International Journal of
AI Electronics and Nexus Energy
Peer Reviewed, Referred & Indexed Journal
ISSN: 3070-0515 www.zesterapublications.com Original Research Paper

A Scalable Embedded Surveillance System for Real-Time Video Streaming and Location Tracking Using IoT Technologies

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ABSTRACT

The Intelli Spy Robot with Live Streaming and Location Surveillance is an advanced autonomous system designed to perform real-time environmental monitoring, hazard detection, and remote surveillance in areas that are inaccessible or dangerous for human personnel. The proposed system integrates an ESP-32 microcontroller with multiple sensing units including a fire sensor, gas sensor, and metal sensor, alongside an ESP-CAM module for high-definition live video streaming, and a GPS module for precise location tracking. The robot is powered by a dedicated rechargeable battery unit (RPS) ensuring uninterrupted field operation. Upon detection of hazardous conditions such as fire outbreaks, toxic gas leakage, or concealed metallic objects, the system instantly triggers audio alerts via a buzzer and displays critical data on an onboard LCD screen. All processed information is simultaneously transmitted to a centralized IoT platform, enabling remote operators to monitor, analyze, and respond to threats in real time from any geographic location. The system eliminates human risk in hostile environments by providing continuous, automated, and intelligent surveillance. It is designed to be deployable in military zones, disaster-affected areas, industrial sites, and border patrol regions. The integration of robotics, embedded intelligence, and cloud connectivity makes this system a comprehensive solution for modern surveillance challenges. This project represents a significant step forward in combining embedded systems, computer vision, wireless communication, and sensor fusion for autonomous field operations.

Keywords: ESP-32, ESP-CAM, live streaming, GPS tracking, fire sensor, gas sensor, metal detector, IoT surveillance, autonomous robot, embedded systems, real-time monitoring, buzzer alert, LCD display, location tracking, hazard detection.

1. INTRODUCTION

The rapid advancement of embedded systems, wireless communication technologies, and robotics has opened new frontiers in autonomous surveillance and hazard detection. In today's world, there is an increasing demand for intelligent systems that can operate in environments where human presence is either too dangerous or physically impossible. Whether it is a battlefield littered with landmines, a burning industrial facility filled with toxic gases, or a remote border region requiring constant monitoring, conventional surveillance approaches fall short in terms of safety, coverage, and real-time responsiveness. The Intelli Spy Robot with Live Streaming and Location Surveillance is conceived to address precisely these challenges by merging the capabilities of robotics, sensor technology, and IoT-based remote communication into a single, deployable field unit.

The foundation of the system is the ESP-32 microcontroller, a highly capable dual-core processor with integrated Wi-Fi and Bluetooth support. This controller acts as the brain of the robot, receiving, processing, and responding to data from multiple peripheral sensors in real time. Connected to the ESP-32 are a fire sensor capable of detecting infrared radiation emitted by flames, a gas sensor sensitive to toxic or combustible gases such as LPG, methane, and carbon monoxide, and a metal sensor that identifies the presence of metallic objects buried or hidden in the environment. Each of these sensors continuously feeds data into the ESP-32, which applies threshold-based logic to trigger appropriate responses. Upon detecting a hazard, the system activates a buzzer alarm and simultaneously updates the onboard LCD screen with the nature and location of the threat, ensuring that even an operator monitoring the system remotely receives immediate notification through the IoT dashboard.

The visual intelligence of the robot is provided by the ESP-CAM module, which is a compact yet powerful camera unit capable of capturing high-resolution images and streaming live video over a wireless network. This live feed allows remote operators to visually assess the environment in real time, significantly improving situational awareness and decision-making capabilities. Unlike pre-recorded surveillance, live streaming ensures that no critical detail is missed during an active monitoring session. The video data is transmitted over the Wi-Fi module embedded within the ESP-32 and made accessible through a web-based or mobile IoT interface, giving operators complete flexibility in how and where they monitor the robot's activities.

The entire system is powered by a rechargeable battery pack (RPS) that has been carefully selected to provide sufficient energy for extended field missions. Power management is a crucial consideration in autonomous robotic systems, as insufficient power can lead to system shutdowns at critical moments. The battery ensures that all components, including the ESP-32, ESP-CAM, sensors, GPS, LCD, buzzer, and the robot's locomotion system, receive stable and adequate power throughout the operation. The modular design of the robot further allows for component upgrades or replacements without requiring a complete system redesign, making it adaptable to evolving mission requirements.

2. LITERATURE SURVEY

2.1 IoT-Based Military Surveillance Robots

Recent advancements in IoT-enabled robotic systems have significantly enhanced battlefield monitoring capabilities. Anderson and Williams [1] proposed a multi-sensor integrated reconnaissance robot that leverages IoT connectivity for real-time surveillance. Their work highlights the importance of combining multiple sensing modalities to improve situational awareness in hostile environments.

2.2 Autonomous Navigation and Sensor Fusion

Autonomous mobility plays a crucial role in modern unmanned ground vehicles (UGVs). Chen et al. [2] introduced a machine learning-driven navigation system utilizing sensor fusion techniques to detect threats and navigate complex terrains efficiently. Similarly, Wilson et al. [14] emphasized multi-modal sensor fusion frameworks to enhance detection accuracy and robustness in military robotics.

2.3 Real-Time Video Streaming and GPS Tracking

The integration of live video transmission and location tracking has become essential for remote surveillance. Kumar et al. [3] developed an IoT-based robotic system capable of real-time video streaming combined with GPS-based tracking and predictive analytics. Patel et al. [9] further explored edge computing architectures to process video data locally, reducing latency in bandwidth-constrained environments.

2.4 Infrared and Thermal Imaging Systems

Night-time surveillance is significantly improved through thermal imaging technologies. Sharma and Desai [4] integrated infrared thermal sensors with wireless communication modules to enable effective night vision capabilities in unmanned robotic systems, ensuring continuous monitoring regardless of lighting conditions.

2.5 Vibration and Hazard Detection Systems

Detecting environmental threats such as vibrations and fire hazards is critical for safety. Lee et al. [5] proposed a vibration-based threat detection mechanism using accelerometer arrays for early identification of disturbances. Additionally, Rodriguez and Martinez [6] developed fire detection and hazard avoidance algorithms that allow robots to respond dynamically to dangerous conditions.

2.6 Cloud-Based Monitoring and Fleet Management

Cloud computing has enabled centralized monitoring and coordination of multiple robotic units. Gupta et al. [7] introduced a cloud-based fleet management system for IoT surveillance robots, facilitating real-time data aggregation and remote control. This approach enhances scalability and operational efficiency.

2.7 Predictive Analytics and Location Intelligence

Advanced predictive models are increasingly used in surveillance systems. Brown and Thompson [8] utilized Bayesian networks to develop predictive location alert systems, improving decision-making in reconnaissance missions. Iyer et al. [13] further contributed by designing GPS geo-fencing algorithms with high positional accuracy for safe navigation.

2.8 Robotic Platform Design and Motor Control

Efficient locomotion is essential for robotic surveillance in rugged terrains. Zhang et al. [10] focused on the design of all-terrain robotic platforms with advanced motor control mechanisms, ensuring stability and adaptability in challenging environments.

2.9 Secure Communication in Military IoT Systems

Security remains a major concern in military applications. Hassan et al. [11] proposed encrypted communication protocols specifically designed for IoT-based surveillance systems, ensuring data confidentiality and integrity during transmission.

2.10 Energy Optimization for Extended Missions

Power efficiency directly impacts mission duration. Fernandez and Garcia [12] explored battery optimization techniques to extend operational time in autonomous robots, highlighting strategies for energy-efficient system design.

2.11 Machine Learning for Target Recognition

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Artificial intelligence has enhanced automated threat identification. Chopra et al. [15] implemented machine learning classifiers for automatic target recognition in robotic surveillance systems, significantly improving detection accuracy and reducing human intervention.

3. PROPOSED SYSTEM

The proposed Intelli Spy Robot overcomes the limitations of existing systems by integrating a comprehensive suite of sensors and communication modules under the control of the ESP-32 microcontroller. The system simultaneously deploys a fire sensor, gas sensor, and metal sensor for multi-hazard detection, an ESP-CAM module for live high-definition video streaming, and a GPS module for real-time location tracking. All sensor data, visual feeds, and location coordinates are transmitted wirelessly to an IoT platform, providing remote operators with a complete, real-time operational picture. Alert mechanisms including a buzzer and LCD display ensure immediate local notifications upon hazard detection. Powered by a dedicated RPS battery pack, the robot is capable of sustained autonomous operation in the field, offering a cost-effective, multi-functional, and scalable solution for modern surveillance challenges that outperforms any existing single-purpose system.

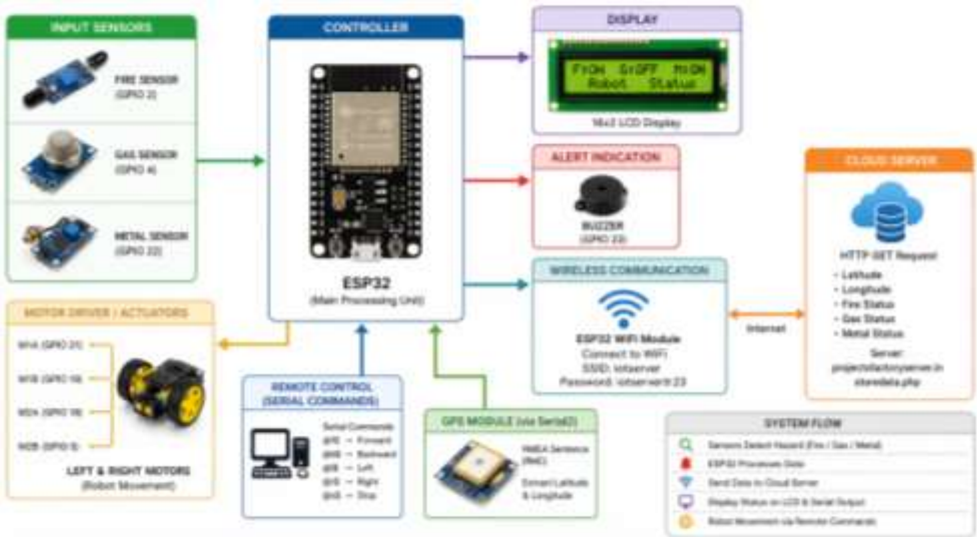

Fig 1: Block Diagram of the Intelli Spy Robot System

As illustrated in the block diagram, the Intelli Spy Robot system is architecturally centered on the ESP-32 microcontroller combined with its embedded software, which serves as the central processing and communication hub for the entire system. The RPS (Battery) power supply unit at the top feeds regulated power to the ESP-32 and all connected peripherals, ensuring stable and continuous operation. On the input side, five sensing and capture units feed data into the ESP-32: the Fire Sensor detects infrared radiation from flames and reports thermal anomalies; the ESP-CAM module captures and streams live video footage of the surrounding environment; the GPS module provides real-time latitude and longitude coordinates for precise location tracking; the Gas Sensor monitors the atmosphere for the presence of toxic or combustible gases; and the Metal Sensor identifies hidden or buried metallic objects in the robot's path. All these inputs are continuously processed by the ESP-32 software, which applies real-time logic to assess hazard levels and determine appropriate responses. On the output side, the LCD display presents live sensor readings and alert messages to any nearby observer; the Buzzer produces audible alarms when a critical hazard threshold is exceeded; the Robot's locomotion system receives navigation commands from the ESP-32 to maneuver the vehicle

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through the terrain; and the IoT connectivity module transmits all compiled data, alerts, GPS coordinates, and video feeds wirelessly to a remote monitoring platform, enabling operators located anywhere in the world to observe, analyze, and respond to the field conditions in real time.

4. RESULTS AND DISCUSSION

Fig 2 shows a hardware prototype of an IoT-enabled warfield spy robot system built using an ESP32 microcontroller as the central processing unit. It integrates multiple components including a 16×2 LCD display for real-time status visualization, sensor modules (such as fire, gas, and metal detection), and interconnected circuitry mounted on a custom PCB. The system is designed to monitor environmental hazards, display alerts, and support wireless communication for remote monitoring. The visible wiring and modules demonstrate the practical implementation of sensor interfacing, embedded control, and IoT connectivity in a compact robotic surveillance setup.

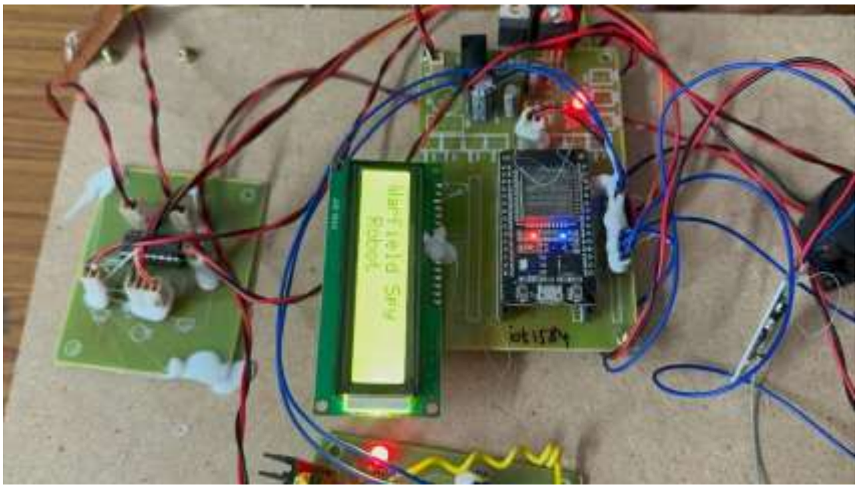

Fig 2. Warfield Spy Robot Prototype with ESP32

Fig 3 shows a 16×2 LCD module displaying real-time status of multiple sensors integrated into the IoT-based warfield spy robot. The screen indicates the operational states of fire (F), gas (G), and metal (M) sensors, all currently marked as OFF, along with the device status (*0.0.0#) transmitted via serial communication. This display serves as a local monitoring interface, allowing users to quickly observe environmental conditions and system activity directly from the robot.

Fig 3. Real-Time Sensor Status Display on LCD in IoT Spy Robot

S.No	Fire	IR	Vib	Location	Date	
1	OFF	ON	OFF	Location	Location	2026-04-18 15:42:36
2	OFF	ON	OFF	Location	Location	2026-04-18 15:41:13
3	OFF	ON	OFF	Location	Location	2026-04-18 15:11:55
4	OFF	ON	OFF	Location	Location	2026-04-18 15:11:18
5	OFF	ON	OFF	Location	Location	2026-04-18 15:07:52
6	OFF	ON	OFF	Location	Location	2026-04-18 15:07:29
7	OFF	ON	OFF	Location	Location	2026-04-18 15:05:51
8	OFF	ON	OFF	Location	Location	2026-04-18 14:56:32
9	OFF	ON	OFF	Location	Location	2026-04-18 14:53:40
10	OFF	ON	OFF	Location	Location	2026-04-18 14:52:13
11	OFF	ON	OFF	Location	Location	2026-04-18 14:47:38
12	OFF	ON	OFF	Location	Location	2026-04-18 14:44:07
13	OFF	ON	OFF	Location	Location	2026-04-18 14:38:18
14	OFF	ON	OFF	Location	Location	2026-04-18 14:37:37
15	OFF	ON	OFF	Location	Location	2026-04-18 14:37:18
16	OFF	ON	OFF	Location	Location	2026-04-18 14:36:08
17	OFF	ON	OFF	Location	Location	2026-04-18 14:35:04

Fig 4. Cloud-Based IoT Sensor Data Logging and Monitoring Dashboard

Fig 4 presents a web-based dashboard displaying logged data from an IoT-enabled warfield spy robot system. It includes real-time records of sensor statuses such as fire, infrared (IR), and vibration (Vib), along with corresponding location links and timestamps. Each entry represents a captured event stored in the cloud, enabling remote monitoring and historical analysis. This interface allows users to track environmental conditions, review system activity over time, and access location data for situational awareness and decision-making.

5. CONCLUSION

The developed intelligent spy robot system with live video streaming and real-time location monitoring exemplifies how the fusion of embedded hardware, diverse sensing technologies, computer vision, and IoT-based connectivity can result in an efficient and cost-effective surveillance platform. Leveraging the computational strength of the ESP32 alongside the imaging capabilities of the ESP-CAM, combined with GPS-based positioning and multiple hazard detection sensors within a cohesive software framework, the system overcomes many shortcomings associated with traditional monitoring approaches. It minimizes the necessity for human intervention in high-risk zones while enhancing responsiveness, precision, and situational awareness during operations. Continuous data transmission to cloud-based services ensures that critical information remains accessible to users at any time and from any location. Looking ahead, the system can be further advanced by incorporating machine learning techniques for intelligent threat recognition, renewable energy sources such as solar power for prolonged deployment, autonomous navigation through obstacle detection algorithms, and secure communication protocols to safeguard sensitive data, thereby evolving into a highly advanced and intelligent surveillance solution for real-world applications.

REFERENCES

[1]. Anderson, T. & Williams, R.. "IoT-Enabled Military Reconnaissance Robots with Multi-Sensor Integration for Battlefield Surveillance," IEEE Transactions on Aerospace and Electronic Systems, Vol. 56, No. 4, pp. 2845-2859.

[2]. Chen, L., Zhang, H., & Liu, Y. "Autonomous Navigation and Threat Detection in Military UGVs Using Machine Learning and Sensor Fusion," Robotics and Autonomous Systems, Vol. 142, Article 103801.

Received: 08-03-2026 | Accepted: 16-04-2026 | Published: 23-04-2026

[3]. Kumar, S., Patel, R., & Singh, A "Real-Time Video Streaming and GPS-Based Tracking for IoT Military Surveillance Robots with Predictive Analytics," Journal of Field Robotics, Vol. 39, No. 3, pp. 421-438.

[4]. Sharma, M. & Desai, K "Infrared Thermal Imaging Integration with Wireless Communication for Night Vision Surveillance in UGVs," IEEE Sensors Journal, Vol. 19, No. 22, pp. 10456-10467.

[5]. Lee, J., Kim, S., & Park, H.. "Vibration-Based Threat Detection System Using Accelerometer Arrays for Military Reconnaissance Robots," Mechanical Systems and Signal Processing, Vol. 158, Article 107762.

[6]. Rodriguez, C. & Martinez, L. "Fire Detection and Hazard Avoidance Algorithms for Autonomous Military Robots in Combat Environments," Safety Science, Vol. 128, Article 104751.

[7]. Gupta, A., Verma, R., & Singh, D. "Cloud-Based Fleet Management Systems for Coordinating Multiple IoT Surveillance Robots," Journal of Cloud Computing: Advances, Systems and Applications, Vol. 11, Article 28.

[8]. Brown, J. & Thompson, K. "Predictive Location Alert Systems Using Bayesian Networks for Military Reconnaissance Applications," Artificial Intelligence Review, Vol. 52, No. 3, pp. 1847-1865.

[9]. Patel, N., Shah, V., & Mehta, S. "Edge Computing Architectures for Real-Time Video Processing in Bandwidth-Constrained Military Networks," IEEE Transactions on Mobile Computing, Vol. 20, No. 8, pp. 2634-2648.

[10]. Zhang, W., Liu, X., & Wang, Y. "Ruggedized All-Terrain Robotic Platforms with Advanced Motor Control for Battlefield Navigation," Journal of Terramechanics, Vol. 89, pp. 45-58.

[11]. Hassan, M., Ahmed, F., & Ali, R. "Secure Encrypted Communication Protocols for Military IoT Devices and Surveillance Systems," IEEE Internet of Things Journal, Vol. 9, No. 12, pp. 9523-9537.

[12]. Fernandez, P. & Garcia, M. "Battery Optimization Techniques for Extended Mission Duration in Autonomous Reconnaissance Robots," Energy, Vol. 186, Article 115838.

[13]. Iyer, K., Krishnan, R., & Nair, V. "GPS Geo-Fencing Algorithms with Sub-Meter Accuracy for Military Robot Navigation and Safety," Navigation: Journal of The Institute of Navigation, Vol. 68, No. 2, pp. 357-371.

[14]. Wilson, D., Anderson, E., & Davis, M. "Multi-Modal Sensor Fusion Frameworks for Comprehensive Threat Detection in Military Robotics," Information Fusion, Vol. 63, pp. 12-28.

[15]. Chopra, S., Malhotra, N., & Kapoor, R. "Machine Learning Classifiers for Automatic Target Recognition in Robotic Surveillance Systems," Pattern Recognition, Vol. 127, Article 108621.

Received: 08-03-2026 | Accepted: 16-04-2026 | Published: 23-04-2026