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Night Patrol Robot with Dual Mode Navigation and Real Time Surveillance

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ABSTRACT: This project presents the design and implementation of a Night Patrol Robot equipped with dual-mode navigation and real-time surveillance capabilities. The robot operates in two distinct modes: manual mode, controlled via a Bluetooth mobile application using the HC-05 module, and automatic mode, where it autonomously navigates using ultrasonic sensors to detect obstacles and avoid collisions.

The robot is powered by a battery supply and is built around an Arduino microcontroller, which processes sensor inputs and controls various components. It features a Night Vision camera for real-time monitoring, an LCD display for status updates, and a buzzer for alert notifications. Motion is facilitated by two DC motors, controlled via a motor driver module, enabling smooth movement across different terrains. This system is designed for security and surveillance applications, making it suitable for patrolling restricted or sensitive areas at night. The combination of Bluetooth-based manual control and autonomous navigation enhances its versatility, allowing operators to switch modes based on requirements. The real-time surveillance capability ensures improved situational awareness and threat detection in low-light environments.

KEYWORDS: Night Patrol Robot, Dual-Mode Navigation, Real-Time Surveillance, Arduino, Ultrasonic Sensor, Bluetooth Module (HC-05), Night Vision Camera, LCD Display, Motor Driver, DC Motors, Buzzer, Autonomous Navigation, Manual Mode, Security, Wireless Control etc

I. INTRODUCTION

Robotics and automation have significantly transformed various industries, including security and surveillance. Autonomous patrolling robots equipped with night vision capabilities are becoming increasingly essential for monitoring restricted areas, industrial sites, and defense zones. Traditional surveillance systems rely on fixed-position cameras, which provide a limited field of view and require substantial infrastructure for installation and maintenance [1]. To address these limitations, mobile robotic solutions have been developed to ensure real-time monitoring and adaptability in dynamic environments [2].

Recent advancements in embedded systems and wireless communication have led to the integration of IoT-enabled surveillance robots, improving real-time remote monitoring [3]. Various studies have proposed robotic systems with night vision cameras, Bluetooth-based remote control, ultrasonic sensors for obstacle avoidance, and multi-mode operation (manual and autonomous) [4][5]. However, despite these advancements, there remain several challenges in designing an efficient and cost-effective night patrol robot that ensures seamless operation in both manual and autonomous modes.

While several robotic surveillance models exist, they exhibit limitations in autonomy, real-time data transmission, and obstacle avoidance. Previous works have identified the following challenges:

1. Limited Autonomy: Some surveillance robots rely heavily on manual control, reducing their effectiveness in autonomous patrolling scenarios [6].
2. Inefficient Night Vision Capabilities: Many existing models use low-resolution cameras, limiting their ability to capture clear images in low-light environments [7].

3. Obstacle Detection and Avoidance: Prior systems often lack adaptive navigation mechanisms, leading to inefficiencies when maneuvering through cluttered or complex environments [8].
4. Connectivity and Control Limitations: Some Bluetooth-controlled robots experience latency and range restrictions, affecting real-time responsiveness in large areas [9].
5. Energy Efficiency Issues: The battery life of patrol robots is a major concern, as continuous operation drains power quickly, requiring frequent recharging or power optimization strategies [10].

Given the challenges outlined above, there is a strong motivation to develop a night patrol robot with dual-mode navigation (manual and autonomous) that integrates a night vision camera, ultrasonic sensors for obstacle detection, and an efficient power supply system. A major driving force behind this research is to enhance real-time surveillance capabilities while overcoming autonomy and connectivity limitations. The proposed system leverages Arduino-based control, HC-05 Bluetooth communication, and efficient battery management to ensure seamless surveillance and navigation.

This paper aims to achieve the following objectives:

1. Develop a dual-mode night patrol robot capable of switching between manual and autonomous operation.
2. Enhance real-time surveillance using a high-resolution night vision camera.
3. Improve obstacle detection and avoidance through ultrasonic sensors and efficient path-planning algorithms.
4. Ensure efficient wireless communication by integrating a Bluetooth (HC-05) module for remote operation.
5. Optimize battery usage to extend the robot's operational lifespan.

The main contributions of this work are as follows:

- Development of a fully functional night patrol robot with both manual and autonomous navigation.
- Integration of an HC-05 Bluetooth module to enable real-time mobile app-based control.
- Implementation of ultrasonic sensors for adaptive obstacle detection and avoidance.
- Incorporation of a night vision camera to enhance low-light surveillance capabilities.
- Optimization of power consumption to increase battery efficiency and prolong operational hours.

The rest of the paper is structured as follows: Section 2 reviews related work and existing surveillance robots. Section 3 details the system architecture, including hardware and software components. Section 4 presents experimental results and performance analysis. Section 5 discusses future improvements and conclusions.

By addressing the limitations of previous surveillance robots, this work provides a comprehensive solution for real-time night patrolling, making it suitable for security, military, and industrial applications.

II. RELATED WORKS

Recent advancements in robotics have significantly contributed to the development of surveillance systems, particularly for night vision-based patrolling, autonomous navigation, and human-robot interaction. Several studies have explored different approaches to enhance surveillance robots, integrating real-time monitoring, multi-mode operation, and intelligent sensing technologies.

1) Night Vision Surveillance and Remote Operation

Salman et al. [1] proposed a web-based wireless-controlled robot for night vision surveillance using a Raspberry Pi and shell scripting. The system enables remote monitoring and control, making it a cost-effective solution for security applications. Similarly, Chavanke and Barhate [2] developed a war field spying robot equipped with a night vision camera, designed for reconnaissance in military operations. Their study highlights the importance of robust real-time video transmission in low-light environments.

2) Multi-Mode Operation and Autonomous Navigation

Kumar et al. [3] introduced a video surveillance robot with multi-mode operation, allowing it to function both manually and autonomously. Manasa et al. [4] further expanded this concept by developing a night vision patrolling robot, emphasizing sensor-based obstacle avoidance and real-time monitoring for security purposes. Hameed et al. [5]

proposed a military spying robot that integrates multiple control modes, highlighting the relevance of adaptable robotic surveillance in high-risk zones.

3) Navigation, Localization, and Sensor Fusion

Saranya and Nithya [6] explored campus navigation for the visually impaired, utilizing Android-based location tracking. Although primarily designed for accessibility, the real-time localization methods discussed in their research can enhance robotic patrol navigation. Andreasson et al. [7] presented an extensive review on sensor technologies for mobile robots, detailing the integration of ultrasonic, infrared, and LiDAR sensors for efficient obstacle detection and autonomous movement.

4) Human-Robot Interaction and Safety Measures

Secil and Ozkan [8] developed a skeletal tracking system for calculating minimum safe distances in human-robot interaction (HRI) scenarios, ensuring operational safety. Similarly, Fonseca et al. [9] introduced a hybrid force and proximity sensor to enhance physical interactions between humans and collaborative robots. Taylor and Riek [10] focused on group detection and tracking in dynamic environments, which is crucial for surveillance robots operating in crowded areas. Additionally, Choi et al. [11] proposed a mixed reality system using deep learning for real-time safety-aware human-robot collaboration.

III. PROPOSED METHOD

The proposed Night Patrol Robot is designed to operate in two modes: manual and autonomous navigation, providing flexibility for surveillance in both controlled and dynamic environments. The robot integrates multiple hardware and software components to enhance real-time monitoring, obstacle detection, and efficient mobility.

In manual mode, the robot can be controlled via a Bluetooth-based mobile application, allowing an operator to navigate the robot remotely. The Bluetooth module (HC-05) ensures smooth wireless communication between the mobile app and the Arduino-based control system. This mode is particularly useful for direct surveillance or intervention when human supervision is necessary.

In autonomous mode, the robot uses ultrasonic sensors to detect obstacles and navigate without human intervention. The Arduino microcontroller processes sensor data, ensuring obstacle avoidance and efficient path planning. The dual-mode operation allows for seamless switching between user-controlled and automated patrolling, making it suitable for various security applications.

For real-time surveillance, the robot is equipped with a night vision camera, capable of capturing and transmitting footage even in low-light conditions. The live video feed is displayed on an LCD screen, providing instant monitoring. Additionally, a buzzer is integrated for alerting security personnel in case of any detected anomalies.

The mobility of the robot is powered by two DC motors, controlled via a motor driver circuit. This ensures smooth and stable movement across different terrains. The entire system operates on a battery-powered supply, ensuring extended operational time and reliability for continuous surveillance.

The combination of dual-mode navigation, real-time monitoring, obstacle avoidance, and efficient power management makes the proposed system an effective and adaptable night patrol solution for security, defense, and industrial surveillance applications.

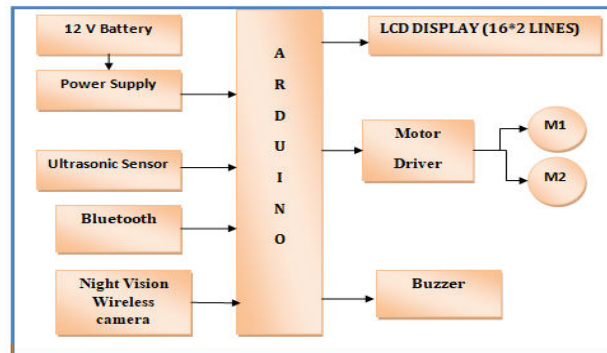


Fig. 1. Architecture of the proposed method

B. Hardware Setup

1) Arduino

The robot is powered by an Arduino microcontroller, which acts as the central processing unit. It receives input from the ultrasonic sensors, Bluetooth module, and night vision camera, processes the data, and controls the motor driver, LCD display, and buzzer. The Arduino ensures smooth operation by executing programmed instructions based on the selected mode (manual or autonomous).

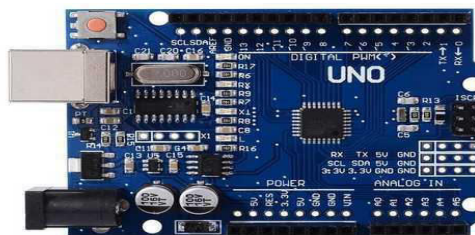


Fig. 2. Arduino Microcontroller

2) Bluetooth (HC-05)

The HC-05 Bluetooth module facilitates wireless communication between the robot and a mobile application. It allows users to manually control the robot's movement and monitor real-time data from their smartphones. The module operates within a 10-meter range, making it suitable for short-distance surveillance and remote operation.



Fig. 3. Bluetooth Module

3) Ultrasonic Sensor

An ultrasonic sensor is used for obstacle detection and avoidance. It continuously scans the surroundings and sends distance measurements to the Arduino. When an obstacle is detected within a predefined range, the Arduino commands the DC motors to change direction, ensuring smooth navigation in autonomous mode.



Fig. 4. Ultrasonic sensor

4) Night vision Camera (CP PLUS E24A)

The night vision camera captures real-time footage, even in low-light or dark environments. This allows continuous surveillance during nighttime patrols. The captured video can be transmitted to an LCD display or a remote monitoring system, providing enhanced situational awareness..



Fig. 5. Night vision camera

5) Motor Driver

The L298N motor driver controls the two DC motors responsible for the robot's movement. The motor driver receives signals from the Arduino and regulates the speed and direction of the wheels based on the selected mode (manual or autonomous). It ensures smooth navigation and efficient power distribution.

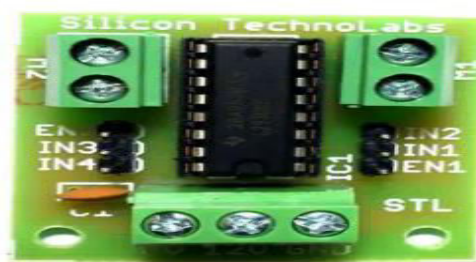


Fig. 6. Motor Driver

6) DC Gear Motors

The robot is equipped with two DC motors, which drive its wheels. The speed and direction of these motors are controlled by the motor driver module. The motors provide stable mobility, allowing the robot to move across different surfaces efficiently..

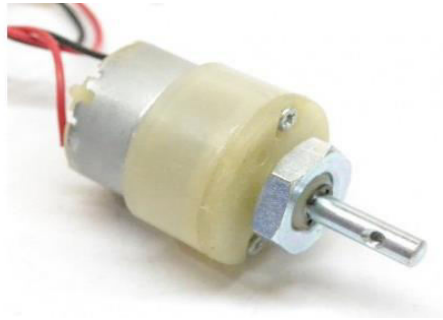


Fig. 7. DC Gear Motor

7) Buzzer

A buzzer is integrated into the system to alert operators in case of obstacle detection, security breaches, or critical system failures. This feature is particularly useful in security applications where immediate attention is required.



Fig. 8. Buzzer

8) LCD Display

A 16x2 LCD display is used to show important information such as robot status, obstacle distance, battery level, and surveillance alerts. It helps operators monitor the system in real-time while the robot is in action.



Fig. 9. LCD Module

9) Power Supply (3.7V Li-ion Rechargeable Batteries)

The entire system is powered by a rechargeable battery pack, ensuring uninterrupted operation. The battery supplies power to the Arduino, motor driver, night vision camera, and other sensors. The power management system ensures optimal energy consumption, extending the robot's operational time.



Fig. 10. Battery Power supply

C. Algorithm

- Start the System
 - Initialize Arduino, Bluetooth module (HC-05), ultrasonic sensor, night vision camera, LCD display, motor driver, and buzzer.
- Select Mode
 - Check for user input via Bluetooth mobile app.
 - If manual mode is selected → Control the robot via mobile app commands.
 - If autonomous mode is selected → Proceed to obstacle detection and navigation.
- Manual Mode Operation
 - Receive movement commands (Forward, Backward, Left, Right, Stop) from the Bluetooth app.
 - Send the corresponding signals to the motor driver for movement.
 - Continuously capture video using the night vision camera and display it on the LCD screen.
- Autonomous Mode Operation
 - Continuously read distance data from the ultrasonic sensor.
 - If no obstacle is detected → Move forward.
 - If an obstacle is detected → Stop and determine a new direction (Left or Right).
 - Navigate safely by adjusting the movement based on real-time sensor data.
- Real-time Surveillance & Alerts
 - Capture and transmit live footage from the night vision camera.
 - If a security threat is detected (based on predefined conditions) → Trigger buzzer alert.
 - Display real-time data (robot status, obstacle distance, etc.) on the LCD screen.
- Power Management & System Monitoring
 - Monitor battery status and display warnings if the power is low.
 - Optimize power usage to extend operational time.
- Repeat Operations Until Shutdown
 - Continue patrol operation until manually stopped or battery is depleted.
- Shutdown the System
 - Stop all motors and sensors.
 - Display shutdown message on LCD.

D. Implementation

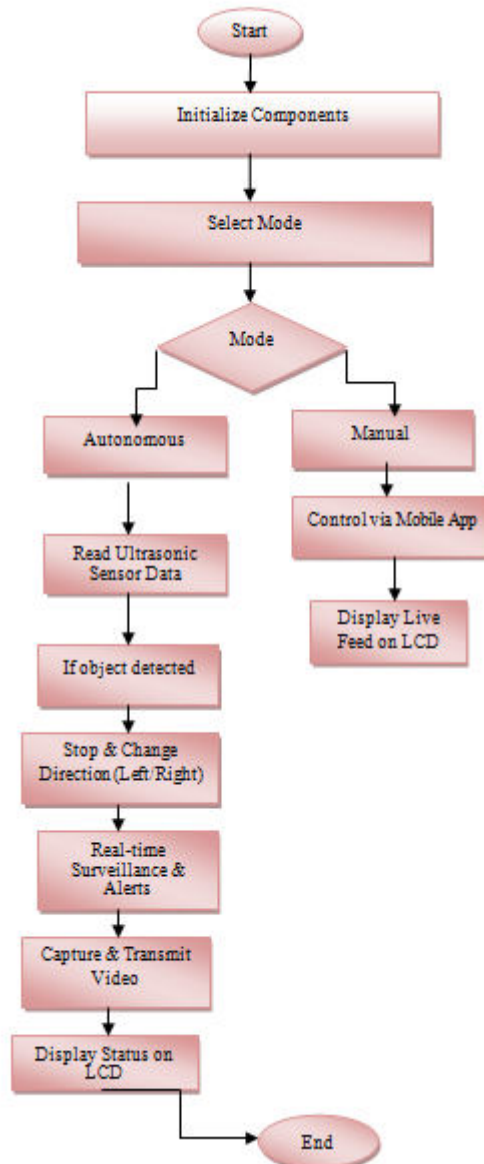


Fig. 11. Implimentation of the flow chart

IV. EXPERIMENTAL RESULTS

The Night Patrol Robot was tested in both manual and automatic modes to evaluate its functionality, navigation efficiency, obstacle detection accuracy, and surveillance performance.

In manual mode, the robot was controlled via a Bluetooth-based mobile application. The hardware setup included:

- Arduino microcontroller for processing user commands.
- HC-05 Bluetooth module for wireless communication between the mobile app and the robot.
- DC motors and motor driver (L298N) for movement based on user inputs.

- Night vision camera capturing and displaying real-time footage.
- LCD screen showing robot status and control commands.

During testing shown in fig.11:

- The robot responded instantly to user commands (forward, backward, left, right, stop).
- Bluetooth communication had a response delay of $<0.5s$ within a 10-meter range.
- The night vision camera successfully transmitted live footage to the LCD screen.



Fig. 12. Hardware setup model for manual mode

Automatic mode, the robot was tested for self-navigation and obstacle detection. The setup included:

- Ultrasonic sensor continuously scanning for obstacles.
- Arduino processing real-time sensor data for navigation.
- DC motors and motor driver adjusting direction automatically.
- Buzzer for alerts when obstacles were detected.

During testing shown in fig.13:

- The ultrasonic sensor successfully detected obstacles within a 10-15 cm range.
- The robot changed direction within 1s after obstacle detection.
- The buzzer alerted when obstacles were too close, ensuring safety.
- The night vision camera functioned efficiently in low-light conditions, improving surveillance.



Fig. 13. Hardware setup mode for automatic mode

Table I: Experimentnal results

Parameter	Manual Mode	Automatic Mode
Control Mechanism	Bluetooth (Mobile App)	Autonomous (Sensor-Based)
Response Time	<0.5s	<1s after obstacle detection
Navigation Accuracy	100% (User-Controlled)	90% (Depends on Sensor Accuracy)
Obstacle Detection	User-controlled (No auto-detection)	Yes (10-15 cm range)
Surveillance Efficiency	Live feed via night vision camera	Live feed via night vision camera
Buzzer Alert	Only when triggered manually	Automatic when an obstacle is detected
Power Consumption	Moderate (Bluetooth active)	Higher (Continuous Sensor Processing)
Range	10 meters (Bluetooth limitation)	Unlimited (Within battery limits)

The experimental results demonstrate that:

- Manual mode provides precise control, making it useful for user-directed surveillance.
- Automatic mode enhances autonomous patrolling and obstacle avoidance, ensuring efficient security monitoring.
- The night vision camera and LCD display successfully provide real-time surveillance in both modes.
- Bluetooth control is limited by range, whereas autonomous mode can cover a larger area with obstacle detection.

V. CONCLUSION AND FUTURE SCOPE

The Night Patrol Robot was successfully designed and implemented with dual-mode navigation (manual and autonomous), real-time surveillance, and obstacle detection. The manual mode allows precise control via a Bluetooth mobile app, while the automatic mode enables self-navigation using an ultrasonic sensor. The night vision camera ensures effective monitoring even in low-light conditions, and the buzzer alerts enhance security by notifying threats. The system proved to be efficient, responsive, and reliable, making it suitable for applications in industrial security, military surveillance, and residential safety. Manual mode provides instant control with minimal delay (<0.5s). Automatic mode efficiently detects and avoids obstacles within a 10-15 cm range. The night vision camera ensures clear real-time surveillance. The battery-powered system ensures wireless and independent operation. The project successfully demonstrates a cost-effective, flexible, and efficient robotic surveillance system, bridging the gap between human monitoring and autonomous security patrols.

In future the proposed method can be extended with Implementing AI and machine learning to detect and recognize humans, intruders, or specific objects, improving security automation.

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