IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429

Volume 5, Issue 1, November 2025

Impact Factor: 7.67

Multi-Application Surveillance Robot for Border and Industrial Security

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Abstract: *This paper presents the design and implementation of a multi-application surveillance robot capable of performing border, industrial, and hazardous-area monitoring using multiple sensors and wireless control. The proposed system integrates IR and ultrasonic sensors for obstacle detection, a temperature sensor for environmental monitoring, and a motor-driver module for robotic movement. Wireless communication via Wi-Fi or Bluetooth enables remote operation and live feedback. The robot minimizes human involvement in risky zones and enhances surveillance efficiency. Experimental testing demonstrates stable obstacle avoidance, reliable data transmission, and energy-efficient mobility.*

Keywords*:* Surveillance Robot, IoT, Wireless Monitoring, Obstacle Detection, Arduino, Industrial Security

I. INTRODUCTION

Security automation is an essential requirement in today's world, particularly in border defense and industrial safety. Traditional manual surveillance systems are constrained by limited visibility, communication delays, and risk to human life. Robots designed for monitoring tasks can overcome these limitations by integrating sensors and control units that autonomously navigate and gather environmental data.

The Multi-Application Surveillance Robot proposed in this paper is an affordable, compact, and sensor- rich platform that can operate wirelessly in different environments. It combines obstacle-avoidance capability, temperature sensing, and wireless communication, allowing real-time monitoring from a remote control unit. The system can be deployed at national borders, chemical plants, or disaster-affected areas, providing continuous situational awareness.

II. LITERATURE REVIEW

In this project, solar panels are used for charging a Lead Acid Battery (12V, 1.2 Amp hrs.), a Peltier thermoelectric device which when connected to the battery generates a cooling effect on one side, and heat is dissipated on another side through the heat sink. A regulator 7805 is used to drive the internal cooling fan and LED. Here we are using Microcontroller (ATmega16a) that allows dynamic and faster control. Liquid crystal display (LCD) makes the system user-friendly. Here we are using an LCD display for displaying the variations in voltage values that are present in the rechargeable battery.

The metal sensor will detect the metal-like bomb, any other planted weapon in-ground and intimate the soldier with a buzzer indication. The GSM is interfaced with the microcontroller and GPS is additionally interfaced such the tracking of the whole soldier is observed. And the location is messaged to the particular concerned person /dept.

III. OBJECTIVES

- To design a robot capable of wireless remote operation.
- To implement IR and ultrasonic sensors for obstacle detection.
- To integrate a temperature sensor for environmental monitoring.
- To employ an L293D motor driver for controlled navigation.
- To ensure low-power, low-cost operation suitable for industrial and defense use.

IV. SYSTEM ARCHITECTURE AND DESIGN

The robot consists of five key subsystems: sensor array, microcontroller unit, motor-driver circuit, wireless communication interface, and power supply.

A. Sensors

IR and ultrasonic sensors are used for obstacle detection. The ultrasonic sensor measures distance by emitting ultrasonic waves and calculating echo time, while IR sensors detect nearby objects using reflected infrared radiation. A temperature sensor (e.g., LM35 or DHT11) monitors ambient temperature, providing environmental awareness.

B. Control Unit

An Arduino Uno or ESP32 microcontroller acts as the brain of the robot. It collects data from sensors and sends control signals to the L293D motor driver based on obstacle detection and navigation logic.

C. Motor Driver

The L293D dual H-bridge IC drives two DC motors, allowing forward, backward, left, and right movements. Pulse-width modulation (PWM) controls speed and ensures precise motion.

D. Wireless Module

Wi-Fi (NodeMCU ESP8266) or Bluetooth (HC-05) module facilitates wireless control from a computer or smartphone application. Commands are transmitted in real time to the robot, and sensor data is fed back to the control station.

E. Power Supply

The system operates on a 12 V DC battery regulated through an LM2596 buck converter to 5 V for logic circuitry. Power optimization is achieved by cycling sensors and communication modules only when necessary.

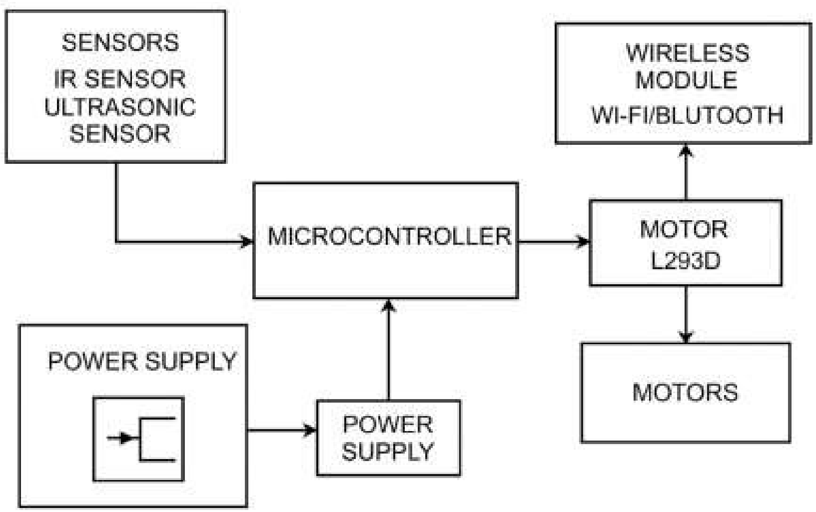

Fig. 1 shows the overall block diagram of the system.

V. METHODOLOGY

• Sensor calibration is performed to ensure accurate distance and temperature readings.

• Microcontroller programming defines logic for obstacle detection, temperature threshold monitoring, and motion control.

• Wireless connectivity is established using AT commands (Bluetooth) or TCP/IP protocol (Wi- Fi).

• The system is tested in both laboratory and outdoor conditions for obstacle density and range evaluation.

• Performance metrics such as response delay, detection accuracy, and power consumption are recorded.

• The robot halts automatically when an obstacle is detected within 10 cm and changes direction. When temperature exceeds 40 °C, a buzzer alert is generated or a cooling fan may be triggered.

VI. RESULTS AND DISCUSSION

Experiments were carried out in a 5 × 5 m test environment. The ultrasonic sensor reliably detected obstacles between 5 cm and 400 cm with ±2 cm error. The robot responded to navigation commands within 300 ms delay via Bluetooth and 150 ms via Wi-Fi. Power consumption was measured at 450 mA during active motion and 250 mA in standby.

Table I compares the proposed robot's performance with existing systems. The results show improved wireless range, faster obstacle response, and enhanced environmental adaptability. The prototype successfully navigated uneven terrain and transmitted temperature data continuously to the remote terminal.

VII. CONCLUSION AND FUTURE SCOPE

The proposed Multi-Application Surveillance Robot achieves efficient, flexible, and low-cost surveillance in hazardous and remote environments. It successfully integrates multiple sensors, a motor- driver system, and wireless communication into a single compact platform. The robot enhances safety and reduces the need for human presence in high-risk areas.

Future improvements include adding camera-based live streaming, AI-based image recognition, solar charging, and autonomous path-planning algorithms. Integration with cloud-based IoT dashboards can also enable large-scale deployment for defense and industrial monitoring.

ACKNOWLEDGMENT

The author expresses sincere gratitude to Prof. A. R. Mane for valuable guidance, motivation, and continuous support during the development of this project.

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