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FACE RECOGNITION BASED AUTOMATIC DOOR ACCESS AND ATTENDANCE SYSTEM USING ESP32

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Abstract - In the era of smart automation and enhanced security systems, facial recognition technology has emerged as a reliable and efficient solution for access control applications. Despite the availability of traditional security mechanisms such as keys, RFID tags, and biometric fingerprint systems, these approaches often face limitations including susceptibility to theft, duplication, unhygienic contact-based authentication, and higher costs. To address these challenges, this project presents the design and implementation of a Face Recognition-Based Automatic Door Open and Close System using the ESP32-CAM microcontroller.

The proposed system offers a cost-effective, compact, and efficient alternative by leveraging the capabilities of the ESP32-CAM module, which integrates a high-resolution camera, Wi-Fi, and Bluetooth connectivity on a single platform. The system is programmed to capture the face of a person at the door and employs built-in real-time face detection and recognition algorithms to authenticate users. The detected face is compared against a pre-stored dataset of authorized individuals. Upon successful authentication, the ESP32-CAM activates a servo motor or electronic lock to open the door, which subsequently closes automatically after a preset delay, thereby improving both convenience and security.

In addition to on-device processing, the system supports remote access and updates through Wi-Fi connectivity, allowing administrators to seamlessly add or remove users via a secure web interface. This enhances adaptability in dynamic environments such as residential complexes, corporate offices, and institutional campuses. The design emphasizes low power consumption, minimal hardware requirements, and efficient data processing, making it practical for real-world deployment.

The novelty of this work lies in its integration of affordable embedded hardware with intelligent access control, eliminating the dependency on physical keys, RFID cards, or third-party biometric systems. Moreover, the system provides a contactless and hygienic access solution, particularly relevant in the post-pandemic era where touchless authentication has become increasingly important. This project demonstrates the feasibility of combining embedded programming, image processing, IoT communication, and automation control into a unified prototype for secure access management. Future enhancements may include cloud-based user databases, mobile app notifications, integration with AI-driven anomaly detection, and blockchain-enabled authentication to strengthen system robustness, scalability, and data privacy. The proposed system contributes toward the vision of smart, sustainable, and user-friendly access control infrastructures for modern society.

The developed prototype has been successfully designed, implemented, and tested under real-time conditions, where it consistently demonstrated accurate face recognition, quick response times, and reliable door operation. Unlike many conceptual models that remain limited to simulation or theoretical frameworks, this system has been physically realized and proven to function effectively in practice. Its ability to operate continuously with low latency and minimal hardware requirements ensures that it can be directly integrated into everyday use without significant modifications. Thus, this project not only establishes a proof of concept but also validates the feasibility of real-time application, bridging the gap between academic research and practical implementation. The prototype demonstrates that smart, secure, and contactless access management can be achieved using open-source hardware and software, paving the way for widespread adoption of IoT-enabled security systems in modern society.

Keywords: ESP32 CAM, Camera Module, PIR Sensor, Servo Motor, Display.

1. INTRODUCTION

In today's rapidly evolving technological environment, the integration of automation into daily life has become indispensable, transforming the way people live, work, and interact with their surroundings. From residential complexes and educational institutions to corporate offices and industrial facilities, automation offers the dual advantages of improved convenience and enhanced security. Among the many areas influenced by this shift, door access control systems have undergone a notable transformation. Access to secured spaces has traditionally been managed through mechanical keys, RFID cards, or PIN-based security systems. While these solutions have served their purpose for decades, they present inherent shortcomings such as the risks of theft, duplication, unauthorized access, and in some cases, inconvenient user interaction. In light of these challenges, there is a clear demand for more intelligent, secure, and contactless solutions that can adapt to modern requirements.

The limitations of traditional methods became even more apparent during the COVID-19 pandemic, when hygiene concerns surrounding frequently touched surfaces highlighted the need for contactless authentication mechanisms. Mechanical keys can be misplaced, duplicated, or stolen, posing significant security risks, while access cards and PIN codes can be shared or hacked, weakening their reliability. Moreover, conventional attendance management systems, whether based on manual registers or fingerprint scanners, remain time-consuming, error-prone, and inefficient. These issues collectively underscore the necessity for a more advanced access control solution that not only ensures security but also prioritizes convenience, hygiene, and efficiency.

One of the most promising developments in this domain is biometric authentication, which offers a reliable and accurate method of identity verification. Among the various biometric techniques available, facial recognition has emerged as a leading choice. Unlike fingerprint or iris scanning, which require direct user interaction, face recognition is completely contactless and non-intrusive, making it both hygienic and user-friendly. Modern algorithms are capable of detecting and verifying individuals in real time with high accuracy, even under varying environmental conditions. Its ability to integrate seamlessly into daily workflows while maintaining robust security standards makes it particularly suitable for environments where both security and ease of access are essential.

The growing influence of the Internet of Things (IoT) further enhances the potential of face recognition systems. IoT enables connectivity, real-time communication, and smart decision-making among devices, making it possible to build intelligent access control environments. By combining IoT with biometric authentication, door operations can be automated based on the authenticated identity of individuals, creating seamless and adaptive smart environments. In this context, the ESP32-CAM module has gained significant attention due to its compact size, low cost, and powerful features. Equipped with an onboard camera, built-in Wi-Fi and Bluetooth connectivity, and sufficient processing capabilities, the ESP32-CAM can handle real-time image capture, face detection, and recognition on a single embedded platform without relying on expensive external servers. This affordability and versatility make it a practical choice for small- to medium-scale applications such as homes, offices, classrooms, and laboratories.

To further improve usability, the system can be enhanced with the integration of a Passive Infrared (PIR) sensor, which detects human motion. While the face recognition module ensures secure entry from outside, the PIR sensor enables automatic door opening from inside, allowing individuals to exit the room hands-free. This feature not only enhances convenience but also makes the system more inclusive for elderly users, children, and individuals with physical disabilities. Thus, the combination of ESP32-CAM for facial recognition and PIR sensor for motion detection creates a comprehensive access control system that balances security, convenience, and inclusivity.

An important extension of such a system is its application in attendance management and access logging. In many organizations, attendance tracking remains a manual or semi-automated process that is prone to errors, inefficiencies, and delays. By integrating the access control system with a mobile application or cloud platform, each entry and exit can be recorded automatically, complete with timestamps. Administrators can monitor access logs in real time, thereby improving both security oversight and attendance tracking in institutions such as schools, universities, offices, and research laboratories. This automation significantly reduces the administrative burden, eliminates manual errors, and provides reliable data for performance monitoring and resource management.

The objectives of the proposed research are thus threefold: first, to design and implement a face recognition-based door access control system using the ESP32-CAM module; second, to enhance user experience and operational efficiency through the integration of a PIR sensor for motion-based exit; and third, to develop a mobile application interface that enables real-time attendance monitoring and remote management. Collectively, these objectives aim to provide a cost-effective, secure, and user-friendly system that addresses the shortcomings of existing access control methods.

The scope of the project is focused on small- to medium-scale applications where convenience and security are priorities but where high-end, enterprise-level infrastructure may not be feasible. Examples include residential homes, classrooms, offices, and laboratories. While the system effectively integrates face recognition, IoT-based connectivity, and attendance management, it does not extend to advanced features such as large-scale multi-door integration, high-end server-based image processing, or advanced encryption protocols suitable for military or government-grade security environments. Instead, the emphasis is on delivering a practical, affordable, and deployable solution tailored to common real-world needs.

The system architecture revolves around the ESP32-CAM module, which serves as the core processing unit. The device continuously captures video frames at the entry point and performs local face detection and recognition. Upon successful authentication, a signal is sent to the door's actuation mechanism—such as a servo motor or an electronic lock—to grant access. Unauthorized individuals are denied entry, ensuring that only authenticated users can access the secured area. On the other hand, when motion is detected inside the room by the PIR sensor, the door automatically opens to facilitate hands-free exit. A mobile application interface provides remote access to logs, allowing administrators to view entry and exit records in real time. This integration creates a closed-loop access and monitoring system that balances performance, cost, and user experience.

In summary, the proposed Face Recognition-Based Automatic Door Access System leverages biometric authentication, IoT integration, and embedded system capabilities to address the shortcomings of traditional access methods. By employing the ESP32-CAM module and PIR sensor, the system ensures secure, contactless entry and exit, while its mobile application interface extends functionality to include real-time attendance tracking and remote monitoring. The solution is designed to be cost-effective, energy-efficient, and easy to deploy, making it highly suitable for small to medium-scale environments. Through this research, the project contributes toward the development of intelligent, secure, and user-centric access control systems that align with the evolving needs of the modern world.

2. LITERATURE REVIEW

Hteik Htar Lwin et al. proposed an automatic door access system using face recognition, showing its superiority over traditional methods like keys or RFID cards. Later studies integrated IoT with facial recognition for remote monitoring , while others combined it with RFID or PIN for stronger security. Recent works highlight the use of low-cost modules like ESP32-CAM for real-time detection and PIR sensors for motion-based automation. Despite these advancements, challenges such as lighting variations and data privacy still persist **[1].**

Sadeque Reza Khan et al. developed a low-cost home security system using the GSM network, emphasizing affordability and accessibility for residential users. Their system enabled real-time communication between the security device and the user through SMS alerts, thereby ensuring quick response during unauthorized access attempts. Unlike expensive surveillance setups, this GSM-based approach provided a practical solution for developing regions with limited infrastructure. However, while effective in terms of cost and communication reliability, the system's dependence on GSM networks introduced challenges such as coverage issues and slower response compared to modern IoT-enabled security frameworks **[2].**

B. Udaya Kumar et al. proposed a low-cost home security system using an Ethernet-based wireless sensor network, focusing on real-time monitoring and communication. The system utilized interconnected sensors to detect unauthorized activities and transmitted alerts over Ethernet, ensuring faster data transfer and reliability compared to GSM-based approaches. By leveraging wireless sensor networks, the design provided scalability and flexibility in deployment. However, the reliance on Ethernet limited its applicability in areas lacking proper network infrastructure, making it less adaptable than emerging IoT-based solutions **[3].**

Sandesh Kulkarni et al. proposed a door lock management system based on face recognition to enhance security and convenience by replacing traditional keys with biometric authentication. Their system utilized image processing techniques to identify and verify users, ensuring that only authorized individuals could access secured areas. While effective in providing a user-friendly and keyless solution, the system's performance was influenced by environmental factors such as lighting variations and camera quality, highlighting the need for more robust algorithms to improve reliability in real-world applications **[4].**

Zhong et al introduced S Face, a novel face recognition method employing Sigmoid-Constrained Hypersphere Loss to enhance robustness and accuracy. Their approach effectively addressed challenges such as variations in pose, illumination, and occlusion by improving feature discrimination in high-dimensional space. The method demonstrated superior performance compared to traditional loss functions, making it highly suitable for real-world applications requiring reliable and secure identity verification **[5].**

Garvin discussed the development of automatic door and window control systems designed specifically for individuals with disabilities, emphasizing accessibility and ease of use. The study highlighted how automation technology could significantly improve independence and mobility for disabled users by reducing reliance on physical effort or assistance. While the focus was primarily on enhancing convenience and inclusivity, the work also laid an early foundation for integrating automation into modern smart home and security systems **[6].**

Garvin examined domestic automatic door and window control systems aimed at improving accessibility for elderly and disabled individuals. The report emphasized the role of automation in enhancing safety, convenience, and independent living by reducing physical barriers in everyday activities. It provided practical insights into design considerations, usability, and reliability, making it a valuable early contribution to the integration of assistive technologies within residential environments **[7].**

Jain, Ross, and Prabhakar provided a comprehensive introduction to biometric recognition, outlining the fundamental concepts, methodologies, and applications of biometric systems such as fingerprint, face, and iris recognition. The study highlighted the advantages of biometrics over traditional authentication methods, emphasizing their reliability, security, and resistance to impersonation. It also discussed key challenges, including accuracy, scalability, and privacy concerns, thereby laying the groundwork for advancements in biometric-based security systems **[8].**

Zhao, Chellappa, Phillips, and Rosenfeld presented a comprehensive survey of face recognition research, reviewing techniques ranging from appearance-based methods to 3D modeling and statistical approaches. The study analyzed challenges such as variations in illumination, pose, expression, and occlusion, while also highlighting performance evaluation standards and benchmark datasets. Their work served as a foundational reference, offering a critical overview of progress and limitations in face recognition, and guiding future research directions in developing more robust and reliable systems **[9].**

Turk and Pentland introduced the Eigenfaces method for face recognition, which employed principal component

analysis (PCA) to extract key facial features and represent them in a reduced-dimensional space. Their approach demonstrated how faces could be efficiently recognized by projecting images into an eigenface space and comparing feature weights, significantly reducing computational complexity. This pioneering work laid the foundation for appearance-based face recognition systems and remains one of the most influential contributions in the field, inspiring subsequent advancements in biometric identification **[10].**
The OpenCV Library is a widely used open-source computer vision and machine learning framework that provides a comprehensive set of tools for real-time image and video processing. Its extensive collection of algorithms supports applications such as object detection, face recognition, motion tracking, and image filtering, making it highly adaptable for research and industrial use. Due to its cross-platform compatibility and active community support, OpenCV has become a fundamental resource for developing efficient and scalable computer vision-based systems, including intelligent security and access control applications **[11].**
The ESP32-CAM Development Board Technical Reference Manual provides detailed insights into the hardware and software features of the ESP32-CAM, highlighting its low-cost, low-power design with integrated Wi-Fi, Bluetooth, and camera support, making it highly suitable for embedded vision and IoT-based security systems. Complementing this, Li and Jain's Handbook of Face Recognition (2011) presents a comprehensive overview of face recognition technologies, covering theoretical foundations, algorithms, and practical applications. Together, these resources underline the synergy between advanced embedded platforms and robust biometric recognition methods for developing intelligent, efficient, and reliable security solutions **[12].**
Lawrence et al. (1997) introduced one of the first applications of convolutional neural networks (CNNs) for face recognition, demonstrating their ability to learn hierarchical features directly from images. Their approach outperformed traditional methods like eigenfaces, showing greater robustness to variations in expression, lighting, and orientation, and laying the foundation for modern deep learning–based face recognition **[13].**

3. METHODOLOGY

The methodology adopted for this project emphasizes a structured and systematic approach to the design, development, and implementation of a facial recognition–based door access automation system using the ESP32-CAM module. The primary objective of this methodology is to ensure that the system operates with high efficiency, reliability, and security by integrating hardware components with intelligent software algorithms in a real-time embedded environment.
This chapter outlines the approach taken to achieve the project objectives, beginning with image acquisition and face recognition, followed by access decision-making, motor actuation, web application integration, and overall system evaluation. The methodology is built on modular principles, allowing each functional unit—such as face detection, face matching, servo motor control, and the web interface—to be developed and tested independently before being integrated into the complete system.
At the core of the proposed design lies the ESP32-CAM, which serves as both the processing unit and the control hub. It performs tasks such as image capturing, feature extraction, template matching, and decision-making, while also managing hardware components like the servo motor and communication with the web application. By hosting a lightweight local web server, the ESP32-CAM additionally provides features such as user enrollment, system monitoring, and attendance logging.
An incremental development strategy has been followed to ensure effective testing, debugging, and optimization of each module. This approach not only increases system reliability but also makes it easier to upgrade or scale the project in the future. Each stage of the methodology has been carefully designed to address specific functional requirements, ranging from capturing facial data and executing recognition tasks to controlling access decisions and maintaining secure operation.

3.1 Camera Module (Face Capture)

The process begins with the ESP32-CAM's integrated camera module, which continuously monitors the entrance area. When an individual approaches, the camera captures a real-time image of the face. This image acts as the primary input for the recognition process. To achieve reliable performance, the system is designed to function under varying lighting conditions, ensuring consistent accuracy during both daytime and nighttime use. The placement of the camera is critical for optimal detection; it is generally mounted at face level and angled appropriately to cover the height range of most individuals. This ensures that the captured image is both clear and well-positioned for subsequent processing.

3.2 Face Detection and Recognition

Once the image is captured, the face detection module isolates the facial region from the background. Advanced machine vision algorithms are used to locate key features of the face, such as eyes, nose, and mouth. Following this, the recognition process extracts unique biometric patterns — including the distance between eyes, jawline shape, and nose structure. These features are then converted into a digital template, which is compared with pre-stored templates in the system's database.
The recognition task relies on machine learning or neural network-based models, trained to distinguish between

different faces with high accuracy. These models are robust enough to handle variations in facial appearance caused by glasses, masks, or slight changes in facial expressions. This stage forms the backbone of the system, ensuring that only authorized users are identified correctly while minimizing errors such as false positives or false negatives.

3.3 ESP32-CAM as Processing Unit

The ESP32-CAM microcontroller serves as the central processing unit of the system. This low-cost yet powerful device integrates Wi-Fi, Bluetooth, and the OV2640 camera, making it ideal for embedded vision applications. Apart from capturing images, the ESP32-CAM executes recognition tasks, manages stored data, and makes real-time decisions regarding access control.

The microcontroller retrieves facial data from its internal memory or from a connected database and performs matching operations instantly. It also controls other components, such as the servo motor for door operation and the web application for event logging. The availability of wireless communication enables seamless integration between local processing and remote monitoring, making the system more efficient and user-friendly.

4. DECISION POINT – AUTHORIZED VS. UNAUTHORIZED FACE

After processing the facial data, the ESP32-CAM evaluates whether the captured template matches any record in the database. This decision point determines the next action:

- **Authorized Face:** The system grants access unlocks the door, and logs the entry event.
- **Unauthorized Face:** Access is denied, and the attempt may be logged for security auditing.

To improve reliability, a confidence threshold is used during recognition. This ensures that matches are accurate and reduces the chances of errors, thereby enhancing the overall security of the system.

4.1 Authorized Face – Access Granted

When a match is confirmed, the ESP32-CAM recognizes the person as an authorized user. The system then activates the door-opening mechanism and simultaneously records the event in the database. The log includes details such as the user’s name, time of entry, and status.

This feature is particularly beneficial in academic and workplace environments, where the system doubles as an automatic attendance system. Students or employees can be marked present as soon as their face is recognized, eliminating the need for manual attendance-taking.

4.2 Unauthorized Face – Access Denied

If the system fails to find a match in its records, the individual is flagged as unauthorized. In such cases, the door remains locked. Additionally, the system can log the attempt, along with the image and timestamp, for future review. Depending on the configuration, an alert or buzzer may also be triggered to notify administrators of the failed attempt. This feature significantly strengthens the security aspect of the system by ensuring that only registered individuals gain entry.

4.3 Servo Motor Control (Door Operation)

Upon authorization, the ESP32-CAM sends a control signal to a servo motor, which acts as the actuator for the door mechanism. The servo motor is chosen for its precision, energy efficiency, and ease of digital control. It rotates to unlock the door and keeps it open for a predefined duration, or until a motion/proximity sensor confirms that the person has entered. This ensures smooth and reliable door operation without requiring manual effort.

4.4 Web Application Integration

An important extension of the system is its web application interface, which provides monitoring and logging capabilities. The application maintains a real-time database of registered users and their entry logs. It also supports remote access, allowing administrators to manage users and review records.

For academic institutions, this integration enables automatic attendance tracking, as students are marked present as soon as they are recognized by the system. The data can be stored locally or transmitted over Wi-Fi to cloud storage, where advanced dashboards and analytics can be implemented for better institutional management.

4.5 Person Entry

Once the door opens, the authorized user is allowed to enter. To prevent unauthorized tailgating or piggybacking, the system can be enhanced with motion or proximity sensors, which verify that only one person enters at a time. These sensors also reset the system timer, ensuring that the door remains open just long enough for safe passage. This step enhances both usability and security, maintaining a smooth flow of operation.

4.6 Automatic Door Closing

After the user has entered, the system automatically triggers the door to close. This is managed by either a timer circuit or a software-based routine within the ESP32-CAM. The servo motor rotates back to lock the door, and optional feedback sensors confirm successful closure. Automatic door closing prevents the door from being left open accidentally, thereby maintaining security and conserving energy in controlled environments.

This structured methodology ensures that each functional block of the system is designed, tested, and validated in a systematic manner before integration. By leveraging the ESP32-CAM for both image processing and control, the system achieves low latency, improved data privacy, and reduced dependency on external services. The modular and step-by-step approach not only simplifies testing and debugging but also enhances scalability for future improvements such as multi-user support, cloud integration, or advanced security features. Overall, this methodology provides a strong foundation for developing a reliable, efficient, and user-friendly facial recognition–based door automation system.

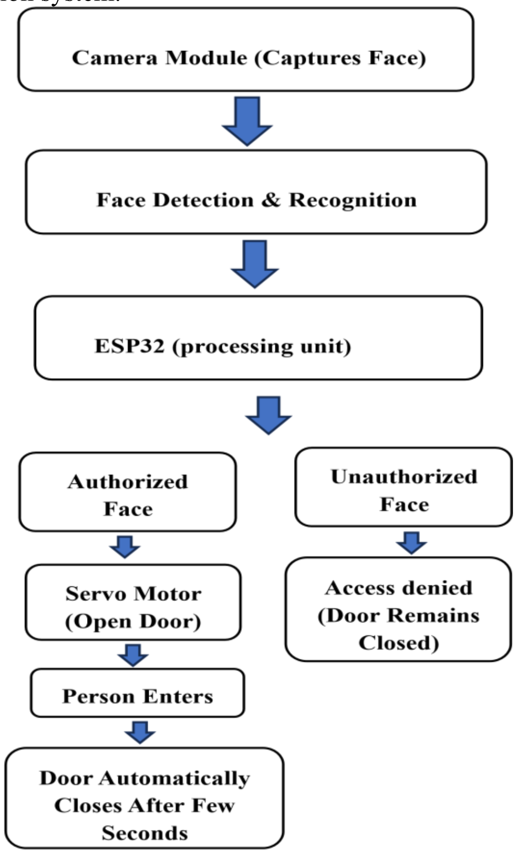

Fig. 4.1 Block Diagram

5. RESULT AND DISCUSSION

The proposed Face Recognition–Based Automatic Door Access and Attendance System was successfully designed, implemented, and tested. The results obtained during the evaluation of the system are presented in this section. The discussion highlights hardware setup, software initialization, access control flow, attendance management, exit mechanism, overall performance, and future scalability of the system.

5.1 Project Setup and Initialization

The prototype system consists of three primary hardware components: the ESP32-CAM module, a Passive Infrared (PIR) sensor, and a servo motor. The ESP32-CAM, chosen for its integrated camera and Wi-Fi capabilities, performs both image acquisition and face recognition. The PIR sensor enhances system usability by detecting user motion, while the servo motor provides reliable control of the door lock mechanism.

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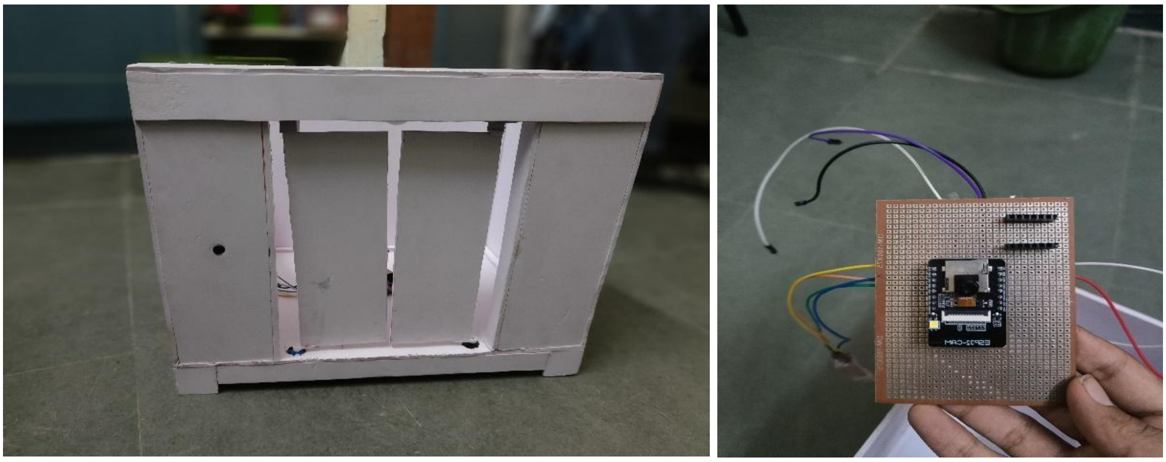

Fig. 5.1 ESP 32 Cam and Working Model

On the software side, the ESP32-CAM was programmed using the Arduino IDE. The required libraries for face recognition, camera interfacing, and server communication were successfully installed. The module was connected to a Wi-Fi network, enabling real-time face detection and attendance data transmission. During testing, the serial monitor output confirmed correct code upload and successful network configuration.

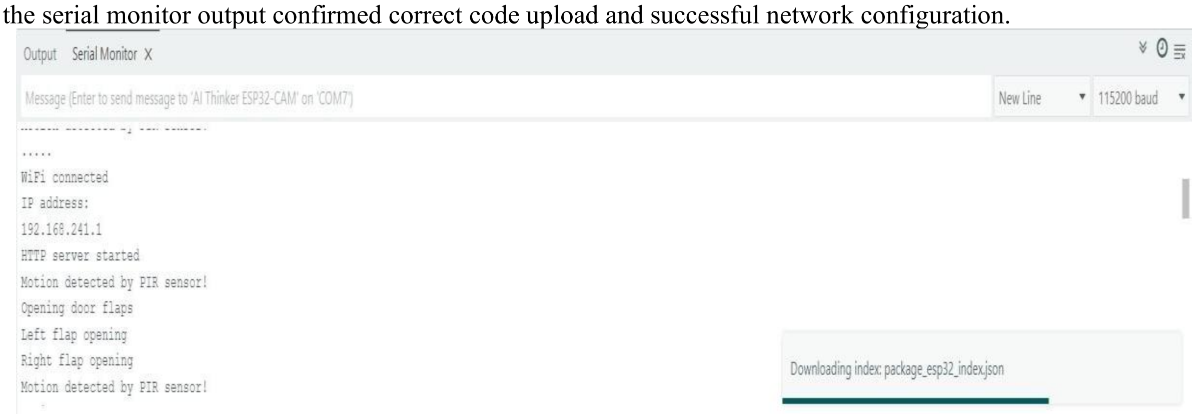

Fig. 5.2 Arduino IDE with Code Upload and Successful Serial Monitor Output

5.2 Face Recognition and Access Control Flow

The face recognition process is initiated when a person stands in front of the ESP32-CAM. The module captures the individual's face image and compares it with the stored dataset. If a match is found, the access-grant sequence is triggered, during which the servo motor rotates to unlock the door. A confirmation message is displayed on the server interface, ensuring both physical and digital acknowledgement of successful authentication.

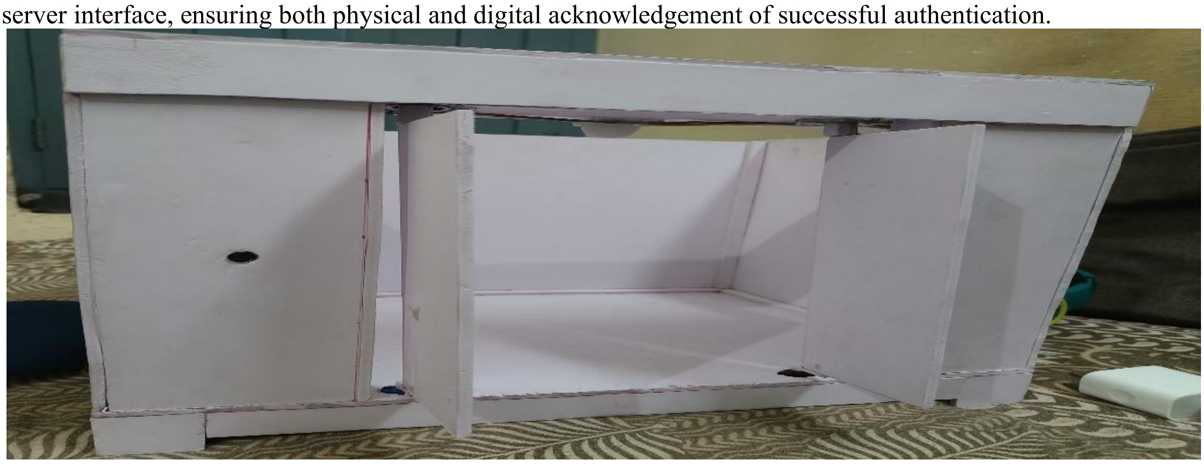

Fig. 5.3 The Servo Motor Rotating and The Door Opening

In the case of unregistered or unauthorized individuals, the system triggers the access-denied sequence. Here, the servo motor remains in its locked state, while the web server interface displays a warning or error message indicating unauthorized access. This dual-mode control ensures robust access security and minimizes the risk of false acceptance.

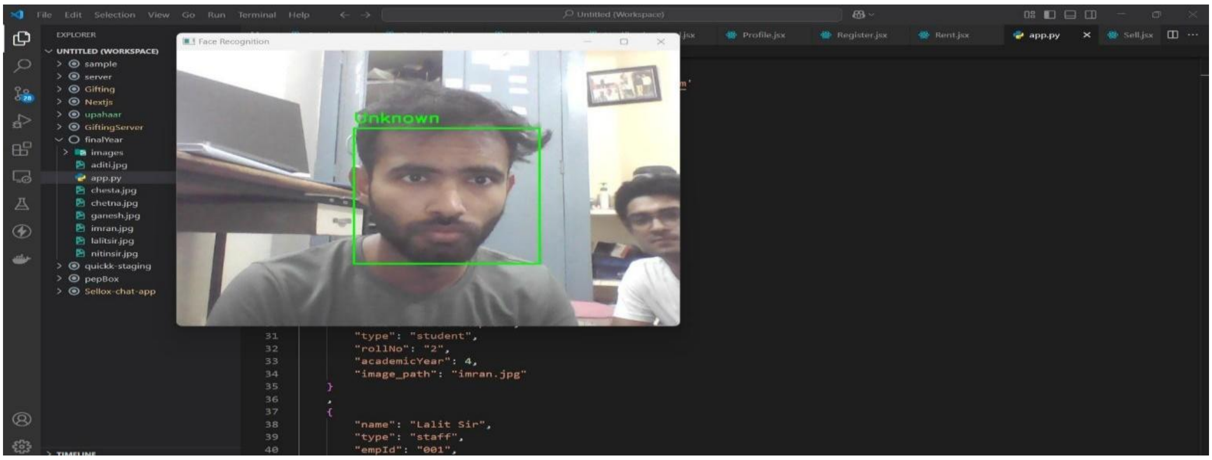

Fig. 5.4 Photograph of The Access Denied State and Error Message Display Unknown

5.3 Attendance Logging and Data Storage

In addition to secure access control, the system automatically records attendance whenever a registered user is recognized. Each successful recognition event is logged with a timestamp, and the data is transmitted over Wi-Fi to a cloud server for real-time monitoring. Administrators can view and manage the records through a web-based interface, which provides structured logs and enables easy retrieval of attendance data. This eliminates the need for manual attendance marking, improving both accuracy and efficiency.

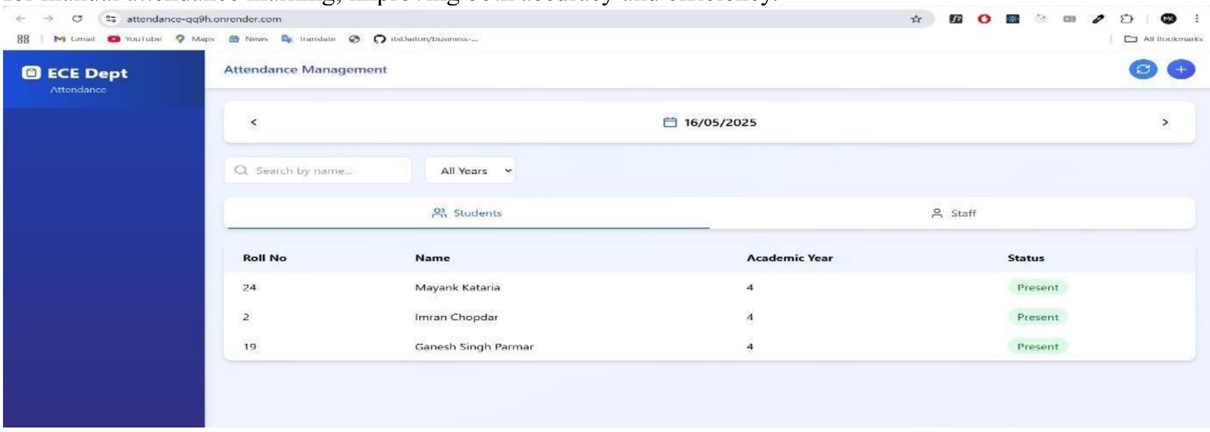

Fig. 5.5 The Web Interface Displaying Attendance Logs

5.4 Exit Mechanism Using PIR Sensor

To simplify user exit while maintaining security, a PIR sensor was integrated into the system. When motion is detected from inside the secured room, the PIR sensor triggers the servo motor to open the door automatically. Unlike entry, no face recognition is required for exit. This design ensures a smooth and user-friendly egress process, while the entry path remains strictly controlled through face recognition. The dual-mode mechanism thus balances convenience and security effectively.

5.5 Overall System Performance and Observations

During experimental evaluation, the prototype system demonstrated high accuracy in face detection under well-lit conditions, with reliable recognition of registered users. The servo motor provided consistent door control, and the PIR-based exit mechanism improved usability without compromising security.

The attendance logging feature performed efficiently, with real-time updates visible on the cloud-based web interface. The latency between face recognition and data entry into the cloud database was approximately **1–2 seconds**, which is acceptable for institutional and office applications.

Overall, the system provides three major advantages:

- **Contactless Authentication** – reducing hygiene concerns and minimizing physical contact.
- **Automated Attendance Management** – integrating access control with attendance logs to streamline record-keeping.
- **Cloud Connectivity** – enabling scalability, remote monitoring, and analytics through dashboards and reporting tools.

However, certain limitations were observed. Recognition accuracy decreases under low-light conditions or when the face orientation deviates significantly. Moreover, occasional network delays affected the speed of cloud synchronization. These limitations can be addressed in future versions by integrating infrared cameras, edge AI accelerators for faster recognition, and multi-factor authentication methods (e.g., RFID + Face ID).

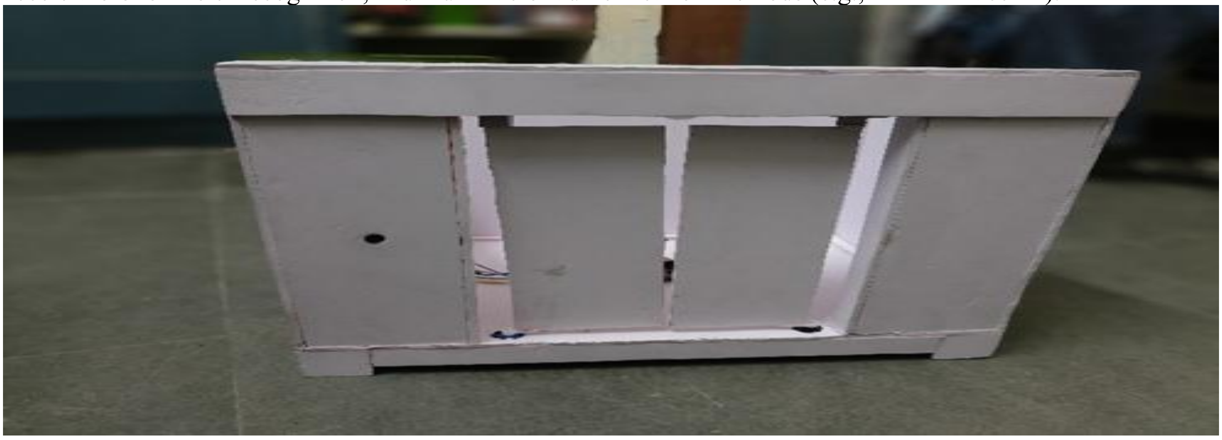

Fig. 5.6 Overall Working Model

5.6 Prototype Validation and Future Scope

It is important to highlight that the current design represents a working prototype. The system has been validated in real-time conditions and has shown reliable performance in providing automated, contactless door access and attendance management. Given its successful operation at the prototype level, the system can be scaled for large-scale deployment in academic institutions, offices, residential complexes, and high-security environments. With the integration of robust hardware and advanced recognition algorithms, the system has the potential to evolve into a commercial-grade solution capable of managing thousands of users while maintaining speed, reliability, and security.

CONCLUSION

The research and successful implementation of the Face Recognition–Based Automatic Door Access and Attendance System using ESP32 demonstrates the potential of combining biometric technology with IoT and embedded systems to deliver secure, intelligent, and automated solutions. Unlike traditional methods such as manual registers, RFID cards, or password-based access, the proposed system provides a contactless, reliable, and efficient approach that addresses the shortcomings of conventional techniques.

The system employs the ESP32-CAM module to capture and recognize faces in real time, unlocking the door for authorized individuals while simultaneously recording their attendance. Unauthorized attempts are denied, ensuring secure access. This dual functionality makes the system particularly suitable for environments where both security and attendance tracking are equally important, such as academic institutions, workplaces, hostels, and residential complexes.

A key strength of the system lies in its contactless authentication, which is highly relevant in today's health-conscious environment. The ESP32 microcontroller further enhances the design with its low cost, compact size, built-in Wi-Fi, and sufficient computational capability for image processing and data transmission. The integration with cloud storage and a web interface enables remote monitoring, real-time updates, and long-term data management.

The system offers several practical benefits: enhanced security, automated attendance management, scalability, cost-effectiveness, and user convenience. At the same time, certain limitations remain, such as reduced recognition accuracy under poor lighting, slower performance with large databases, and vulnerability to advanced spoofing techniques. These challenges can be addressed in future work by integrating deep learning algorithms, anti-spoofing mechanisms, and multi-factor authentication methods (e.g., combining face recognition with RFID or voice recognition).

Overall, the study highlights that ESP32-based face recognition systems are a powerful, scalable, and affordable solution for modern access control and attendance management. With further refinement, optimization, and large-scale deployment, such systems can play a transformative role in schools, universities, offices, industries, and residential complexes. By uniting biometric accuracy, IoT connectivity, and automation, this work contributes meaningfully to the advancement of smart security and attendance systems, paving the way for future applications in smart cities and digital transformation.

Finally, it is important to note that the present work is a prototype developed and tested under controlled conditions, successfully demonstrating its feasibility and effectiveness. The same concept can be extended and deployed on a larger scale by integrating high-resolution cameras, cloud-based face databases, and advanced AI models, thereby enabling real-world implementation across wide networks of institutions and organizations. This scalability emphasizes that our prototype not only works in real-time conditions but also provides a strong foundation for future expansion into practical, industrial, and societal use cases.

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