



INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

LINE FOLLOWER WIFI SURVEILLANCE BOT

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Abstract: This research paper presents the design and development of a smart surveillance bot capable of autonomous navigation along predefined paths using a line-following mechanism. The system integrates an ESP32-CAM module for live video streaming, a color sensor for line detection, an ultrasonic sensor for obstacle avoidance, and a voltage sensor for battery monitoring. The bot is designed to enhance security and industrial monitoring by providing real-time surveillance and automated patrolling. The integration of multiple sensors ensures efficient navigation, making it a cost-effective and scalable solution for security applications. The proposed system is tested under different environmental conditions, ensuring reliability and efficiency in various real-world applications

Index Terms – robotics, autonomous navigation, live video streaming, surveillance system.

INTRODUCTION

With the growing need for enhanced security and automation, surveillance technology has evolved significantly over the years. Traditional surveillance systems, such as fixed CCTV cameras, offer limited coverage and require constant human monitoring. This limitation has led to the development of mobile surveillance systems that can autonomously patrol designated areas while providing real-time monitoring capabilities.

The proposed line-following surveillance bot aims to bridge the gap between static surveillance systems and mobile robotic patrolling. This bot is designed to navigate autonomously along predefined paths using a color sensor that detects and follows a marked line on the floor. It is equipped with an ESP32-CAM module to provide real-time video streaming, enabling remote monitoring without requiring direct human intervention. Additionally, the bot integrates an ultrasonic sensor for obstacle detection and avoidance, ensuring smooth operation in dynamic environments. A voltage sensor is incorporated to monitor power levels, allowing for efficient energy management and timely recharging.

The primary objective of this project is to develop a cost-effective, reliable, and scalable surveillance system that can be deployed in various environments, such as industrial facilities, warehouses, commercial buildings, and security-sensitive zones. The integration of multiple sensors and wireless connectivity enhances its functionality, making it a viable solution for both security monitoring and industrial automation.

LITERATURE SURVEY

J. Smith et al. (2018) Smith and colleagues explored the application of line-following robots in industrial automation. Their research highlighted the advantages of using color sensors for guided navigation in warehouse management. The study demonstrated the efficiency of line-following bots in automating material transport, reducing labor costs, and increasing operational accuracy

R. Kumar and P. Sharma (2019) Kumar and Sharma investigated the integration of ESP32-CAM modules in IoT-based surveillance systems. Their study demonstrated how real-time video streaming can be achieved over a wireless network with minimal latency. They emphasized the cost-effectiveness of ESP32-CAM compared to traditional CCTV systems, making it an ideal solution for mobile security applications. variables for the period of 5 years. The data collection period is ranging from January 2010 to Dec 2014. Monthly prices of KSE -100 Index is taken from yahoo finance.

L. Fernandez et al. (2020) Fernandez and co-researchers examined the role of ultrasonic sensors in autonomous robots. Their findings indicated that ultrasonic sensors significantly improve obstacle detection, preventing collisions and enhancing mobility. The study tested various sensor configurations to optimize response time and accuracy in detecting objects within a 4-meter range systematic risk is the only independent variable for the CAPM and inflation, interest rate, oil prices and exchange rate are the independent variables for APT model.

T. Brown (2021) Brown analyzed the implementation of PID control algorithms in line-following robots. The research concluded that proportional-integral-derivative (PID) controllers enhance the stability and precision of robot movements, reducing deviations from the intended path. The study also introduced an adaptive PID model to adjust robot speed based on environmental conditions.

M. Gupta and A. Patel (2022) Gupta and Patel focused on the use of voltage sensors for efficient power management in autonomous robots. Their work demonstrated that continuous monitoring of battery levels helps extend operational time by enabling predictive charging alerts. The study provided insights into energy-efficient navigation strategies for prolonged surveillance applications.

METHODOLOGY

The bot follows a predefined path using a color sensor, ensuring accurate navigation along black or white tracks. The ESP32- CAM module streams live footage to a remote server for real-time monitoring, where users can access video feeds via a web interface. The ultrasonic sensor detects obstacles, prompting the bot to adjust its path accordingly by stopping or changing direction. The voltage sensor continuously tracks battery levels, providing alerts for low power conditions.

The system is programmed using the Arduino IDE, with libraries such as OpenCV for image processing, Wi-Fi libraries for remote connectivity, and PID algorithms for precise movement control. The communication between sensors and microcontroller follows a hierarchical decision-making model, ensuring smooth operation even in dynamic environments.

SYSTEM DESIGN

The system is designed to function autonomously with an integrated combination of sensors and a microcontroller. The main components and their roles are:

1 Architecture Overview Input Sensors: Color sensor (line following), ultrasonic sensor (obstacle detection), and voltage sensor (battery monitoring). Processing Unit: ESP32-CAM serves as the main microcontroller,

handling sensor data and controlling the motors. Communication Module: ESP32-CAM transmits live video feed over Wi-Fi. Power System: A rechargeable battery powers the bot, with continuous monitoring via the voltage sensor.

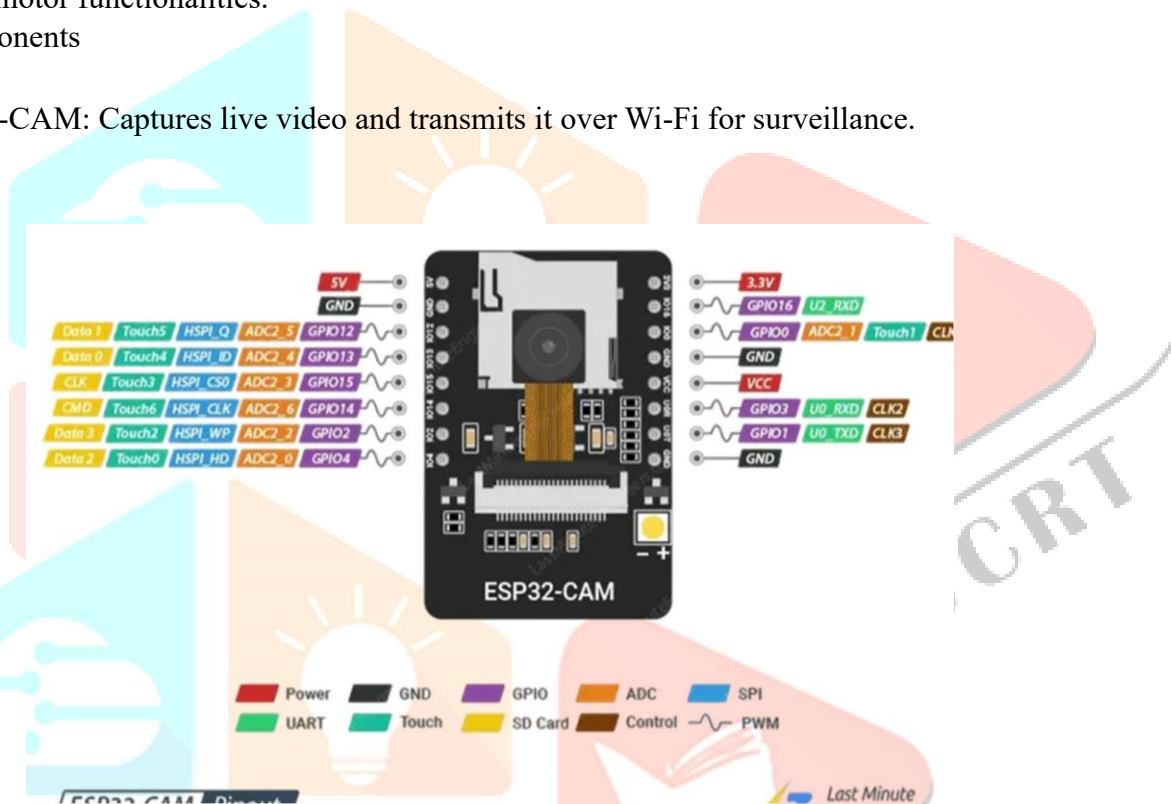
System Flow The bot scans the floor for a guiding line using the color sensor. If an obstacle is detected by the ultrasonic sensor, the bot calculates an alternate path. Live video is captured by the ESP32-CAM and transmitted to a remote user interface. Battery levels are monitored in real time, triggering alerts when charging is required. The bot autonomously navigates based on sensor inputs while ensuring continuous surveillance

Circuit Design & Implementation

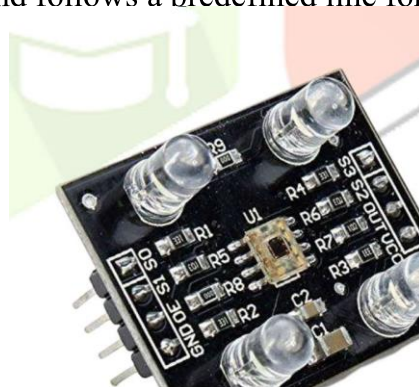
The circuit diagram includes connections between the ESP32-CAM, sensors, motor driver, and power supply. The following steps were taken during implementation: Configured the ESP32-CAM for live video streaming. Integrated the color sensor to detect and follow a predefined line. Implemented obstacle avoidance logic with the ultrasonic sensor. Set up the voltage sensor to continuously monitor battery levels. Assembled the chassis and tested motor functionalities.

Components

ESP32-CAM: Captures live video and transmits it over Wi-Fi for surveillance.



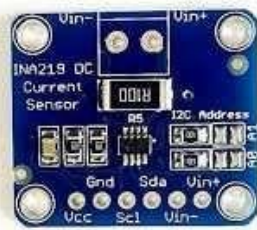
Color Sensor: Detects and follows a predefined line for autonomous navigation.



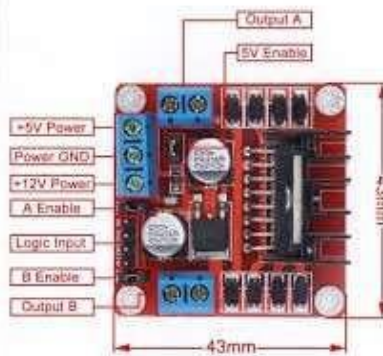
Ultrasonic Sensor: Measures distance to detect and avoid obstacles



Voltage Sensor: Monitors battery levels to ensure sufficient power supply.



Motor Driver (L298N): Controls the movement of the motors based on sensor inputs .



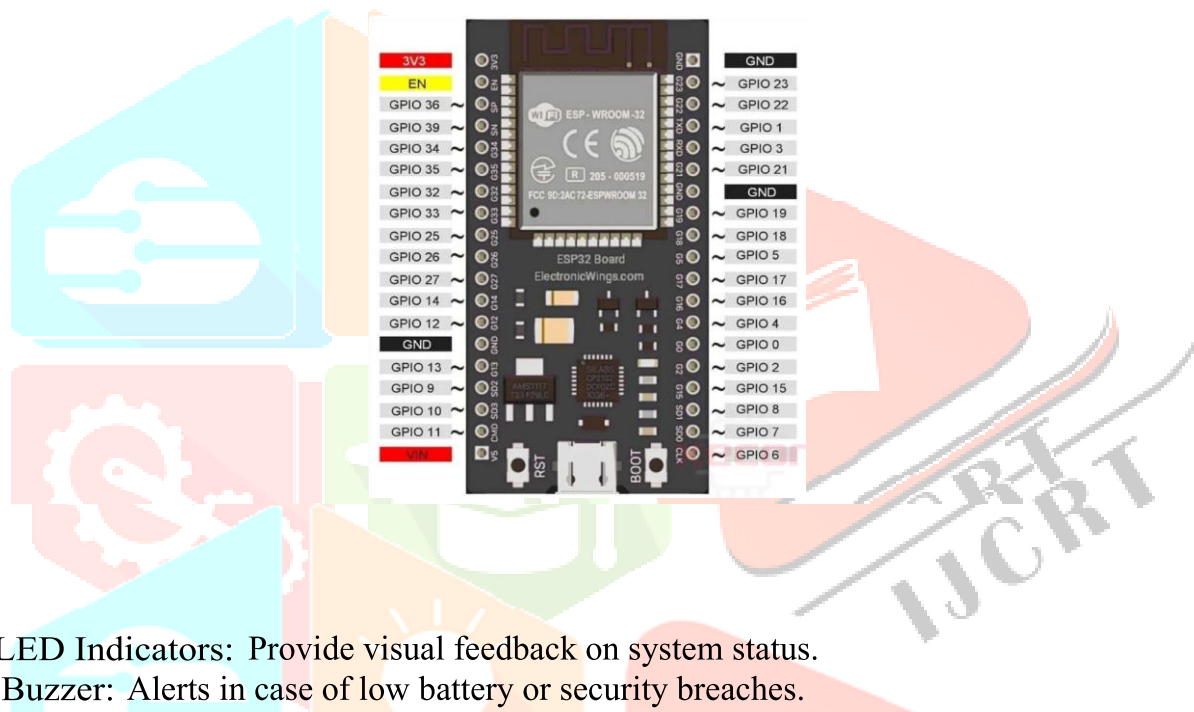
DC Motors: Drive the bot forward, backward, and enable turns



Chassis: Provides structural support for mounting components.

Rechargeable Battery (Li-ion / Li-Po): Powers all electronic components

Microcontroller (ESP32 or Arduino): Processes sensor data and controls bot movement



- LED Indicators: Provide visual feedback on system status.
- Buzzer: Alerts in case of low battery or security breaches.

WORKING PRINCIPLE

The Line Following Surveillance Bot operates by integrating multiple sensors to achieve autonomous movement and real-time surveillance. The working principle is as follows:

1. Line Detection: The colour sensor continuously scans the surface to detect a predefined line, guiding the bot's movement.
2. Navigation Control: Based on the colour sensor input, the microcontroller adjusts the motor speeds to keep the bot aligned with the line.
3. Obstacle Avoidance: The ultrasonic sensor detects obstacles in the bot's path. If an obstacle is detected, the bot stops and reroutes.

4. Live Surveillance: The ESP32-CAM module streams real-time video to a remote interface, providing security monitoring.
5. Battery Monitoring: The voltage sensor tracks battery levels, triggering alerts when recharging is needed.
6. Autonomous Decision Making: The microcontroller processes sensor data and adjusts navigation, ensuring uninterrupted surveillance.

EXPERIMENTAL SETUP AND TESTING

1 Experimental Setup

The experimental setup involved assembling the bot with all components and testing it in a controlled environment. The key setup steps included:

- Placing a predefined path with a contrasting line for the bot to follow.
- Setting up obstacle placements to evaluate avoidance mechanisms.
- Configuring a remote monitoring station for live video feed verification.
- Powering the bot with a fully charged battery to assess energy consumption.

2 Testing Procedures

The following tests were conducted to validate system functionality:

1. Line Following Test:

The bot was placed on a black line against a white background.

The accuracy of the colour sensor in detecting the line was assessed.

Adjustments were made to motor speeds for smooth navigation.

- 2. Obstacle Avoidance Test:
 - Objects were placed in the bot's path at varying distances.
 - The ultrasonic sensor was tested for timely detection and navigation.
 - Different avoidance strategies were evaluated for efficiency.
- 3. Live Video Streaming Test:
 - The ESP32-CAM module was connected to a remote interface.
 - Video clarity and real-time transmission speed were analysed.
 - Network latency and streaming consistency were monitored.
- 4. Battery Monitoring Test:
 - The voltage sensor was used to track power levels over time.
 - Low battery alerts were tested under different conditions.
 - Power consumption was optimized to extend operational time.
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RESULTS AND DISCUSSION

1 Observations and Performance Analysis

- The bot successfully followed a predefined line with high accuracy, demonstrating the effectiveness of the colour sensor in varied lighting conditions.
- The ultrasonic sensor accurately detected obstacles and rerouted the bot without significant delays.
- Live video streaming via the ESP32-CAM provided real-time surveillance with minimal latency.
- Battery monitoring worked efficiently, triggering alerts when power levels were low.

2 Challenges Encountered

- Sensor Calibration: Initial tests required fine-tuning sensor sensitivity to ensure precise line following and obstacle detection.
- Wi-Fi Connectivity Issues: In some environments, the ESP32-CAM faced network interruptions, impacting real-time video transmission.
- Power Consumption: The bot's battery life was a limiting factor, necessitating optimization strategies such as energy-efficient motor control.

3 Discussion

The experimental results indicate that the Line Following Surveillance Bot effectively integrates multiple sensor-based functionalities. While it performed well in controlled environments, real-world applications may require

additional enhancements such as AI-based decision-making and improved network stability. Future iterations could incorporate GPS for outdoor tracking and a more robust power management system.

ADVANTAGES AND LIMITATION

1 Advantages

- **Autonomous Navigation:** The bot efficiently follows a predefined path, reducing the need for human intervention.
- **Real-Time Surveillance:** Live video streaming via ESP32-CAM enhances security monitoring. **Obstacle Avoidance:** The ultrasonic sensor ensures smooth navigation by detecting and avoiding obstacles.
- **Energy Efficiency:** The voltage sensor helps optimize power consumption by tracking battery levels.
- **Versatile Applications:** The bot can be used in security, industrial automation, and warehouse monitoring.

2 Limitations

- **Limited Battery Life:** Continuous operation requires frequent recharging or an external power source.
- **Wi-Fi Dependency:** Real-time video streaming depends on a stable network connection. **Line-Following Constraints:** The bot can only operate effectively on predefined paths with high contrast lines.
- **Environmental Sensitivity:** Sensor accuracy may be affected by lighting conditions, floor texture, and obstacles.
- **Processing Limitations:** The ESP32-CAM has limited processing power, which may impact future enhancements like AI-based tracking.

CONCLUSION

The Line Following Surveillance Bot successfully integrates multiple sensors and control mechanisms to create a functional autonomous surveillance system. The bot effectively follows a predefined path, avoids obstacles, and provides real-time video streaming, making it a valuable tool for security and monitoring applications.

Through extensive testing, the bot demonstrated high accuracy in line following, efficient obstacle detection, and reliable video transmission. The battery monitoring system ensured uninterrupted operation by alerting users to low power levels. However, challenges such as Wi-Fi dependency and limited battery life indicate areas for improvement.

Future enhancements could include AI-based object detection, GPS tracking for outdoor navigation, and a mobile app for remote control. With these upgrades, the bot has the potential to serve as an advanced security and automation solution in various industries.

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