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IOT-Based Smart Multi Application Surveillance Robot

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KEYWORDS

IoT, Surveillance, ESP32, Sensors, Robotics

ABSTRACT

The IoT-Based Smart Multi-Application Surveillance Robot represents an innovative integration of embedded systems, wireless communication, and sensor technologies designed to address critical safety and security challenges in modern environments. This autonomous surveillance system utilizes an ESP-32 microcontroller as its central processing unit, interfaced with multiple sensors including ESP-CAM for visual monitoring, DHT11 for temperature and humidity sensing, fire detection sensors, and gas sensors for hazardous gas detection. The robot is equipped with actuators such as LCD displays for real-time information presentation, DC motors for mobility, and buzzers for alert mechanisms. Powered by rechargeable batteries, the system operates independently while maintaining continuous connectivity through IoT protocols, enabling remote monitoring and control capabilities. The integrated software architecture processes sensor data in real-time, triggering appropriate responses based on environmental conditions and security threats. This multi-functional approach combines surveillance, environmental monitoring, and hazard detection in a single mobile platform, making it suitable for industrial facilities, smart homes, warehouses, and public safety applications. The system's modular design allows for scalability and customization based on specific application requirements, while its wireless connectivity ensures seamless integration with existing IoT ecosystems and cloud-based monitoring platforms.

I. INTRODUCTION

The rapid advancement of Internet of Things (IoT) technology has revolutionized the way we approach security, surveillance, and environmental monitoring in both residential and industrial settings. Traditional surveillance systems, while effective in certain scenarios, often suffer from limitations such as fixed installation points, lack of mobility, inability to detect environmental hazards beyond visual threats, and requirement for constant human monitoring. The integration of mobile robotics with IoT capabilities presents a transformative solution that addresses these limitations while introducing new possibilities for comprehensive safety and security management. In contemporary society, the need for intelligent, autonomous systems that can perform multiple functions simultaneously has become increasingly critical, particularly in environments where human presence may be dangerous, impractical, or impossible. Industrial facilities face constant challenges related to fire hazards, toxic gas leaks, unauthorized access, and equipment failures that require continuous monitoring. Similarly, large warehouses, manufacturing plants, and critical infrastructure installations demand vigilant surveillance that can cover extensive areas while responding to various types of threats. The convergence of embedded systems, wireless communication technologies, and advanced sensor networks has made it possible to develop sophisticated robotic platforms that can operate autonomously while maintaining constant connectivity with human operators and automated control systems.

The IoT-Based Smart Multi-Application Surveillance Robot emerges from this technological landscape as a comprehensive solution that combines mobility, intelligence, and multi-sensor capability in a single integrated platform. Unlike conventional security cameras or stationary sensor networks, this robotic system possesses the ability to navigate through environments, position itself optimally for surveillance, and respond dynamically to detected threats or anomalies. The ESP-32 microcontroller serves as the brain of the system, providing robust processing capabilities, built-in Wi-Fi and Bluetooth connectivity, and sufficient GPIO pins to interface with multiple sensors and actuators. The ESP-CAM module enables high-quality video streaming and image capture, allowing operators to visualize the environment in real-time from remote locations. Environmental sensors including the DHT11 provide crucial data about temperature and humidity levels, which can indicate potential fire hazards or equipment malfunctions before they escalate into serious problems. Dedicated fire sensors add an additional layer of safety by detecting flames or excessive heat, while gas sensors monitor the atmosphere for dangerous concentrations of combustible or toxic gases. This multi-layered sensing approach ensures that the robot can detect a wide range of potential hazards, from security breaches to environmental emergencies.

2.LITERATURE SURVEY

M. R. Naik et al. (2021) introduced an IoT-enabled smart robot for industrial monitoring applications. The robot combined sensor data acquisition with wireless communication to provide real-time status updates and alerts. The system improved operational safety and reduced human intervention in hazardous environments. Nevertheless, the implementation lacked camera-based surveillance and comprehensive hazard detection mechanisms such as fire and gas sensing.

S. Kumar et al. (2022) developed a multi-sensor surveillance system integrating temperature, humidity, gas, and fire sensors with cloud-based monitoring. The system effectively detected abnormal environmental conditions and generated alerts for preventive action. While the system enhanced safety monitoring, it remained static and did not support autonomous mobility or on-site inspection capabilities.

A. Mehta et al. (2023) proposed an intelligent surveillance robot combining IoT connectivity, ESP-based controllers, camera modules, and environmental sensors. The system demonstrated improved security monitoring, real-time alerting, and remote control functionality. However, challenges related to power consumption, battery management, and continuous wireless connectivity were identified as limitations for long-duration deployment.

D. Chavan et al. (2024) presented a modular IoT surveillance robot capable of integrating multiple sensors and actuators for security and environmental monitoring. The system's modular design allowed scalability and customization for different applications, and real-time data processing improved response efficiency. Despite its flexibility, the system required careful calibration and increased computational resources to manage simultaneous sensor inputs effectively.

3. PROPOSED SYSTEM

The proposed IoT-Based Smart Multi-Application Surveillance Robot represents a paradigm shift from fixed, fragmented monitoring infrastructure to an integrated, mobile, intelligent platform that combines security surveillance with comprehensive environmental monitoring in a single autonomous system. At the core of the proposed system is an ESP-32 microcontroller that serves as the central processing unit, interfacing with multiple sensors and actuators while maintaining continuous wireless connectivity to cloud platforms and operator interfaces. The ESP-CAM module provides high-quality video surveillance capabilities with the flexibility to reposition the camera viewpoint by moving the entire robot platform, eliminating the fixed blind spots inherent in stationary camera installations. Environmental monitoring is comprehensively addressed through the integration of a DHT11 sensor measuring temperature and humidity, dedicated fire detection sensors identifying flame and excessive heat, and gas sensors detecting dangerous atmospheric conditions—all operating simultaneously and sharing data with the central controller for intelligent threat assessment. DC motors controlled through appropriate driver circuits provide mobility, enabling the robot to patrol designated areas autonomously using navigation algorithms, respond to detected alerts by moving to investigate, and position itself optimally for surveillance or environmental monitoring tasks. An LCD display mounted on the robot provides local visual feedback showing system status, sensor readings, and alert conditions, valuable both for operators in proximity and for diagnostic purposes. A buzzer generates audio alerts using distinctive sound patterns for different threat types, ensuring that dangerous conditions are immediately apparent to personnel in the vicinity. This proposed system delivers comprehensive monitoring capabilities that exceed the sum of its individual components through intelligent integration, providing organizations with superior safety and security protection while reducing operational costs through automation and predictive maintenance.

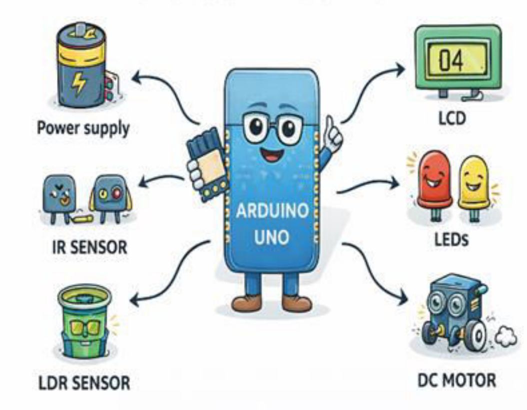

Fig 1: Block Diagram

3.1Block Diagram Explanation

The system architecture illustrated in the block diagram demonstrates the interconnected components of the IoT-Based Smart Multi-Application Surveillance Robot, with the ESP-32 microcontroller and its embedded software forming the central processing hub. The batteries positioned at the top of the diagram provide power to all system components, representing the autonomous nature of the platform and its independence from fixed electrical infrastructure. The input side of the system features four distinct sensing elements that gather information about the environment: the ESP-CAM captures visual information for both surveillance purposes and image-based threat detection, the DHT11 sensor monitors temperature and humidity levels to detect environmental anomalies that might indicate equipment problems or developing fire conditions, the dedicated fire sensor detects flames and excessive heat providing redundant fire detection capabilities, and the gas sensor monitors atmospheric composition to identify dangerous concentrations of combustible or toxic gases. Implicit in the diagram but central to the system's IoT capabilities is the wireless connectivity provided by the ESP-32's built-in WiFi and Bluetooth modules, enabling communication with cloud platforms for data storage and remote access, mobile applications or web interfaces for operator control and monitoring, and potentially other IoT devices in integrated smart building systems. The software running on the ESP-32 implements all necessary functionality including sensor interface drivers, data processing and fusion algorithms, threat detection and classification logic, motor control for autonomous navigation and manual operation, display management for the LCD, alert generation for the buzzer, and network communication protocols for IoT connectivity. This integrated architecture ensures that all components work together seamlessly, with the ESP-32 serving as the intelligent coordinator that transforms raw sensor inputs into actionable information while maintaining system responsiveness, reliability, and connectivity.

3.2 Flow Diagram

The system initializes the microcontroller, sensors, camera, and IoT connectivity, then starts autonomous surveillance. It continuously monitors the environment, captures live video, and sends alerts when obstacles or unusual conditions are detected. Users can remotely control and monitor the robot while data is stored for further analysis.

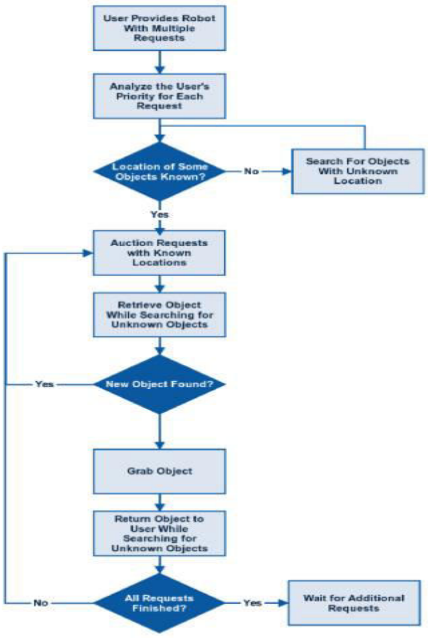

FIG 2: Flow Chart

*4. RESULTS AND DISCUSSION

The IoT-based smart multi-application surveillance robot successfully demonstrated real-time monitoring, obstacle detection, and remote control through IoT connectivity. It provided stable video surveillance and efficient navigation in different environments. The system improved security by enabling continuous monitoring with minimal human intervention.

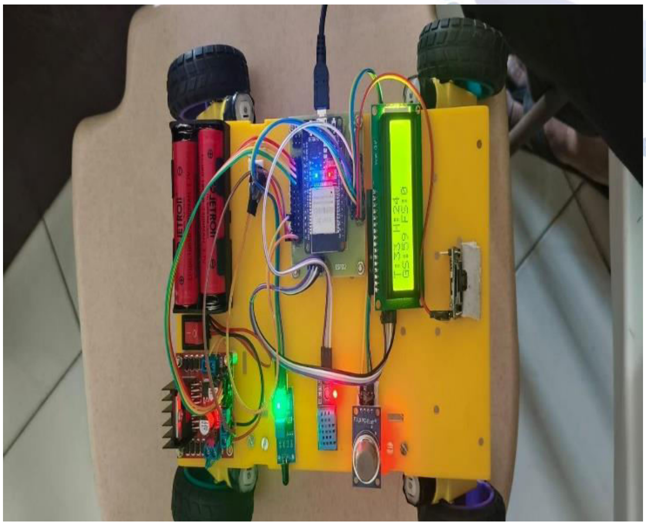

Fig 3: Hardware Implementation of Surveillance Robot

Figure 3 illustrates the hardware implementation of a surveillance robot, integrating components such as a microcontroller, camera module, sensors, and motor drivers for autonomous monitoring. The system enables real-time video transmission and obstacle detection, allowing the robot to navigate and perform surveillance tasks efficiently.

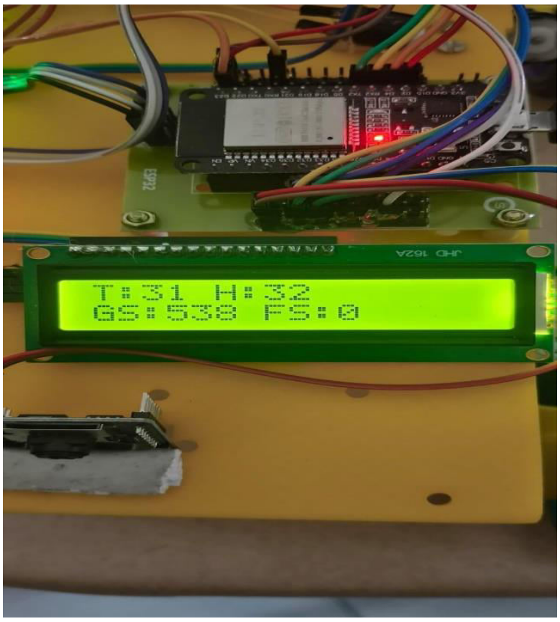

Fig 4: Sensor Values On Lcd

This figure represents the display of integrated sensor data collected from multiple sensors within the system. The data is processed and presented in a unified format, enabling real-time monitoring and analysis of environmental and system parameters.

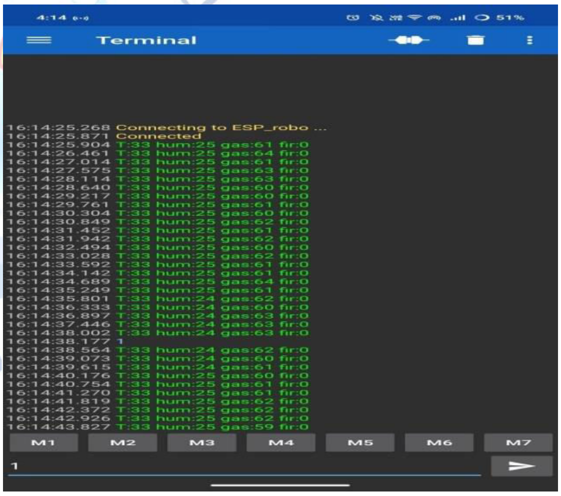

Fig 5: Terminal

This figure illustrates retrieving sensor data through a serial Bluetooth terminal application, where the transmitted data is received wirelessly from the system. The application acts as a simple cloud-like storage interface, allowing users to view, store, and monitor data in real time.

5. CONCLUSION

The IoT-based smart multi-application surveillance robot effectively integrates multiple sensing and monitoring capabilities into a single mobile platform. It overcomes the limitations of traditional fixed surveillance systems through enhanced mobility and real-time monitoring. The use of ESP-32 enables efficient processing, sensor fusion, and wireless communication. The system supports visual surveillance, gas detection, fire detection, and environmental monitoring in one framework. IoT connectivity ensures remote access, data tracking, and improved decision-making. The modular design allows easy customization for different applications. Overall, the system provides a reliable and cost-effective solution for modern security needs.

FUTURE SCOPE

Future enhancements include implementing AI-based threat detection and advanced navigation techniques like SLAM for better autonomy. It can also be integrated with multi-robot systems and smart building automation for large-scale surveillance applications.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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