Design and Implementation of Smart Robot Based on AI for Block Detection

N. Harathi[1], S Yashokeerthi[2], K. Balaji Achari[3], K. Sanjay Karthik[4] and B. Tejo Sai[5]
{nimmalaharathi@gmail.com[1], yashokeerthisanikanti@gmail.com[2], pandubalaji975@gmail.com[3], kasanisanjay8@gmail.com[4], btejosai6720@gmail.com[5]}

Electronics and Communication Engineering, Mohan Babu University (Erstwhile Sree Vidyanikethan Engineering College), Tirupati, Andhra Pradesh, India[1]
Electronics and Instrumentation Engineering, Mohan Babu University (Erstwhile Sree Vidyanikethan Engineering College), Tirupati, Andhra Pradesh, India[2, 3, 4, 5]

Abstract. Currently, most surveillance robots have limitations of autonomous navigation, a single mode of control, inability of detecting obstacles under low illumination, and low durability due to insufficient power. To overcome these limitations, in this paper we propose a versatile surveillance robot that can be used in manual automatic and voice operated mode. This system is combined with: Dual Ultrasonic sensor for accurate obstacle detection, CP-E24A 2MP Full HD Wi-Fi PT Camera for real night vision live video, Android APP for Bluetooth module (HC-05) for flexible remote control. An arduino microcontroller manages sensor inputs and user commands, operated by a 12V battery for resource-efficient usage. Experiments have shown navigation as well as real-time monitoring in dark environment and responsive and multi-modal control of the system. It is a low-cost robot that can serve as an alternative for the home security, patrolling and remote surveillance since it is not similar to existing expensive counterparts.

Keywords: Surveillance Robot, Arduino, Ultrasonic Sensors, Bluetooth Module (HC-05), Voice Control, Night Vision Camera, Obstacle Detection, Android Bluetooth App, Motor Driver, DC Motors, IoT, Remote Monitoring, Home Security, etc.

1 Introduction

Surveillance robots are increasingly used in security, defense, and industrial monitoring, but existing systems often struggle with limited autonomous navigation, inefficient obstacle detection, and lack of flexible control modes. While current robots leverage embedded controllers, wireless communication, and sensors for autonomous navigation, they frequently fail in unknown or low-light environments and cannot adapt efficiently to multi-modal control requirements. Previous studies have explored microcontrollers, wireless modules, and AI-based decision-making to improve surveillance robot performance; however, these approaches often remain limited in operational flexibility and real-time adaptability. For example, Abdalla and Veeramanikandasamy (2017) developed a Raspberry Pi-based surveillance robot for remote monitoring, while Wilson et al. (2014) implemented motion detection with night vision using OpenCV. Despite these advancements, most systems are either fully manual or fully autonomous, lack multi-modal control, and face limitations in connectivity, obstacle detection, and energy efficiency. Despite the advancements, existing surveillance robots face several challenges:

ICITSM-Part II 2025, April 28-29, Tiruchengode, India

DOI 10.4108/eai.28-4-2025.2358029

- Limited Autonomous Navigation**:** Many surveillance robots rely on predefined paths or manual control, making them inefficient in unknown environments.
- Lack of Multi-Mode Control: Most surveillance robots are either fully autonomous or manually controlled, limiting flexibility in operation.
- Connectivity and Range Constraints: While Wi-Fi and Bluetooth-based communication have been used in several studies, they are often limited by range and network dependency.
- Power Efficiency Issues: Many surveillance robots depend on high-power computing units, resulting in reduced battery life and operational endurance.
- Inefficient Obstacle Detection: Some implementations rely solely on vision-based navigation, which is ineffective in low-light or obstructed conditions.

Motivated by these limitations, this research aims to develop a cost-effective, versatile surveillance robot that addresses connectivity, control, obstacle avoidance, and energy efficiency challenges in current systems.

To address these issues, the proposed robot integrates ultrasonic sensors for obstacle detection, a night vision camera for low-light monitoring, and Bluetooth-based remote control, coordinated by an Arduino microcontroller. These features collectively improve navigation, adaptability, and operational efficiency.

The primary objectives of this research are as follows:

- Develop a surveillance robot capable of manual, automatic, and voice-controlled operation to address multi-mode control limitations.
- Integrate ultrasonic sensors for efficient obstacle detection in all directions to overcome navigation and low-light challenges.
- Incorporate a night vision camera to enable real-time monitoring in low-light conditions.
- Use a Bluetooth module and Android app for flexible remote operation, mitigating connectivity constraints.
- Ensure energy-efficient operation with an Arduino microcontroller and 12 V battery for extended deployment.

This paper makes the following key contributions:

- Multi-mode operation: Manual, automatic, and voice-controlled modes improve operational flexibility over prior systems.
- Enhanced obstacle detection: Dual ultrasonic sensors allow safe navigation in unknown and low-light environments.
- Real-time night vision monitoring: Enables continuous surveillance even in dark conditions.
- Improved communication: Bluetooth and Android app provide seamless remote control, overcoming connectivity limitations.
- Energy-efficient implementation: 12 V battery and Arduino control enable extended operation, addressing power consumption challenges.

The rest of the paper is organized as follows Section 2 presents the literature review analysis and elaborates the relevant work of surveillance robots as well as identifies research gaps in this work. Section 3 presents the system design and implementation, which consists of hardware components, control architecture, and operational principle. The experimental platform and results are provided in Section 4, in which the performance of the robot is illustrated under various conditions. Section 5 concludes future work and describes possible improvement and application.

2 Related Works

Surveillance and service robots have been widely studied in recent years, leveraging microcontrollers, sensors, and wireless communication technologies for autonomous and semi-autonomous operation. However, most existing systems face challenges in multi-modal control, low-light monitoring, power efficiency, and adaptability.

Vijayalakshmi and Harish [1] proposed an ATmega328-based system for air pollution monitoring, demonstrating how embedded controllers can efficiently manage environmental data collection. While effective for static sensing, such systems lack navigation and obstacle avoidance capabilities, making them unsuitable for mobile surveillance applications. Similarly, Selvam [2] developed a smartphone-controlled robotic platform for surveillance, enabling wireless operation via Android devices. However, the design was limited to manual control without autonomy or advanced sensing.

Navigation and mobility remain central issues in robotics. MacMillan et al. [3] introduced a range-based navigation system for mobile robots, showing the importance of sensor fusion in path planning. Likewise, Jenifer et al. [4] presented a Bluetooth-enabled mobile robot for temperature monitoring, but its reliance on short-range communication restricted operational flexibility. Pannaga and Harish [5] further explored self-balancing robots using embedded control, which demonstrated stability improvements but offered limited practical application in real-world surveillance tasks.

For surveillance-specific applications, Abdalla and Veeramanikandasamy [6] implemented a Raspberry Pi–based spy robot with IP-based communication, providing real-time monitoring but constrained by internet dependency and single-mode control. Wilson et al. [7] designed a low-cost security camera system with night vision and OpenCV-based motion detection, but it lacked mobility and obstacle avoidance. Kaur and Kumar [8] extended robotic applications into military surveillance with a wireless multifunctional robot, yet its cost and complexity made it less suitable for civilian or low-budget use cases.

Recent works emphasize the integration of AI into robotic systems. K. C. R., Raja et al. [9] highlighted the role of AI algorithms in enhancing autonomous navigation, while the U.S. Department of Defense [10] provided a strategic framework for AI in defense, identifying challenges in ethics and deployment. Da Silva et al. [11] applied 2D laser sensors for quadruped robot navigation in uneven terrain, showcasing progress in terrain adaptability but requiring computationally expensive hardware. Kashif et al. [12] developed an image-capture sentry gun robot, focusing on automated object tracking but limited to static defense contexts.

Other research has integrated advanced weaponized and targeting systems. Hema et al. [13] proposed a smartphone-controlled robot with automatic firing capabilities, and Prasad et al. [14] implemented a gun-targeting system using face detection and ultrasonic sensors. These systems demonstrated automation but emphasized military applications rather than general-purpose surveillance.

The latest studies combine IoT and Edge-AI technologies for greater adaptability. Ahammed et al. [15] presented an IoT-driven vision surveillance robot capable of real-time object detection, addressing the demand for intelligent monitoring. Similarly, Valentino and Leonen [16] proposed an IoT-based smart security robot with enhanced threat detection and night vision. While these works improve adaptability, they often demand high computational resources and may not be cost-effective for broader adoption.

3 Proposed Method

Three control methods are available for controlling the monitoring robot, which includes the manual, automatic and voice-controlled modes, which provides high adaptiveness and wider range of application. Setup and design the system is designed to be operated with a 12V battery and an Arduino microcontroller is used as a central processor to control the various logging nodes in the system. Its two ultrasonic sensors - front and rear - help the robot accurately detect obstacles mating navigation in either autonomous or manual modes a cinch. The robot is equipped with Bluetooth module (HC-05), whereby an android Bluetooth app is used to control the robot wirelessly. Moreover, voice commands are available for robot operation, thereby improving user-friendliness and supporting accessibility.

CP-E24A 2MP FULL HD WI-FI PT CAMERA AND LIVE VIEW To power real time monitoring and live streaming, the Puli robot has been installed with an CP-E24A 2Mp Full HD Wi-Fi PT camera which/and supports night vision. This avails clear view even in low light conditions making it ideal for indoor and outdoor security applications. Robot locomotion is actuated by two DC motors controlled by a motor driver module, providing accurate and smooth movement. An LCD screen shows system status and running mode at real time, and a buzzer gives warnings when obstacles or menaces detected.

Thresholding The integration of multi-modal control, real-time monitoring, and obstacle avoidance makes this system a cost-effect alternative for security and surveillance applications. This system not only greatly improves autonomy, human interaction, and portability over current systems, but also overcomes challenges such as limited navigation, inadequate low-light navigation, a passive user-feedback mechanism. Fig. 1 shows the architecture of the proposed method.

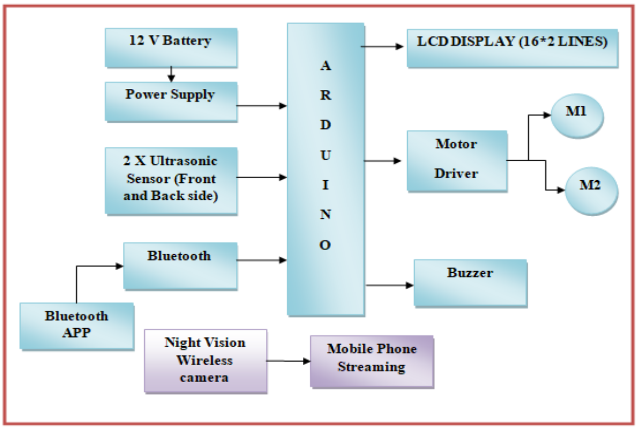

Fig. 1. Architecture of the proposed method.

3.1 Hardware Setup

3.1.1 Arduino Microcontroller

The Arduino (fig. 2) acts as the brain of the surveillance robot which processes sensor outputs, motors control and communication. It accepts the input signal from ultrasonic sensor, Bluetooth module, voice command and performs the required task.

Fig. 2. Arduino Microcontroller.

3.1.2 Ultrasonic Sensor

Two ultrasonic sensors (Fig. 3) are mounted in front and rear end of robot for obstacle sensing and avoidance. These sensors measure the distance continuously and allow the automatic driving in safety, avoiding possible contacts.

Fig. 3. Ultrasonic Sensor.

3.1.3 Motor Driver

Two DC motors (Fig. 4) are managed by the motor driver module, which receives speed and direction control signals from the Arduino. It secures even more pillow-like navigation and mobility on a variety of terrains.

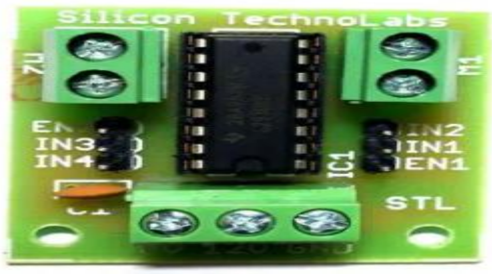

Fig. 4. Motor Driver.

3.1.4 DC Motor

Left and right wheels of robot are driven by two DC motors. These motors allow movement and turning with accuracy and efficiency in both manual and automatic control modes (Fig. 5).

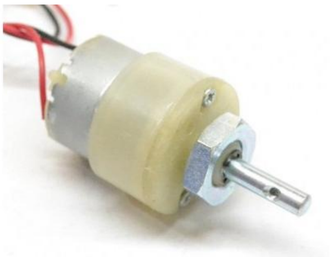

Fig. 5. DC Motor.

3.1.5 Night Vision Camera

A CP-E24A 2MP full HD Wi-Fi PT camera is fixed on the robot for video streaming. Utilizing pan-tilt with night vision, this surveillance camera provides great coverage night or day (Fig. 6).

Fig. 6. Night Vision Camera.

3.1.6 LCD Display

A 16x2 LCD (Fig. 7) display is included to show current system condition such as operational mode, connectivity status, and obstacle detection alert.

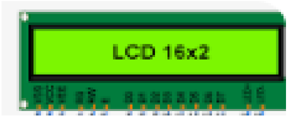

Fig. 7. LCD Display.

3.1.7 Bluetooth Module

Wireless communication is achieved using an Android Bluetooth application on a mobile phone and the HC-05 Bluetooth module to the robot. This makes it possible to operate the robot by hand with a smartphone increasing remote control operation (Fig. 8).

Fig. 8. Bluetooth Module.

3.1.8 Buzzer

A bell (fig. 9) is used as alarm device. It awakens as soon as the robot encounters an obstacle or a risk and alerts users. The Hardware integration combines to form a Robust, Intelligent surveillance Courtesy BOT with multi-modal controls and real-time monitoring options.

Fig. 9. Buzzer.

3.1.9 Battery Power supply

A 12V rechargeable battery powers the robot, ensuring extended operation. It supplies necessary voltage to the Arduino, motor driver, and sensors, maintaining system efficiency while optimizing power consumption (fig. 10).

Fig. 10. 12 V Battery Power Supply.

3.2 Algorithm

Step 1: Initialization

- Power on the Arduino microcontroller and initialize all hardware components.
- Set up communication with the HC-05 Bluetooth module for remote control.
- Activate the ultrasonic sensors for obstacle detection.
- Initialize the night vision camera for real-time video streaming.
- Display system status on the LCD screen.

Step 2: Mode Selection

Wait for user input from the Android app or voice command:

- Manual Mode: Controlled via Bluetooth commands.
- Automatic Mode: Moves forward while avoiding obstacles.
- Voice-Controlled Mode: Executes voice-based movement commands.

Step 3: Manual Mode Operation

- Receive movement commands (forward, backward, left, right, stop) from the Android app.
- Send appropriate signals to the motor driver module to control the DC motors.
- Continuously update the LCD with the robot's movement status.

Step 4: Automatic Mode Operation

- Read distance values from the ultrasonic sensors.
- If no obstacle detected, move forward.
- If an obstacle is detected in the front, stop and scan for a clear path:
    - If space is available on the left, turn left.
    - If space is available on the right, turn right.
    - If both sides are blocked, move backward and retry.
- Repeat obstacle detection and movement adjustments continuously.

Step 5: Voice-Controlled Mode

- Receive and process voice commands via Bluetooth.
- Execute corresponding movement commands (move forward, turn left, stop, etc.) based on voice input.

Step 6: Surveillance and Alerts

- Continuously stream live video from the night vision camera.
- If any suspicious activity or obstacle is detected, trigger the buzzer.
- Send an alert notification via the Android app.

Step 7: System Monitoring and Shutdown

- Continuously monitor battery voltage and update status on the LCD display.

3.3 Implementation

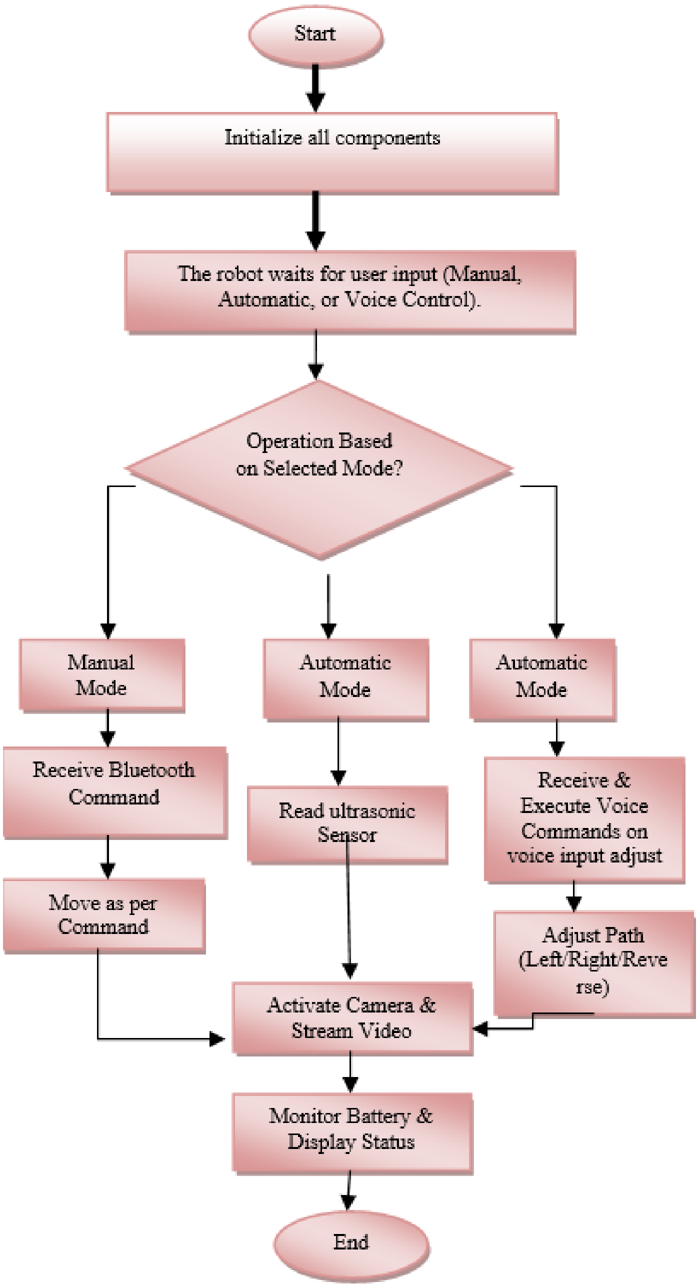

Fig. 11. Implementation of the flow chart.

Fig. 11 shows the Implementation of the flow chart for the proposed system.

4 Experimental Results

The experimental setup, as shown in Fig. 12, consists of the assembled surveillance robot with all hardware components integrated and functioning as per the design specifications. The robot was tested in various scenarios to evaluate its performance in manual, automatic, and voice-controlled modes, along with its surveillance and obstacle detection capabilities.

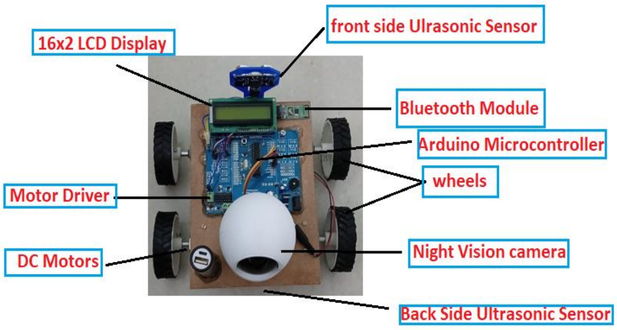

Fig. 12. Experimental Hardware Setup.

4.1 Hardware Integration and Functional Testing

The Arduino microcontroller successfully managed all sensor inputs, motor control signals, and Bluetooth communication. The 12V battery provided adequate power for uninterrupted operation. The LCD display accurately showed real-time system status, including mode selection and obstacle detection alerts. The buzzer effectively generated alerts when obstacles were detected or security threats were identified.

4.2 Manual Mode Performance

- The robot responded to Bluetooth commands from the Android application with minimal latency.
- Movement directions (forward, backward, left, right, stop) were executed smoothly without any delays.
- The real-time video feed from the night vision camera functioned well, providing clear visuals in both daylight and low-light conditions.

4.3 Automatic Mode Performance

- The ultrasonic sensors successfully detected obstacles within a range of 2 to 400 cm, allowing the robot to navigate autonomously.
- The robot correctly adjusted its path by turning left or right when encountering an obstacle.
- If no clear path was available, the system moved backward and retried an alternative route.

4.4 Voice-Controlled Mode Performance

- The voice recognition system accurately detected commands such as "Move forward," "Turn left," "Stop," and executed them accordingly.

- The response time between voice command input and robot movement was observed to be under 1 second, ensuring real-time operation.

4.5 Surveillance and Security Features

- The night vision camera provided a live video feed to a connected mobile device, ensuring effective remote monitoring.
- The camera's pan-tilt functionality improved coverage, reducing blind spots.
- The buzzer provided an instant audio alert when obstacles were detected or when a suspicious activity was identified.

4.6 Power Consumption and System Efficiency

- The system operated efficiently on a fully charged 12V battery for approximately 2-3 hours, depending on motor usage and camera operation.
- Power consumption was optimized, with minimal voltage drops affecting performance.

5 Conclusion and Future scope

The surveillance robot was successfully designed and implemented with manual, automatic, and voice-controlled operation modes. The integration of Arduino, ultrasonic sensors, Bluetooth communication, a night vision camera, and a motorized navigation system enabled efficient real-time monitoring and security surveillance. The experimental results validated the system's capability to navigate autonomously, avoid obstacles, respond to voice commands, and provide real-time video streaming. The low-latency control and high accuracy in obstacle detection ensured reliable operation in both indoor and outdoor environments. The robot's buzzer alert mechanism further enhanced its security functionality, making it a cost-effective and efficient solution for surveillance applications.

In future the proposed method can be extended to implement machine learning algorithms to identify and classify objects or intruders in the surveillance area. Integrate facial recognition to distinguish between authorized and unauthorized individuals.

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