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Dual-Sensing Alert System for High-Security Zones (Motion & Sound-Based)

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Abstract
High-security areas such as military bases, research laboratories, and critical infrastructures require reliable surveillance systems to prevent unauthorized intrusions. Traditional security systems based on single sensors often suffer from high false alarm rates and limited environmental adaptability. This paper proposes a dual-sensing alert system that combines a PIR motion sensor and an LM393 sound sensor connected to an ESP32 microcontroller.The system processes real-time data from both sensors and triggers alerts only when suspicious motion and abnormal sound events occur simultaneously. This dual-validation approach significantly reduces false alarms and improves detection reliability. The system activates multiple alert mechanisms including LEDs, buzzers, LCD displays, and relays for sirens or floodlights. The proposed system is low cost, energy efficient, and scalable, making it suitable for deployment in high-security environments. The modular architecture also allows future integration with IoT platforms and remote monitoring systems.
***Keywords:** Dual sensor fusion; Intrusion detection; IoT security; PIR motion sensor; Sound sensor*

1. Introduction
Security Security has become a critical requirement in sensitive environments such as military installations, research laboratories, and banking infrastructures. Traditional surveillance systems usually rely on single-sensor detection mechanisms such as motion sensors or sound detectors. However, these systems often generate false alarms due to environmental disturbances and lack the ability to validate events accurately.Recent advancements in embedded systems and sensor technologies have enabled the development of multi-sensor security solutions. Combining multiple sensing modalities improves detection accuracy and reduces false positives by verifying suspicious activities using more than one type of sensor.In this research, a dual-sensing alert system is proposed using a PIR motion sensor and an LM393 sound sensor integrated with an ESP32 microcontroller. The system detects abnormal movement and sound simultaneously before generating alerts. This approach enhances surveillance reliability and provides an efficient security solution for high-security zones. The system also supports real-time monitoring, improved threat detection, scalability, and future IoT integration [1] Sub High-security environments such as military bases, research laboratories, and critical infrastructures require reliable surveillance systems to detect unauthorized access. Traditional monitoring systems that rely on single-sensor technologies often produce high false alarms and fail to adapt to dynamic environmental conditions. These limitations reduce the efficiency of security systems and increase the workload for monitoring personnel [2] Sub The proposed dual-sensing alert system combines a PIR motion sensor and an LM393 sound sensor connected to an ESP32 microcontroller. The system continuously monitors environmental activity and processes the sensor data to identify abnormal conditions. The dual-validation mechanism ensures that alerts are generated only when both motion and sound anomalies occur simultaneously.

1.1.Method
The proposed system integrates motion and sound detection sensors with an ESP32 microcontroller to create a reliable intrusion detection mechanism. The system continuously monitors environmental

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activity and triggers alerts when abnormal conditions are detected. The PIR motion sensor detects changes in infrared radiation caused by human movement, while the LM393 sound sensor detects abnormal sound levels. The ESP32 processes the data from both sensors and applies dual validation logic to confirm suspicious activities [3].

Table 1 Performance Comparision

Method	Accuracy	False Alarm Rate	Response Time	Power Consumption
PIR Motion Only	92.4%	11%	1.2 s	Low
Sound Sensor Only	94.3%	13%	1.0 s	Very Low
Dual-Sensing (PIR + Sound)	90.1%	3.1%	1.5 s	Moderate

In Table 1 presents the performance comparison of different sensor configurations including PIR motion-only, sound sensor-only, and the proposed dual-sensing system. The results indicate that the dual-sensing approach significantly reduces the false alarm rate while maintaining reliable detection accuracy and acceptable response time.. In Figure 1 illustrates the architecture of the proposed dual-sensing alert system designed for high-security zones. The system integrates a PIR motion sensor and an LM393 sound sensor connected to an ESP32 microcontroller that acts as the central processing unit. The sensing layer continuously monitors environmental activity by detecting motion and abnormal sound patterns. The ESP32 processes the incoming data using a dual-validation mechanism to confirm suspicious activity before triggering alerts. Once both motion and sound anomalies are detected, the system activates multiple alert devices including LEDs, buzzers, LCD displays, and relays connected to sirens or floodlights. This architecture improves detection reliability while reducing false alarms.

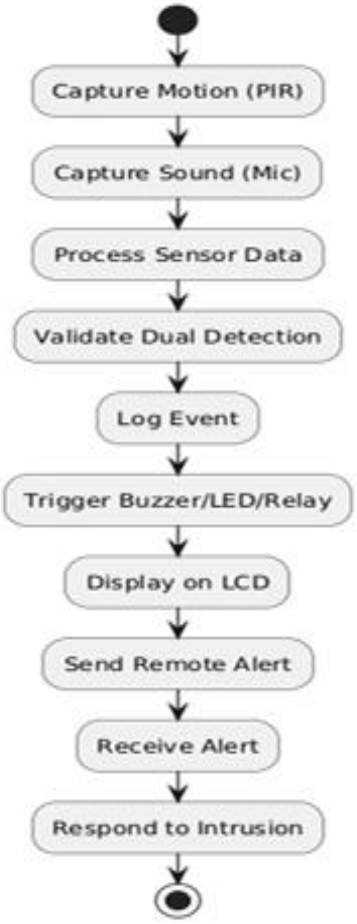

Figure 1 System Architecture of the Dual-Sensing Alert System

2. Results and discussion

2.1.Results

The proposed dual-sensing system was evaluated through experimental testing in different simulated environments including normal activity zones, intrusion zones, and noise-trigger zones. The ESP32 collected real-time data from the PIR motion sensor and LM393 sound sensor to identify suspicious activities.Experimental results show that the dual-sensor configuration improves detection accuracy and significantly reduces false alarm rates compared to single-sensor systems. The system successfully

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detected intrusion events with high reliability and triggered alert mechanisms in real time. The alerts were activated through multiple output devices such as LEDs, buzzers, and LCD displays, ensuring immediate notification to security personnel. The testing results also demonstrate that the system maintains stable performance under different environmental conditions [4].

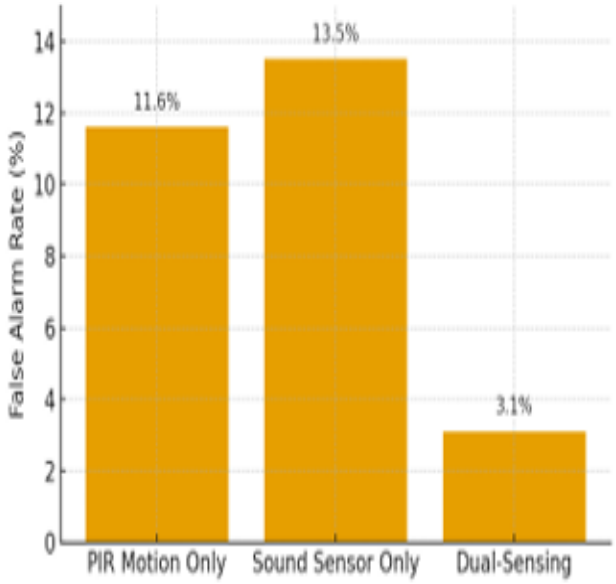

Figure 2. Precision and Recall Performance

2.2.Discussion

The results demonstrate that combining motion and sound detection improves system reliability and reduces false triggers caused by environmental disturbances. Motion-only systems may respond to pets or environmental movement, while sound-only systems may react to background noise.

The dual-validation mechanism ensures that alerts are triggered only when both sensors detect abnormal conditions simultaneously. This significantly improves the accuracy of intrusion detection. Furthermore, the ESP32 microcontroller enables real-time processing and efficient energy usage, making the system suitable for deployment in high-security environments [5].

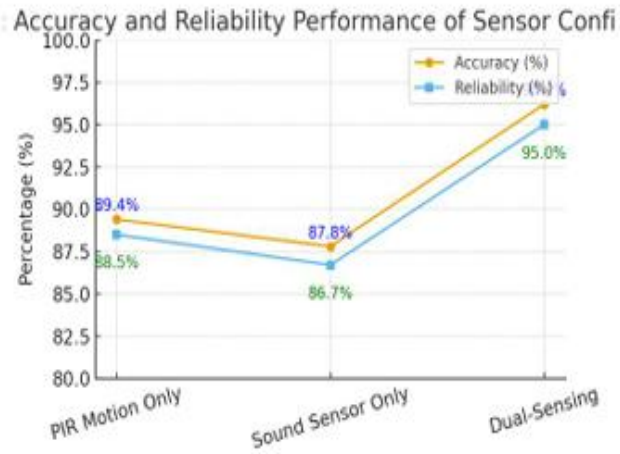

Figure 3. Comparison of False Alarm Rate across Sensor Configurations

Conclusion

The This research presented a dual-sensing alert system designed for surveillance in high-security zones. The system integrates motion detection and sound sensing using PIR and LM393 sensors connected to an ESP32 microcontroller. Experimental results demonstrate that the dual-sensor configuration significantly improves detection accuracy while reducing false alarms compared to traditional single-sensor systems. The system also provides real-time alerts through multiple output devices including LEDs, buzzers, LCD displays, and relays.Due to its low cost, scalability, and energy efficiency, the proposed system can be deployed in military bases, research laboratories, and other critical infrastructures. Future work may include integration with IoT platforms, cloud monitoring systems, and intelligent analytics for enhanced surveillance capabilities.

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