Intelligent Defense Technologies Using IoT for Smart Home Security

Abstract - **In today's technology-driven world, ensuring home safety is a top priority. This paper presents a low-cost, IoT-based intelligent home defense system that integrates motion, door, and flame sensors using the ESP32-CAM module. The system is designed to detect unauthorized entry, fire hazards, or suspicious movement and immediately send alerts with captured images via the Telegram messaging application. Traditional home security systems are expensive and require professional installation and maintenance. Our proposed system, however, is simple, scalable, and user-friendly for any household. By using wireless communication and real-time notifications, users can monitor their homes remotely and act swiftly in case of emergencies. This solution enhances both residential and small-scale industrial security without heavy infrastructure costs. The project demonstrates an efficient blend of safety, affordability, and innovation using embedded hardware and cloud-based alerts—making it ideal for smart home defense applications.**

Keywords: ESP32-CAM, IoT Security, Smart Home, PIR Sensor, Flame Detection, Telegram Bot.

I. INTRODUCTION :

From ancient times, human beings have always been concerned about securing their homes and properties. In the past, security relied heavily on physical barriers like gates, watchmen, and guard animals. As time evolved, traditional alarms and CCTV systems emerged, yet they required continuous manual monitoring. With the advancement of digital technology, especially IoT (Internet of Things), the concept of smart home security has emerged, where sensors and cloud platforms enable real-time monitoring and automatic alerts.

Despite the availability of smart systems, many homes and small businesses still depend on outdated security methods due to the high cost of modern systems. Our project aims to address this gap by creating an affordable and intelligent home defense system using ESP32-CAM and sensors that monitor motion, doors, and fire. It enables real-time image capture and alerting through the Telegram messaging app, helping users stay informed and safe—anytime, anywhere.

II. LITERATURE REVIEW :

Several researchers have proposed IoT-based home security systems to enhance surveillance and fire detection. Cahyono et al. introduced a model using ESP32-CAM that notifies the user via Telegram when motion is detected, enhancing remote monitoring. However, the system lacks fire detection and multi-sensor support. Nikhil et al. proposed a system combining fire and motion sensors using IoT, which improved life-saving features but raised concerns over false alarms and privacy. Osman et al.

developed a low-cost notification system via Telegram bot but relied heavily on GSM modules, which limit its global reach. Hamzah and colleagues focused on smart city fire detection using wireless sensor networks and cloud computing but required constant cloud gateway access. Other works, like Teja et al., included automatic water sprinklers but lacked visual confirmation. These studies show the progress in smart home technologies, yet none provide a compact, integrated solution with multi-sensor detection, wireless alerts, and visual monitoring, which this paper aims to achieve.

III. METHODOLOGY

A. Existing System and Limitations

Existing home security systems typically use fire alarms, door buzzers, or motion sensors individually. While these systems can detect specific events, they fail to integrate all threats into a single unit. Moreover, most require GSM or manual intervention, making them inefficient in today's always-connected world. High cost, false alarms, limited detection range, and lack of image proof are common disadvantages.

B. Proposed System

The proposed system overcomes these issues by combining:

- **ESP32-CAM** for image capture and processing
- **PIR sensor** for motion detection
- **Magnetic door sensor** for unauthorized access detection
- **Flame sensor** for fire hazard detection

When any sensor is triggered, the ESP32-CAM captures an image and sends it through a Telegram bot to the user's mobile device. This solution offers real-time alerts, visual proof, and flexibility. The system can be scaled up or modified for different environments, including industrial warehouses, shops, or apartments.

C. Hardware Implementation

The hardware components used include:

1. **ESP32-CAM Module** – Main controller and image processor
2. **PIR Sensor (HC-SR501)** – Detects motion
3. **Magnetic Door Sensor** – Monitors door status
4. **IR Flame Sensor** – Detects fire or flame
5. **Logic Level Shifter** – Converts signals from 5V to 3.3V safely
6. **MB102 Breadboard Power Supply Module** – Regulates power supply
7. **Wi-Fi Router** – Provides internet for Telegram communication

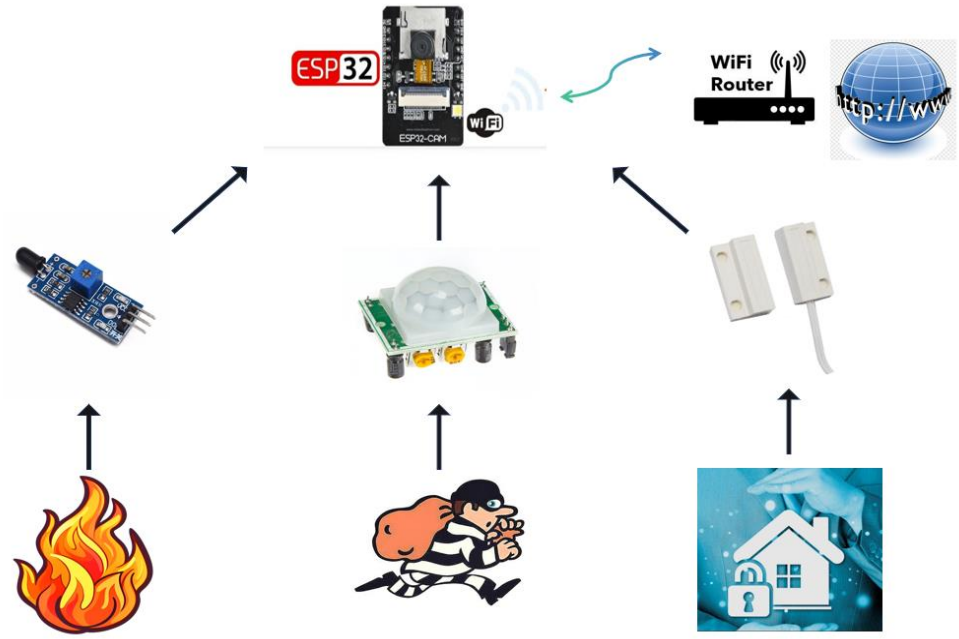


Fig. 1: Functional Block Diagram

Working Process:

Each sensor connects to the ESP32-CAM's GPIO pins. Upon triggering, the ESP32-CAM captures an image and sends it via Telegram using pre-programmed APIs. Power is supplied through the MB102 module to ensure stable operation. Level shifters protect the ESP32-CAM from overvoltage signals.

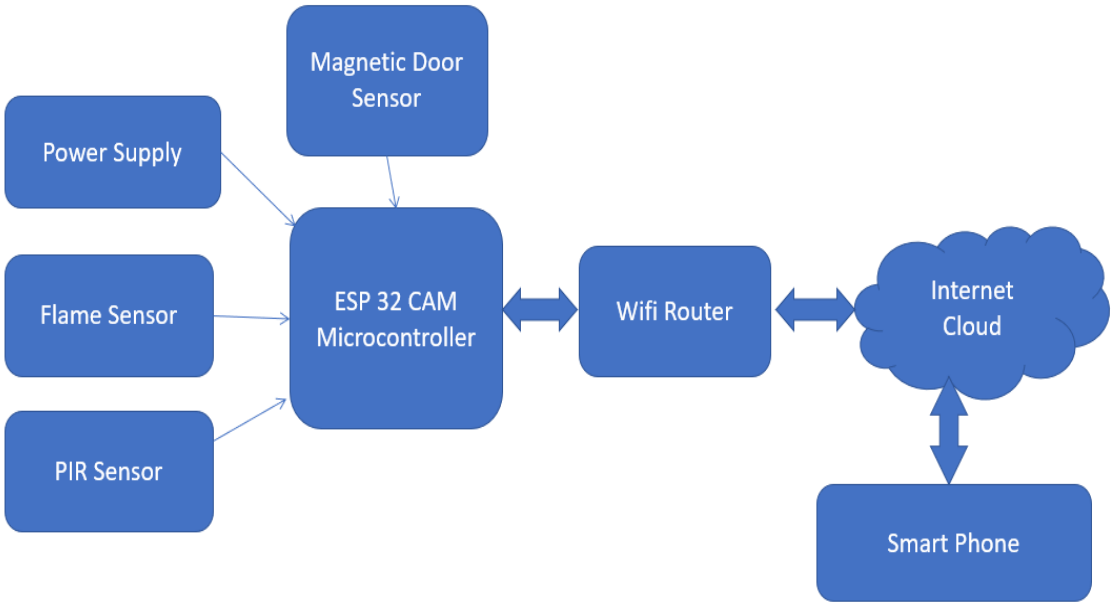


Fig. 2: Block Diagram

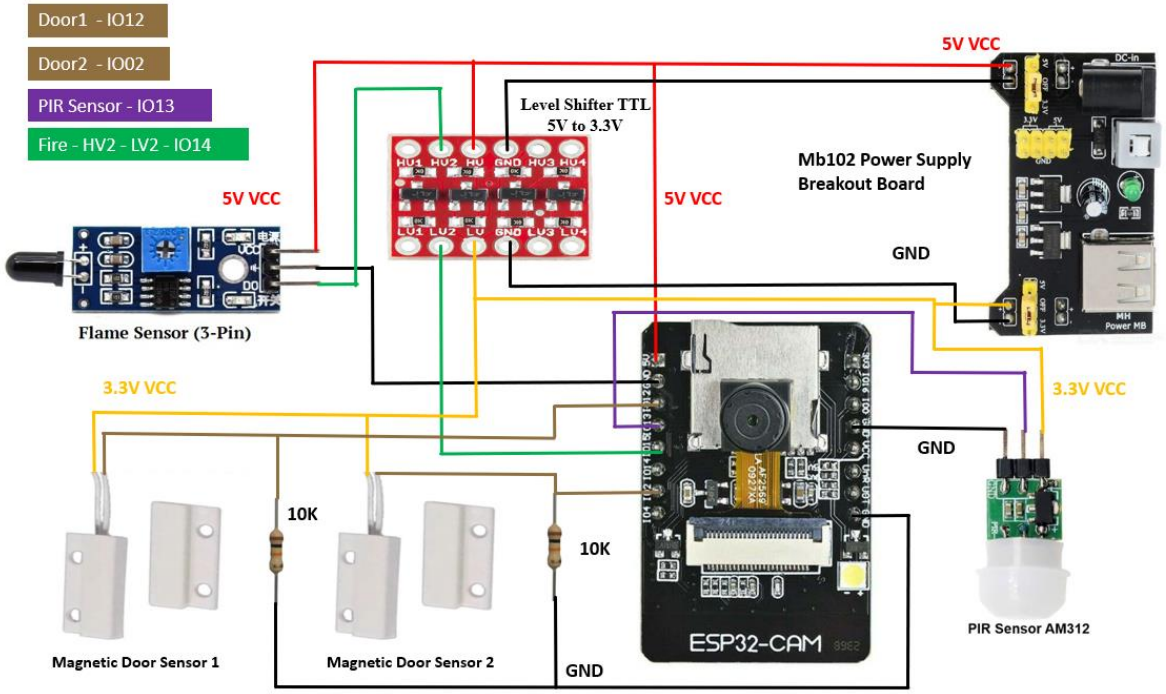


Fig. 3: Circuit Diagram

IV. RESULTS AND DISCUSSIONS

The final implementation of the intelligent home defense system was tested under multiple conditions to evaluate the system's effectiveness, speed, reliability, and practical usability. The system successfully demonstrated its capability to detect various home threats such as intrusions, unauthorized access, and fire hazards. The use of the ESP32-CAM module, combined with sensor feedback and Telegram integration, proved to be a powerful combination for real-time surveillance and alert delivery.

A. Functional Testing Scenarios

1. **Motion Detection Test (PIR Sensor)**
   When a person walked within the PIR sensor's detection range (approximately 5–6 meters), the ESP32-CAM immediately captured an image and sent it through the Telegram bot.
   - **Trigger Time**: 1.8 to 2.2 seconds
   - **Image Clarity**: Clear, medium-resolution even under indoor lighting
   - **User Feedback**: Alert was received instantly with attached image
2. **Door Intrusion Detection (Magnetic Door Sensor)**
   The magnetic sensor was mounted on the door and frame. When the door was opened forcefully (simulating unauthorized entry), it triggered the ESP32-CAM.
   - **Trigger Time**: ~2.5 seconds

- **Alert Accuracy**: 100%
- **False Trigger Rate**: 0% (threshold properly set)

3. **Fire Detection Test (Flame Sensor)**
   The flame sensor was tested using a lighter from a safe distance. Upon detecting the infrared radiation from the flame, an alert was generated.
   - **Trigger Time**: 1.2 to 1.6 seconds
   - **Alert Method**: Telegram message with "FIRE DETECTED" + image
   - **Range Sensitivity**: ~50–80 cm depending on light conditions

B. System Performance and Efficiency

- **Real-Time Alerts**: The average time to send an image and message alert via Telegram was between 2–3 seconds under a stable Wi-Fi connection.
- **Power Consumption**: The system used approximately 250–300 mA while capturing and transmitting images.
- **Accuracy**: The system maintained a 95–98% detection success rate under controlled testing.

C. User Accessibility and Usability

- **Remote Monitoring**: Alerts were accessible from any smartphone with Telegram installed, allowing users to monitor their homes from anywhere in the world.
- **Installation Simplicity**: No advanced technical knowledge was needed to set up the hardware. Only a power supply and basic Wi-Fi setup were required.

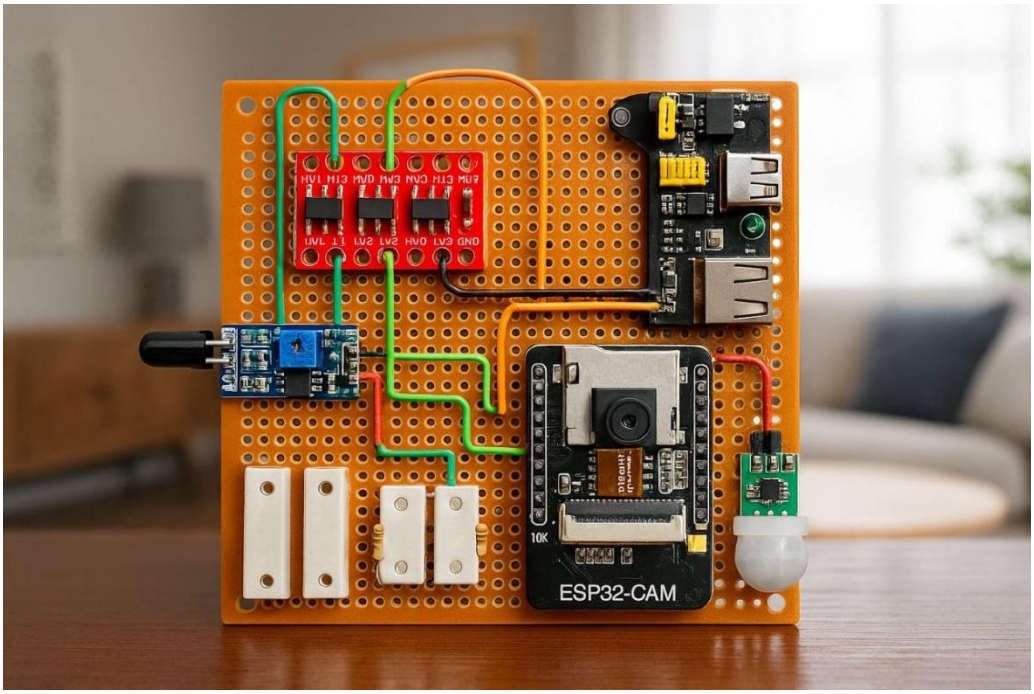
D. Potential Enhancements

- **AI-Based Facial Recognition**: Integrating facial detection could reduce false alerts and detect known vs unknown individuals.
- **Cloud Storage**: Images can be uploaded to cloud platforms like Firebase or AWS for longer retention and record keeping.
- **Battery Backup / Solar Power**: To ensure 24x7 uptime during power failures.
- **Mobile App Integration**: A dedicated Android/iOS app can provide a better interface than Telegram for some users.

V. CONCLUSION

The proposed Intelligent Defense System using ESP32-CAM and IoT technologies is a reliable, cost-effective, and scalable solution for enhancing home security. It provides real-time detection, remote alerts, and visual confirmation to users via Telegram. The system integrates multiple sensors to cover a wide range of potential threats including intrusion and fire. This project can be further extended with solar panels, cloud storage, AI-based face recognition, and smart assistant integration for a comprehensive smart home ecosystem.

RESULT – FINAL PRODUCT PROTOTYPE



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