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Research Article

Seamless Home Automation: Integrated Smart Security and Comfort Systems

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ABSTRACT

Introduction: Traditional home security systems often lack the capability for real-time remote monitoring, intelligent control, and timely alerts, making them vulnerable to break-ins and delays in emergency response. With the rise in smart home adoption and the need for affordable, automated solutions, the limitations of conventional door lock systems have become more evident. The growing demand emphasizes the need for a user-friendly, IoT-integrated system that enables efficient, secure, and responsive home protection.

Objectives: The primary objective of this project was to design and implement an IoT-based smart door locking system that combines real-time image monitoring, motion sensing, and remote control functionalities. The system aimed to enhance security, enable user interaction via a Telegram bot, and ensure energy efficiency through intelligent automation using low-cost and easily available components. The final goal was to deliver a cost-effective, reliable, and scalable smart home solution

Methods: The methodology of this project involves the systematic design, development, and testing of an IoT-enabled smart door lock system using ESP32 and related components. The process begins with hardware selection, where key components such as the ESP32-CAM module, solenoid lock, relay module, PIR motion sensor, and power supply units are chosen for their affordability, ease of use, and compatibility. The ESP32-CAM is programmed to connect to Wi-Fi and communicate with a Telegram bot, acting as the core controller for image capture and communication functions. The solenoid lock is controlled through a relay module, which acts as an electronic switch triggered by the ESP32-CAM based on commands received via Telegram.

Results: The experimental evaluation of the SecureShield smart door lock system demonstrated significant enhancements in home security through multiple integrated technologies. Real-time visual tracking via the ESP32-CAM enabled prompt image capture and transmission, providing users with immediate remote verification through the Telegram bot interface. The laser-based intrusion detection system successfully differentiated between legitimate access attempts and false alarms, ensuring reliable security monitoring.

Conclusions: In conclusion, the proposed smart door lock system using ESP32-CAM, solenoid lock, relay, and sensors offers an effective and affordable solution for home security. By integrating Telegram for communication, it enables real-time image capture, remote control, and motion detection alerts, enhancing user convenience and safety. The system's design balances functionality with cost-effectiveness, making advanced home automation accessible to a wider audience. This project highlights how IoT technologies can be harnessed to deliver reliable, user-friendly security solutions that surpass many existing commercial options.

Keywords: Smart home, home automation, motion sensors, ESP32-CAM, energy efficiency, mobile app, security.

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INTRODUCTION

Internet of Things (IoT) is revolutionizing numerous industries by connecting everyday devices to the internet, enabling real-time data exchange, automation, and remote control. Among its most impactful applications is smart home automation, which enhances convenience, security, and energy efficiency for homeowners. The growth of smart home technology is projected to accelerate, with an increasing emphasis on accessible, low-cost solutions that allow users to monitor and manage home security remotely. This paper presents a smart door lock system as a contribution to this rapidly evolving field, leveraging IoT technology to create a secure, efficient, and user-friendly solution.

The advent of microcontrollers like the ESP32 has been instrumental in making IoT applications accessible to hobbyists, students, and professionals alike. The ESP32 microcontroller, with its low power consumption, Wi-Fi connectivity, and robust processing capabilities, has emerged as a leading choice for IoT projects. Additionally, the ESP32-CAM module, which integrates a camera and Wi-Fi capabilities, allows for visual monitoring—a crucial feature in home security applications. By utilizing ESP32-CAM, this project provides a real-time, image-enabled solution that strengthens security measures at the entry point of a residence.

Furthermore, this system is designed with an emphasis on ease of use and installation. The primary components—the ESP32-CAM, solenoid lock, relay module, and PIR motion sensor—are chosen for their affordability, availability, and compatibility with open-source platforms. The solenoid lock, powered by a 12V power supply, provides a reliable physical locking mechanism, while the relay module allows safe switching and control of higher voltages required by the lock. The use of a 5V supply for the ESP32 cam ensures compatibility with typical microcontroller setups, providing a balance between security features and ease of power management.

This paper is organized as follows. Section II provides a comprehensive literature review, highlighting existing smart lock systems and discussing relevant studies on IoT-based security and communication protocols. Section III describes the components used in the project, covering the technical aspects of the ESP32-CAM, solenoid lock, relay, PIR motion sensor, and Telegram bot integration. Section IV outlines the system design and architecture, detailing the hardware and software setup and communication protocols. Section V discusses the implementation process, including code snippets, hardware assembly instructions, and Telegram bot configuration. Section VI presents the testing methodology and results, examining the system's reliability, latency, and responsiveness. Section VII discusses the advantages and limitations of the proposed system, while Section VIII concludes the paper and suggests avenues for future improvements, such as incorporating facial recognition for enhanced security.

OBJECTIVES

The main objective of this project is to develop a cost-effective and user-friendly IoT-based smart door lock system that enhances home security and convenience. This system is designed to allow users to remotely lock and unlock their doors using a Telegram bot, providing easy access control from any location with internet connectivity. An important feature of the system is the integration of the ESP32-CAM module, which captures real-time images of the entrance when motion is detected or upon user request, enabling visual monitoring to strengthen security. Additionally, the system includes a PIR motion sensor to detect human presence or inactivity, which is used to control lights automatically, thus improving energy efficiency. The use of Telegram ensures secure and encrypted communication between the user and the device, enhancing the reliability of remote interactions. The project aims to use low-cost and easily available components such as the ESP32, solenoid lock, and relay module, making it accessible and practical for everyday home users. Furthermore, the system is designed to be scalable, allowing for future upgrades such as facial recognition or integration with broader smart home automation platforms.

Ultimately, the project aims to deliver a reliable, secure, and practical solution that addresses common home security challenges while embracing the benefits of modern IoT technology.

METHODS

The methodology of this project involves the systematic design, development, and testing of an IoT-enabled smart door lock system using ESP32 and related components. The process begins with hardware selection, where key components such as the ESP32-CAM module, solenoid lock, relay module, PIR motion sensor, and power supply units are chosen for their affordability, ease of use, and compatibility. The ESP32-CAM is programmed to connect to

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Wi-Fi and communicate with a Telegram bot, acting as the core controller for image capture and communication functions. The solenoid lock is controlled through a relay module, which acts as an electronic switch triggered by the ESP32-CAM based on commands received via Telegram.

1. Power Consumption Analysis

Objective: Ensure the system operates efficiently within power constraints.

Components Power Calculations:

- ESP32-CAM Power Consumption:
  - Operating voltage: 5V
  - Current consumption: IESP32-CAM=200 mA
  - Power consumption:

PESP32-CAM=5V×0.2A=1 W

- Solenoid Lock Power Consumption:
- Operating voltage: 12V
- Current during lock activation: Ilock=1A
- Power consumption:

Plock=12V×1A=12 W

2. Wi-Fi Communication Latency Calculation

Data Transmission Time (TTT) Calculation:

T= Data Size (bits) / Bandwidth (bits/second)

For a typical image captured by ESP32-CAM (50KB):

- Data size: 50×1024×8 bits=409,600 bits
- Bandwidth (ESP32 Wi-Fi, 802.11b/g/n): ~5 Mbps (Megabits per second)

T= 409,600 bits / 5×10^6 bits/ second = 0.08192 seconds

3. Motion Detection Response Time

PIR Sensor Calculation:

- Detection Range: Adjustable between 3m and 7m.
- Signal Propagation Delay (td): Time for the signal to travel from the sensor to ESP32: negligible (< 1 ms).
- Processing Delay (tp): Time for ESP32 to process the signal: ~10 ms.

Total Response Time (Tr):

Tr= td + tp =1 ms+10 ms =11 ms

4. Reliability and Failure Rate Calculation (MTTF and MTBF)

Mean Time to Failure (MTTF): Average operational time before the system fails.

Given failure rate (λ): Assume λ=0.0001 failures/hour

MTTF=1 / λ= 1 / 0.0001= 10,000 hours

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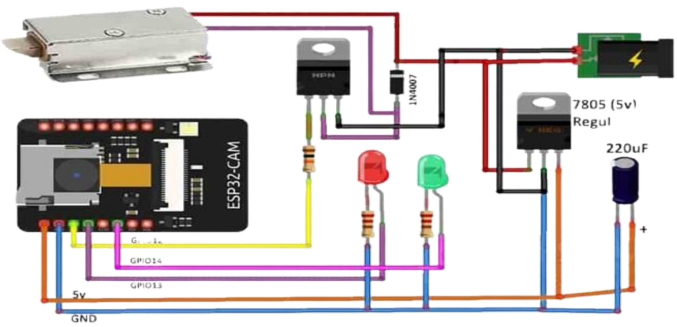
Mean Time Between Failures (MTBF): If repairs are possible:

MTBF=MTTF+MTTR (Mean Time to Repair)

Assume repair time is negligible; hence, MTBF ≈ MTTF = 10,000 hours.

SYSTEM ARCHITECTURE



IMPLEMENTATION

Step 1: Gather Components

1. ESP32-CAM module
2. Solenoid lock (12V)
3. Relay module (5V)
4. PIR motion sensor
5. Push button
6. Breadboard or prototype board
7. Jumper wires
8. 12V Power supplies
9. Resistors (for button pull-down if necessary)
10. Optional: LEDs for visual feedback

Step 2: Positioning the Components

Arrange the components on the breadboard or a prototype board in a layout that minimizes wire crossing.

Place the ESP32-CAM close together since they will communicate directly.

Position the relay module near the solenoid lock for short wiring.

Step 3: Wiring Connections

Solenoid Lock to Relay:

- Connect one terminal of the solenoid lock to the relay's normally open (NO) terminal.
- Connect the other terminal of the solenoid lock to the 12V power supply ground.
- Connect the common (COM) terminal of the relay to the 12V power supply positive.

Relay to ESP32 Cam:

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- Connect the relay control pin to a GPIO pin on the ESP32 Cam (e.g., GPIO 12).
- Connect the relay's VCC and GND pins to the ESP32 Cam's 5V and GND.

PIR Motion Sensor:

- Connect the VCC of the PIR sensor to the 5V power supply.
- Connect the GND of the PIR sensor to ground.
- Connect the output pin of the PIR sensor to another GPIO pin on the ESP32 (e.g., GPIO 13).

Push Button:

- Connect one terminal of the push button to a GPIO pin on the ESP32 (e.g., GPIO 2).
- Connect the other terminal to GND.
- Optionally, add a pull-down resistor between the GPIO pin and GND to ensure a stable signal.

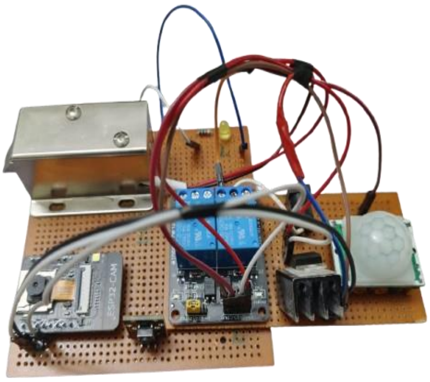
Optional LED Indicator:

- Connect an LED with a current-limiting resistor to another GPIO pin to provide visual feedback (e.g., GPIO 14 for indicating lock status).

Step 4: Power Up and Test Connections

Verify all connections before powering up the system.

Connect the 5V power supply to the ESP32 and the 12V power supply to the solenoid lock.



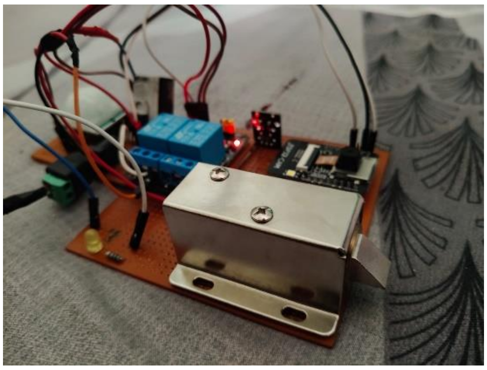


Fig . Solenoid Lock in Lock Position

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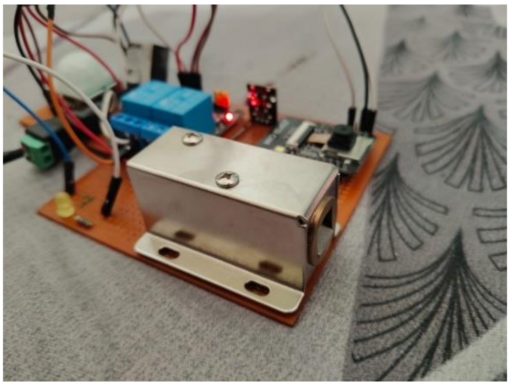

Fig . Solenoid Lock in Unlock Position

DISCUSSION

The proposed IoT-enabled smart door lock system successfully integrates multiple components—ESP32-CAM, solenoid lock, relay module, PIR motion sensor, and Telegram bot—to provide a secure, interactive, and remote-controlled access solution for home automation. The implementation of this system demonstrates how low-cost microcontrollers and open-source tools can be effectively used to build a practical security system for smart homes. By using the ESP32-CAM, the system not only allows users to control the door remotely but also provides real-time visual monitoring, which adds an essential layer of security by allowing homeowners to identify visitors before granting access.

One of the major strengths of the system is its use of the Telegram bot for communication. Telegram's secure and fast messaging infrastructure ensures real-time interaction between the user and the device. Users receive instant alerts, images, and can issue commands such as lock or unlock, all within a familiar mobile app. This approach eliminates the need for complex third-party applications or additional user interfaces, making the system highly user-friendly.

The PIR motion sensor adds value by enhancing automation. It detects motion near the door and triggers the ESP32-CAM to capture and send an image, and also controls lighting based on activity. This not only improves security but also contributes to energy efficiency by turning lights off during periods of inactivity.

Despite its many benefits, the system also presents certain limitations. The image quality of the ESP32-CAM may be affected in low-light conditions, which could hinder user identification. Additionally, the reliability of the system depends heavily on the stability of the internet connection; in areas with poor connectivity, performance may degrade. Security concerns such as unauthorized access or bot spoofing also exist and need to be mitigated through secure coding practices and possibly additional authentication layers.

Another consideration is the scalability of the project. While the current system is designed for a single door, future versions could support multiple entry points or integrate with other smart home systems like alarms, door sensors, or facial recognition modules for enhanced security. Power supply management is also critical—since different components require different voltage levels, a more compact and integrated power solution could improve safety and efficiency.

Overall, this project demonstrates a viable, affordable solution for smart home security. It shows how readily available components can be combined to build a responsive, feature-rich system that meets the growing demand for accessible smart home technologies.

REFRENCES

[1] H. E. K. Alazab, S. A. Khedher, M. A. F. Almuhammed, and M. F. G. Mohamed, "Internet of Things (IoT): Smart Home Systems Using ESP32," International Journal of Computer Applications, vol. 179, no. 38, pp. 24-30, Oct. 2018.
[2] D. S. S. Kumar, R. J. Leitao, and A. S. Da Silva, "Design and Implementation of an IoT-Based Smart Door Lock System," IEEE Access, vol. 9, pp. 387-396, 2021. DOI: 10.1109/ACCESS.2020.3035515.

[3] A. T. A. Dammak and M. H. S. Ali, “IoT-Based Smart Door Lock System Using ESP32 and Blynk,” International Journal of Advanced Computer Science and Applications, vol. 12, no. 9, pp. 502-508, 2021. DOI: 10.14569/IJACSA.2021.0120955.
[4] T. Pratama, Y. S. Warsono, and A. M. J. Suhadi, “Smart Locking System with ESP32 and Camera Module Based on Telegram Bot,” in 2020 3rd International Conference on Computer and Information Sciences (ICCIS), 2020, pp. 1-6. DOI: 10.1109/ICCIS49332.2020.9231225.
[5] S. B. Z. Abbas, Y. M. Tharwat, and R. N. D. F. Omar, “A Review of IoT-Based Security Systems for Smart Homes,” Journal of Information Security and Applications, vol. 58, pp. 1-9, 2021. DOI: 10.1016/j.jisa.2020.102786.
[6] R. S. Barik and P. A. K. Patil, “Design and Development of Smart Security System Using IoT,” International Journal of Innovative Technology and Exploring Engineering (IJITEE), vol. 8, no. 12, pp. 982-987, Oct. 2019.
[7] L. T. Hoang, V. H. Le, and T. H. Pham, “Development of a Smart Door Lock System Based on IoT Technology,” Journal of Electrical Engineering and Automation, vol. 3, no. 1, pp. 35-40, 2021. DOI: 10.26642/jeea-2021-1-035-040.
[8] Y. J. Lee, Y. R. Park, and J. M. Lee, “The Design of an IoT-Based Smart Door Lock Using RFID and Mobile Communication,” Wireless Communications and Mobile Computing, vol. 2019, 2019. DOI: 10.1155/2019/7197345.
[9] A. M. Saleh, “Smart Home Automation System Based on IoT: A Review,” International Journal of Advanced Research in Computer Science and Software Engineering, vol. 8, no. 10, pp. 1-6, Oct. 2018.
[10] S. Mukherjee and A. D. P. Tiwari, “Internet of Things (IoT) Based Smart Home Security System,” in Proceedings of the 2020 IEEE 2nd International Conference on Electronics and Communication Engineering (ICECE), 2020, pp. 9-14. DOI: 10.1109/ICECE48562.2020.9213731.
[11] M. A. Khan, A. S. K. N. K. S. A. Choudhury, and S. K. Sharma, “IoT Based Home Automation and Security System Using ESP32,” International Journal of Computer Applications, vol. 182, no. 33, pp. 17-22, Dec. 2018.
[12] N. C. L. G. R. R. K. H. Chhaya and J. D. P. Z. V. V. Thakkar, “Smart Lock System Using ESP32 and Mobile Application,” in 2021 International Conference on Smart Electronics and Communication (ICOSEC), 2021, pp. 1-5. DOI: 10.1109/ICOSEC49056.2021.9370440.
[13] V. B. N. and A. M. Ali, “IoT-Based Smart Door Security System with ESP32 and Camera,” Journal of Sensors, vol. 2021, 2021. DOI: 10.1155/2021/5543426.
[14] R. Arora, M. Gupta, and H. Jain, “Review on IoT-Based Smart Home Security Systems,” International Journal of Computer Applications, vol. 979, no. 9, pp. 1-6, 2020. DOI: 10.5120/21948-1031.
[15] P. P. R. V. Shankar and D. R. F. S. Satish, “Smart Home Security Using IoT with ESP32 and Telegram,” in 2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS), 2020, pp. 1-5. DOI: 10.1109/ICACCS48705.2020.9074406.