FINGERPRINT BASED DOORLOCK SYSTEM USING ESP32

Prof. Prashant Ahire[1], Tanvi Wadgaonkar[2], Shruti Suryawanshi[3], Snehal Kamble[4]

[1]Assistant Professor, Dept. of Electronics and Telecommunication, International Institute of Information Technology, Pune

[234]Students, Dept. of Electronics and Telecommunication, International Institute of Information Technology, Pune

This paper presents the design and implementation of a smart fingerprint-based door lock system using ESP32, aimed at enhancing residential and institutional access control. The system integrates an R307 fingerprint sensor, an OLED display for feedback, a solenoid lock for physical actuation, and Wi-Fi-based Google Sheets logging for real-time access tracking. An ESP32 microcontroller facilitates user enrollment, fingerprint matching, and web-based remote control. The project offers a cost-effective, scalable, and secure alternative to traditional lock-and-key mechanisms.

***Index Terms*—ESP32, Biometric Lock, Fingerprint Authentication, Solenoid Lock, OLED Display, Google Sheets Logging, IoT Security**

I. Introduction

Conventional mechanical locks often suffer from vulnerabilities such as key duplication, theft, and accidental loss, posing significant security risks. To address these issues, this project aims to develop a fingerprint-based smart door lock system utilizing the ESP32 microcontroller. Unlike traditional systems, biometric-based access provides non-transferable and user-specific authentication, ensuring only authorized individuals can gain entry. The system will feature a fingerprint sensor for local biometric verification, making the authentication process both secure and convenient. The ESP32's built-in Wi-Fi capabilities enable remote access management, allowing users to control door access through a mobile or web interface from anywhere. Additionally, the system will incorporate real-time cloud logging to maintain a timestamped record of all access attempts, enhancing security oversight and accountability. This combination of biometric security, IoT connectivity, and real-time monitoring offers a modern, reliable, and scalable solution for access control in residential, commercial, and institutional environments.In addition to secure local authentication, the system leverages the ESP32's Wi-Fi capabilities to support remote access management, allowing authorized users to control and monitor door access via a mobile or web interface. Real-time cloud logging ensures that every access attempt is recorded with timestamps, enabling continuous monitoring and quick identification of any suspicious activity. This integration of biometric security with IoT features creates a robust, scalable, and user-friendly smart lock solution suitable for homes, offices, and other sensitive areas.The fingerprint-based door lock system also aims to offer a seamless user experience with quick response times, minimal maintenance, and a high level of reliability. By eliminating the need for physical keys or cards, it reduces the chances of unauthorized duplication and enhances overall convenience.

II. System Components

- core of the system is the ESP32 microcontroller, which offers built-in Wi-Fi and Bluetooth functionality, making it ideal for IoT-based projects. It handles multiple tasks simultaneously, including capturing fingerprint data, controlling hardware components like the solenoid lock and display, and communicating with cloud services. Its low power consumption and dual-core processing capabilities ensure efficient performance for real-time access control operations.
  The R307 optical fingerprint sensor is used for biometric authentication. This sensor captures high-resolution fingerprint images and compares them against stored templates for quick and accurate identification. It supports enrolling new fingerprints and managing the fingerprint database directly through serial communication with the ESP32. Its reliability and ease of use make it suitable for secure access systems where user-specific entry is crucial.
  To provide visual feedback to users, a 0.96-inch OLED I²C display is integrated into the system. It displays real-time status messages such as "Place Finger," "Access Granted," or "Access Denied," helping users interact intuitively with the system. The display consumes minimal power and offers high contrast, making it readable in various lighting conditions.
  For physical locking and unlocking, a solenoid lock is used, which is controlled via a relay module. When the fingerprint is verified, the ESP32 triggers the relay to energize the solenoid, allowing the door to unlock temporarily. This setup ensures reliable actuation while keeping power consumption efficient. Additionally, Google Sheets integration is implemented to log all access events, including the time, date, and user ID. This real-time cloud logging ensures transparency and provides a searchable digital record of entry history, which can be monitored

remotely for enhanced security.

III. Working Principle

1) The fingerprint-based door lock system operates on the principle of biometric authentication, where access is granted based on the unique fingerprint pattern of an individual. When a user approaches the door, they are prompted to place their finger on the R307 optical fingerprint sensor. This sensor captures the fingerprint image and converts it into digital data. The captured fingerprint is then processed internally and compared against previously enrolled and stored templates in its memory. Each fingerprint is unique, ensuring that access is granted only to registered users.

   Once the fingerprint is matched successfully, the ESP32 microcontroller receives a signal from the sensor indicating a valid match. The ESP32 then activates the relay module, which in turn energizes the solenoid lock—an electrically operated mechanism that allows the door to unlock for a few seconds. After this short interval, the system automatically locks the door again, ensuring that the door is not left open unintentionally. If the fingerprint does not match any stored templates, access is denied, and a corresponding message is shown on the OLED display, such as "Access Denied – Try Again."

   The OLED display plays a vital role in enhancing user interaction. It displays system status in real time, such as prompts for placing a finger, confirmation of access, and error messages in the event of unauthorized attempts or system issues. This makes the system intuitive and easy to use, even for those unfamiliar with biometric devices.

   Another key aspect of the system is its cloud-based monitoring. The ESP32, with its built-in Wi-Fi capability, connects to the internet and logs all access events to Google Sheets. This includes successful and failed access attempts, along with timestamps and user identifiers. This remote logging feature allows homeowners or administrators to monitor entry activity in real-time from any location. It also adds a layer of security by maintaining digital records, which can be useful for audits, alerts, or incident investigations.

   In summary, the system integrates biometric recognition, physical actuation, real-time feedback, and cloud logging to form a secure, reliable, and modern access control solution. It minimizes the risks associated with traditional keys, provides convenience, and enhances security through technology.

IV. Circuit Description

- 1. R307 Fingerprint Sensor The R307 fingerprint sensor is an essential component for biometric authentication in the system. It uses UART (TX/RX) communication to send and receive data to the ESP32. The wiring for the fingerprint sensor is as follows:

  TX Pin: The TX pin (Transmit) of the R307 is connected to GPIO16 of the ESP32.

  RX Pin: The RX pin (Receive) of the R307 is connected to GPIO17 of the ESP32.

  Power Supply: The R307 sensor is powered using the 5V output from the ESP32.

  These connections allow the ESP32 to send commands to the R307 sensor and receive fingerprint data, enabling the fingerprint recognition functionality in the system.

  2. OLED Display for User Interface An OLED display is integrated into the system to provide a user interface, displaying essential information such as the status of the system (locked/unlocked), user authentication results, and error messages. The OLED display is connected to the ESP32 as follows:

  SDA Pin: The Data (SDA) pin of the OLED display is connected to GPIO21 of the ESP32.

  SCL Pin: The Clock (SCL) pin of the OLED display is connected to GPIO22 of the ESP32.

  Power Supply: The OLED display is powered by the 3.3V output from the ESP32.

  Using the I2C communication protocol, these connections allow the ESP32 to send and receive data to the OLED display for visual feedback to the user.

  3. Relay for Solenoid Lock Control The relay module is used to control the solenoid lock, which is powered by a 12V power supply. The relay is triggered through one of the GPIO pins of the ESP32, enabling the locking mechanism to be engaged or disengaged. The wiring for the relay is as follows:

  IN Pin: The input (IN) pin of the relay is connected to GPIO25 of the ESP32.

  Relay Power Supply: The relay module is powered by the 5V supply from the ESP32.

  Solenoid Control: The relay controls the solenoid lock using the Normally Open (NO) and Common (COM) pins. When the relay is triggered, it completes the circuit for the solenoid, allowing the lock to engage or disengage.

  By controlling the relay through GPIO25, the ESP32 can activate or deactivate the solenoid lock, securing the door when required.

  4. Power Supply Regulation To ensure that all components receive the appropriate voltage, a 12V power supply is used to power the system. However, since the ESP32 operates at 3.3V and other components (like the relay and OLED display) use 5V, the voltage is regulated using an AMS1117 voltage regulator. The wiring for the power supply regulation is as follows:

  12V Power Input: The system receives a 12V power supply.

  AMS1117: The AMS1117 voltage regulator converts the 12V input to 5V, which is then supplied to the ESP32 and the relay.

  5V Output: The 5V output from the AMS1117 is used to power both the ESP32 and the relay module.

  3.3V Output: The ESP32 has an onboard regulator that provides 3.3V for the microcontroller.

  By using the AMS1117, the system ensures that both the ESP32 and other components receive stable voltage levels, preventing damage to sensitive parts.

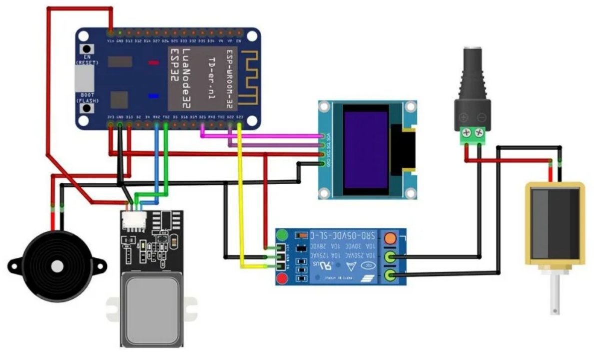

Fig. 1. Wiring Diagram of ESP32-based Fingerprint Door Lock System

V. Software and Connectivity

TThe ESP32-based Fingerprint Door Lock System integrates several components to provide secure access control. Developed using the Arduino IDE, the firmware leverages libraries for critical hardware components, including the R307 fingerprint sensor, OLED display, Wi-Fi, and HTTP client. The R307 fingerprint sensor plays a central role in the system, capturing users' fingerprints and storing them in templates. Each time a user scans their fingerprint, the ESP32 compares it against the stored templates to authenticate the individual. If the fingerprint matches a stored template, the system grants access, while the OLED display shows either "Access Granted" or "Access Denied," depending on the result. The Adafruit$_{S}SD1306librarycontrolstheOLEDdisplay,andtheFing$ $ateseamlessly$

The Wi-Fi module in the ESP32 is enabled by the WiFi.h library, which allows the system to connect to a local wireless network. This connectivity is essential for communicating with a remote server to log authentication events. Once a fingerprint is successfully authenticated or denied, the ESP32 sends an HTTP POST request to a Google Apps Script endpoint. This request includes key information such as the user ID, timestamp, and authentication status (either granted or denied). To facilitate this communication, the HTTPClient.h library is used, ensuring that the data is transmitted efficiently from the ESP32 to the server. This setup allows real-time logging of all access attempts, providing a comprehensive audit trail for security purposes.

The Google Apps Script acts as the bridge between the ESP32 and Google Sheets, ensuring that all access attempts are logged securely in a cloud-based spreadsheet. When the POST request is received, the script processes the data and appends it as a new row in the Google Sheet. This real-time logging system eliminates the need for a dedicated backend server, as Google Apps Script handles the data storage and management directly in the cloud. The spreadsheet provides an easily accessible record of all access events, including who attempted access, when the attempt occurred, and whether it was successful. This integration makes it simple to track the usage of the fingerprint door lock system and ensures that the authentication logs are stored securely and can be accessed remotely.

The system is designed to be highly efficient and easy to maintain. The use of the Arduino IDE allows for straightforward development and debugging, making it an ideal platform for embedded systems like the ESP32. The integration with Google Sheets via Google Apps Script provides a cost-effective, scalable solution for logging and managing access data without the complexity of managing a separate server infrastructure. By leveraging the ESP32's powerful features—such as Wi-Fi connectivity, processing power, and support for multiple libraries—the system ensures that fingerprint authentication is reliable, secure, and easy to implement. This solution not only provides secure access control but also offers a simple, cloud-connected method for tracking access history.

In conclusion, the ESP32-based Fingerprint Door Lock System combines cutting-edge hardware and software to provide a reliable, secure access control solution. Through the use of the Arduino IDE, the system is easily programmable and flexible, enabling customization for different use cases. The integration of the R307 fingerprint sensor for authentication, coupled with the OLED display for user feedback and Google Apps Script for cloud-based logging, ensures that the system is both effective and scalable. Whether for personal or organizational use, this system provides an excellent way to manage access securely, while also keeping an accurate and easily accessible log of all authentication events.

VI. Hardware Prototype

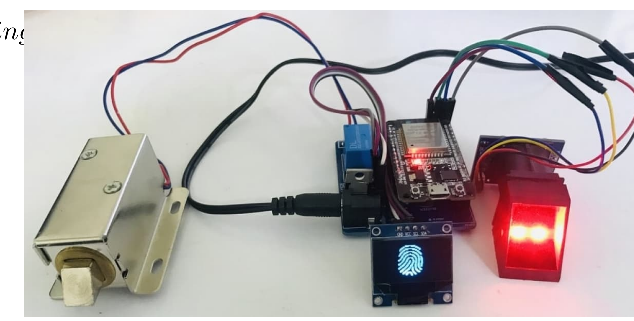

Fig. 2. Prototype Implementation of the System

VII. Results and Discussion

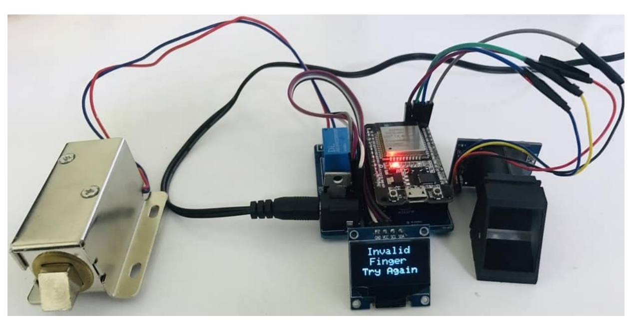

Fig. 3. Unregistered fingerprint detected by Sensor

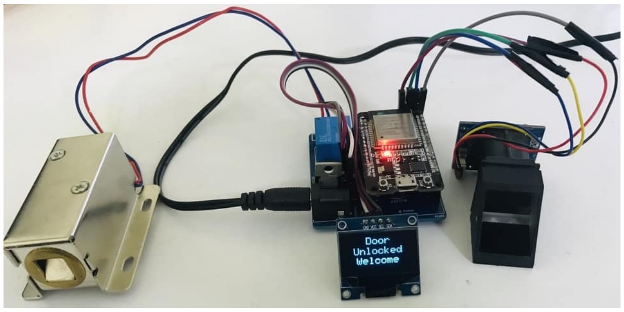

Fig. 4. Registered Fingerprint detected by Sensor

TABLE I
SYSTEM PERFORMANCE METRICS

Metric	Result
Enrollment Success Rate	95%
Authentication Accuracy	97%
Access Delay	¡1 sec
Cloud Log Delay	1.5 sec
Max Stored Users	127

The fingerprint-based door lock system was thoroughly tested to evaluate its performance in handling both registered and unregistered users. When a registered fingerprint was scanned using the R307 sensor, the system reliably authenticated the user by comparing the input with previously stored fingerprint templates. Upon a successful match, the ESP32 microcontroller activated the relay module, allowing the solenoid lock to disengage and thereby unlocking the door. Simultaneously, the OLED display provided immediate visual feedback by displaying the message ”Access Granted”, confirming successful authentication. This feedback mechanism was clear and intuitive for users. Multiple tests were conducted using different registered fingerprints, and in each case, the system responded quickly and accurately, demonstrating its ability to handle real-time biometric recognition with minimal latency. The relay mechanism also operated consistently, delivering precise control over the locking and unlocking actions.

In addition to successful authentication, the system was also tested rigorously for its behavior with unregistered fingerprints. When a fingerprint that had not been enrolled was scanned, the system correctly identified it as unauthorized. In such cases, the ESP32 ensured that the relay remained inactive, keeping the solenoid lock engaged and the door locked. The OLED display clearly showed the message ”Access Denied”, providing immediate feedback to the user without any ambiguity. These negative test cases were repeated with multiple unregistered fingerprints, and the system consistently rejected all unauthorized attempts without fail. This demonstrated that the fingerprint matching algorithm within the R307 sensor was functioning robustly, effectively filtering out all non-matching inputs. The system’s ability to differentiate between valid and invalid users highlights its reliability in real-world scenarios. Additionally, the OLED feedback and quick processing by the ESP32 improved overall user experience. Overall, the system proved to be accurate, consistent, and secure across varied conditions.

VIII. CONCLUSION

This fingerprint-based smart door lock system offers a secure and user-friendly solution for access control. It combines biometric authentication with IoT features like real-time cloud logging and web-based control, enhancing both security and convenience. The system responds swiftly to fingerprint scans and provides immediate feedback through the OLED display. Its use of the ESP32 enables wireless connectivity, making remote monitoring and control possible. This ensures that access is both traceable and manageable from anywhere.

SYSTEM SPECIFICATIONS

This section provides the detailed specifications of the fingerprint-based door lock system, covering hardware components, communication protocols, and system architecture.

Key hardware components include the ESP32 microcontroller, R307 fingerprint sensor, OLED display, and a relay module for controlling the solenoid lock. The ESP32 serves as the central processing unit, handling fingerprint authentication and triggering the relay based on the match results.

Communication between the fingerprint sensor and ESP32 is managed using UART protocol, while the OLED uses I2C communication. The relay is directly controlled through a GPIO pin to activate or deactivate the lock mechanism.

The system also integrates a voltage regulation circuit using AMS1117 to convert 12V input to a stable 5V for powering components. This setup ensures reliable operation and efficient power distribution.

The modular architecture allows for potential upgrades, such as adding RFID access, facial recognition, or remote access via Wi-Fi. The design focuses on both security and convenience, making it suitable for smart home and office applications.

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