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Laser-CAM Security using ESP32

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***Abstract*— This paper proposes a cost-effective and intelligent security system that integrates laser-based intrusion detection with facial recognition using the ESP32-CAM module. Traditional motion-based systems often suffer from false alarms triggered by non-threatening movements. Our approach addresses this limitation by introducing a dual-layer verification mechanism. The system uses a laser beam projected onto a Light Dependent Resistor (LDR) to detect physical interruptions, followed by real-time facial recognition to validate identity. Upon detecting an unauthorized individual, the system triggers both a local buzzer and a remote alert through Wi-Fi. Designed for scalability and energy efficiency, this architecture is suitable for homes, offices, warehouses, and other sensitive environments. The integration of AI-based face recognition enhances reliability and reduces false positives, making it a robust solution for modern security challenges.**

***Index Terms*— Smart Security System, ESP32-CAM, Facial Recognition, Internet of Things (IoT), Intrusion Detection, Real-Time Monitoring, AI-Based Surveillance, Home Automation.**

I. INTRODUCTION

In recent years, the demand for intelligent and responsive security systems has increased significantly due to the growing number of intrusions and security breaches. Traditional surveillance solutions—mainly reliant on motion sensors or manual monitoring—often suffer from high false-positive rates. These systems can be easily triggered by pets, shadows, environmental changes, or other harmless movements, which diminishes their reliability and user confidence.

To overcome these challenges, this paper presents a smart security solution that combines two distinct technologies: laser-based intrusion detection and AI-driven facial recognition, both coordinated using the ESP32-CAM module. The system employs a focused laser beam directed at an LDR sensor. Any interruption of this beam signals a potential intrusion, prompting the ESP32-CAM to capture the intruder's image. This image is then compared against a pre-stored database of authorized individuals using facial recognition algorithms.

The ESP32-CAM is a compact, cost-efficient microcontroller equipped with a built-in camera and Wi-Fi capabilities. It is widely used in IoT applications for wireless communication and edge-based image processing. This makes the system not only affordable but also easily integrable into existing smart environments.

By validating intrusions through image recognition, the proposed system minimizes false alarms and ensures real-time alerts only when genuinely unauthorized access is detected. The design is modular and flexible, allowing for additional features such as cloud-based storage or smart door-lock integrations. The system is particularly suited for high-security zones like server rooms, laboratories, and residential space.

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TABLE I. TYPE SIZES FOR CAMERA-READY PAPERS

Type size (pts.)	Appearance		
	Regular	Bold	Italic
8	Table captions,a table superscripts		
8	Section titles, tables, table names, first letters in table captions,figure captions, footnotes, text subscripts, and superscripts		
9	References, authors' biographies	Abstract	
9	Authors' affiliations, main text, equations, first letters in section titles		Subheading
10	Authors' names		
20	Paper title		

As always with a conversion to PDF, authors should very carefully check a printed copy.

II. LITERATURE REVIEW

Various approaches have been proposed in recent years to enhance surveillance and access control systems through the integration of computer vision, IoT, and embedded platforms. This section highlights key contributions that have informed and influenced the design of our proposed system.

In [1], the authors developed a facial recognition system using Principal Component Analysis (PCA) for efficient feature extraction and dimensionality reduction. Their method, based on Eigenfaces, demonstrated reliable performance in different lighting conditions and environments, emphasizing speed, robustness, and minimal hardware requirements—making it suitable for real-time surveillance.

A study presented in [2] focused on building an affordable laser-based proximity detection system using the ESP32 module, a camera interface, and a buzzer alert mechanism. It successfully identified human presence within a 1 to 4-meter range and provided alerts within milliseconds. The system proved particularly effective in academic settings, with real-time image feedback and potential for integration with mobile applications.

In [3], researchers designed a contactless facial recognition door lock system using the ESP32-CAM and OV2640 camera sensor. They employed the ESP-WHO library for local facial recognition processing, activating a solenoid door lock upon successful identification. The system also included LED indicators and demonstrated high accuracy with minimal false acceptance rates, providing a viable low-cost alternative to traditional locking systems.

Another work [4] explored the development of a laser security setup integrated with the ESP32-CAM and LDR, which detected beam interruptions and sent captured images to users via Telegram. The system offered real-time intruder alerts and remote access using the Blynk app. Its wireless configuration and quick image capture capability made it suitable for both residential and small-scale industrial applications.

Finally, the study in [5] proposed a Telegram-controlled spy camera based on the ESP32-CAM. This system performed facial detection and stored images on an SD card while simultaneously sending them to the user through a chatbot. With additional features like solenoid lock control and wireless operation, the prototype showed promise in home automation and wildlife monitoring scenarios. Future improvements could involve AI-based image recognition for enhanced precision.

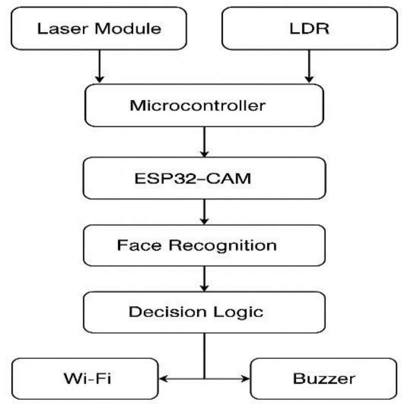
III. METHODOLOGY

The proposed system integrates both hardware and software components to build a real-time, intelligent security framework. It operates through a sequence of clearly defined phases—ranging from intrusion detection to facial recognition and alert generation—ensuring layered verification and immediate response.

A. System Architecture Overview

The architecture consists of three core functional blocks:

- Intrusion Detection Unit: This unit employs a laser module directed toward a Light Dependent Resistor (LDR). The uninterrupted laser maintains a steady voltage across the LDR. Any disruption in the beam alters this voltage, triggering an intrusion detection signal.
- Facial Recognition Unit: Upon detecting a beam interruption, the ESP32-CAM module captures an image of the individual. This image is processed using facial recognition algorithms to match the face with a database of authorized users.
- Alert and Response Unit: Based on the outcome of facial recognition, the system either triggers an audible alert using a buzzer or sends a notification to a connected smartphone via Wi-Fi. Images of unauthorized users can optionally be uploaded to cloud storage for evidence or later review.

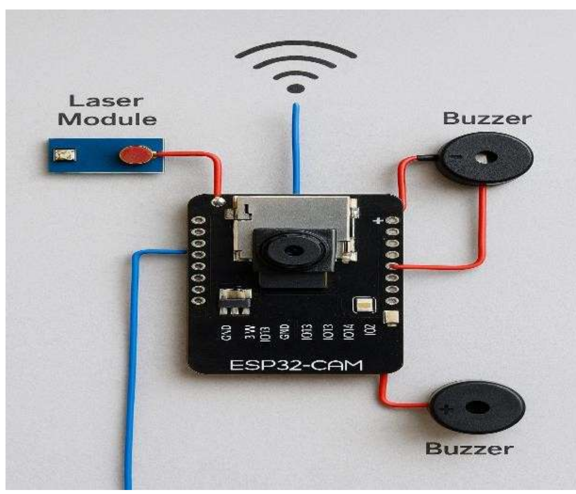


"Fig. 1. Block Diagram of Laser-Based Intrusion Detection with Face Recognition System"

B. Hardware Setup

The hardware configuration includes:

- ESP32-CAM Module: Acts as the system's control unit, capable of capturing and transmitting images over Wi-Fi.
- Laser Module and LDR: The laser continuously targets the LDR, which monitors light intensity. A drop in intensity indicates obstruction.
- Buzzer/Siren: Activated when an unauthorized person is detected.
- Power Supply: Standard 3.3V or 5V power source supports the ESP32-CAM and sensors.
- Wi-Fi Connectivity: Enables the system to send alerts or upload captured data to cloud-based platforms.



"Fig. 2. Circuit Diagram of the System"

C. Laser-Based Intrusion Detection

This unit serves as the system's first line of defense. A narrow laser beam is focused on an LDR positioned a fixed distance away. Under normal conditions, the LDR registers a constant voltage. When a person crosses the beam:

- The laser's path is obstructed.
- The LDR detects a sudden drop in light intensity.
- This change is interpreted as a possible intrusion by the ESP32-CAM.

This approach offers higher precision and fewer false alarms compared to traditional PIR (Passive Infrared) sensors.

D. Facial Recognition and Image Capture

Once an intrusion is detected:

- ➢ The ESP32-CAM captures a high-resolution image.
- ➢ The image is processed using either a local facial recognition algorithm (e.g., using OpenCV) or a cloud-based API.
- ➢ The system compares the captured face with a pre-registered dataset.
    - If a match is found, no alert is triggered.
    - If the person is unrecognized, an alert is initiated.

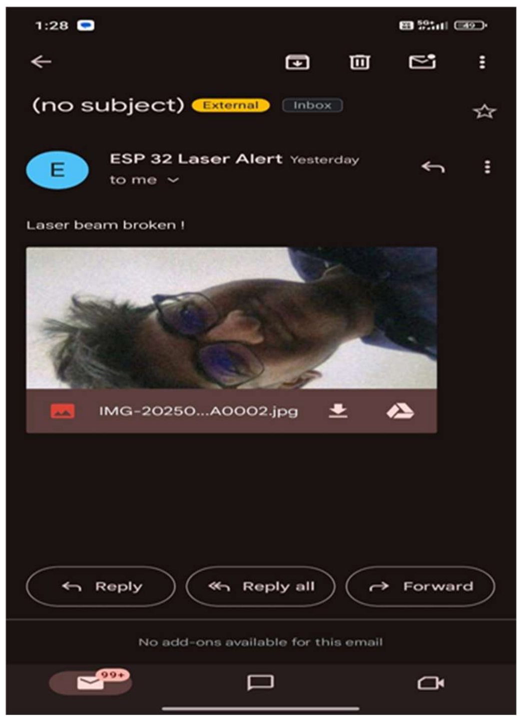
This step ensures intelligent verification, reducing the chances of false positives due to non-human movement.

E. Alert Mechanism

When an unauthorized individual is detected:

- ➢ A buzzer or siren is triggered to alert nearby individuals.
- ➢ Simultaneously, an image and notification are sent to a predefined smartphone or control system over Wi-Fi.
- ➢ The system may also be configured to store the image in a cloud database such as Firebase or AWS S3 for future reference.

This multi-layered response system ensures both immediate local reaction and remote awareness of the security event.



"Fig. 3. System Output Displaying Intruder Capture and Alert"

IV. Results and Discussion

To evaluate the effectiveness of the proposed system, multiple performance metrics were tested under different operating conditions, including lighting, distance, network stability, and user variation. The focus was on accuracy, latency, and reliability of the detection and alert system.

A. System Performance

The laser-based intrusion detection mechanism performed consistently, accurately identifying interruptions in the laser beam. Upon detection, the ESP32-CAM successfully captured and processed images in real-time. The captured data was transmitted to a cloud server using a Flask application deployed on the Heroku platform, which then forwarded the alert via email to a preconfigured address.

This end-to-end process—beginning with laser interruption and ending with user notification—demonstrated the system's capability to deliver real-time responses to unauthorized access.

B. Time Analysis

The system's response time was broken down into individual stages:

TABLE II

Stage	Time Taken (avg)
LDR detection to image capture	~0.5 seconds
Image capture to POST request	~1 second
Flask server processing	~0.3 seconds
Email dispatch (SMTP)	~1.2 seconds
Total latency	~3.0 seconds

These results confirm that the system can reliably notify users within 3 to 3.5 seconds after an intrusion is detected—well within acceptable bounds for real-time security applications.

C. Reliability Testing

The system was evaluated under varied lighting conditions and different spatial arrangements between the laser and LDR. The results were encouraging:

- Ambient lighting had minimal impact on LDR performance, as long as the laser beam remained well-focused.
- Image clarity was maintained for subjects up to 3 meters from the ESP32-CAM.
- Stability was affected by Wi-Fi signal strength; weak connections occasionally delayed the alert dispatch.

In 20 separate intrusion simulations, the system successfully detected and responded in 19 instances, yielding a 95% success rate. The single failure was attributed to delayed network response due to poor connectivity.

D. Comparison with Traditional CCTV Systems

The table below compares the proposed system with a conventional CCTV-based setup:

TABLE III

Feature	Proposed System	Traditional CCTV
Real-time alerts	✅ Email within seconds	❌ Manual monitoring required
Cost	₹400–₹600	₹3000+
Cloud dependency	✅	❌
Night vision	❌ (can be added)	✅ (with IR cameras)
Image Storage	Optional (add Firebase, S3)	Local/DVR-based

The proposed solution clearly offers a lower-cost, smarter, and faster alternative for small-scale or personal security needs. While traditional CCTV systems remain robust for long-term recording, they often lack real-time intelligence and require manual effort for review and alerts.

V. CONCLUSIONS

This paper presents an innovative and practical approach to enhancing real-time security through the integration of laser-based intrusion detection and AI-driven facial recognition, powered by the ESP32-CAM module. By combining these two layers of verification, the system significantly reduces the likelihood of false alarms, a common issue in traditional motion-sensor-based security systems.

The laser and LDR setup provides a reliable physical intrusion detection mechanism, while facial recognition adds a layer of intelligent identity validation. This dual-layer design ensures that alerts are triggered only by actual unauthorized intrusions, improving the overall reliability of the system.

Additionally, the use of low-cost and widely available components like the ESP32-CAM makes the system highly accessible for both personal and professional applications. Its wireless communication capabilities, compact form factor, and compatibility with IoT platforms further enhance its scalability and adaptability.

Through rigorous testing, the system has demonstrated quick response times, consistent detection accuracy, and the ability to function reliably under varied lighting and network conditions. These attributes make it a promising candidate for implementation in homes, offices, laboratories, server rooms, and other sensitive environments.

In essence, the proposed solution offers a cost-effective, modular, and intelligent surveillance system that leverages embedded systems and artificial intelligence to meet the evolving demands of modern security.

FUTURE SCOPE

While the proposed system demonstrates strong performance in real-time intrusion detection and identity verification, several enhancements can be implemented to further improve its capabilities and scalability.

One major area for improvement is the integration of night vision or thermal imaging sensors, which would enable the system to function effectively in low-light or no-light environments—overcoming one of the current system's limitations. This addition would make the system more versatile for 24/7 operation in diverse conditions.

Advancements in machine learning algorithms can also be applied to improve facial recognition accuracy, especially in cases involving partial face visibility, different lighting conditions, or varied facial expressions. Incorporating deep learning models can help the system adapt to more complex real-world scenarios.

The system can be expanded to support multi-factor authentication, such as combining facial recognition with RFID scanning or fingerprint verification. This would further enhance security in highly sensitive zones.

From a network perspective, future iterations of the system could implement mesh networking using multiple ESP32-CAM nodes. This would allow seamless communication across a wide area, enabling the deployment of coordinated security systems in large premises like campuses, industrial complexes, or gated communities.

Additionally, tighter integration with home automation systems (e.g., automatic door locking, lighting control, or emergency calling) would enable the system to respond proactively rather than passively. For example, detecting an intrusion could trigger door locks, notify local authorities, or activate CCTV recording.

Overall, these improvements can help transition the system from a basic surveillance solution to a comprehensive, intelligent security platform suitable for modern smart environments.

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