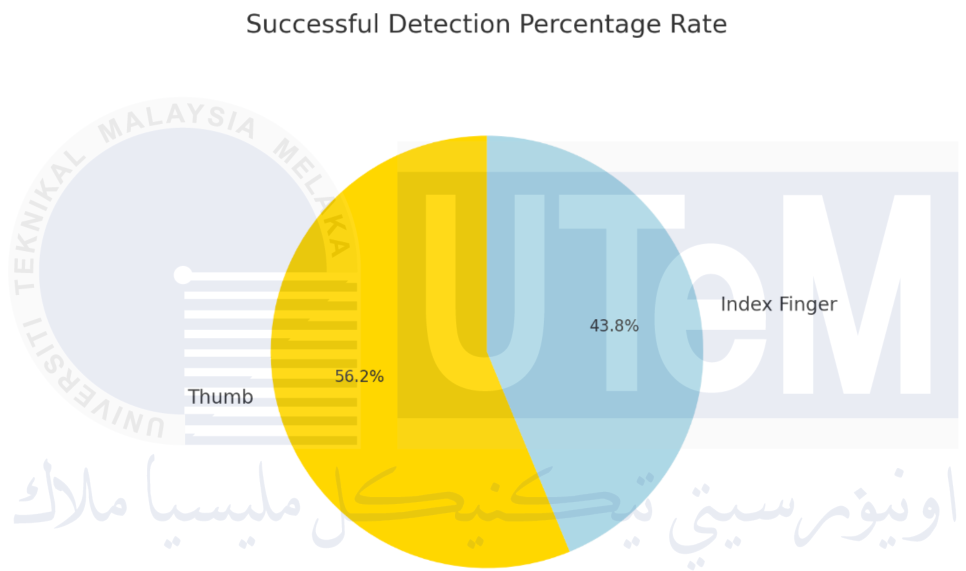


Figure 4.9 Thumb and Index finger Detection Performance

The pie chart on Figure 4.9 demonstrates the successful detection percentage rates for fingerprint recognition using the thumb and index finger. The thumb accounts for 56.2% of the total successful detection rate, with a high success rate of 90% across 10 attempts, indicating its superior reliability in biometric systems when compared to the index finger. In contrast, the index finger represents 43.8% of the total successful detection rate, achieving a success rate of 70% out of 10 attempts. Overall, the chart highlights the thumb's superior performance in detecting fingerprints relative to the index finger.

Fingerprint Detection Analysis

Based on the tests conducted and the calculations made, the success detection rate for the thumb and index finger may not achieve 100% accuracy due to several key factors, including:

1) Finger Shape and Size

   Every finger has certain traits that influence the quality of the fingerprint that is taken. The thumb usually has more noticeable and uniformly spaced ridge patterns since it is wider and has a larger surface area. The scan's precision is improved because of the larger surface area, which makes it possible to detect more tiny points. Furthermore, the thumb typically has more stable ridge patterns, which reduces its vulnerability to alterations brought on by repeated use. The index finger, on the other hand, is often smaller and may have less clear ridge patterns, which makes it more challenging to record tiny details. The success rate of fingerprint matching may be lowered because the index finger's reduced size results in fewer identifying points. Additionally, the index finger may be worn down from continuous use, which can add irregularities and gently change its ridge patterns.

2) Pressure

   The quality of the image that is taken is greatly impacted by the pressure used when placing the finger into the scanner. A fingerprint that is faint or incomplete due to inadequate pressure may miss important characteristics like ridge bifurcations and tiny details. On the other hand, too much pressure could cause the ridges to become stretched, compressed, or even overlapped, which would result in inaccurate readings. To guarantee that the fingerprint is captured with all of its important characteristics intact, the right amount of pressure must be applied consistently. The reliability of the identification method can be increased by variations in the pressure used throughout various scans, which may result in inconsistent fingerprint images.

3) Skin Condition

The clarity of the fingerprint is greatly influenced by the condition of the skin. Dry skin can cause the ridge patterns to appear cracked, which makes it harder for the scanner to pick up on the fingerprint's fine features. For example, ridge bifurcations, the division of a ridge into two may become weak or nonexistent due to dry skin, which could lead to an imprecise or incomplete reading. Similar to this, skin injuries like cuts, abrasions, or calluses can alter the fingerprint's normal pattern, making some of the ridges unidentifiable. For instance, calluses can develop into thick skin patches that change the fingerprint pattern and may hide significant characteristics. Additionally, sweat or oils on the skin can cause the fingerprint to smudge, blurring the ridges and warping the overall pattern, which lowers the scan's accuracy.

4) Rotation and Orientation

The accuracy of the fingerprint scan is greatly influenced by the direction of the finger when it is placed on the scanner. Parts of the ridge pattern may get lost or distorted if the finger is not flat or is turned at the wrong angle. An incomplete scan might result from even minor misalignments that cover crucial fingerprint features. The usefulness of the identification procedure may be reduced if the scanner is unable to catch specific features. When using the index finger, which has less pronounced ridge patterns, this becomes more challenging. If the finger is positioned incorrectly, the scan may not have enough information for accurate identification.

In conclusion, plenty of factors affect the accuracy of fingerprint recognition, such as the state of the skin, the pressure used while scanning, and the natural diversity of the fingers. Skin disorders like dryness, wounds, or oil buildup may affect the fingerprint image quality. Errors are also caused by inconsistent pressure and incorrect finger alignment when scanning. Furthermore, the accuracy of the scans varies due to the inherent disparities in ridge patterns between fingers, especially the thumb and index finger. All these elements work together to make it difficult to identify fingerprints with 100% accuracy.

4.2.2 Software

4.2.2.1 Arduino coding for Color sensor

The code in Appendix B detects colours and displays the results on an LCD while tracking a total score. It uses a colour sensor to identify blue, green, red, orange, green-blue, purple, or white. Two libraries are essential: Wire.h for communication and LiquidCrystal_I2C.h to control the LCD. The setup() function initializes the LCD, configures the sensor pins, and sets the sensor to measure colours with 100% accuracy. At the start, the program briefly shows "Colour Sensor" on the LCD before clearing it.

The main functionality is in the loop() function, which repeatedly measures colour intensities using the color() function. Based on the readings, the program determines the detected colour and updates the score. White is detected if all three colours are similar, and no score is added. The program adds RM1 for blue, RM5 for green, RM10 for red, RM20 for orange, RM50 for green-blue, and RM100 for purple. The detected colour is shown on the first row of the LCD, while the total score appears on the second row. Debugging information, including colour values, is printed to the Serial Monitor.

The color() function measures the intensity of blue, green, red, orange, green-blue, or purple by controlling the sensor's s2 and s3 pins to select the appropriate filter. It uses the pulseIn() function to measure the pulse duration, indicating the intensity of the selected colour. These values are then used to classify the detected colour.

4.2.2.2 Arduino coding for Fingerprint scanner

To Store Fingerprint:

Based on Appendix C, the LiquidCrystal_I2C library enable the system to controls a 16x2 LCD to display prompts, and the Adafruit_Fingerprint library allows communication with the fingerprint sensor via a software serial connection on pins 2 and 3. During setup, the code initialises the LCD, verifies the fingerprint sensor using 'finger.verifyPassword()', and retrieves sensor parameters. The user is guided through the process with instructions on the LCD and the serial monitor, including entering a unique ID (1–127) for fingerprint storage.

The 'getFingerprintEnroll()' function controls the fingerprint enrolment procedure, taking two fingerprints and processing them to guarantee accuracy. After being transformed into templates by 'finger.image2Tz(1)' and 'finger.image2Tz(2)', respectively, the first and second fingerprint images are compared with 'finger.createModel()'. If successful, 'finger.storeModel(id)' is used to store the fingerprint under the selected ID. The LCD displays feedback like "Stored!" while the serial monitor shows comprehensive messages about the procedure and any faults that occurred, including mismatched fingerprints or poor image quality. For access control applications, this technology provides a safe and easy way to enrol fingerprints.

Table 4.3 Fingerprint enrollment process for thumb and index finger

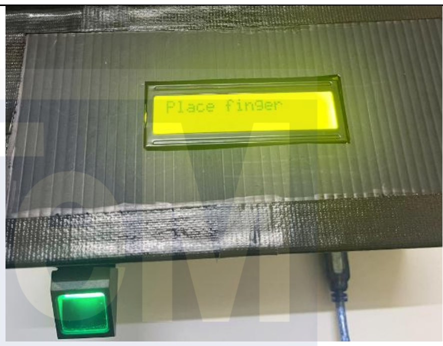
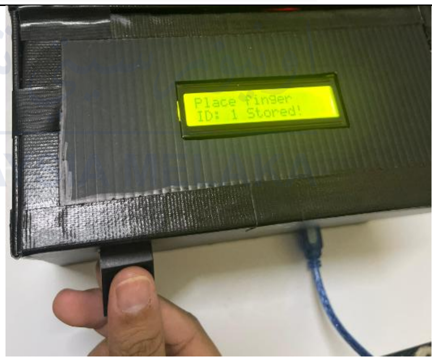
NO	**DETAILS**	**PICTURE**
1	The LCD will display "Place finger" and user are require to scan their thumb twice on the fingerprint scanner for enrollment.	
2	The right thumb fingerprint is stored as ID 1. The LCD confirms the storage with the message "ID: 1 is stored."	
3	The right index finger fingerprint is stored as ID 2. The LCD confirms the storage with the message "ID: 2 is stored."	

Table 4.3 illustrate the fingerprint enrolment process for the thumb and index finger. In both cases, the LCD first displays the message “Place Finger,” prompting the user to position their finger on the fingerprint scanner. The user must place their finger twice to ensure accurate data capture. For the thumb, the fingerprint is assigned ID 1 in the Arduino IDE’s Serial Monitor, and upon successful storage, the LCD confirms with the message: “ID: 1 is stored.” Similarly, for the index finger, the fingerprint is assigned ID 2, and the LCD displays the confirmation: “ID: 2 is stored.”

Fingerprint confirmation to unlock the solenoid:

The coding shown in Appendix D is used for the fingerprint confirmation process and is managed by the getFingerprintIDez() function, which captures, processes, and matches fingerprints. Several steps are used by this function to validate a fingerprint: ‘Finger.getImage()’ takes a picture of the fingerprint, ‘Finger.image2Tz()’ turns it into a template, and ‘Finger.fingerFastSearch()’ compares the template against fingerprints that have been stored. The fingerprint's ID is returned if a match is found; if not, '-1' is returned by the function. By doing this, the solenoid lock mechanism is guaranteed to be activated only by authorised fingerprints.

The ‘unlockSolenoid()’ function is invoked after a legitimate fingerprint has been identified. To activate the solenoid and unlock the physical lock, this function sets the SOLENOID_PIN to LOW. At the same time, the LCD gives the user feedback by showing "Verified," which reassures them that access has been authorised. The ‘lockSolenoid()’ function is used to relock the solenoid by setting the pin to HIGH once the solenoid has been unlocked for 10 seconds, which is managed by a delay of 100,000 in the main loop.

These procedures are smoothly combined to guarantee safe and easy operation. The ‘getFingerprintIDez()’, ‘unlockSolenoid()’, and ‘lockSolenoid()’ functions are essential for controlling security and delivering real-time response in a dependable access system that combines fingerprint verification, solenoid control, and LCD feedback.

Table 4.4 Fingerprint confirmation to unlock the solenoid

NO	**DETAILS**	**PICTURE**
1	The LCD display prompts the user with "Place Finger" to scan their fingerprint for authentication.	
2	When the fingerprint is successfully verified, the solenoid will be unlock and LCD display that the total amount saved will be reset to RM0.	
3	After 8 seconds of inactivity, the LCD shows "Locked," and the solenoid lock automatically secures the box.	
4	If the fingerprint verification fails, the LCD displays "No Match," and the solenoid lock remains secured.	

Table 4.4 illustrates the process of fingerprint confirmation required to unlock the solenoid lock of the money box. When the user places their finger on the fingerprint scanner, the LCD initially prompts "Place Finger" to instruct the user to scan their fingerprint again

for a second verification. If the fingerprint matches the stored data, the LCD displays the total saved amount reset to RM0, and the solenoid lock is unlocked, granting access to the box. After 8 seconds of inactivity, the solenoid lock automatically re-engages to secure the box. However, if the fingerprint does not match, the LCD will display "No Match," and the solenoid lock remains locked, ensuring the security of the contents. This system provides an added layer of security through double verification and automatic re-locking.

4.3 Summary

In this chapter, the final outcomes of the project are presented and analyzed. It begins with an overview of the money box system, which incorporates a counter and fingerprint lock using a microcontroller. A detailed explanation of the circuit diagram is provided to illustrate the functionality of the fingerprint scanner and color sensor. The analysis focuses on the performance and accuracy of the components, considering factors such as fingerprint recognition reliability, sensor responsiveness, and compatibility with the microcontroller. The color sensor, however, was only able to detect 3 out of the 6 Malaysian currency notes: the blue RM1, green RM5, and red RM10. The remaining notes orange RM20, green-blue RM50, and purple RM100 could not be detected by the sensor, highlighting a limitation that requires improvement. The chapter also evaluates how well the system meets the predefined objectives and identifies areas for further enhancement. Overall, this chapter provides valuable insights into the effectiveness of the developed system and its potential for practical application.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

To help users who need safe and practical cash management solutions, a microcontroller was used to create an improved money box with a counter and fingerprint lock. This concept guarantees accurate currency note counting and strong protection against unauthorized access by combining cutting-edge sensors, microcontroller technology, and biometric security features. An additional degree of security is offered by the fingerprint lock, giving users peace of mind when storing their belongings. With features like alerts for important events and a real-time currency value display, this project helps users prioritize security and ease of use while managing their finances. However, the objective was not fully achieved as the color sensor TCS3200 used can only detect 3 out of the 6 Malaysian currency notes which is blue:RM1, green:RM5 and red:RM10, indicating room for improvement in future versions. In conclusion, this all-inclusive and creative money box solution meets user demands and offers a modern and astute method of managing funds.

5.2 Potential for Commercialization

The project "Development of an Improved Money Box with Counter and Fingerprint Lock Using Microcontroller" presents several potential routes for commercialization. It might be released as a retail item, attracting those looking for safe and convenient financial management solutions, whether for individuals, families, and companies. Educational kits aimed at schools, STEM education providers, and enthusiasts interested in microcontrollers and security systems could also be created. Partnerships with security solution providers might enable the fingerprint lock technology to be integrated into current security settings, while collaborations with financial institutions could lead to customized versions of the money box supplied as incentives or promotional products. Additionally, a subscription-based business plan can provide clients with simple access to safe cash management options that include ongoing maintenance and customer support.

5.3 Future Works

To enhance the project "Development of an improved money box with counter and fingerprint lock using microcontroller" in the future, several recommendations can be considered:

i) Advanced Sensors: Utilize more advanced and suitable sensors, such as the AS7341 spectral color sensor, which can detect a wider range of colors with high precision. The AS7341 is a highly versatile sensor capable of analyzing up to 11 channels of spectral data, making it ideal for applications requiring accurate color differentiation. This can improve the accuracy and functionality of the money box's color detection system.

ii) Improved Security: Enhance security by implementing multi-layered biometric systems. For example, integrating facial recognition alongside the fingerprint lock can provide an additional layer of protection. This approach ensures that even if one biometric is compromised, the second layer can still secure the system. Furthermore, incorporating encryption protocols to safeguard the stored data can further protect against unauthorized access.

iii) Connectivity Features: Incorporate wireless technologies like Wi-Fi or Bluetooth, using platforms such as Blynk, to enable remote monitoring and management. Blynk allows users to control and monitor the money box in real time through a mobile app. Notifications can be sent directly to the user's smartphone to alert them of events, such as when the box is opened or when a specific amount of money has been deposited.

iv) User-Friendly Interfaces: Improve the user experience by adding intuitive features such as a touchscreen display for easy operation. The interface could include visual prompts, transaction logs, and customizable settings. Additionally, developing a companion mobile app with simple navigation and functionality will allow users to manage their money box more efficiently, such as checking balances or reviewing transaction histories.

v) Camera Integration for Verification: Integrate a camera to capture and verify the type of money notes being inserted. When a user inserts a note, the color sensor (e.g., AS7341) detects the color, and the camera simultaneously captures an image of the note. The captured image is then compared with pre-saved reference images of different currency notes in the system's database. This double-checking mechanism ensures greater accuracy in identifying the denomination of the money note and reduces the likelihood of errors caused by similar-colored notes. This feature enhances both functionality and reliability, making the system more robust.

vi) On/Off Button: Introduce an on/off button to give users full control over the system's power state. This feature ensures that the system can be powered down when not in use, reducing unnecessary energy consumption and extending the lifespan of the internal components. Additionally, incorporating low-power components and a sleep mode for idle periods can further optimize energy efficiency, making the money box more sustainable and cost-effective for long-term use.

These future directions offer significant potential to improve the functionality and security of the money box system, enhancing its user experience, energy efficiency, and overall reliability for more practical and widespread use.

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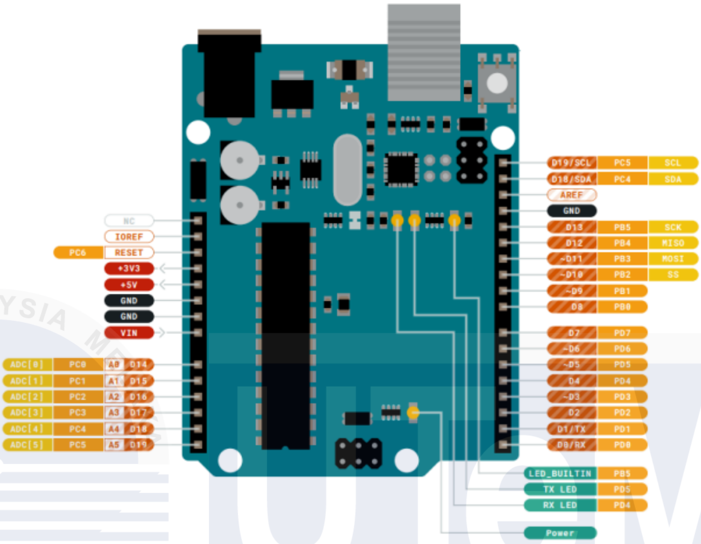
APPENDICES

Appendix A : Arduino Uno R3 Datasheet



5.1 JANALOG

Pin	Function	Type	Description
1	NC	NC	Not connected
2	IOREF	IOREF	Reference for digital logic V - connected to 5V
3	Reset	Reset	Reset
4	+3V3	Power	+3V3 Power Rail
5	+5V	Power	+5V Power Rail
6	GND	Power	Ground
7	GND	Power	Ground
8	VIN	Power	Voltage Input
9	A0	Analog/GPIO	Analog input 0 /GPIO
10	A1	Analog/GPIO	Analog input 1 /GPIO
11	A2	Analog/GPIO	Analog input 2 /GPIO
12	A3	Analog/GPIO	Analog input 3 /GPIO
13	A4/SDA	Analog input/I2C	Analog input 4/I2C Data line
14	A5/SCL	Analog input/I2C	Analog input 5/I2C Clock line

5.2 JDIGITAL

Pin	Function	Type	Description
1	D0	Digital/GPIO	Digital pin 0/GPIO
2	D1	Digital/GPIO	Digital pin 1/GPIO
3	D2	Digital/GPIO	Digital pin 2/GPIO
4	D3	Digital/GPIO	Digital pin 3/GPIO
5	D4	Digital/GPIO	Digital pin 4/GPIO
6	D5	Digital/GPIO	Digital pin 5/GPIO
7	D6	Digital/GPIO	Digital pin 6/GPIO
8	D7	Digital/GPIO	Digital pin 7/GPIO
9	D8	Digital/GPIO	Digital pin 8/GPIO
10	D9	Digital/GPIO	Digital pin 9/GPIO
11	SS	Digital	SPI Chip Select
12	MOSI	Digital	SPI1 Main Out Secondary In
13	MISO	Digital	SPI Main In Secondary Out
14	SCK	Digital	SPI serial clock output
15	GND	Power	Ground
16	AREF	Digital	Analog reference voltage
17	A4/SD4	Digital	Analog input 4/I2C Data line (duplicated)
18	A5/SD5	Digital	Analog input 5/I2C Clock line (duplicated)

Appendix B : Arduino Coding for Colour sensor

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

const int s0 = 12;
const int s1 = 13;
const int s2 = 10;
const int s3 = 9;
const int out = 8;

// LCD setup: I2C address 0x27, 16 characters, 2 rows
LiquidCrystal_I2C dis(0x27, 16, 2);  // LCD object with I2C address

// Variables to store color frequency values
int red = 0;
int green = 0;
int blue = 0;

// Variable to store the total score
int total = 0;

void setup() {
  Serial.begin(9600);

  // Initialize the LCD
  dis.init();
  dis.backlight();

  // Set pin modes for the sensor
  pinMode(s0, OUTPUT);
  pinMode(s1, OUTPUT);
  pinMode(s2, OUTPUT);
  pinMode(s3, OUTPUT);
  pinMode(out, INPUT);

  // Set scaling to 100% (both S0 and S1 HIGH)
  digitalWrite(s0, HIGH);
  digitalWrite(s1, HIGH);

  // Initial display on the LCD
  dis.setCursor(0, 0);
  dis.print("Color Sensor");
  delay(1000);
  dis.clear();
}

void loop() {
  // Call function to read color frequencies
```

```
  color();

  // Determine the detected color based on intensity values and update the total
  String colorText;
  dis.setCursor(0, 0);
  dis.print("                ");

  // Check for white (if all color values are high and close to each other)
  if (red > 150 && green > 150 && blue > 150 && abs(red - green) < 50 && abs(green -
blue) < 50 && abs(blue - red) < 50) {
    colorText = "RM0";  // White gives RM0
  }
  // Check for red color
  else if (red < blue && red < green && red > 0) {
    colorText = "RM10";  // Red gives RM10
    total += 10;         // Add 10 for red
  }
  // Check for blue color
  else if (blue < red && blue < green && blue > 0) {
    colorText = "RM1";  // Blue gives RM1
    total += 1;         // Add 1 for blue
  }
  // Check for green color
  else if (green < red && green < blue && green > 0) {
    colorText = "RM5";  // Green gives RM5
    total += 5;         // Add 5 for green
  }
  else {
    colorText = "RM0";  // No color detected
  }

  // Print the detected color and frequencies to Serial Monitor
  Serial.print("R: ");
  Serial.print(red);
  Serial.print(" G: ");
  Serial.print(green);
  Serial.print(" B: ");
  Serial.print(blue);
  Serial.print(" - Detected: ");
  Serial.println(colorText);

  // Display the RM value on the first row
  dis.setCursor(0, 0);   // Move to the first row
  dis.print(colorText);  // Display RM value for the detected color

  // Clear the second row and display the total score on the second row
  dis.setCursor(0, 1);            // Move to the second row
  dis.print("                ");  // Clear any previous text
  dis.setCursor(3, 1);            // Move to the second row, starting from column 3
  dis.print("Total: RM");
```

```
  dis.print(total);

  delay(1000);  // Delay before the next loop
}

// Function to read color frequency values
void color() {
  // Measure Red
  digitalWrite(s2, LOW);
  digitalWrite(s3, LOW);
  red = pulseIn(out, digitalRead(out) == HIGH ? LOW : HIGH);

  // Measure Blue
  digitalWrite(s3, HIGH);
  blue = pulseIn(out, digitalRead(out) == HIGH ? LOW : HIGH);

  // Measure Green
  digitalWrite(s2, HIGH);
  green = pulseIn(out, digitalRead(out) == HIGH ? LOW : HIGH);
}
```

Appendix C : Arduino Coding for Fingerprint Enrollment

```
#include <LiquidCrystal_I2C.h>
#include <Adafruit_Fingerprint.h>

LiquidCrystal_I2C dis(0x27, 16, 2);
SoftwareSerial mySerial(2, 3); // TX/RX
Adafruit_Fingerprint finger = Adafruit_Fingerprint(&mySerial);

uint8_t id;

void setup() {
  Serial.begin(9600);
  dis.init();
  dis.backlight();
  dis.setCursor(0, 0);
  dis.print("Place finger");
  while (!Serial);  // For Yun/Leo/Micro/Zero/...
  delay(100);
  Serial.println("\n\nAdafruit Fingerprint sensor enrollment");

  // set the data rate for the sensor serial port
  finger.begin(57600);

  if (finger.verifyPassword()) {
    Serial.println("Found fingerprint sensor!");
  } else {
    Serial.println("Did not find fingerprint sensor :(");
    while (1) {
      delay(1);
    }
  }

  finger.getParameters();
}

uint8_t readnumber(void) {
  uint8_t num = 0;

  while (num == 0) {
    while (! Serial.available());
    num = Serial.parseInt();
  }
  return num;
}

void loop() { // run over and over again
  Serial.println("Ready to enroll a fingerprint!");
```

```
  Serial.println("Please type in the ID # (from 1 to 127) you want to save this finger
as...");
  id = readnumber();
  if (id == 0) {// ID #0 not allowed, try again!
    return;
  }
  Serial.print("Enrolling ID #");
  Serial.println(id);

  while (!  getFingerprintEnroll() );
}

uint8_t getFingerprintEnroll() {

  int p = -1;
  Serial.print("Waiting for valid finger to enroll as #"); Serial.println(id);
  while (p != FINGERPRINT_OK) {
    p = finger.getImage();
    switch (p) {
      case FINGERPRINT_OK:
        Serial.println("Image taken");
        break;
      case FINGERPRINT_NOFINGER:
        //Serial.println(".");
        break;
      case FINGERPRINT_PACKETRECIEVEERR:
        Serial.println("Communication error");
        break;
      case FINGERPRINT_IMAGEFAIL:
        Serial.println("Imaging error");
        break;
      default:
        Serial.println("Unknown error");
        break;
    }
  }

  // OK success!

  p = finger.image2Tz(1);
  switch (p) {
    case FINGERPRINT_OK:
      Serial.println("Image converted");
      break;
    case FINGERPRINT_IMAGEMESS:
      Serial.println("Image too messy");
      return p;
    case FINGERPRINT_PACKETRECIEVEERR:
      Serial.println("Communication error");
      return p;
```

```
  case FINGERPRINT_FEATUREFAIL:
    Serial.println("Could not find fingerprint features");
    return p;
  case FINGERPRINT_INVALIDIMAGE:
    Serial.println("Could not find fingerprint features");
    return p;
  default:
    Serial.println("Unknown error");
    return p;
}

Serial.println("Remove finger");
delay(2000);
p = 0;
while (p != FINGERPRINT_NOFINGER) {
  p = finger.getImage();
}
Serial.print("ID "); Serial.println(id);
p = -1;
Serial.println("Place same finger again");
while (p != FINGERPRINT_OK) {
  p = finger.getImage();
  switch (p) {
    case FINGERPRINT_OK:
      Serial.println("Image taken");
      break;
    case FINGERPRINT_NOFINGER:
      //Serial.print(".");
      break;
    case FINGERPRINT_PACKETRECIEVEERR:
      Serial.println("Communication error");
      break;
    case FINGERPRINT_IMAGEFAIL:
      Serial.println("Imaging error");
      break;
    default:
      Serial.println("Unknown error");
      break;
  }
}

// OK success!

p = finger.image2Tz(2);
switch (p) {
  case FINGERPRINT_OK:
    Serial.println("Image converted");
    break;
  case FINGERPRINT_IMAGEMESS:
    Serial.println("Image too messy");
```

```
    return p;
  case FINGERPRINT_PACKETRECIEVEERR:
    Serial.println("Communication error");
    return p;
  case FINGERPRINT_FEATUREFAIL:
    Serial.println("Could not find fingerprint features");
    return p;
  case FINGERPRINT_INVALIDIMAGE:
    Serial.println("Could not find fingerprint features");
    return p;
  default:
    Serial.println("Unknown error");
    return p;
}

// OK converted!
Serial.print("Creating model for #");  Serial.println(id);

p = finger.createModel();
if (p == FINGERPRINT_OK) {
  Serial.println("Prints matched!");
} else if (p == FINGERPRINT_PACKETRECIEVEERR) {
  Serial.println("Communication error");
  return p;
} else if (p == FINGERPRINT_ENROLLMISMATCH) {
  Serial.println("Fingerprints did not match");
  return p;
} else {
  Serial.println("Unknown error");
  return p;
}

Serial.print("ID "); Serial.println(id);
dis.setCursor(0, 1);
dis.print("ID: ");
dis.print(id);
p = finger.storeModel(id);
if (p == FINGERPRINT_OK) {
  Serial.println("Stored!");
  dis.print(" Stored!");
} else if (p == FINGERPRINT_PACKETRECIEVEERR) {
  Serial.println("Communication error");
  return p;
} else if (p == FINGERPRINT_BADLOCATION) {
  Serial.println("Could not store in that location");
  return p;
} else if (p == FINGERPRINT_FLASHERR) {
  Serial.println("Error writing to flash");
  return p;
} else {
```

```
    Serial.println("Unknown error");
    return p;
  }

  return true;
}
```

Appendix D : Arduino Coding for Fingerprint Access to Unlock Solenoid

```
#include <LiquidCrystal_I2C.h>
#include <Adafruit_Fingerprint.h>

#define SOLENOID_PIN 7   // Pin to control the relay/transistor for solenoid

SoftwareSerial mySerial(2, 3); // RX, TX
Adafruit_Fingerprint finger = Adafruit_Fingerprint(&mySerial);
LiquidCrystal_I2C dis(0x27, 16, 2); // Set the LCD address to 0x27 for a 16x2 display

byte ID = 1; // Enter your fingerprint ID

void setup() {
  Serial.begin(9600);
  dis.init();
  dis.backlight();
  dis.setCursor(0, 0);
  dis.print("Place finger");
  pinMode(SOLENOID_PIN, OUTPUT);
  lockSolenoid();  // Ensure solenoid is initially locked

  // Initialize the fingerprint sensor
  finger.begin(57600);
  delay(5);
  if (finger.verifyPassword()) {
    Serial.println("Found fingerprint sensor!");
  } else {
    Serial.println("Did not find fingerprint sensor :(");
    while (1) delay(1);
  }

  finger.getParameters();
  finger.getTemplateCount();
  if (finger.templateCount == 0) {
    Serial.print("Sensor doesn't contain any fingerprint data. Please run the 'enroll'
example.");
  } else {
    Serial.println("Waiting for valid finger...");
    Serial.print("Sensor contains "); Serial.print(finger.templateCount); Serial.println("
templates");
  }
}

void loop() {
```

```
  int value = getFingerprintIDez();

  if (value == ID) {
    // Verified fingerprint detected
    dis.setCursor(0, 1);
    dis.print("Verified   ");       // Display "Verified" if matched

    // Unlock the solenoid
    unlockSolenoid();

    // Keep the solenoid unlocked for 10 seconds
    delay(10000);

    // After delay, lock the solenoid again
    lockSolenoid();
  }
  else {
    // No fingerprint detected or unverified fingerprint
    dis.setCursor(0, 1);
    dis.print("Unverified ");        // Display "Unverified" if not matched
    lockSolenoid();                  // Keep solenoid locked
  }

  delay(100);  // Small delay to avoid rapid checks
}

// Function to unlock the solenoid
void unlockSolenoid() {
  digitalWrite(SOLENOID_PIN, LOW); // Unlock solenoid
}

// Function to lock the solenoid
void lockSolenoid() {
  digitalWrite(SOLENOID_PIN, HIGH);  // Lock solenoid
}

// Returns -1 if failed, otherwise returns the ID #
int getFingerprintIDez() {
  uint8_t p = finger.getImage();
  if (p != FINGERPRINT_OK) return -1;

  p = finger.image2Tz();
  if (p != FINGERPRINT_OK) return -1;

  p = finger.fingerFastSearch();
  if (p != FINGERPRINT_OK) return -1;

  return finger.fingerID;
}
```

Appendix E : Gantt chart BDP1

NO.	Project Activities	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1.	Project title planning	■													
2.	Final Year Project briefing by JK PSM		■												
3.	Register project title			■											
4.	Writing Chapter 1: Introduction				■	■									
5.	Writing Chapter 2: Literature review						■	■	■						
6.	Methodology									■	■	■			
7.	Preliminary testing/results												■	■	
8.	Report writing												■	■	
9.	Submit PSM draft to supervisor and panels													■	
10.	PSM 1 presentation														■

Appendix F : Gantt chart BDP2

No	Project Activities	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1.	Final Year Project Briefing by JK PSM														
2.	Shows the latest progress to supervisor														
3.	Design prototype hardware														
4.	Data collection														
5.	Shows supervisor the data collection														
6.	Make demo video for supervisor														
7.	Updating Chapter 4: Results & discussion														
8.	Report writing														
9.	Submit PSM draft to supervisor and panels														
10.	PSM presentation														

Appendix G : Turnitin

psm ros

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