



ESP-32 CAM SMART HOME SECURITY SYSTEM WITH GMAIL ALERT

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ABSTRACT

This paper presents the design and implementation of an ESP32-CAM Smart home security system with Gmail alert that provides real-time monitoring and instant alert mechanisms. The proposed system integrates a Passive Infrared (PIR) motion sensor, ESP32-CAM module, and Wi-Fi communication to detect human presence and capture images of intrusions. Upon detecting motion, the system automatically activates the camera, captures an image, and transmits it to the user through Gmail using the Simple Mail Transfer Protocol (SMTP). The system is developed as a compact and cost-effective embedded solution that eliminates the need for continuous human monitoring and expensive surveillance infrastructure. Unlike traditional CCTV systems, which rely on continuous recording and manual observation, the proposed system operates only when motion is detected, thereby reducing power consumption and storage requirements. The use of ESP32-CAM enables seamless integration of image processing and wireless communication within a single module. Overall, the system is portable, scalable, and easy to deploy, making it suitable for residential, office, and small-scale security applications. Future enhancements may include night vision capability, cloud storage integration, and mobile application support to further improve functionality and user experience.

1. INTRODUCTION

The rapid advancement of Internet of Things (IoT) technologies and embedded systems has led to the development of intelligent and automated security solutions for modern homes and workplaces. Security has become a major concern due to increasing incidents of theft and unauthorized access, making traditional surveillance systems such as Closed-Circuit Television (CCTV) less efficient. These systems require continuous monitoring, large storage capacity, and involve high installation and maintenance costs. Similarly, alarm-based systems that use sensors like Passive Infrared (PIR) sensors provide only sound alerts without any visual confirmation, limiting their effectiveness in real-time decision-making. As a result, there is a growing need for a smart, cost-effective, and automated security system that can provide instant alerts along with visual evidence.

To address these limitations, this project proposes an ESP32-CAM based smart home security system that integrates motion detection, image capture, and wireless communication into a single compact platform. The ESP32-CAM module, equipped with a built-in camera and Wi-Fi capability, works in coordination with a PIR sensor to detect motion and capture images of the detected event. These images are then transmitted to the user via Gmail using the Simple Mail Transfer Protocol (SMTP), enabling real-time notification and remote monitoring. The system operates only when motion is detected, thereby reducing power consumption and eliminating the need for continuous monitoring. This approach

provides a reliable, low-cost, and efficient solution for enhancing home security, demonstrating the practical application of IoT and embedded systems in real-world scenarios.

2. PROBLEM IDENTIFICATION

Existing security systems face several challenges that reduce their effectiveness in real-time monitoring. CCTV systems require continuous human observation and large storage capacity, making them inefficient and costly. Alarm systems only provide sound alerts and do not offer visual confirmation, which makes it difficult to understand the situation remotely.

In addition, many IoT-based systems rely heavily on cloud platforms, increasing complexity and cost while introducing delays due to network dependency. These limitations highlight the need for a smart system that provides instant alerts, visual evidence, and remote accessibility. Therefore, a simple, cost-effective, and real-time security system is required to improve overall safety and user convenience.

3. LITERATURE REVIEW

3.1 Introduction and Background

Smart home security systems have evolved significantly with the advancement of Internet of Things (IoT), embedded systems, and wireless communication technologies. Earlier security systems mainly relied on basic motion detection using sensors such as PIR, which could only trigger alarms without providing detailed information. Camera-based surveillance systems improved monitoring capabilities by enabling video recording, but they required continuous observation and large storage capacity, making them less efficient. With the development of IoT, modern systems now support remote monitoring and real-time notifications, allowing users to access security data from anywhere.

3.2 Motion Detection and Sensor-Based Systems

Motion detection plays a crucial role in security systems, and PIR sensors are widely used due to their simplicity and low cost. These sensors detect infrared radiation changes caused by human movement and generate signals accordingly. However, traditional sensor-based systems lack intelligence and cannot provide visual confirmation of detected events. This limitation reduces their effectiveness in real-world applications where visual evidence is important for decision-making.

3.3 Camera-Based and IoT Security Systems

Camera-based systems, especially those integrated with IoT, have improved the functionality of security solutions by enabling image capture and remote communication. Devices such as Raspberry Pi and ESP32-CAM are commonly used in modern systems for real-time monitoring. These systems can capture images or video and send alerts through mobile applications or email. However, many IoT-based solutions rely heavily on cloud infrastructure, increasing system complexity, cost, and dependency on stable internet connectivity.

3.4 Research Gap and Motivation

Despite advancements, existing systems often lack proper integration of motion detection, image capture, and instant alert mechanisms in a single compact platform. Many systems either focus on detection without communication or provide monitoring without real-time alerts. The proposed ESP32-CAM system addresses these limitations by combining all functionalities into a single embedded solution, providing real-time alerts with visual evidence while maintaining low cost and simplicity.

4. METHODOLOGY / SYSTEM DESIGN

The proposed system consists of a PIR sensor, ESP32-CAM module, and Wi-Fi communication. The PIR sensor detects motion and sends a signal to the ESP32-CAM, which then captures an image of the detected event. The captured image is processed and transmitted to the user via Gmail using the SMTP protocol. This ensures real-time alert delivery and immediate notification.

The system operates automatically without manual intervention and is designed to be compact and energy-efficient. It integrates sensing, processing, and communication into a single platform, making it suitable for continuous monitoring applications. The simple architecture reduces complexity while maintaining high efficiency and reliability.

4.1 SYSTEM ARCHITECTURE

The system architecture includes input, processing, and output stages. The PIR sensor acts as the input device, detecting motion based on infrared radiation changes. The ESP32-CAM serves as the processing unit, handling image capture and communication tasks.

The output stage consists of sending email alerts with captured images to the user. All components work together in real-time to provide seamless operation. This integrated design improves system efficiency and ensures quick response to security events.

4.2 BLOCK DIAGRAM

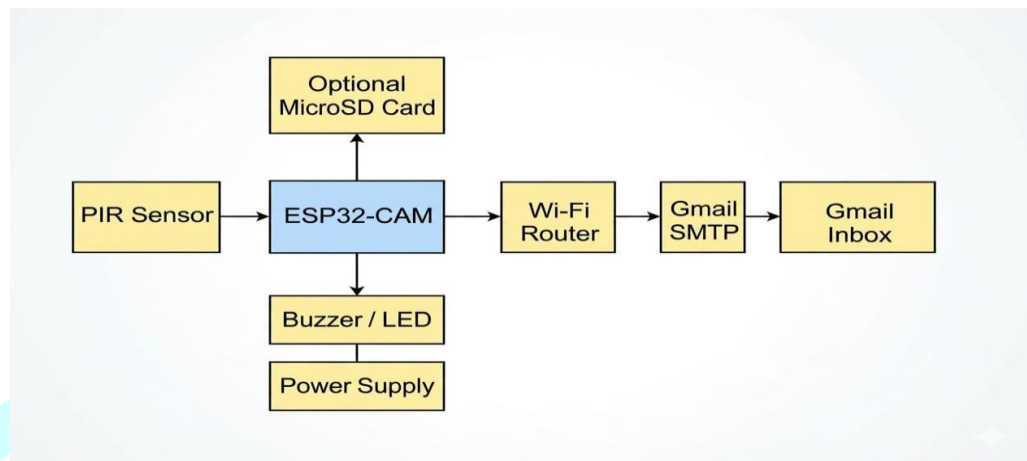


Figure 1: block diagram

The block diagram represents the overall system flow, including motion detection, image capture, and email transmission. The PIR sensor detects motion and triggers the ESP32-CAM, which processes the signal and captures an image.

The ESP32-CAM then uses Wi-Fi connectivity to send the image via Gmail. This simple and effective block structure ensures reliable operation and easy implementation. The design reduces complexity while maintaining functionality.

4.3 FLOW CHART

The flowchart represents the working process of the ESP32-CAM smart security system. The system starts with initialization, where all components such as the PIR sensor, camera, and Wi-Fi module are set up. It then continuously checks for intrusion; if no intrusion is detected, the system keeps monitoring in a loop. When an intrusion is detected, the system proceeds to check Wi-Fi connectivity. If Wi-Fi is not connected, it repeatedly attempts to establish a connection. Once the Wi-Fi connection is successful, the system sends an alert (such as an email or cloud notification) with the captured information to the user. After sending the alert, the process ends or resets, and the system continues monitoring for further intrusions.

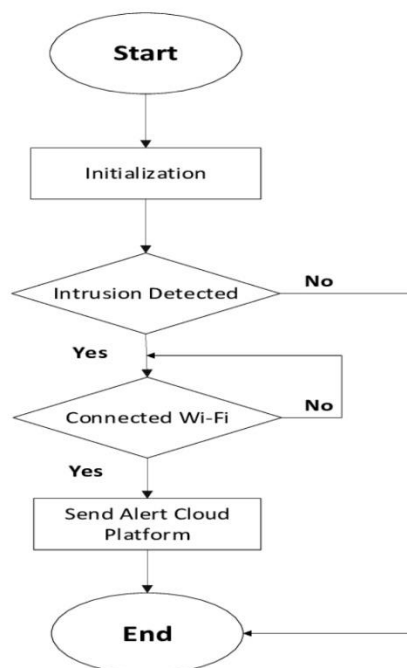


Figure 2: Flowchart

5. RESULTS

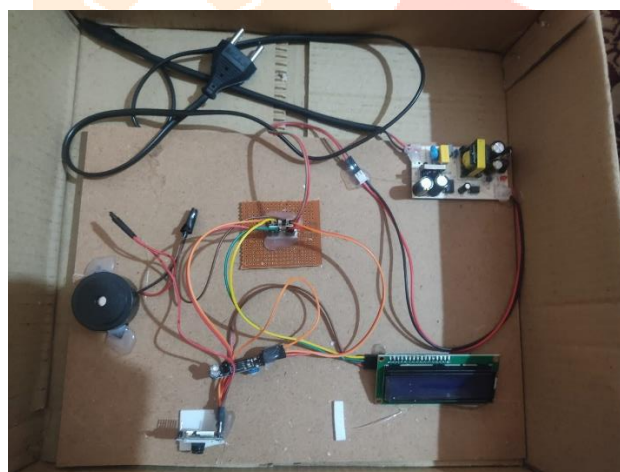


Figure 3: Developed ESP-32 CAM SMART HOME SECURITY SYSTEM WITH GMAIL ALERT Prototype

5.1 Motion Detection Result

The PIR sensor was tested under different environmental conditions to evaluate its performance. It successfully detected human motion within its sensing range with high reliability. The sensor responded quickly to movement and generated accurate signals, ensuring proper activation of the ESP32-CAM module.

However, minor variations were observed due to environmental factors such as temperature changes and background heat sources. Despite these limitations, the sensor performed effectively in most practical scenarios, making it suitable for real-time intrusion detection.

5.2 Image Capture Result

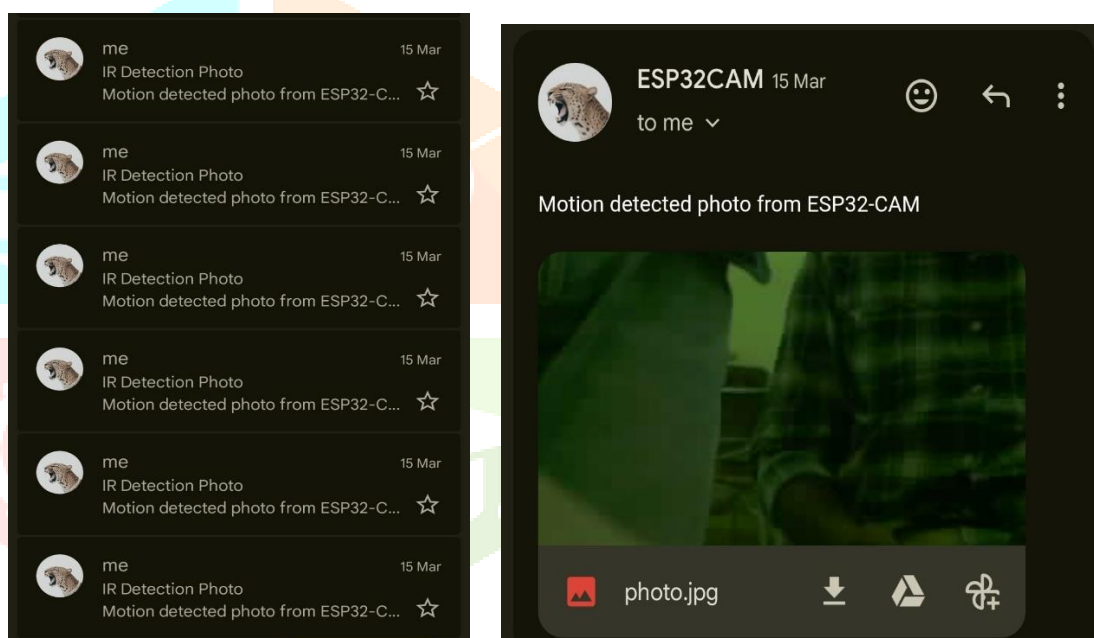
The ESP32-CAM module captured images of the detected events with good clarity under normal lighting conditions. The resolution and quality of images were sufficient for identifying objects and individuals in the monitored area, in low-light conditions, the image quality slightly decreased due to the absence of advanced lighting or night vision features. However, the overall performance remained acceptable for basic security applications, and improvements can be made by adding external lighting.



Figure 4: Captured image

5.3 Email Alert Result

The system successfully sent email alerts containing captured images to the user using the SMTP protocol. The alerts were delivered within a few seconds after motion detection, ensuring real-time notification. The communication between the ESP32-CAM and the email server was stable, and the system maintained consistent performance during multiple test cycles. This feature significantly improves the usability of the system by enabling remote monitoring.



Figures 5&6: Email inbox notifications

5.4 System Performance Analysis

The overall system performance was evaluated based on response time, reliability, and efficiency. The system demonstrated fast response with minimal delay between motion detection and alert delivery. It also showed stable operation over extended periods, with low power consumption and efficient resource utilization. The integration of all components ensured smooth and synchronized functioning of the system.

6. CONCLUSION

The ESP32-CAM Smart Home Security System presents a reliable, cost-effective, and real-time solution for modern security applications. By integrating a PIR motion sensor, ESP32-CAM module, and Wi-Fi communication, the system successfully detects intrusions, captures images, and sends instant email alerts to users. The implementation demonstrates how embedded systems and IoT technologies can be effectively combined to eliminate the need for continuous monitoring while ensuring quick response and improved safety.

The experimental results confirm that the system provides fast response time, stable performance, and efficient communication under normal conditions. Similar IoT-based security systems using ESP32 have shown response times of less than 2 seconds for real-time alerts, proving the effectiveness of such architectures. Additionally, the use of SMTP-based email alert systems in ESP32 applications ensures reliable and automated notification mechanisms during critical events. Although minor limitations exist, such as reduced performance in low-light conditions and dependence on network connectivity, the overall system is highly efficient and scalable. Future enhancements can include night vision support, cloud integration.

7. REFERENCES

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