

SMART PATROL ROBOT USING IOT AND DUAL MICROCONTROLLER ARCHITECTURE FOR REAL-TIME SURVEILLANCE

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Abstract: Security and surveillance systems play a vital role in residential, industrial, and public environments. However, manual monitoring requires continuous human effort and may not always be efficient. To address this issue, a smart patrol robot is proposed for real-time surveillance and remote monitoring. The system utilizes dual microcontrollers, namely ESP32 Dev Module and ESP8266, integrated with a camera module, sensors, and a motor driver. The ESP32 Dev Module is responsible for motor control and robot movement, while the ESP8266 handles sensor data acquisition and wireless communication. The robot can be controlled wirelessly via Wi-Fi, enabling users to monitor the surroundings remotely through a mobile application. The camera module provides live video streaming for effective surveillance. The proposed system is compact, cost-effective, and easy to implement. It enhances security monitoring, reduces human effort, and provides flexible mobility for surveillance applications in homes, offices, industries, and restricted areas.

Keywords: ESP32, ESP8266, IoT, Smart Patrol Robot, Real-Time Surveillance, Flutter Application.

I. INTRODUCTION

Security and surveillance systems are essential for maintaining safety in residential, commercial, and industrial environments. Traditional surveillance systems mainly rely on fixed cameras and human monitoring, which may not provide complete coverage and require continuous human involvement. In many situations, it becomes difficult to monitor large areas effectively using stationary systems. Therefore, there is a need for a mobile surveillance system capable of real-time monitoring across different locations.

With advancements in Internet of Things (IoT) technology and embedded systems, smart surveillance robots have gained significant attention. These systems can navigate environments, capture live video, and transmit data wirelessly, thereby reducing human effort and improving monitoring efficiency. The integration of microcontrollers, sensors, and wireless communication enables the development of compact and cost-effective patrol robots.

This paper presents a smart patrol robot based on a dual microcontroller architecture using ESP32 Dev Module and ESP8266 for real-time surveillance and remote monitoring. The ESP32 Dev Module is responsible for motor control and robot movement, while the ESP8266 handles sensor data acquisition and wireless communication. The system incorporates a camera module for live video streaming and a motor driver for movement control. The robot can be controlled remotely via Wi-Fi, allowing users to monitor surroundings using a mobile application.

The main objectives of the proposed system are to develop a low-cost patrol robot, enable real-time monitoring, and provide remote control for security applications. The system is designed to be simple, reliable, and suitable for various environments such as homes, offices, and industrial areas.

II. LITERATURE REVIEW

Several research works have been carried out in the field of surveillance robots and IoT-based monitoring systems using embedded platforms and wireless communication.

In paper [1], *Surveillance Monitoring Using ESP32-CAM Module*, the authors developed an IoT-based surveillance system using ESP32-CAM and sensors for intrusion detection and live monitoring. The system allowed users to receive notifications and view surveillance footage remotely. However, the proposed system mainly focused on stationary monitoring and lacked mobility for covering larger areas.

In paper [2], *IoT Based Surveillance Robot* by Anandravisekar et al., the authors developed a mobile surveillance robot using Arduino, ESP8266 Wi-Fi module, and sensors. The system enabled remote monitoring and control using IoT platforms and supported both manual and automatic modes. However, the system required multiple hardware components and lacked a dedicated mobile application for user-friendly control and live monitoring.

In paper [3], *IoT Based Smart Night Patrolling Robot*, the authors designed a surveillance robot using Arduino Uno, camera module, ultrasonic sensor, sound sensor, and NodeMCU. The robot could patrol an area autonomously and provide real-time updates through a web-based interface. However, the system relied on web interfaces instead of a dedicated mobile application and lacked efficient real-time control features.

In paper [4], *IoT Based Smart Night Patrolling Robot* published in IRJMETS, the proposed system utilized Arduino, camera module, ultrasonic sensor, sound sensor, and motor driver for surveillance applications. Although the robot was capable of detecting unusual activity and sending alerts, the system involved complex hardware design and increased implementation cost.

In paper [5], *Night Patrolling Robot Using Raspberry Pi*, the authors developed a surveillance robot using Raspberry Pi, sound sensors, and a night vision camera. The system transmitted captured video data to a server for monitoring and control and supported obstacle detection and autonomous movement. However, Raspberry Pi-based systems generally increase power consumption and cost compared to microcontroller-based solutions.

Additionally, another research work proposed a patrol robot using fuzzy logic for building automation and surveillance. The system employed multiple sensors and wireless communication for monitoring and obstacle avoidance. Although it improved surveillance flexibility, the implementation involved complex algorithms and higher computational requirements. From the analysis of the above research works, it is observed that most existing systems focus on basic surveillance, stationary monitoring, or web-based control. Many systems also involve complex hardware configurations or lack a user-friendly mobile interface for real-time monitoring and control.

To overcome these limitations, the proposed system introduces a smart patrol robot based on a dual microcontroller architecture using ESP32 Dev Module and ESP8266. The system is integrated with a Flutter-based mobile application that enables users to remotely control robot movement, view live video surveillance, and monitor real-time sensor data. This approach improves system efficiency, reduces complexity, and enhances real-time performance compared to existing solutions. The proposed system is compact, cost-effective, and suitable for various surveillance applications.

III. PROPOSED SYSTEM

The proposed system presents a smart patrol robot designed for real-time surveillance, environmental monitoring, and remote control using IoT technology. The system is developed to enhance security and monitoring by integrating multiple sensors, live video surveillance, and a Flutter-based mobile application.

The proposed robot is capable of monitoring environmental conditions such as temperature, gas leakage, sound detection, motion detection, and obstacle detection. The collected sensor data is transmitted to a Flutter-based mobile application, where users can view real-time data and monitor surroundings remotely. Additionally, the system provides 24/7 live video streaming and remote control of the robot movement.

The proposed system utilizes a dual microcontroller architecture consisting of ESP32 Dev Module and ESP8266. The ESP32 Dev Module acts as the main controller responsible for motor control and movement of the robot. The ESP8266 is used for collecting sensor data from ultrasonic, PIR, temperature, gas, and sound sensors, and for transmitting this data to the mobile application via Wi-Fi communication. Communication between ESP32 and ESP8266 is established using serial communication to ensure coordinated operation.

The system also includes an ESP32-CAM module for real-time video streaming, a motor driver for controlling DC motors, and a battery power supply for portable operation. The Flutter-based mobile application communicates wirelessly with the system to enable real-time monitoring and remote control.

The proposed system is divided into three main sections:

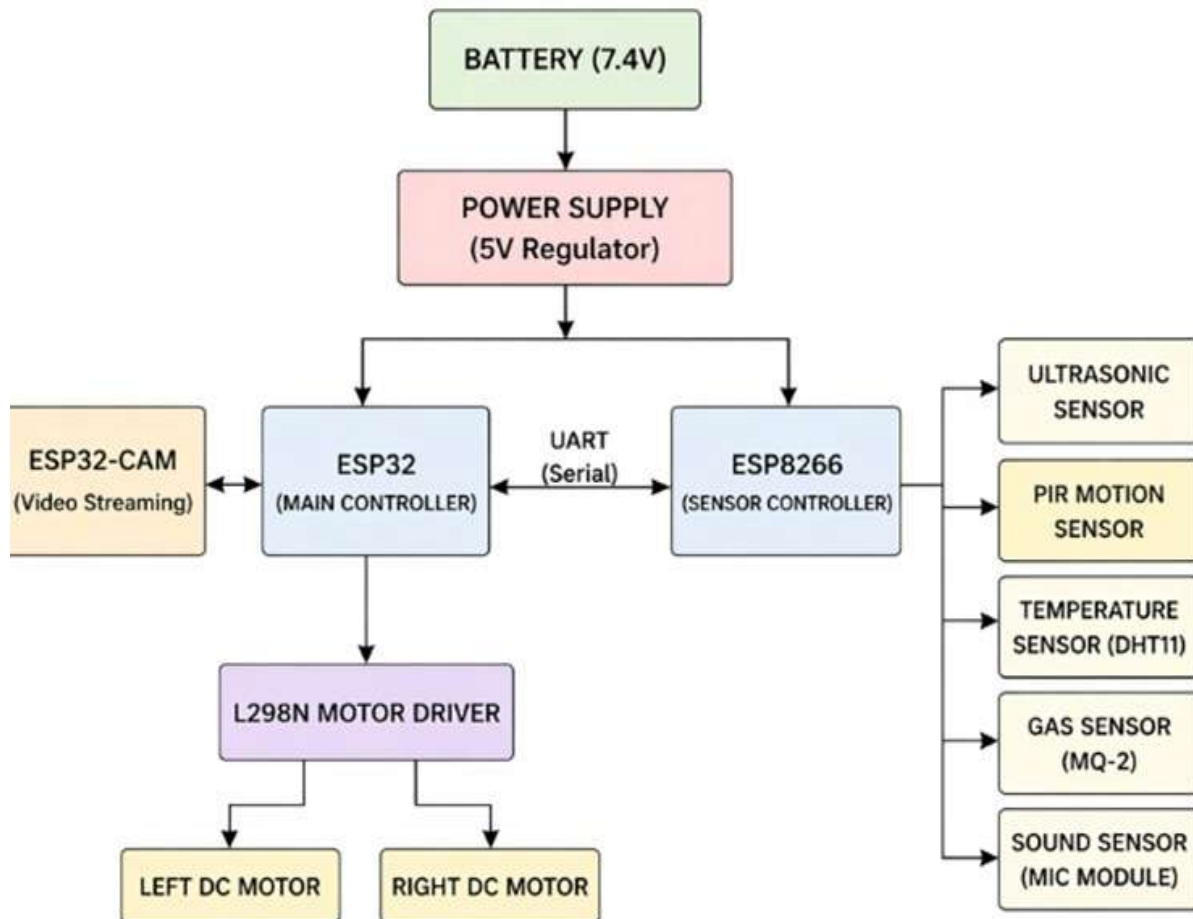
A. Block Diagram

Fig. 1 Block diagram of the system

B. Hardware Components

The proposed system consists of the following hardware components:

1. **ESP32 Microcontroller**
ESP32 acts as the main controller of the system. It collects sensor data, controls robot movement, and handles Wi-Fi communication. The ESP32 processes commands received from the Flutter mobile application.
2. **ESP32-CAM Module**
ESP32-CAM module is used for real-time video surveillance. The camera captures live video and streams it to the mobile application. The system supports 24/7 live video monitoring.
3. **Ultrasonic Sensor**
Ultrasonic sensor is used for obstacle detection. It helps the robot avoid obstacles while moving and improves navigation.
4. **PIR Motion Sensor**
PIR sensor detects human movement or motion. When motion is detected, the system sends updates to the mobile application.
5. **Temperature Sensor**
Temperature sensor monitors environmental temperature. The real-time temperature data is displayed in the mobile application.
6. **Gas Sensor**
Gas sensor detects harmful gases or gas leakage in the environment. This improves safety and helps detect hazardous situations.
7. **Sound Sensor**
Sound sensor detects unusual sounds in the surroundings. The detected sound data is transmitted to the mobile application.

8. Motor Driver (L298N)
Motor driver controls the DC motors and enables robot movement in different directions.
9. DC Motors
DC motors are used for robot movement. The robot can move forward, backward, left, and right.
10. Power Supply
Battery power supply is used to provide power to the ESP32, sensors, motor driver, and camera module

C. Software Description

The software part of the proposed system includes ESP32 programming and Flutter mobile application development.

1. ESP32 Programming

ESP32 is programmed using Arduino IDE. The program collects sensor data, controls motor movement, and streams video from ESP32-CAM. The ESP32 sends real-time data to the mobile application via firebase database.

2. Flutter Mobile Application

A Flutter-based mobile application is developed for real-time monitoring and remote control. The application provides:

- Real-time sensor data display
- 24/7 live video streaming
- Remote robot control
- User-friendly interface

Users can monitor temperature, gas levels, sound detection, motion detection, and obstacle detection through the mobile application. The application also allows users to remotely control robot movement in real time. This makes the proposed system more advanced and user-friendly compared to existing surveillance robots.

IV. ADVANTAGES AND LIMITATIONS

A. Advantages

The proposed smart patrol robot provides several advantages compared to traditional surveillance systems.

1. Real-Time Monitoring
The system provides real-time sensor data and live video streaming through the Flutter mobile application, enabling continuous monitoring.
2. Remote Control
The robot can be controlled remotely using the mobile application, allowing users to monitor and navigate the robot from any location.
3. Multiple Sensor Integration
The system integrates ultrasonic, PIR, temperature, gas, and sound sensors, improving environmental monitoring and safety.
4. 24/7 Live Surveillance
The ESP32-CAM module provides continuous live video streaming for effective surveillance.
5. User-Friendly Mobile Application
The Flutter-based mobile application provides an easy-to-use interface for monitoring and control.
6. Low Cost Implementation
The system uses low-cost components such as ESP32 and sensors, making it economical.
7. Compact and Portable Design
The robot is compact and can be deployed in various environments such as homes, offices, and industries.
8. Reduced Human Effort
The robot reduces the need for manual monitoring and improves security automation.

B. Limitations

Despite its advantages, the proposed system has some limitations.

1. Wi-Fi Dependency
The system depends on Wi-Fi connectivity. Poor internet connection may affect performance.
2. Limited Battery Life
Since the robot is battery-powered, continuous operation depends on battery capacity.
3. Limited Camera Range
The camera field of view is limited and may not cover large areas in a single position.
4. Environmental Constraints
Extreme environmental conditions such as poor lighting or obstacles may affect system performance.
5. Processing Limitations
ESP32 has limited processing power compared to high-end processors, which restricts advanced AI feature

V.RESULTS AND DISCUSSION

The proposed smart patrol robot was successfully designed and implemented using ESP32, ESP32-CAM module, multiple sensors, and a Flutter-based mobile application. The system was tested in real-time conditions to evaluate its performance in surveillance, monitoring, and remote control.

The robot successfully captured live video using the ESP32-CAM module and transmitted it to the Flutter mobile application. The system provided 24/7 live video streaming, allowing users to monitor the surroundings remotely. The video transmission was stable and provided real-time surveillance with minimal delay.

The robot movement was controlled remotely using the Flutter mobile application. The user was able to move the robot forward, backward, left, and right using control buttons in the mobile application. The movement control was responsive and operated smoothly through Wi-Fi communication.

The sensors integrated into the system successfully monitored environmental conditions. The ultrasonic sensor detected obstacles and helped in safe navigation of the robot. The PIR sensor detected motion and provided real-time updates. The temperature sensor monitored environmental temperature, while the gas sensor detected gas leakage or hazardous gases. The sound sensor detected unusual sounds in the environment.

All sensor data was displayed in real time on the Flutter mobile application. The user could continuously monitor sensor readings along with live video surveillance. This provided an efficient and user-friendly monitoring system.

The proposed system demonstrated reliable performance in surveillance and monitoring applications. The integration of multiple sensors, real-time video streaming, and mobile application-based control improved system flexibility and usability. The system is suitable for applications such as home security, office monitoring, industrial surveillance, and restricted area monitoring.

The experimental results show that the proposed smart patrol robot is efficient, cost-effective, and capable of real-time monitoring and remote control.

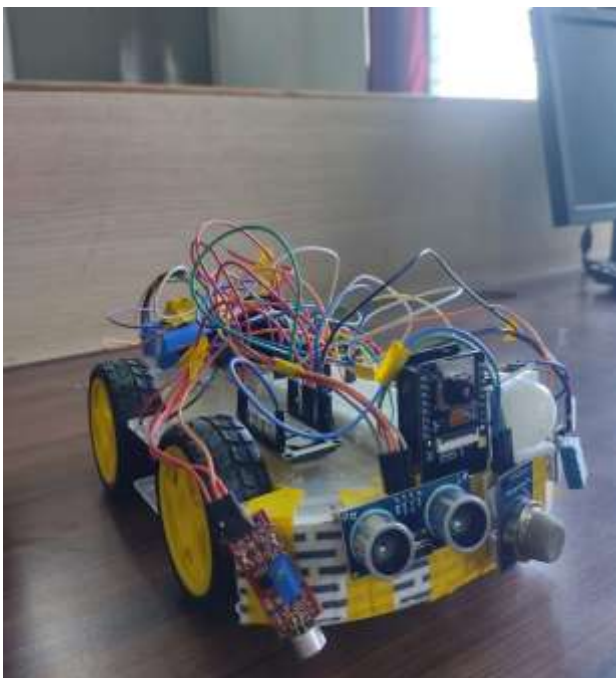


Fig.2 model image



Fig.3 login page

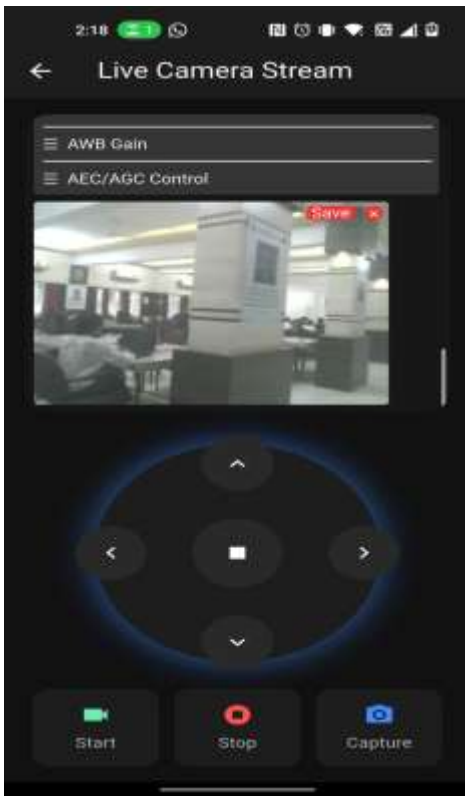


Fig.4 monitoring page

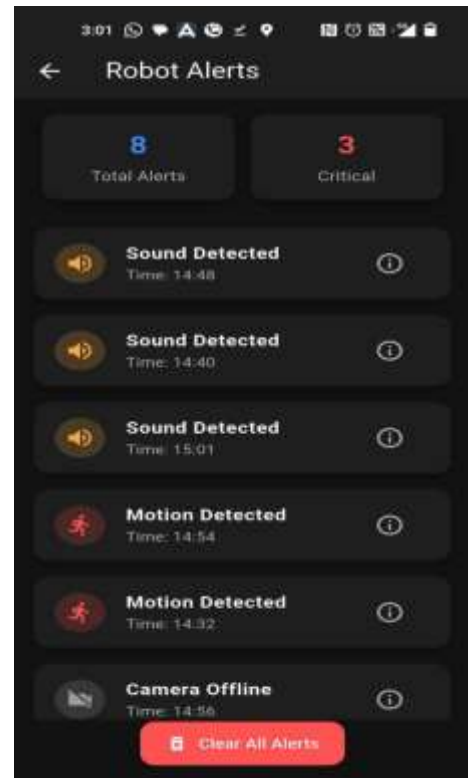


Fig.5 Alerts page

Sr. No.	Parameter	Measured Result
1	Video Streaming Delay	3– 5 sec
2	Wi-Fi Communication Range	25 – 30 meters
3	Obstacle Detection Range	2 cm – 400 cm
4	PIR Motion Detection Range	5 – 7 meters
5	Temperature Sensor Accuracy	$\pm 1^{\circ}\text{C}$
6	Gas Sensor Detection Response Time	2 – 4 sec
7	Sound Sensor Detection Range	Up to 3 meters
8	Robot Movement Speed	0.5 m/s
9	Battery Backup Time	2 – 3 hours
10	Mobile Application Response Time	Less than 1 sec
11	Camera Resolution	640 × 480 pixels
12	System Operating Voltage	5V – 12V DC

V.I.FUTURE SCOPE

The proposed smart patrol robot can be further enhanced by integrating advanced technologies and intelligent features for improved surveillance and monitoring applications. In future, Artificial Intelligence (AI) and Machine Learning (ML) algorithms can be incorporated for automatic object detection, facial recognition, and suspicious activity identification. The system can also be upgraded with autonomous navigation and path planning techniques to enable self-operating patrol functionality without manual control.

GPS and GSM modules can be integrated to provide real-time location tracking and alert notifications during emergency situations. Cloud storage and IoT platforms may also be used for secure data storage, remote access, and analysis of surveillance data from any location. Additionally, night vision cameras and advanced sensors can be added to improve monitoring performance in low-light and harsh environmental conditions.

The system can further be expanded for applications such as military surveillance, border security, smart city monitoring, industrial safety, and disaster management. These improvements would enhance system intelligence, reliability, and efficiency for next-generation smart surveillance solutions.

VII. CONCLUSION

In this paper, a smart patrol robot based on ESP32 and IoT technology has been designed and implemented for real-time surveillance and environmental monitoring. The proposed system integrates multiple sensors, live video streaming, and a Flutter-based mobile application for remote control and monitoring. The robot is capable of capturing live video, detecting motion, monitoring environmental parameters, and transmitting real-time data to users.

The ESP32 microcontroller acts as the main controller of the system, while the ESP32-CAM module provides 24/7 live surveillance. The integration of ultrasonic sensor, PIR sensor, temperature sensor, gas sensor, and sound sensor enhances the monitoring capability of the system. The collected sensor data is transmitted to the mobile application, where users can monitor real-time information and control the robot remotely.

The Flutter-based mobile application provides a user-friendly interface for real-time monitoring, live video streaming, and remote robot control. This improves system flexibility and makes the proposed solution more efficient compared to traditional surveillance systems.

The developed smart patrol robot is cost-effective, compact, and easy to implement. The system can be used in various applications such as home security, office surveillance, industrial monitoring, and restricted area security. The results demonstrate that the proposed system provides reliable performance and improves security monitoring while reducing human effort.

Thus, the proposed smart patrol robot offers an efficient and intelligent solution for real-time surveillance and remote monitoring applications.

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