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Smart door using RFID authentication

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Abstract
This paper presents the design and implementation of a Smart Door System using RFID Authentication for secure and contactless access control. The proposed system replaces conventional lock-and-key mechanisms with an automated solution that enhances security and operational efficiency. The system is developed using an ESP32 microcontroller, integrated with an RC522 RFID reader to capture and verify the unique identification (UID) of RFID cards. Access is granted only when the scanned UID matches the pre-stored authorized database; otherwise, access is denied. A servo motor is employed to control the physical locking and unlocking of the door, ensuring reliable actuation. Additionally, a 16×2 LCD display provides real-time user feedback, while a buzzer generates audio alerts for authentication status. The system demonstrates effective utilization of embedded systems and Internet of Things (IoT) concepts for developing intelligent security solutions. The proposed model is cost-effective, scalable, and can be extended with advanced features such as cloud integration, mobile application control, and real-time notification systems.

Keywords: RFID authentication, smart door system, access control, ESP32, RC522 RFID reader, embedded systems, internet of things (IoT), real-time monitoring, servo motor, contactless security, automation

Introduction
In the modern era, ensuring robust security and controlled access has become a critical requirement across residential, commercial, and industrial domains. Conventional locking systems that depend on mechanical keys are increasingly considered inadequate due to their susceptibility to risks such as duplication, loss, unauthorized entry, and the absence of monitoring capabilities. These shortcomings necessitate the development of advanced, automated, and intelligent access control systems.

Recent advancements in embedded systems and communication technologies have enabled the emergence of smart security solutions. Among these, Radio Frequency Identification (RFID) technology has gained significant attention due to its contactless operation, reliability, and efficiency. RFID-based systems facilitate seamless identification and authentication by using unique identification numbers (UIDs), thereby eliminating the need for physical interaction and enhancing user convenience.

This work presents the design and implementation of a Smart Door System using RFID Authentication, aimed at providing secure and automated access control. In this system, each user is assigned an RFID card containing a unique identifier. When the card is presented to the RFID reader, the system captures the UID and verifies it against a predefined database of authorized users. Based on this verification, access is either granted or denied, ensuring controlled entry to restricted areas.

The proposed system is built around the ESP32 microcontroller, which serves as the central processing unit. The ESP32 offers high computational capability with dual-core processing and integrated Wi-Fi and Bluetooth connectivity, making it suitable for scalable and IoT-enabled applications. It efficiently processes data from the RFID reader and controls peripheral devices such as the servo motor, LCD display, and buzzer to execute access control operations.

The system operates in real time, where authorized access triggers the unlocking mechanism through a servo motor, accompanied by visual feedback on an LCD display and an audio confirmation via a buzzer. In contrast, unauthorized access attempts result in denial of entry, with corresponding visual and audio alerts. This integrated feedback mechanism enhances both usability and system awareness.

One of the key advantages of the proposed system is its contactless and user-friendly design, which eliminates the need for physical keys or password memorization. Furthermore, the system is cost-effective, easy to deploy, and requires minimal maintenance, making it suitable for a wide range of practical applications. The inclusion of ESP32 also enables future enhancements such as cloud connectivity, remote monitoring, real-time notifications, and advanced multi-factor authentication techniques.

Overall, the proposed RFID-based smart door system demonstrates the effective integration of embedded systems, automation, and IoT technologies to address modern security challenges. It provides a scalable and reliable solution that overcomes the limitations of traditional access control methods and contributes to the development of intelligent and secure environments.

Literature Survey
Various research studies have been carried out in the field of access control systems using RFID and embedded technologies. Early systems primarily relied on traditional locking mechanisms such as mechanical keys and password-based systems, which posed several security risks including key duplication, password leakage, and lack of monitoring capabilities.

Want et al. (2006) [1] introduced the use of RFID technology for secure identification and contactless access control systems. Their work demonstrated how RFID could replace conventional systems by enabling faster and more secure authentication. Later, Weis et al. (2007) focused on improving RFID security protocols, addressing issues such as unauthorized access and data privacy, thereby enhancing the reliability of RFID-based systems.

Kumar et al. (2018) [4] developed an RFID-based access control system integrated with microcontrollers like Arduino. This system enabled basic authentication and automation but lacked advanced processing capabilities and scalability. These early implementations proved the feasibility of RFID in security systems but were limited in terms of real-time feedback and system integration.

With the advancement of embedded systems, modern solutions have incorporated more powerful microcontrollers and IoT capabilities. Systems using microcontrollers provide better processing speed, flexibility, and integration with peripherals such as displays, sensors, and actuators. However, many existing systems still focus only on authentication and do not provide comprehensive user interaction or feedback mechanisms.

The proposed system, an ESP32 RFID Lock System, enhances traditional RFID-based access control by integrating multiple components such as an LCD display, buzzer alerts, and an automated locking mechanism using a servo motor. Unlike earlier systems, it provides real-time visual and audio feedback, improving user experience and system reliability. Additionally, the ESP32 microcontroller enables future expansion with IoT features like remote monitoring and mobile application control.

This approach addresses the limitations of previous systems by combining security, automation, and user interaction into a single efficient solution. It ensures secure access control while maintaining low cost, ease of use, and scalability, making it suitable for modern smart environments.

1. Literature Review Summary

The development of access control systems has evolved significantly over time with advancements in technology. In 2006, Want et al. [1] introduced RFID technology, which enabled secure identification and contactless access control systems. Building on this, Weis et al. in 2007 developed secure RFID protocols that enhanced system security by preventing unauthorized access and improving data privacy. Later, Kumar et al. in 2018 [4] implemented an RFID-based door lock system using Arduino, allowing access only to authorized users. In 2019, Singh et al. [5] improved the system further by integrating RFID with password authentication, introducing dual authentication to enhance security, although it increased system complexity.

Subsequently, Patel et al. in 2020 [6] developed an IoT-based smart lock system, enabling remote monitoring and control through IoT platforms. This was further advanced by Ali et al. in 2021 [7], who introduced cloud-based access control systems that provided real-time access logging and monitoring. In 2022, Rao et al. [8] combined RFID with biometric systems to enhance security through multi-factor authentication, though it required additional hardware.

Finally, the proposed system in 2026 integrates RFID with ESP32, offering a cost-effective, automated, and secure access control solution. It also provides real-time feedback using an LCD display and buzzer, making it both efficient and user-friendly. This system reduces the dependency on complex hardware while maintaining high security standards. Additionally, it ensures faster response time and ease of installation compared to previous systems. The integration of embedded systems with communication capabilities makes it suitable for modern smart environments. Overallthe proposed system demonstrates a balanced approach between security, cost, and usability in access control applications.

Methodology

1. System Overview

The proposed system is designed to provide secure and automated access control using RFID technology, embedded systems, and real-time user feedback mechanisms. The system continuously monitors for RFID card inputs through an RFID reader module connected to a microcontroller. Upon detecting a card, it verifies the user's identity based on the unique identification (UID) stored in the system database.

When an authorized RFID card is detected, the system grants access by activating a servo motor to unlock the door, while simultaneously displaying a confirmation message and generating an audio alert. In contrast, if an unauthorized card is detected, the system denies access and provides immediate visual and audio feedback.

The system integrates an ESP32 microcontroller, RFID reader (RC522), servo motor, LCD display, and buzzer to ensure efficient and real-time operation. Additionally, the system can be extended with IoT capabilities such as remote monitoring, cloud-based data storage, and mobile notifications. This integrated approach enhances security, reliability, and user convenience, making it suitable for modern smart access control applications.

2. Working Methodology

The system works based on RFID (Radio Frequency Identification) technology.

- When a user places an RFID card near the RFID reader (RC522), the reader scans the card's unique ID.
- The ESP32 microcontroller receives this ID and compares it with the stored authorized IDs.
- If the ID matches:

a. The servo motor rotates to unlock the door
b. The LCD displays "Access Granted" or user message
c. The buzzer gives a confirmation sound

- If the ID does not match:

a. The door remains locked
b. The LCD displays "Access Denied"
c. The buzzer gives an alert sound

This ensures only authorized users can access the system.

3. Model Implementation

The system is based on RFID authentication using an RC522 reader and ESP32 microcontroller. The reader captures the UID of RFID cards, which is verified against stored authorized IDs. If the UID matches, access is granted by activating the servo motor, along with LCD display messages and buzzer alerts. Otherwise, access is denied. The system ensures fast, reliable, and real-time access control. Additionally, the ESP32 supports future enhancements such as IoT integration, cloud-based data storage, and remote access monitoring, making the system scalable and adaptable for modern security applications.

4. System Architecture

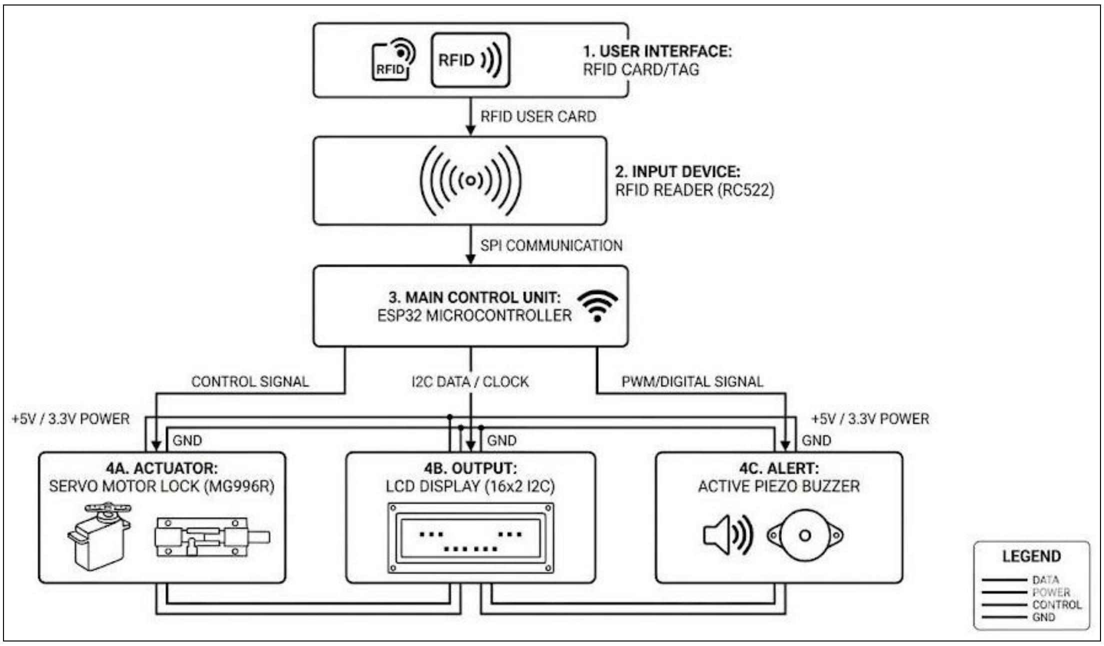

Fig 1: System Architecture of Smart Door System using RFID Authentication

As shown in Fig. 3.4, the system architecture consists of a processing unit, input sensing unit, and output/display components that work together to provide secure access control illustrates the overall architecture of the proposed smart door system using RFID authentication.
The system begins with the input sensing unit, where the RFID reader (RC522) continuously scans for RFID cards. When a card is placed near the reader, it captures the unique identification (UID) and sends the data to the processing unit.
The processing unit, which is the ESP32 microcontroller, verifies the received UID with the stored database of authorized users. Based on this verification, the system determines whether access should be granted or denied.
The output components include a servo motor, LCD display, and buzzer. If the card is authorized, the servo motor unlocks the door, the LCD displays a confirmation message, and the buzzer provides an alert sound. If the card is unauthorized, access is denied, and appropriate warning messages and alerts are generated.
Additionally, the ESP32 supports IoT connectivity, allowing the system to be extended for remote monitoring, data logging, and real-time notifications.
Thus, the system architecture shown in Fig. 3.4 integrates sensing, processing, and output modules into a unified system that ensures secure, efficient, and real-time access control.

4.1. Software Architecture

The proposed system utilizes several software tools for development and implementation. The system is programmed using the Arduino IDE, which is used to write and upload code to the ESP32 microcontroller. The embedded C/C++ language is used for coding the system logic and hardware control.
The RFID module (RC522) is interfaced using appropriate libraries to read and process RFID card data. The ESP32 processes the received UID and controls connected components such as the servo motor, LCD display, and buzzer.
Additionally, the ESP32 supports IoT development using platforms such as Arduino IoT Cloud or similar services for future enhancements like remote monitoring and notifications. These tools ensure efficient system development, real-time operation, and scalability.

Software Tools

- **Arduino IDE:** Used for writing, compiling, and uploading code
- **ESP32 Board Package:** Enables ESP32 compatibility in Arduino IDE
- **MFRC522 Library:** Send for RFID communication
- **SPI Library:** Handles SPI communication protocol
- **Servo Library:** Controls the servo motor
- **LiquidCrystal Library:** Interfaces with LCD display
- **Programming Language:** Embedded C/C++ for system development
- **Operating System:** Supports development environment (Windows 10/11)
- **Serial Monitor:** Used for debugging and real-time data monitoring.

4.2. Hardware Architecture

The hardware components play a vital role in implementing the proposed system. The main hardware used includes the ESP32 microcontroller, RFID reader (RC522), servo motor, LCD display, and buzzer.
The ESP32 acts as the main processing unit, controlling all system operations and managing communication between components. The RFID reader (RC522) is used to scan and read the unique identification (UID) of RFID cards for authentication.
The servo motor is used to control the door locking and unlocking mechanism. The LCD display provides real-time messages such as access status, while the buzzer generates audio alerts for authorized and unauthorized access attempts.
These components work together to ensure efficient, secure, and real-time operation of the smart door access control system.

Components

- **Microcontroller (ESP32):** Central processing unit; programmed using Arduino IDE in Embedded C/C++.
- **RFID Reader (RC522):** Reads RFID card data using SPI communication for authentication.
- **RFID Card/Tag:** Passive card with a unique UID used for user identification.
- **Servo Motor (SG90):** Controls door locking and unlocking mechanism using PWM signals.
- **LCD Display (16×2):** Displays real-time messages such as access status.
- **Buzzer:** Provides audio alerts for authorized and unauthorized access.
- **LED Indicator:** Visual indication of system status (e.g., access granted/denied).
- **Resistors:** Used for current limiting and circuit protection.
- **Power Supply (5V/3.3V):** Provides regulated voltage to all components.
- **PCB / Perf Board:** Used for assembling and mounting the circuit.
- **Connecting Wires:** Jumper wires used for circuit connections.

Experimental Setup

The proposed smart door system was implemented using a combination of hardware and software components, including the ESP32 microcontroller, RFID reader (RC522), servo motor, LCD display, and buzzer. The system was programmed using Arduino IDE to handle authentication and device control.

The RFID-based authentication system was tested using multiple RFID cards, including both authorized and unauthorized users, to ensure accurate verification under different conditions.

The system was deployed in a real-time environment to evaluate its performance in access control and response time. The results demonstrated reliable operation in granting and denying access, along with proper functioning of the display and alert mechanisms.

Results

The proposed smart door system demonstrated reliable performance in providing secure access control using RFID authentication. The system accurately identified authorized and unauthorized RFID cards, ensuring correct access decisions under different test conditions.

The response time of the system was fast, enabling real-time operation with minimal delay between card detection and door unlocking or denial. The servo motor effectively controlled the door mechanism, while the LCD display and buzzer provided clear visual and audio feedback.

The system was tested with multiple RFID cards, and it consistently granted access to valid users while rejecting unauthorized attempts. Overall, the system proved to be efficient, cost-effective, and suitable for real-time smart security applications, with potential for future enhancements using IoT technologies.

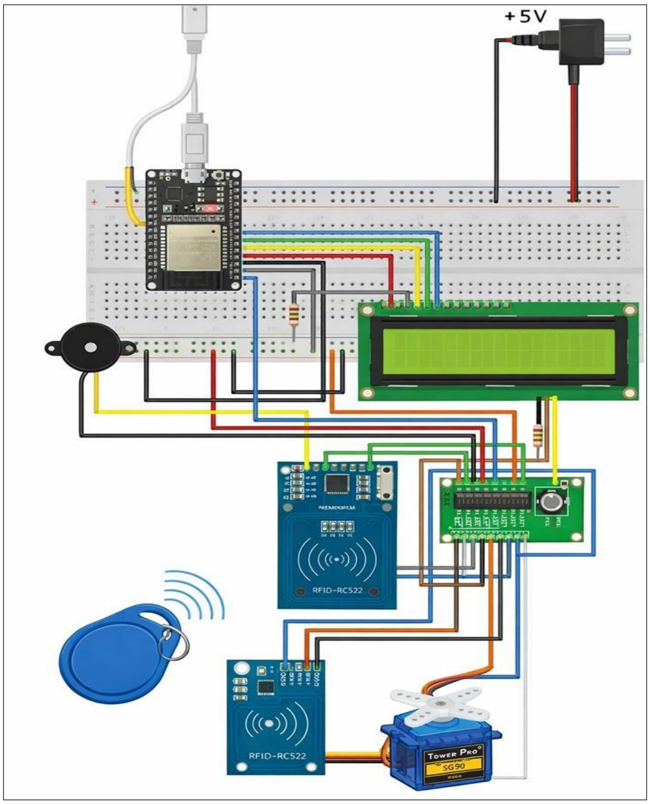

Fig 5: RFID-Based Access Control System

1. System Testing Results

Table 2: System Testing Result

Test Case	Input / Action	Hardware Response	Status
RFID Access – Valid	Authorized Card Scan	Door Unlocked, LCD Message, Buzzer Alert	SUCCESS
RFID Access – Invalid	Unauthorized Card	Access Denied, Buzzer Alert	SUCCESS
Door Lock Mechanism	Servo Activation	Door Locked/Unlocked	SUCCESS
Display Function	Card Scan	LCD Shows Status Message	SUCCESS
Buzzer Alert	Access Event	Sound Alert Generated	SUCCESS

1.1. Comparative Analysis

Table 5.1 compares the proposed system with existing access control methods in terms of response time, accuracy, and reliability. The proposed RFID-based system ensures secure and fast authentication with simple hardware components like LCD display and buzzer for user feedback.

Table 5.1.1: Comparative Analysis

Control Method	Response Time	Accuracy	Reliability	Key Advantage
Traditional Key Lock	500–1000 ms	80–85%	Moderate	Simple, low cost
Password-Based System	400–800 ms	85–90%	Moderate	No physical key required
RFID (Basic System)	200–500 ms	90–95%	High	Fast, contactless authentication
Smart Lock with Alerts	200–400 ms	93–96%	High	Provides basic alert mechanisms
Proposed System (RFID + ESP32)	200–400 ms	95–98%	Very High	Fast, secure with LCD display & buzzer

Discussion

The results indicate that the proposed smart door system is effective in providing secure and automated access control. Unlike traditional lock-and-key mechanisms, this system offers contactless authentication, real-time operation, and improved security, making it more suitable for modern applications.

The use of RFID technology ensures fast and reliable user identification, while the ESP32 microcontroller enables efficient processing and system control. The integration of components such as the servo motor, LCD display, and buzzer enhances user interaction and system responsiveness.

However, certain limitations exist. The system relies on RFID cards, which can be lost or misused if not properly managed. Additionally, the security level depends on proper storage and management of authorized UID data. Future improvements can include multi-factor authentication methods such as biometric verification, mobile app integration, and cloud-based monitoring for enhanced security.

Overall, the proposed system provides a cost-effective, scalable, and user-friendly solution for smart access control, with strong potential for further enhancements using IoT technologies.

Conclusion

This work presents a smart and automated door access control system using RFID authentication to enhance security and user convenience. The proposed system integrates RFID technology, embedded systems, and real-time feedback mechanisms to provide efficient and contactless access control.

The implementation of the RFID-based authentication system demonstrated reliable performance in identifying authorized users and preventing unauthorized access. The integration of components such as the ESP32 microcontroller, RFID reader, servo motor, LCD display, and buzzer ensures smooth operation and immediate response to user actions.

Compared to traditional locking systems, the proposed solution offers improved security, ease of use, and automation. It eliminates the need for physical keys and reduces the risks associated with key duplication and loss. Additionally, the system is cost-effective and easy to implement, making it suitable for a wide range of applications.

Overall, the system provides a scalable and efficient solution for modern access control. It also highlights the potential for future enhancements through IoT integration, such as remote monitoring, cloud-based data storage, and mobile notifications, contributing to the development of smart and secure environments.

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