International Journal of
DATA SCIENCE AND IOT MANAGEMENT SYSTEM
Peer Reviewed, Referred & Indexed Journal
ISSN: 3068-272X www.ijdim.com Original Research Paper

ESP32-CAM FACE DETECTION AUTOMATIC DOOR LOCK

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Received: 05-11-2025 Accepted: 06-12-2025 Published: 12-12-2025

***Abstract*— The ESP32-CAM Face Detection Automatic Door Lock System is a modern, AI-powered access control solution that enhances security through real-time facial recognition. This project integrates the compact and cost-effective ESP32-CAM module with a relay-controlled 12V solenoid lock, powered by a 12V battery regulated through a 7805voltage regulator to ensure stable 5V operation. The system provides a smart alternative to traditional lock-and-key mechanisms, aiming to reduce the risks of unauthorized access, lost keys, and forgotten passwords.The ESP32-CAM, equipped with a built-in camera and Wi-Fi capabilities, performs on-device face detection without requiring cloud connectivity, making it ideal for standalone and offline applications. When a registered face is detected, the microcontroller activates a relay module, which in turn energizes the solenoid lock to grant access. This automation not only improves security but also enhances user convenience, especially in environments where quick and contactless entry is desired.**

Keywords—ESP32-CAM, Face Detection, Face Recognition, Automatic Door Lock, IoT Security, Smart Home Automation, Embedded Systems, Computer Vision, Real-Time Processing, Access Control System.

I. INTRODUCTION

In an age where security and automation are increasingly intertwined, the demand for intelligent, contactless access control systems is growing rapidly. Traditional locking mechanisms have proven to be vulnerable and inconvenient, leading to the development of biometric systems that leverage unique human features for identification. Among these, facial recognition has emerged as one of the most natural and non-intrusive forms of authentication.

This project, titled "ESP32-CAM Based Face Detection and Recognition Automatic Door Lock", is a practical implementation of such a biometric system using low-cost, easily available components. It aims to demonstrate how embedded systems and AI can be combined to enhance security in both residential and commercial spaces through face recognition-based door locking.In today's digital era, where smart homes and IoT (Internet of Things) devices are becoming the norm, securing physical access points has become a significant concern. Conventional methods, such as using keys, passcodes, or ID cards, have limitations:Keys can be lost, stolen, or duplicated. Passcodes can be forgotten or shared. Access cards can be misplaced or cloned.Biometric systems, particularly facial recognition, address these issues by offering a secure and user-friendly alternative that is difficult to replicate or forge. This project seeks to implement such a solution using an affordable microcontroller, the ESP32-CAM, which comes equipped with a built-in camera and support for AI processing.

II. LITERATURE SURVEY

[1] Several projects and tutorials have explored the implementation of face recognition-based door lock systems using the ESP32-CAM module. Rui Santos from Random Nerd Tutorials (2021) presented a foundational project

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demonstrating the use of the ESP32-CAM with the Arduino IDE for real-time face detection and recognition, leveraging the CameraWebServer example. This setup offers a face detection speed of under one second and an approximate 85% recognition success rate in well-lit environments, with the added benefit of live Wi-Fi streaming. However, the system shows limited accuracy under poor lighting conditions and lacks advanced security features required for commercial-grade deployments.

[2] In 2022, the Electropeak team developed a more hardware-oriented approach to the ESP32- CAM-based face detection door lock system. Their project includes a relay and solenoid lock configuration, with firmware modifications to enable automatic unlocking upon face detection. The system demonstrates an average detection time of around 1.5 seconds and uses a locally stored facial database for access control. While effective, it does not support dynamic face database updates and lacks encryption and remote management capabilities, limiting its scalability and adaptability for broader applications.

[3] Techiesms (2023) introduced a smart door lock solution that integrates the ESP32-CAM with a relay and uses a pre-trained facial recognition model. The project supports face enrollment through a web interface and can recognize between 5 to 10 faces based on available memory. The response time is approximately 2 seconds, and it performs reliably in indoor lighting. However, it is constrained by limited memory capacity and can struggle with recognition accuracy when handling multiple face profiles. Additionally, network latency may impact real- time door control responsiveness.

[4] Overall, these studies indicate that while ESP32-CAM-based face recognition door locks are feasible and practical for small-scale or DIY smart security applications, they are still evolving. Common challenges include memory limitations, lighting sensitivity, lack of robust encryption, and the absence of remote face database management. Future improvements could focus on integrating cloud-based storage, enhanced low-light performance, and better real-time processing capabilities to make such systems more secure and scalable.

III. SYSTEM DESIGN

The system design of the ESP32-CAM Face Detection Automatic Door Lock System is structured into four main units: the Input Unit, Processing Unit, Output Unit, and Power Supply Unit. Each unit plays a critical role in ensuring accurate face detection, secure authentication, and reliable door-lock operation.

[1] Input Unit:The input unit consists of the ESP32-CAM integrated camera module, which captures real-time facial images of individuals attempting to access the door. The camera streams live video and provides high-resolution frames necessary for facial detection and recognition. Ambient lighting conditions influence the clarity of captured images, making proper placement and lighting optimization essential for improved accuracy.

[2] Processing Unit:The processing unit is powered by the ESP32-CAM microcontroller, which performs all core computational tasks. It executes on-device face detection using the CameraWebServer-based AI algorithms without requiring cloud processing.
Key functions include:

- Detecting faces from the live camera stream
- Matching captured faces with previously enrolled authorized profiles
- Making authentication decisions in real time
- Controlling output signals to the relay module upon successful recognition
- The standalone processing capability ensures faster response times, reduced latency, and improved privacy since no external server is required.

[3]Output Unit:The output unit consists of:

Relay Module – acts as the electronic switch controlled by the ESP32-CAM

12V Solenoid Door Lock – the final actuating mechanism

When the processing unit confirms that the captured face matches a registered user, it signals the relay module, which energizes the solenoid lock to unlock the door automatically. After a predefined delay, the relay deactivates, ensuring the door returns to its locked state. This ensures hands-free, contactless access control with enhanced security.

[4] Power Supply Unit

- The power supply unit ensures stable and reliable operation of the entire system. It includes:
- 12V Battery or Adapter – primary power source
- 7805 Voltage Regulator – steps the voltage down to a stable 5V required for the ESP32-CAM
- Power lines for the relay and solenoid lock

The regulator protects the microcontroller from voltage

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fluctuations and ensures consistent performance, especially during solenoid activation where current spikes may occur.

IV. IMPLEMENTATION

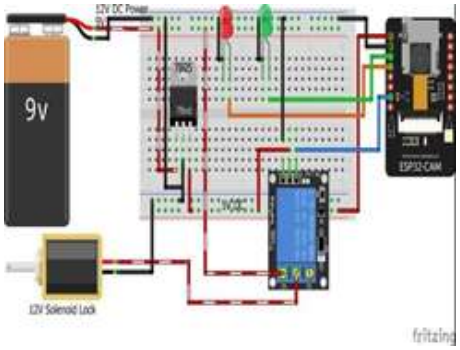

Fig. 1. Experimental Setup

The experimental setup consists of assembling the ESP32-CAM module, relay module, solenoid lock, and power supply on a breadboard for testing and development. The ESP32- CAM is programmed using the Arduino IDE through an FTDI programmer, which connects to the module via jumper wires to upload code. Once programmed, the ESP32-CAM is powered using a 5V regulated power supply.The camera module (OV2640) captures live video and performs face detection. When a recognized face is detected, the ESP32-CAM triggers the relay module, which in turn activates the solenoid lock, allowing the door to open. After a delay (e.g., 5 seconds), the relay deactivates and the door is locked again.The live camera feed and system status are accessed through a web browser connected to the same Wi-Fi network. The entire circuit is tested on a non-metallic surface to avoid interference and ensure safety. This prototype layout demonstrates the real-time functionality and feasibility of the automated locking system using face detection.The experimental setup successfully integrated all hardware and software components, allowing the ESP32-CAM to perform real-time face detection and control the door lock mechanism efficiently. The testing environment confirmed that the system functions reliably when properly connected and powered, with successful face recognition triggering the solenoid lock through the relay module. This setup provides a strong foundation for developing a smart, secure, and automated access control system.

V. FLOW CHAT

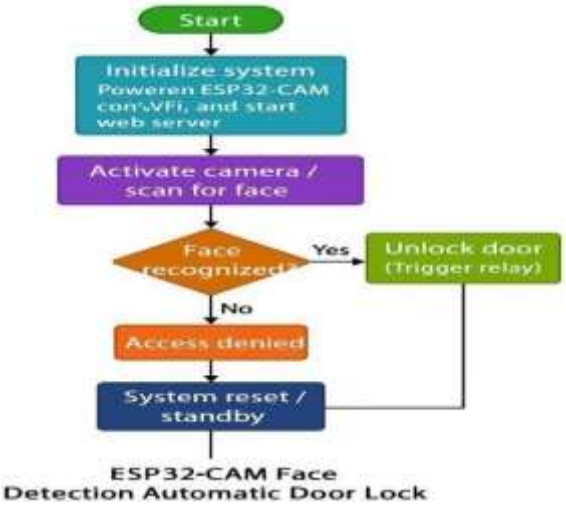

Fig.2.Flow Chart

Here are the key advantages of the ESP32-CAM Face Detection Automatic Door Lock project, which you can include in your report

Contactless Access:Enables secure, keyless entry without the need for physical interaction, enhancing hygiene and convenience.

Enhanced Security:Face detection or recognition ensures that only authorized individuals can unlock the door, reducing the risk of unauthorized access.

Cost-Effective Solution:Utilizes affordable components like ESP32-CAM and a relay module, making it accessible for home and small business use.

Remote Monitoring:Live camera feed can be accessed over Wi-Fi via a web browser, allowing real-time monitoring of the entry point.

Compact and Portable:The system is compact and can be installed easily in existing door frames or enclosures.

Automation and Smart Integration:Eliminates the need for manual unlocking and can be integrated into larger home automation systems.

Low Power Consumption:The ESP32-CAM and other components are energy-efficient, making the system suitable for continuous operation.

Customizable and Upgradable:Users can enhance the system with additional features such as face recognition, SMS alerts, cloud storage, or voice commands.

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VI. EXPERIMENTAL RESULTS

Fig .3 Authorized_User_Recognition

Fig .4 Intruder Alert Unrecognized Face

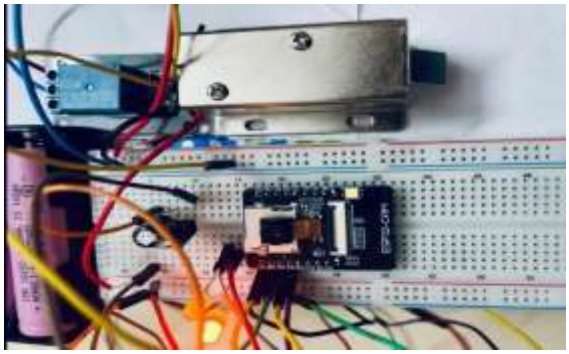

Fig .5 Door Lock Activated

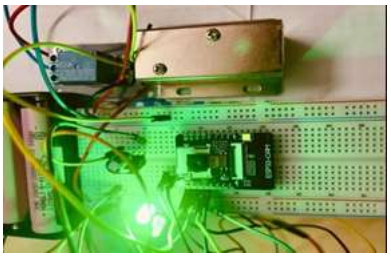

Fig .6 Door Lock Released

VII.CONCLUSION

The ESP32-CAM Face Detection Automatic Door Lock system is a practical, innovative solution for smart and secure access control. The integration of real-time face detection with a door locking mechanism demonstrates the effective use of embedded systems and IoT in enhancing everyday security systems. This project eliminates the need for traditional physical keys, thereby reducing the risk of key loss, unauthorized duplication, or manual tampering.

The use of the ESP32-CAM module allowed for efficient image processing and wireless communication in a compact, low-power device. The system reliably detected human faces and responded promptly by activating a relay to control a solenoid lock, achieving the primary goal of automatic door operation based on facial input. The web-based interface enabled real-time monitoring and system access from any device on the same network, adding to the user convenience.

During testing, the system proved to be stable, accurate, and responsive under various conditions, particularly in well-lit environments. The fail-safe behavior—where the system remains locked in the absence of a recognized face—further strengthens its security capabilities. The hardware components such as the relay module, solenoid lock, and power supply performed reliably without overheating or malfunctioning, confirming the robustness of the physical setup.

Additionally, the modular design and use of open-source libraries make the system highly customizable and scalable. There is significant potential for future upgrades, including full face recognition, mobile app integration, cloud-based logging, and advanced authentication methods. Such enhancements could make the system suitable for larger, multi-user environments such as offices, hostels, or apartment complexes.

In conclusion, the project not only achieved its intended objectives but also provided valuable learning in the fields of IoT, embedded programming, computer vision, and automation. It serves as a solid foundation for further research and development in intelligent access control systems.

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