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Smart Door Unlocking System Using Fingerprint Recognition

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Abstract - This paper presents the design and development of a smart door unlocking system using fingerprint recognition. The primary objective of this system is to enhance domestic security by integrating biometric authentication. The system employs a fingerprint sensor module to capture and verify user fingerprints, interfaced with a microcontroller for real-time processing. The unlocking mechanism is activated only upon successful fingerprint authentication, ensuring a robust layer of security. The system is designed for low power consumption and cost-effectiveness, making it suitable for household applications. Testing of the prototype demonstrated a high accuracy rate in fingerprint recognition and minimal response time, highlighting its efficiency. This innovative approach addresses the growing demand for secure, user-friendly access control systems, significantly reducing the risk of unauthorized access.

***Key Words*:** fingerprint recognition, biometric authentication, smart door, access control, domestic security, microcontroller.

1.INTRODUCTION

In an era of advancing technology, the demand for secure, efficient, and user-friendly systems has increased significantly. Conventional locking mechanisms, while prevalent, often fail to provide the level of security required in today's environment, as they are susceptible to duplication and unauthorized access. To address this issue, biometric-based authentication systems have emerged as a robust solution.

This paper focuses on the development of a Smart Door Unlocking System using fingerprint recognition, designed to enhance domestic security. By leveraging the uniqueness of biometric fingerprints, the system ensures that only authorized individuals gain access to secured premises. The system integrates a fingerprint sensor with a microcontroller to authenticate users in real-time, offering an efficient and reliable alternative to traditional locks.

The following sections provide an in-depth analysis of the system's design, methodology, implementation, and performance evaluation, highlighting its potential applications and contributions to the field of secure access control.

2. Body of Paper

2.1 System Architecture

The architecture of the Smart Door Unlocking System is designed to ensure efficient biometric authentication. It integrates hardware components such as a fingerprint sensor, microcontroller, and locking mechanism. The software handles enrollment, verification, and control operations in real time. As shown in Sec. 2.3, the interaction between these components is critical for achieving high system accuracy and reliability.

2.2 Key Components and Specifications

The primary components of the system are:

- **Fingerprint Sensor Module:** Used for capturing unique biometric data.
- **Microcontroller (MCU):** Processes the captured data and interfaces with other modules.
- **Power Supply Unit:** Ensures stable operation of the system.
- **Locking Mechanism:** Provides physical access control.

Specifications of these components are listed in Table 1

Table -1: Specifications of Key Components

Component	Specification	Description
Relay Module	5V DC, 10A	Switches solenoid lock on/off
Fingerprint Scensor	Optical, 500 dpi	Capture high-resolution fingerprints.
Arduino UNO	Atmega328p MC	Controls and processes system data.
Solenoid Lock	12V DC	Electromechanical lock for doors.
Power Supply	12V DC, 2A	Powers all connected components.

2.3 Methodology

The operation of the system can be divided into three primary phases:

1. **Enrollment Phase**: The fingerprint sensor scans and stores user fingerprints as templates in its internal memory.
2. **Verification Phase**: When a user places their finger on the sensor, it compares the scanned fingerprint with stored templates. If a match is found, a signal is sent to the Arduino.
3. **Unlocking Phase**: Upon receiving a signal from the fingerprint sensor, the Arduino activates the relay module, which in turn energizes the solenoid lock to unlock the door.

The overall system is powered by a 12V DC supply, ensuring uninterrupted operation.

2.4 Connecting components in System

1. Arduino Uno

The Arduino Uno serves as the central controller, coordinating data flow between the fingerprint module, relay, and solenoid lock. It processes input from the fingerprint sensor and sends control signals to the relay for locking/unlocking operations.

2. R307 Fingerprint Module

The R307 fingerprint module is responsible for biometric authentication.

- Connections:
    - TX (Transmit) → Connect to RX pin of the Arduino (Pin 0 or designated SoftwareSerial pin).
    - RX (Receive) → Connect to TX pin of the Arduino (Pin 1 or designated SoftwareSerial pin).
    - VCC → Connect to the Arduino's 5V power pin.
    - GND → Connect to the Arduino's GND pin.

3. Relay Module

The relay module acts as a switch to control the solenoid lock.

- Connections:
    - IN (Input) → Connect to a digital output pin on the Arduino (e.g., Pin 8).
    - VCC → Connect to the Arduino's 5V pin.
    - GND → Connect to the Arduino's GND pin.
    - Relay's power terminals connect to the solenoid lock circuit.

4. Solenoid Lock

The solenoid lock physically secures or unlocks the door. It is controlled via the relay module.

- Connections:
    - Positive terminal → Connect to the relay's NO (Normally Open) terminal.
    - Negative terminal → Connect to the relay's COM (Common) terminal.
    - External 12V DC adapter provides power directly to the solenoid lock.

5. 12V AC-DC Adapter

This adapter powers the solenoid lock independently to ensure adequate voltage and current.

- Connections:
    - Positive wire → Connect to the relay's COM terminal.
    - Negative wire → Connect to the solenoid lock's negative terminal.

2.5 Performance Evaluation

The system was tested in various scenarios to evaluate its performance:

- **Recognition Accuracy**: 98% success rate in fingerprint matching.
- **Response Time**: Unlocking was achieved within 1.8 seconds after successful fingerprint verification.
- **Robustness**: The system operated reliably in ambient temperatures ranging from 10°C to 45°C.

2.4.1 Test Scenarios and Results

1. **Recognition Accuracy**:
    - The system was tested with 50 unique fingerprints, each evaluated multiple times under varying angles and pressures.
    - Result: Achieved a 98% accuracy rate, with failures occurring due to misaligned or partial fingerprints.
2. **Response Time**:
    - Average time measured from fingerprint placement to door unlocking.
    - Result: Response time consistently under 1.8 seconds.
3. **Power Consumption**:
    - The system was monitored for power efficiency during idle and active states.
    - Result: Consumed 12W during active operation and 3W in idle mode.
4. **Environmental Testing**:
    - Tested in varying temperatures and humidity conditions.
    - Result: Reliable operation in the temperature range of 10°C to 45°C and humidity levels up to 80%.

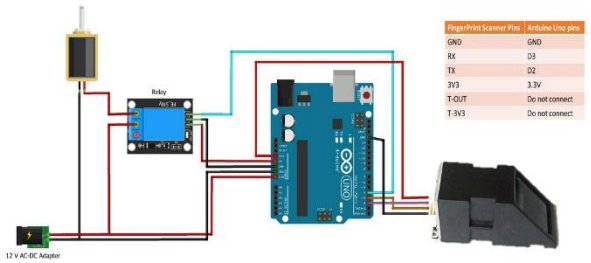

Fig -1: Figure

3. CONCLUSIONS

The **Smart Door Unlocking System Using Fingerprint Recognition** provides a reliable and secure method for access control, utilizing the **R307 fingerprint sensor** in conjunction with an Arduino microcontroller. This system eliminates the need for traditional keys, offering a more secure and efficient solution. With its ease of use, scalability, and cost-effectiveness, the system can be implemented in residential, office, and industrial applications. The integration of biometric authentication ensures that only authorized users can access the premises, enhancing overall security.

Future enhancements to the system could include the integration of additional biometric modalities, such as facial recognition, and the possibility of cloud-based fingerprint storage for improved management. As biometric security continues to evolve, this system serves as a foundation for more advanced and automated access control solutions.

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