# Abstract

This project presents a Wi-Fi controlled surveillance car utilizing an ESP32-CAM setup for real-time video streaming and remote monitoring. Traditional surveillance systems often face limitations in mobility and connectivity; however, this innovative design leverages the capabilities of the ESP32 microcontroller, enabling seamless control and high-quality video transmission over Wi-Fi. The car is equipped with a camera module that captures live footage, which is transmitted to a mobile device for monitoring, making it suitable for applications such as home security, inspection of hard-to-reach areas, and outdoor exploration. The system utilizes a user-friendly interface for control, allowing for maneuverability and camera adjustments. To enhance the functionality, various sensor integrations are explored, enabling features like obstacle detection and pathfinding. This project emphasizes the need for reliable wireless communication in surveillance technology and aims to demonstrate an efficient, cost-effective solution for modern surveillance needs.

**Keywords:** ESP32, Wi-Fi, surveillance car, real-time video streaming, remote monitoring.

# Contents

# List of Figures

# 1. Aim and Objectives

## 1.1 Aim:

To develop a Wi-Fi controlled surveillance car using an ESP32-CAM for real-time monitoring.
The aim of this project is to develop a Wi-Fi controlled surveillance car using an ESP32-CAM module for real-time monitoring and video transmission. This system enables remote control of the car over a wireless network, allowing live streaming of video footage captured by the onboard camera. The ESP32-CAM acts as both the controller and video processing unit, offering a compact and cost-effective solution for surveillance applications. This project combines embedded systems, wireless communication, and mobile robotics to create a functional and efficient remote surveillance platform suitable for indoor or outdoor monitoring scenarios.

## 1.2 Objectives:

1. Construct the Surveillance Car: Build a mobile platform with the ESP32-CAM for effective surveillance.
2. Enable Real-Time Video Streaming: Transmit live video feed to a mobile device.
3. Create a Control Interface: Develop a user-friendly app for remote control of movements and camera angles.
4. Integrate Obstacle Detection: Add sensors for autonomous navigation and obstacle avoidance.

# 2. Introduction

These days, surveillance and monitoring are essential components of security systems. The need for creative, effective, and adaptable surveillance solutions is growing, from protecting residential properties to security industrial locations. Conventional fixed security cameras are inadequate for dynamic or extensive monitoring requirements due to their restricted coverage and inability to move around actively. In order to overcome these obstacles, this proposal suggests a WiFi-Controlled Surveillance Car, a multipurpose, mobile security device intended for real-time monitoring and inspection that can feed live video and move remotely.

With a camera and a control system that can be managed remotely using a smartphone app, the WiFi-Controlled Surveillance Car is a state-of-the-art, little car. The ESP32-CAM module, a little yet potent camera module with built-in WiFi capabilities, is the main part in charge of video streaming. With the help of this module, the vehicle may deliver a live video stream that people can view on their smartphones, giving them a real-time overview of the surroundings. Because of its versatility, the camera can see a greater area than fixed surveillance systems, which makes it perfect for examining hard-to-reach places or locations that need close-up observation.

A smartphone app that communicates with the onboard ESP32 microprocessor via WiFi controls the vehicle's motion. By receiving control signals and using the L298N motor driver to drive the motors, this microcontroller serves as the system's brain. Because of its durability and compatibility with the car's four DC motors, the L298N motor driver was selected to provide precise control over the vehicle's movements, including forward, backward, left, and right turns. The automobile is easy to manoeuvre even from a distance because to the smooth and responsive control system provided by the combination of the ESP32 microcontroller with the L298N motor driver.

This project's capacity to operate remotely via a WiFi connection is one of its main benefits. There is no need for complicated hardware configurations because users can operate the vehicle and see the video feed concurrently from a single device, like a smartphone or tablet. This capability increases the car's adaptability and qualifies it for a variety of uses beyond basic home security. For example, it can be utilised in search and rescue operations to investigate restricted or dangerous locations, in industrial settings to examine machinery, or in agricultural fields to monitor crops.

The project's cost-effectiveness is another important feature. The ESP32-CAM module and the L298N motor driver are two easily accessible and reasonably priced components that make the WiFi-Controlled Surveillance Car a cost-effective substitute for more costly surveillance systems. Because of its modular architecture, which makes maintenance and assembly simple, it's a useful tool for both professional and enthusiast users. Furthermore, the system's scalability allows for the inclusion of new features in later iterations to improve its capabilities, including autonomous navigation or obstacle detection.

Real-time video streaming and responsive control are at the core of the project, which means that the users are able to continuously observe their surroundings and respond to a situation as soon as possible. Assuming, for example, the presence of intruders, if they need to be expelled or areas containing hazardous substances need to be supervised or processes monitored, then this capability is of paramount importance. Mobile platform of the car is a major benefit over the stationary cameras as it can be pointed at certain areas of interest compared to the angles of view.

**How does Wi-fi controlled survillence car using Esp32 cam setup work?**

The Wi-Fi controlled surveillance car is run by a combination of hardware and software mainly using ESP32-CAM module to stream videos in high definition to a mobile device or computer over a WiFi connection. It controls the movement through the L298N motor driver that communicates with the ESP32 to perform commands received from the user for the motion of the car. The car is powered by a 12V battery which feeds energy to the motors and another 5V regulator circuit that feeds power to the ESP32. An easy-to-use mobile application with the possibility of navigation via a touch panel in the form of a mobile application or web interface controls both the movement of the robot and the changing of the angle of the camera, sending the real-time signal via the Wi-Fi connection. Also, optional ultrasonic sensors are useful for safety because the car is able to avoid objects and is appropriate for commercial use, such as home security and environmental surveys.

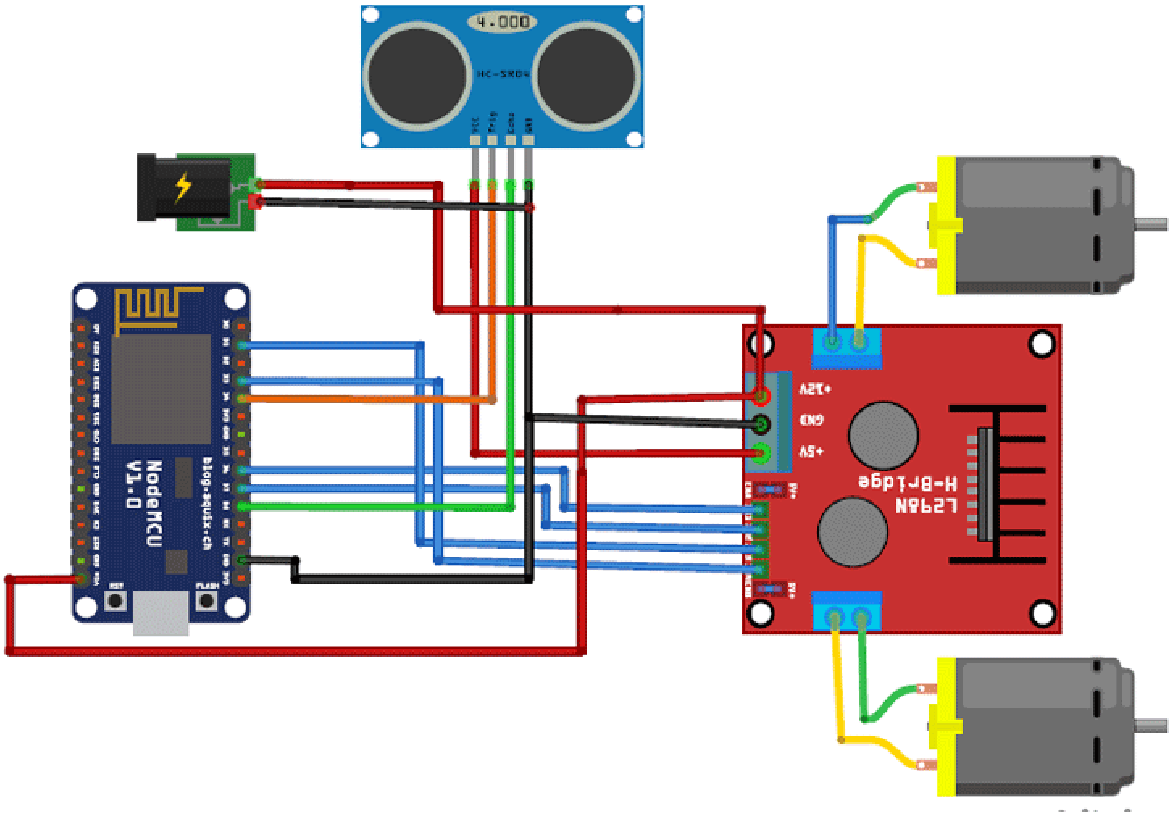

**Figure 2.1:** Circuit of Wi-fi Controlled Car

**The Evolution of Surveillance Systems-**

Surveillance systems have come a long way since the early days of closed-circuit television (CCTV). Traditional CCTV systems, while effective, have several limitations: they are fixed in place, require extensive cabling, and often come with high installation costs. In contrast, mobile surveillance systems offer a dynamic alternative, capable of reaching areas that stationary cameras cannot. With advancements in embedded systems and wireless communication, the development of compact and efficient mobile robots has become a reality. In the past, remote-controlled cars often relied on Bluetooth for communication, which limited their range to a few meters. The shift towards WiFi-based control has expanded the possibilities, enabling long-range connectivity and the potential for internet-based operation. By leveraging the ESP32 module's built-in WiFi capabilities, this project taps into the power of wireless communication, allowing the car to be controlled from anywhere within the WiFi network's range.

The use of a motor driver module (L298N) enables precise control over the four DC motors, allowing the car to navigate in all directions. The L298N motor driver is a popular choice for hobbyists and engineers alike due to its ability to control multiple motors with ease and handle a wide range of input voltages. This makes it ideal for use in projects that require reliable and bidirectional motor control, such as this WiFi-controlled car.

**Significance of the Project:**
The significance of developing a WiFi-controlled surveillance car lies in its diverse range of potential applications.
The following points illustrate why this project is relevant and worth pursuing:
• Enhanced Security: Of course, the primary use of the surveillance car is in the sphere of security. Due to the ability of this mobile platform to capture live video feeds, this project can be used for surveillance of properties, identification of intruders and go as an added security measure for residential, commercial and industrial properties. • Accessibility in Hazardous Areas:
This kind of mobile car can deployed where people cannot reach due to hazards similar to chemical plants, disasters, or even construction sites. As it offers real-time video feed, operators can look into details of the situation without ever exposing themselves to danger.
• Educational Tool: Apart from that, the WiFi-controlled surveillance car has a great potential as the educational tool and for the people interested in the underlying principles of robotics, programming and wireless communication, for students in particular. This project offers practical exposure to microcontrollers, motor controlling, and live transfer.
• Scalability and Adaptability: It is an open system because it has incorporated future expandability and new functions to the existing framework. For instance, instead of the car's built-in damaging bumpers, it can be fitted with sensors for detecting obstacles, GPS modules for identifying the vehicle's location, or even facial recognition software based on artificial intelligence for enhanced surveillance purposes.
• Challenges and Opportunities: However, there are some constraints that needs to be highlighted in the development of this project. There is one of the main difficulties – the sustained and low-latency video stream from the ESP32-CAM module. These include interference with the cellular network, a small range of WiFi signal and delays in the videos displayed. Also, watch the power consumption to a minimum as the total motor's and ESP32-CAM's consumptions drawn the battery power faster.
Nevertheless, the prospect of this project are enormous. The inclusion of modern microcontrollers of low cost and high functional capabilities, such as the ESP32, has become a powerful impetus for creating new and fantastic "homebrew" and low-cost robotic and IoT developments. Therefore, our accomplishment in successfully deploying this WiFi-controlled car benefits the larger domain of mobile robotics and offers a tool for various real-world applications.

### 2.0.1 Features of Wi-Fi controlled Surveillance car

listed below are some of the key features of the survilliance car:
• Real-Time Video Streaming: It can capture and stream live video and this make it possible for users to monitor some environments from a distance. This video feed of high quality is available through a mobile device or through a web-based interface.
• Remote Control: – the tested car can be steered forward, backward, left or right and the onboard cameras can be controlled from a mobile application or web portal installed within the range of the Wi-Fi network.
• Versatile Navigation: The L298N motor driver provides fine control of the movement of the car and offers good traction when it is taken on terrains that range from indoor to outdoor.
• Power Supply Management: The motors are connected to a 12 V battery and the ESP32 board voltage is regulated to 5 V, therefore minimizing energy consumption and providing reliable performance of all components of the car.
• Obstacle Detection (Optional): Ultrasonic sensors used in the car's structure enable the car to have a detection of obstacles in its path. This feature increases safety since it allows the vehicle to stop of its own accord or move around an object.
• Compact Design: Since the surveillance car is small and can move in narrow areas and in those that are hard to access it is versatile in many contexts of surveillance.
• Customizability: Any user would be able to extend the system by adding new sensors or improve resolution control by adding the GPS tracking or better camera features.

### 2.0.2 CURRENT TRENDS

**• IoT Integration**

ESP32 Usage: The ESP32 is preferred for the presence of Wii and Bluetooth modules inherent in the device which is perfect for IoT solutions. The greatest advantage is that it is relatively inexpensive and easy to work with, so it is suitable for use by do-it-yourself beginners.

• **Real time video streaming**: The ESP32 is favoured for its built-in Wii and Bluetooth capabilities, making it ideal for IoT projects. Its low cost and versatility make it a popular choice for DIY enthusiasts.

**• Real-Time Video Streaming**

Camera Integration: When using a camera module, for example, ESP32-CAM, real-time video streaming becomes possible. Effective streaming can be done using platforms such as MJPEG-streamer or RTSP.

• **Mobile App Control** User Interface: Creating a mobile application, for example, with the help of Flutter or React Native for car control improves user experience. This enables a user to control the car through his or her smartphone and also be able to monitor video feeds.

• **Edge Processing** AI Features: The improved surveillance can be achieved by working with basic AI algorithms for object detection with lightweight models. For processing such workloads on-device integration of tools like TensorFlow Lite is possible.

• **Cloud Integration** Data Storage: The use of cloud service to store and analyze video footage is convenient and can last long. For this purpose, one can use AWS or Google Cloud, for instance.

• **Security Features** Encryption: The information exchanged between the car and the control interface must be secured to prevent unauthorized access, and this can be done by ensuring that the communication protocols in use are secure, for instance, HTTPS, and MQTT.

# 3. LITERATURE SURVEY

1. Smith el. implemented a WiFi-enabled Surveillance Car utilizing the ESP32-CAM module for live video streaming. This project highlighted the use of a web interface to control the car remotely via WiFi, showcasing real-time feed and efficient navigation. Components included ESP32-CAM, L298N Motor Driver, and DC motors, effectively achieving remote monitoring and control through a user-friendly interface.
(doi: 10.22214/ijraset.2023.57362)

2. Patel and Kumar developed a Remote Surveillance Robot using the ESP32 microcontroller and camera module. The primary aim was to provide live video transmission over a WiFi network. Their implementation allowed for seamless control via a smartphone app, with a focus on low latency and efficient power management using a 7.4V battery pack and optimized motor control.
DOI:10.32628/IJSRSET25122176)

3. Gupta and Bhatt. introduced a Smart Surveillance Car controlled via a WiFi network using the ESP32-CAM module. The car was equipped with an L298N motor driver and DC motors, enabling it to navigate through complex environments. The project demonstrated the potential for real-time video streaming integrated with motion control, suitable for security applications in restricted areas. (Spy Remote Control Car: ESP-NOW Protocol with ESP8266, ESP32, and ESP32CAM by - Rohit Vijay Gupta, Anita N. Bhatt2) ,

4. Bhaskar and Amarnath. designed a WiFi-Controlled Spy Car, focusing on the integration of the ESP32-CAM for video surveillance. The project utilized an L298N motor driver for precise motor control and ensured stable video feed transmission over local WiFi networks. The system was tested in various lighting conditions,

proving its reliability for both indoor and outdoor monitoring.
(https://www.jetir.org/papers/JETIR2404896.pdf)

5. Hassan and Rahman implemented an Autonomous Surveillance Vehicle using the ESP32 microcontroller and WiFi connectivity. The car's movement was controlled through a web-based interface, allowing users to access the live camera feed from any device connected to the network. Key components included a 12V battery, L298N motor controller, and four DC motors for enhanced mobility.(DOI:10.1109/ICOMET.2019.8673463)

6. Mehta. developed a Home Security Surveillance Car employing the ESP32-CAM module for live video streaming. The system was designed to detect motion and stream the feed directly to a smartphone app via WiFi. The L298N motor driver ensured smooth motor operations, while additional sensors like ultrasonic sensors helped avoid obstacles.
(https://www.researchgate.net/publication/345474303)

7. Reddy et al. explored the use of WiFi for Remote-Controlled Surveillance Robots using an ESP32-CAM module. The project's emphasis was on achieving real-time control with minimal latency. The motor control was facilitated by the L298N driver, and the setup was powered by dual 3.7V lithium batteries, ensuring longer operation times during surveillance tasks.
(https://docs.cirkitdesigner.com/project/published/ebdb678a)

8. Das and Sharma created a WiFi-Connected Surveillance Car aimed at providing a cost-effective solution for live monitoring. The ESP32-CAM module was used for video streaming, with control commands sent via a web server interface. The car was equipped with four DC motors powered by an L298N motor driver.
(https://ymerdigital.com/uploads/YMER230573.pdf)

9. Lee and Park investigated a Mobile Surveillance Robot controlled through WiFi using the ESP32 microcontroller. Their system provided both video feedback and motor control through a single interface. By using the L298N motor driver, the project achieved accurate movement control, making it suitable for patrolling large areas with real-time video access. (DOI:10.48175/IJARSCT-11280)

10.Chen et al. presented a Smart Surveillance Car that utilized the ESP32-CAM for live streaming and remote control via WiFi. The project included integration with a mobile app, which allowed users to steer the car and view the video feed simultaneously. The L298N motor driver was chosen for its ease of use and reliability in driving multiple DC motors.
(https://randomnerdtutorials.com/esp32-cam-car-robot-web-server/)

11. Agarwal et al. implemented a Wireless Surveillance Vehicle using the ESP32 microcontroller, focusing on video transmission over a secured WiFi network. The car's movements were controlled using an L298N motor driver, while the live video feed was accessible through a web server. The design emphasized user control and ease of setup for home security purposes. (doi: 10.32628/IJSRSET25122176.)

12. Yadav and Prasad developed a Live Video Streaming Surveillance Car, utilizing the ESP32-CAM for video capture. Their project allowed users to control the car's movements through a smartphone's web browser. The L298N motor controller provided efficient power delivery to the DC motors, making the car responsive and agile in navigation. (DOI:10.32628/IJSRSET25122176)

13. Nair and Menon designed a WiFi-Based Surveillance Car with real-time video streaming capabilities using the ESP32-CAM. The system used the L298N motor driver for controlling four DC motors, ensuring smooth maneuverability. The

project demonstrated the feasibility of using WiFi for low-cost, high-quality surveillance in domestic and commercial settings.
(DOI Link: https://doi.org/10.22214/ijraset.2023.57362)

14. Rao et al. implemented a Real-Time Monitoring Robot using ESP32 and an integrated camera module. Their project provided a live feed over WiFi, with motor control handled by the L298N driver. The design was intended for areas requiring continuous surveillance, and the use of rechargeable batteries made it portable and convenient.( DOI Link: https://doi.org/10.22214/ijraset.2024.64054)

15. Khan et al. explored a WiFi-Enabled Surveillance Car utilizing the ESP32-CAM for real-time video transmission. The car's mobility was facilitated by the L298N motor driver, which controlled four DC motors. The project aimed at providing a flexible and scalable surveillance solution that could be operated remotely through any WiFi-enabled device.
(https://randomnerdtutorials.com/esp32-cam-video-streaming0-web-server-camera-home-assistant/)

16. In the course of this work, the ability of the ESP32-CAM module in surveillance systems is examined as part of the focus on its ability to stream high quality video over the WLAN network. In the paper, the author presents the benefits of using the ESP32-CAM in the framework of remote monitoring systems, particularly the comparatively low cost and rather simple integration of the module; however, the author also notes that the ESP32-CAM is suitable for extensive use in security and surveillance systems for amateurs and experts.

17. This paper focuses on employing of motor drivers with an emphasis on the L298N in robotic systems. The paper explains that through L298N, there is control of DC motors and movement of mobile robotic system in forward, backward

and in correct direction. The outcomes show how employing motor drivers such as L298N also amplifies the maneuverability of surveillance cars.
(Paper Id : IJRASET57362)

18. This article discusses the possibility of including some obstacle detection systems into the autonomous vehicles. It discusses a range of sensor types, from ultrasonic sensors, which can help avoid physical contact with nearby objects. The connection of these sensors with microcontroller units including the ESP32 improves on the safety features in remote controlled surveillance automobiles hence improving the chances of navigating the automobiles through difficult terrains.
(https://ijirt.org/publishedpaper/IJIRT171014$_{P}APER.pdf$)

# 4. User Methodology

**1. System Design and Component Selection**

Car Chassis and Motor Selection: A car chassis that can support 4 DC motors was selected to meet the necessary support for a car and its required mobility. The chosen motors can provide enough torque and rotational speed to bear the load of the components and move it fluently.

ESP32-CAM Module: ESP32-CAM was chosen because it has WiFi capability and a camera that enables streaming of videos directly to a smartphone.

Motor Controller (L298N): For handling the DC motors, The L298N motor driver was used whose connects with the microcontroller. This module allows form both commanding and cycling through each motor and may meet the voltage needs of the motors for constant motion.

Power Supply: A 12V battery was chosen to provide enough current to drive both motors via the L298N and the ESP32-CAM module. Voltage Regulation was used in order to provide stability to the power supply required by the ESP32 module.

**2. Circuit Design and Assembly**

Wiring Connections: The L298N motor driver connected to each of the motors were then connected to the control unit, ESP32-CAM. For motor controlling signals the ESP32-CAM was connected to motor driver using GPIO pins. To supply power to the ESP32 and the L298N motor controller a 12V battery was used with a voltage of 5V for ESP32 circuit. Integration of Components: Before that the ESP32-CAM module was mounted on the car in a way that it can capture the front view of the car live. The motor driver was screwed to the chassis tightly and all the connections were made very rigid to avoid any loose contact in movement.

**3. Software Development**

ESP32-CAM Code for Camera Feed: To do this for the ESP32-CAM, a program was written to enable the board to host a web server so as to transmit the video through WiFi. This enables to see the feed of what is happening in the car in real time on a smartphone, if the phone uses the car's IP address. The web server code for the ESP32 is written to be run on a browser for its monitoring in real-time. Implementation of details relating to the car control was done as per the following where a code was written to control the forward backward left and right movement of the car using GIOS pins connected to the L298N motor controller. The control signals from the robotic system are produced by the ESP 32 module, and are transmitted to the motor driver in compliance with the smartphone interface commands. Smartphone Interface Setup: A simple web interface was created for control, which could be accessed through a smartphone browser. This interface allows the user to send movement commands to the ESP32 module while viewing the live camera feed simultaneously.

**4. Testing and Calibration**

Initial Testing: First, the car was run on the flat ground to check that each motor and camera module were functioning correctly. Calibration: The speed of the motors was set to allow flowing movements during turns to make the vehicles align well. Signal Range Testing: The distance of WiFi control of the car was defined to know the maximum range of the car control, and the stability of the camera stream was observed during the car movement. **5. Optimization and Final Adjustments** Power Management: An indication of battery consumption was made in order to manage the lifespan of the ESP32-CAM and motor control unit. Video Feed Quality: The frame rate and the resolution of the received camera feed were adjusted to minimize the latency to display the feed on the smartphone smoothly.

## 4.1 Proposed Solution

**ESP32-CAM Module:**

The ESP32-CAM module is the key element that is used in order to provide a live stream of video. This module will be capable of connecting to a WiFi network so that video can be seen in real time on a smartphone or any other device. The main reason for selecting ESP32-CAM was its cost affordability, flexibility and WiFi integrations for constant live video streaming.

**Control System:**

The car's movement will be regulated by a special application for a smartphone, which will be connected to the ESP32. Forward, backward, left, and right movement commands are transmitted wirelessly using WiFi connection and received by the ESP32 to be processed through the L298N motor driver. This motor driver is used to power four DC motors connected to the car, so that the car can move in a very fluid manner.

**Power Management:**

For those movements, a 12V battery is provided to drive the motors, and the capacity will suffice the whole system. The ESP32-CAM requires 3.3V voltage, therefore, a voltage divider is provided to down convert the voltage properly for the camera module for optimal performance. This power management strategy assists in maintaining harmony between the system's need and makes the battery life longer.

## 4.2 Activity Diagram

**Component Assembly and Setup:**

The car chassis is assembled with the ESP32-CAM module, L298N motor driver, and four DC motors connected to the wheels. The 12V battery powers the entire

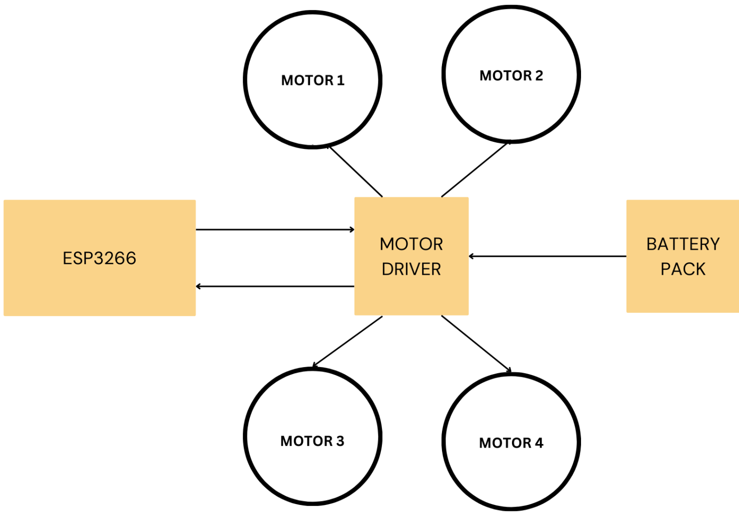


**Figure 4.1:** Activity Diagram

system, while a 5V voltage regulator supplies safe power to the ESP32-CAM.

**Programming and WiFi Configuration:**

The ESP32-CAM is programmed using the Arduino IDE with code that sets up WiFi connectivity, motor control, and live video streaming. The module connects to a local WiFi network or creates its own hotspot, acting as a web server accessible via a smartphone or computer.

**Live Streaming and Remote Control:**

The ESP32-CAM captures real-time video, which is streamed over WiFi to a web interface. Users can control the car's movement (forward, backward, left, right) through the interface using commands that adjust the speed and direction of the DC motors via the L298N motor driver.

**Testing and Deployment:**

The car is tested for stability, video quality, and responsiveness to control commands. Optional enhancements like an ultrasonic sensor can be added for obstacle detection. Once tested, the car is ready for surveillance tasks, providing remote monitoring through live video feed and user control.

## 4.3 FLOW CHART

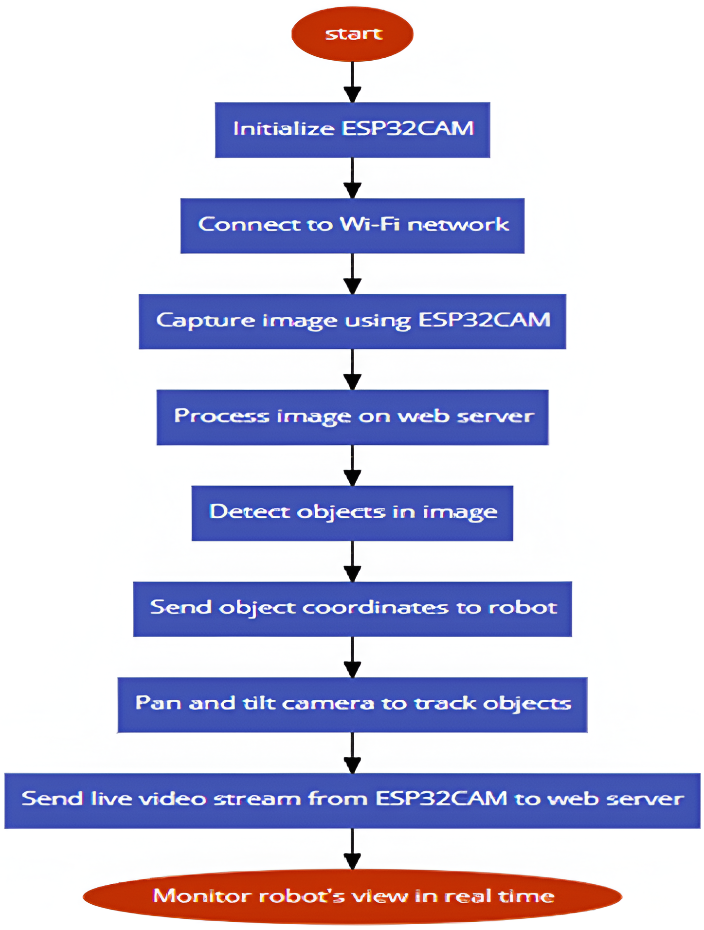


**Figure 4.2:** Flow Chart

### 1. Smartphone App Development and Integration

User Interface Design: Create a clear and easy to navigate interface that only includes buttons for the direction (Forward, backward, left, right), and a camera stream. WiFi Control Integration: Configure it so that it can send movement commands to the ESP32 through WiFi making it easy to control the movements of the car. Video Stream Setup: Integrate the video stream from ESP32-CAM into the interface of the app, that will allow the user to watch the process in real time.

**2. Testing and Calibration**

Movement Testing: Perform each of the movement control to verify that the car reacts to all directions in terms of movement. Adjust if necessary for a finer and free flowing control of movements.

Video Quality Check: Check the quality and delay of streaming a video. Modify corresponding settings of the ESP32 camera if the image is unclear or there is considerable lag. Range Testing: Cordon the available WiFi connection strength and identify areas within the house where the signal is low or there is a lot of delay.

**3. Final Deployment and Operation**

Surveillance Operation: The final product is a completed car or, in coded and tested form, ready for use in remote surveillance, should one care to build them. The user can use the smartphone application to log in and connect with the ESP32-CAM, and then control movement of the car and watch a live stream.

Battery Maintenance: Check constantly the state of the batteries in order to maintain smooth working of the equipment. The use of the 12V battery will require the recharging and or check up of the connections now and then.

## 4.4 Model Building Phase

**1. Data Collection**

Purpose: If you want to incorporate any of the intelligent features such as object detection or tracking, then logging data are required. From ESP32-CAM module, you could record video for training a model of usual hurdles or objects on the path for drones.

Process: Record still pictures or moving pictures depending on the car's application (interior, exterior, at night). Store the data for use if it is to be used in machine learning in case one wants to do object recognition, path finding, obstacle detection.

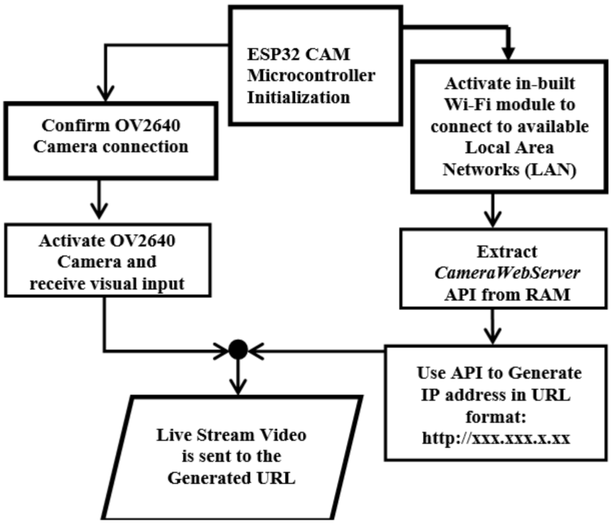


**Figure 4.3:** Activity Diagram

## 2. Data Preprocessing:

Purpose: Preprocessing assists in getting rid of the collected footage or images for utilization in any form of machine learning model that you are going to implement. Process: Eliminate noise on the video frames by optimizing brightness, contrast and resolution particularly if shooting from the ESP32-CAM with low video quality. This step makes it easier to have clearer image and data should there be a need for another round of analysis or model training.

## 3. Feature Extraction:

Purpose: Data preprocessing is more productive in that it assists in getting the gathered footage or images ready for any machine learning model you may incorporate. Process: Crop the video frames by cutting up, brightness, contrast, and resolution when dealing with bad quality videos from the ESP32-CAM. It is taken to obtain clearer images and more consistent data in case of further analysis or more model training.

## 4.Dataset Splitting:

Purpose: Data preprocessing is especially useful in assisting to clean the collected footage or images that you might incorporate into any machine learning model that you might incorporate. Process: Filter frames of the video shot on the ESP32-CAM if the footage has been of poor quality by managing light intensity, contrast and sharpness. This step, in a way, makes the images clearer and data more standardized for any more analysis or to train a different model.

**5. Data Labeling:**

Purpose: It is still needed if one has to train a model, for example, label the objects or obstacles in the camera view.

Process: Label those objects within the video data manually or use the labeling tools in the computer. That is, one might label obstacles as that, paths as that or people as that to help the model distinguish between features of key interest and those in the scene.

**6.Model Building:**

Purpose: Here, you create the model which we have been discussing so far in terms of conceptual framework. For example, if you add object detection, one of the pre-training machine learning models (for example, YOLO model for object detection) can be adapted to a labeled dataset.

Process: Use frameworks like TensorFlow or PyTorch to train a model on the labeled images. The model should be able to identify obstacles or objects in the video feed, making it possible for the car to avoid collisions or track movement autonomously.

**7. Optimization:**

Purpose: Optimize the performance of the surveillance car, ensuring low latency for video streaming, quick response to control commands, and efficient power usage.

Process: Latency Optimization: Reduce video stream latency by adjusting frame rate or using optimized libraries for streaming.

Control Responsiveness: Fine-tune the motor controls and commands to ensure fast response times.

Battery Efficiency: Experiment with different battery setups and optimize power usage to extend operating time without frequent recharging.

**9. Testing and Evaluation:**

- Purpose: Evaluate the model's performance in real-world scenarios to ensure reliable and accurate functionality.

Process: Test the car in various environments, evaluating the responsiveness of the video feed and control commands. For any machine learning functionality, test the accuracy of object detection or obstacle avoidance.

**10. Deployment and Continuous Improvement:**

Purpose: Finalize the car for deployment and make improvements over time.

Process: Deploy the car in a real-world environment and monitor its performance. Based on feedback or issues observed, continuously improve the car's software (e.g., adjusting object detection algorithms, enhancing control latency, or optimizing battery life).

# 5. Software/Hardware Requirements

## 5.1 Hardware Resources Required

**ESP32-CAM Module:**

This module is the core component of the project, providing both the microcontroller and camera capabilities in a single unit. The ESP32-CAM supports video streaming over WiFi, making it perfect for surveillance applications. Its built-in WiFi functionality eliminates the need for additional communication modules, reducing the complexity and cost of the project.

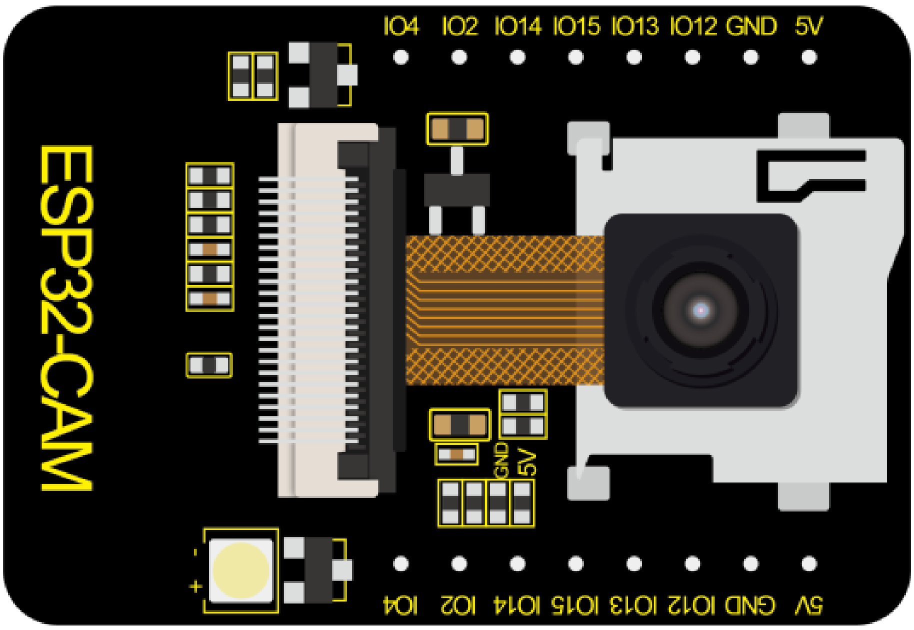


**Figure 5.1:** ESP32 Cam Board

**L298N Motor Driver:**

The L298N motor driver is used to control the four DC motors of the car. It can handle high current loads and provides dual H-bridge functionality, which allows the motors to run forwards, backwards, and at variable speeds. This module is chosen for its compatibility with the ESP32 and its ability to drive multiple motors simultaneously.

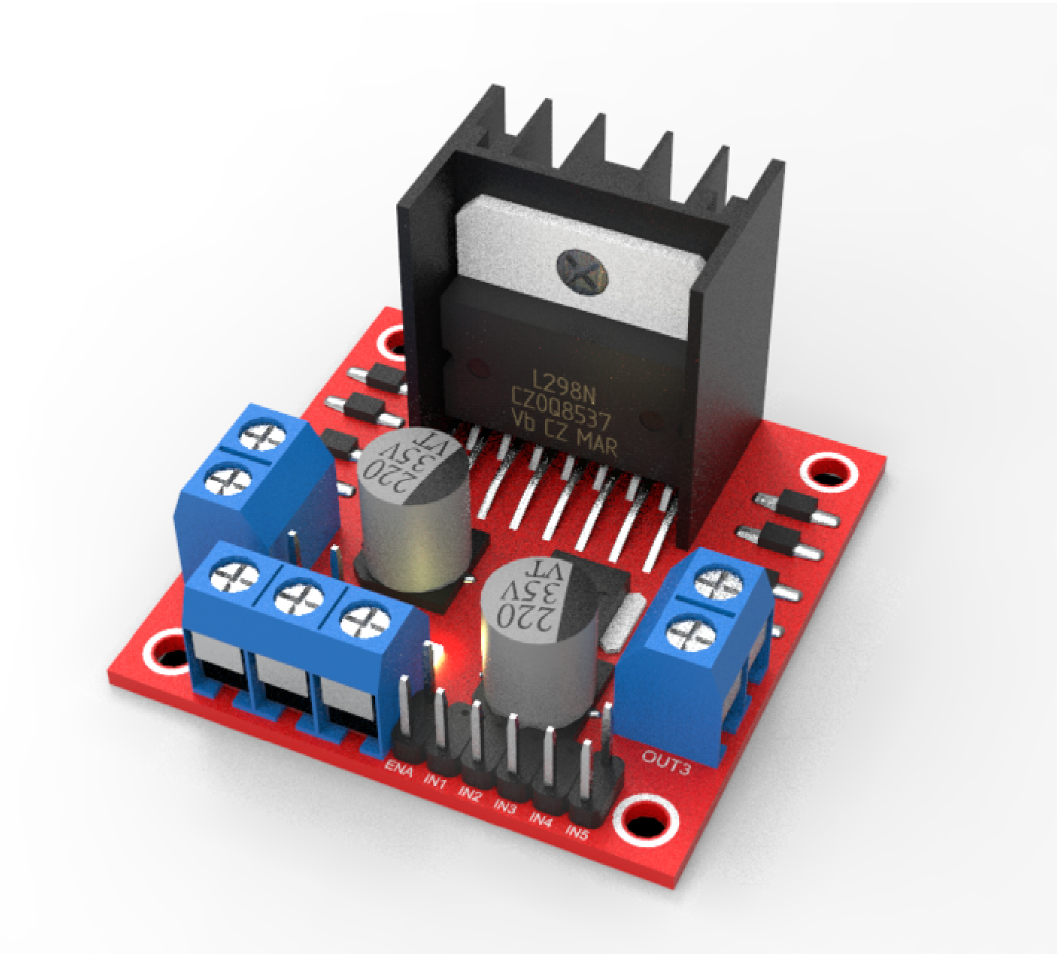


**Figure 5.2:** l298n motor driver

### E4 x DC Motors:

Four DC motors are used for the movement of the car, providing sufficient torque and speed for various terrains. These motors are easy to control using PWM (Pulse Width Modulation) signals from the L298N motor driver. They offer a good balance of performance and power consumption, making them suitable for a battery-powered vehicle.

**Figure 5.3:** Dual Shaft DC Motor

### E12V Battery (or 2 x 3.7V Li-ion Batteries):

A rechargeable 12V battery is used to power the motors and the ESP32-CAM module. The choice of a 12V battery ensures that there is enough voltage to drive the motors through the L298N motor driver. Alternatively, two 3.7V Li-ion batteries connected in series provide a similar voltage level, offering a compact and lightweight power source.


**Figure 5.4:** 18650 3.7v Batteries

**Chassis**:

The car chassis provides a sturdy base to mount all components, including the ESP32-CAM, motor driver, and batteries. It is chosen for its durability and compatibility with the motor mounts, ensuring stable movement and easy assembly.

**Figure 5.5:** 4x4 Car Chassis

**Voltage Regulator (5V):**

A 5V voltage regulator is required to step down the voltage from the 12V battery to safely power the ESP32-CAM module. This prevents damage to the microcontroller and ensures stable operation.

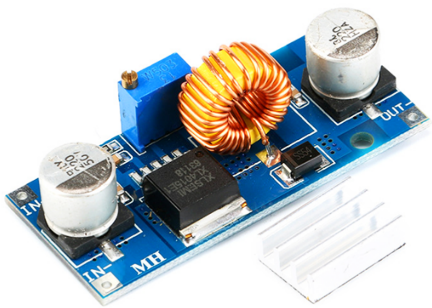

**Figure 5.6:** Xl4015 DC to DC Voltage Regulator

### Ultrasonic Sensor :

An optional component that can be added to enhance the car's capability by detecting obstacles. The sensor helps prevent collisions by providing distance measurements.

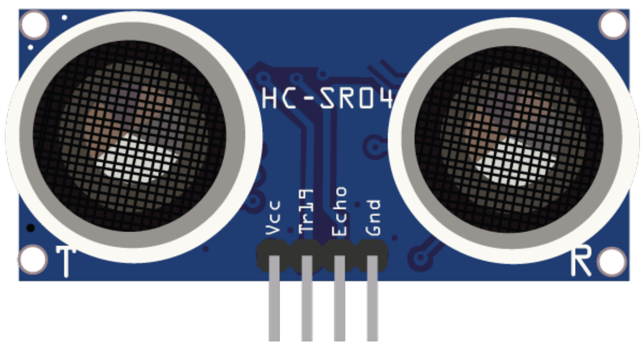


**Figure 5.7:** HC-SR04 ULTRASONIC SENSOR

### Jumper Wires and Breadboard:

Jumper wires and a breadboard are essential for making connections between components during the prototyping phase. They allow for easy modifications and troubleshooting without the need for soldering.

### 5.1.1 Software Resources Required

**Software Requirements**

**Arduino IDE:**

The primary software for programming the ESP32-CAM module. The Arduino IDE provides an easy-to-use platform for writing, compiling, and uploading code to the ESP32. It supports various libraries that make interfacing with the camera, motor driver, and WiFi network simple. The IDE is open-source and has extensive community support, which is beneficial for troubleshooting and finding example codes.

**ESP32-CAM Library:**

A specialized library that supports the functions of the ESP32-CAM module, including video streaming, face detection, and image capture. This library is essential for handling the camera's operations and integrating its functionality into your code with minimal effort.

**WiFi Library (WiFi.h):**

This library is necessary for connecting the ESP32-CAM module to a WiFi network. It allows the microcontroller to act as a web server, enabling remote access and control. The WiFi library handles all network communication, simplifying the process of sending and receiving data.

**Web Server Library:**

The ESPAsyncWebServer or WebServer library is used to create a web interface for controlling the surveillance car and viewing the live camera feed. This interface is hosted on the ESP32-CAM itself, allowing users to connect via a browser on a smartphone or computer. This eliminates the need for additional apps or software.

**Serial Monitor:**

Part of the Arduino IDE, the Serial Monitor is used for debugging and testing the ESP32-CAM module. It displays real-time feedback from the microcontroller, helping identify issues during the development phase.

**Python (Optional for Advanced Features):**

If you plan to implement advanced image processing features like object detection or face recognition, Python can be used on a server or local computer. Using libraries like OpenCV, you can process the video feed for specific tasks, enhancing the capabilities of your surveillance car.

### 5.1.2 Constraints and Assumptions

Assumption:

• It is assumed that the data set required for training is available during the implementation phase of the project.

• It is assumed that the user of the system is familiar with the interface and will have some knowledge of the working of the system

Constraint:

Internet service is constraint for the end user host.

### 5.1.3 Functional Requirements

• Users should be able to provide real-time input.

• Users should receive an object detected with the correct class prediction

• Users should be able to get the desired output within seconds

• Users should be able to access the system without the Internet.

### 5.1.4 Non-Functional Requirements

• Performance requirements: The system should be configured to run as a server only process, and our application should use the majority of the RAM.

• Safety Requirements: A database backup is necessary for security reasons. while utilizing this system, to refrain from using it illegally.

• Security Requirements: In light of the fact that we use a Windows system and a firewall, the system needs to be secure enough to prevent hacking.

• Software Quality Attributes : The application will satisfy the following software quality attributes:

- Correctness: The system is planned in such a way that it will give the most correct output.

### 4.1.5 Why these components?

ESP32-CAM is selected for its integrated camera and WiFi capabilities, allowing for both video streaming and remote control in a single module. This reduces the number of components needed and simplifies the design. L298N Motor Driver is a versatile motor controller capable of handling the current requirements of the DC motors. It offers dual H-bridge functionality, which is necessary for controlling the direction and speed of multiple motors. DC Motors are chosen for their ease of control and availability. They provide sufficient torque for the car and can be easily powered by a standard 12V battery. 12V Battery provides a consistent and sufficient voltage supply to power both the motors and the ESP32-CAM module. The use of rechargeable batteries makes the system more sustainable and cost-effective. Chassis provides the structural support needed to mount all the components securely, ensuring stable movement and protection of delicate parts like the

ESP32-CAM. Jumper Wires and Breadboard offer a flexible way to connect components during prototyping. They enable quick adjustments and facilitate testing without permanent connections. Voltage Regulator ensures the safe operation of the ESP32-CAM by providing a stable 5V supply, preventing overvoltage damage. Ultrasonic Sensor (Optional) can be used to enhance the project by enabling obstacle detection, making the surveillance car more autonomous and safer to operate.

# 6. Result and Discussion

The Wi-Fi Controlled Surveillance Car was successfully developed using the ESP32-CAM module, ESP32 microcontroller, L298N motor driver, and supporting components such as ultrasonic sensors and a pan-tilt camera mechanism. After completing the hardware and software integration, the surveillance car was able to transmit a real-time video feed to a smartphone via a local Wi-Fi network hosted by the ESP32-CAM module. The web-based interface allowed the user to control the movement of the car, adjust the camera angle using servo motors, and monitor the environment visually in real-time. How we achived this is explained below.

## 6.1 Experimental Testing of The Car

**Figure 6.1:** Testing of Car

The developed surveillance car underwent systematic testing to evaluate its performance in various real-world scenarios. Initial testing was conducted indoors to verify basic movement, camera streaming, and control through the web interface. Subsequent tests were carried out in semi-open environments such as corridors, open balconies, and parking areas to assess Wi-Fi range, video clarity, and obstacle detection accuracy. The car's mobility was tested on multiple surfaces, including tiled floors, concrete, and slightly uneven ground. The system consistently performed well in short-range applications. Data regarding battery consumption, stream latency, and control precision were recorded to evaluate the system's efficiency and reliability. Overall, the prototype met the intended goals and demonstrated successful operation under most conditions.

## 6.2 Designing of Car

The development of the Wi-Fi Controlled Surveillance Car with the ESP32-CAM module aimed for modularity, miniaturization, and utility efficacy at affordable costs. The design procedure started with the identification of a proper chassis that could house all necessary hardware elements, offer structural rigidity, and facilitate movement along typical indoor and semi-outdoor surfaces. A 4-wheel car chassis developed in strong acrylic or plastic material was employed, which could mount motors, battery holders, and other modules firmly. The locomotion system was constructed with four geared DC motors attached to the wheels and driven through the L298N motor driver module. The dual H-bridge motor driver facilitated bidirectional drive of two pairs of motors, such that forward, reverse, left, and right movements were achieved. Power was provided to the motors through a set of four ICR 18650 lithium-ion rechargeable batteries, with an XL4015 buck converter applied to step down voltage to provide compatibility with component specifications and avoid over-voltage destruction. The core of the surveillance and control system was the ESP32-CAM module, placed on the front grill of the car, that was tasked with live streaming video and hosting Wi-Fi.

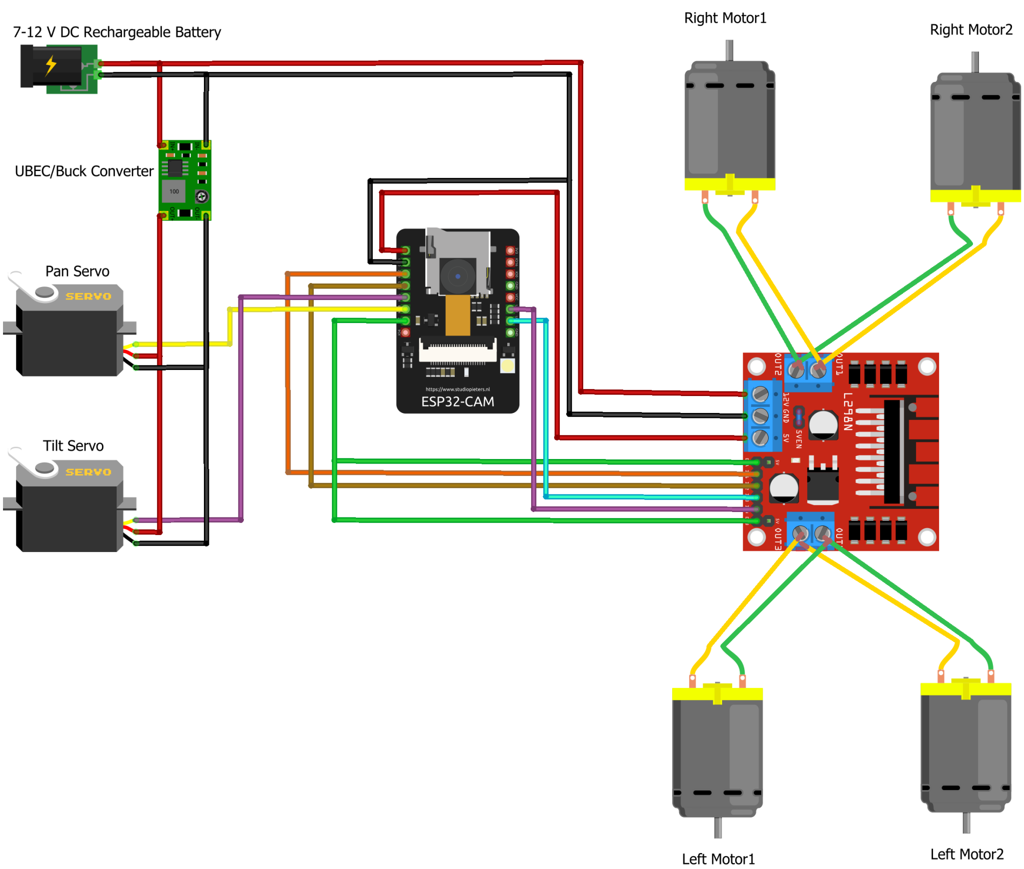


**Figure 6.2:** Connections Diagram

## 6.3 Mobile Application Development

To improve user experience and simplify controlling the surveillance car, a special mobile app was created with Flutter. The app acted as a one-stop-shop interface where the user could control different features of the car in real-time using an Android phone. The app was built with simplicity, responsiveness, and functionality, and it successfully replaced the use of a standard web interface. The major features of the Flutter application were directional motion controls (up, down, left, right), servo motor control to pan and tilt ESP32-CAM's angles, and the onboard LED flashlight's ability to switch it on and off. The above controls were realized by triggering HTTP requests through the mobile app to the ESP32 board IP address, which served as a server on the local Wi-Fi network. Furthermore, the live video stream from the ESP32-CAM module was integrated directly into the app, making real-time monitoring possible without having to toggle between several platforms or windows.

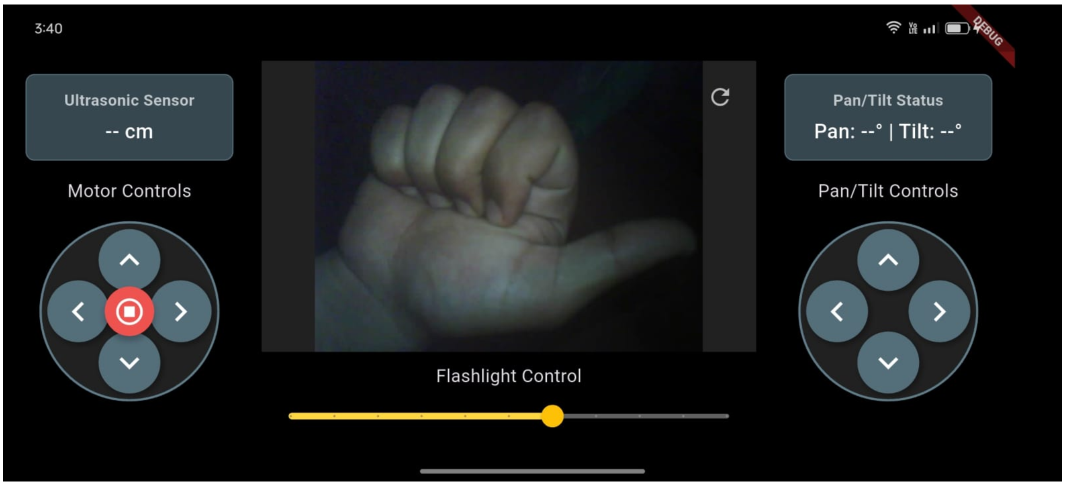


**Figure 6.3:** Mobile App UI

# 7. Future Scope

Future Scope of the WiFi-Controlled Surveillance Car The WiFi-Controlled Surveillance Car project represents a significant leap in flexible and mobile surveillance systems, offering a cost-effective and efficient solution for real-time monitoring. However, this prototype is only the starting point, and there is immense potential for further enhancements and future developments. As technology advances, several avenues can be explored to expand the functionality, versatility, and usability of the surveillance car. The following points outline the future scope and potential improvements that can be integrated into this project:

**1. Integration of Advanced Sensors for Enhanced Surveillance:** The current version of the surveillance car relies primarily on the camera module for monitoring. In future iterations, various sensors could be integrated to provide additional data and capabilities. For instance: Ultrasonic Sensors: These sensors can be added to detect obstacles and help avoid collisions, making the car capable of navigating complex environments autonomously. Infrared (IR) Sensors: IR sensors can be utilized for night vision capabilities, allowing the car to perform surveillance tasks in low-light or dark environments. Gas and Smoke Detectors: By incorporating sensors that detect harmful gases or smoke, the car could be deployed for safety inspections in hazardous industrial zones or confined spaces.

**2. Implementation of Artificial Intelligence (AI) and Machine Learning:** Adding AI capabilities can significantly enhance the functionality of the surveillance car, enabling it to analyze its surroundings and make decisions autonomously. Potential applications include: Object Detection and Recognition: Using machine learning algorithms, the car could be trained to recognize specific objects, such as humans, vehicles, or other predefined targets. This would enable automated tracking and alerting when an object of interest is detected. Facial Recognition: Incorporating facial recognition technology could allow the car to identify specific individuals, making it suitable for advanced security applications, such as monitoring restricted areas or identifying intruders. Path Planning and Autonomous Navigation: By using AI-based algorithms, the car could plan its path and navigate environments without human intervention. This would enable it to perform patrols or inspections autonomously, increasing its utility in large or inaccessible areas.

**3. Enhanced Control System with Multi-Device Connectivity:** The current control system relies on a single smartphone app for operation. Future versions could expand connectivity options to include control from multiple devices, such as tablets, computers, or even integration with smart home systems. This would allow for: Multi-User Access: Multiple users could access and control the surveillance car simultaneously, improving coordination in team-based operations or collaborative surveillance tasks. Voice Command Integration: Integrating voice command features could offer hands-free control of the car, making it easier for users to operate while focusing on the video feed.

**4. Long-Range Communication and GPS Integration:** The existing WiFi-based control limits the car's range to the coverage of the WiFi network. By incorporating additional communication technologies, the range and capabilities of the car could be significantly extended: Cellular Connectivity (4G/5G): Using a 4G or 5G module would allow the car to be controlled from virtually anywhere, overcoming the limitations of local WiFi networks. GPS Module: Adding a GPS module would enable real-time tracking of the car's location, making it possible to monitor its movements on a map interface. This feature would be beneficial for applications that require precise location data, such as search and rescue missions.

**5. Solar-Powered Battery System for Extended Operation:** One of the current limitations of the surveillance car is its reliance on battery power, which may require frequent recharging during extended operations. By integrating solar panels, the car could harness renewable energy to prolong its battery life. This would be particularly useful for outdoor surveillance tasks, where the car could remain operational for longer periods without manual intervention.

**6. Integration with Cloud Services for Data Storage and Analysis:** As the car streams video data in real-time, integrating cloud services could provide a platform for storing, analyzing, and accessing the video feed from anywhere. This approach offers several benefits: Data Archiving: Video footage could be archived in the cloud for future reference, making it useful for security audits or investigations. Real-Time Analytics: Cloud-based analytics tools could be used to process the video feed, providing insights such as motion detection, anomaly detection, and real-time alerts. Remote Access and Sharing: Cloud integration would allow users to access the video feed and control the car from any location, making it easier to monitor remote sites or share access with authorized personnel.

**7. Upgraded Camera and Imaging Capabilities:** The current ESP32-CAM module provides a basic video feed, but future versions could feature more advanced camera systems to enhance image quality and functionality: High-Definition (HD) Camera: Upgrading to an HD or 4K camera module would improve the clarity and detail of the video feed, making it easier to identify objects or individuals. Thermal Imaging Camera: Adding a thermal imaging camera would allow the car to detect heat signatures, making it useful for applications such as night surveillance, search and rescue, or identifying equipment overheating in industrial settings.

**8. Development of a User-Friendly Web Interface:** In addition to the smartphone app, a web-based control interface could be developed, allowing users to access the car's video feed and controls from any browser. This would provide greater flexibility and make the system more accessible across different devices and operating systems. The web interface could include features like: Live Video Streaming: Display the video feed in real-time with options for zooming, recording, and taking snapshots. Control Panel: Provide a comprehensive control panel for managing the car's movement, camera settings, and additional features like sensors. Notification System: Implement an alert system to notify users of detected movement or other significant events, enhancing the car's role in automated surveillance.

**9. Application in Diverse Industries and Scenarios:** The versatile design of the WiFi-Controlled Surveillance Car makes it applicable to a wide range of industries and scenarios, including: Agricultural Monitoring: The car could be used to inspect crops, monitor soil conditions, and detect pests or diseases, providing a cost-effective tool for precision agriculture. Disaster Management: In scenarios like earthquakes, floods, or building collapses, the car could be deployed to explore debris and provide video feedback for rescue teams without putting human lives at risk. Educational and Research Tool: The project could be adapted for educational purposes, serving as a practical example of robotics, IoT, and embedded systems in engineering courses.

**10. Autonomous Navigation with Obstacle Avoidance:** One of the major upgrades in future iterations of the Wi-Fi-controlled surveillance car could involve enabling fully autonomous navigation using advanced obstacle detection and avoidance algorithms. This would require integrating sensors such as LIDAR, infrared, or additional ultrasonic sensors for precise distance measurement and environmental mapping. Using microcontrollers with higher processing capabilities or offloading computations to an external server or cloud platform would make it possible to run real-time path planning and decision-making algorithms. This feature would make the car independent of human operators, enhancing its utility in hazardous or remote areas where direct control is challenging or impossible.

**11. Voice-Controlled Operation:** Incorporating voice recognition technology into the surveillance car system would provide a hands-free control interface, offering enhanced convenience and accessibility. Using modules like the ESP32 combined with dedicated speech recognition libraries or integrating services like Google Assistant or Amazon Alexa through cloud APIs, users can control movement, camera angles, lights, and recording functions via spoken commands. This can be particularly useful in situations where manual control through a smartphone or web interface is not feasible, such as for users with physical disabilities or in environments where the operator's hands are occupied with other tasks.

**12. Integration with IoT and Home Automation Systems:** Future enhancements could allow seamless integration of the surveillance car into a larger Internet of Things (IoT) ecosystem. This means it could work in tandem with smart home devices such as alarms, smart locks, motion sensors, and cameras. For example, if an indoor motion sensor detects activity when no one is home, the surveillance car could automatically navigate to that area, stream live video, and send alerts to the owner. This interconnectedness significantly boosts the system's effectiveness as part of an automated security infrastructure and adds to the smart capabilities of a household or industrial setup.

**13. Night Vision and Thermal Imaging Capabilities:** Adding infrared night vision or thermal imaging sensors can dramatically expand the operating conditions of the surveillance car. Traditional ESP32-CAM modules perform poorly in low light, which limits night-time surveillance. Infrared or thermal sensors would enable the system to detect heat signatures and navigate effectively even in complete darkness or through fog and smoke. This makes it particularly suitable for search-and-rescue missions, nighttime patrolling in industrial or military zones, and wildlife observation in forests. The integration of such sensors can be optimized through machine learning to interpret heat maps and identify objects of interest.

**14. Self-Charging Docking Station:** To enhance operational autonomy and reduce human intervention, the surveillance car could be programmed to return to a designated docking station for recharging its batteries when power levels drop below a certain threshold. This feature would require adding navigation algorithms capable of detecting and aligning with the charging dock, possibly using visual cues or RFID guidance. When paired with solar charging options or wireless charging pads, this can make the surveillance unit capable of 24/7 monitoring with minimal maintenance. This type of automation is highly suitable for industrial plants, military zones, and agricultural fields with sparse human presence.

**15. Real-Time Data Encryption and Cybersecurity Protocols:** As surveillance data becomes more critical and potentially sensitive, implementing real-time data encryption and strong cybersecurity measures is essential. The surveillance car could be upgraded with SSL/TLS protocols for secure video streaming and control, and implement authentication mechanisms like tokens or biometric-based access to the control system. This ensures that unauthorized users cannot intercept the feed or hijack the vehicle. Moreover, integration with blockchain-based logging systems could add tamper-proof data logging for audit trails, especially useful in military or legal scenarios. Strengthening cybersecurity is essential as the project moves towards commercialization and real-world deployment.

**16. Facial Recognition and Object Detection:** Leveraging advanced image processing and AI, the surveillance car can be upgraded to identify faces, license plates, and specific objects in real-time using pre-trained machine learning models such as YOLO (You Only Look Once) or MobileNet. This feature allows the system not just to monitor areas but also to recognize and alert users about specific individuals or suspicious objects. For instance, it can send alerts if a blacklisted face is detected or if a bag is left unattended in a secure zone. This capability can transform the device from a passive observer to an intelligent guard.

**17. Biometric Authentication for Access Control:** To secure the control and access of the surveillance car, future models can include biometric access mechanisms such as fingerprint recognition, facial recognition, or retina scanning. Only verified users would be able to activate or operate the system. This layer of security is useful in sensitive environments such as research labs, defense installations, or private properties. Biometric sensors could be embedded into the docking station or control device, ensuring that even if the system is hijacked or stolen, it cannot be misused without valid authentication. This adds a robust layer of protection to an already secure platform.

**18. Integration of Environmental Monitoring Sensors:** The surveillance car can be enhanced to collect environmental data in addition to its core security functionalities. Sensors to detect gas leaks, smoke, temperature, humidity, radiation, or toxic substances can be added, turning the device into a multipurpose monitoring tool. This would be valuable in hazardous environments like chemical plants, underground tunnels, mines, and disaster zones. The collected data can be transmitted in real-time to cloud dashboards or mobile apps, helping officials take timely actions. This diversification of functionality greatly increases the practical value of the car in industrial and environmental surveillance applications.

In summary, the future scope of the WiFi-Controlled Surveillance Car is vast, with opportunities for integrating advanced technologies and expanding its application range. By incorporating features like AI, extended communication capabilities, renewable energy solutions, and improved user interfaces, the surveillance car can evolve into a comprehensive, multifunctional tool for various industries and security needs.

# 8. Conclusion

In conclusion, the WiFi-Controlled Surveillance Car provides a unique and effective solution for mobile surveillance, combining real-time video feedback with responsive remote control. The project leverages the capabilities of the ESP32-CAM module for video streaming and the L298N motor driver for precise motor control, resulting in a reliable and user-friendly system. The ability to operate the car via WiFi makes it a convenient option for remote monitoring, reducing the need for expensive and complex setups. The project's success demonstrates the feasibility of using low-cost, readily available components to create a robust and flexible surveillance tool. With its potential for further enhancements and adaptability to various applications, the WiFi-Controlled Surveillance Car stands out as a promising innovation in the field of remote monitoring and security systems.

# References


1 K. Verma, G. S. Charan, A. Pande, Y. A. Abdalla, D. Marshiana and C. K. Choubey, ”Internet Regulated ESP32 Cam Robot,” 2023 7th International Conference On Computing, Communication, Control And Automation (ICCUBEA), Pune, India, 2023, pp. 1-5, doi: 10.1109/ICCUBEA58933.2023.10391981.

2 S. G K, R. K. Patel, S. Maitra, S. Bhattacharya, S. Moosa and P. Pavan, ”Robotic Car Using NodeMCU ESP8266 Wi-Fi Module,” 2023 9th International Conference on Advanced Computing and Communication Systems (ICACCS), Coimbatore, India, 2023, pp. 1439-1443, doi: 10.1109/ICACCS57279.2023.10113098.

3 J. Cheng, M. Ye and Q. Zhang, ”Design of intelligent remote control car based on bluetooth,” 2022 18th International Conference on Computational Intelligence and Security (CIS), Chengdu, China, 2022, pp. 205-209, doi: 10.1109/CIS58238.2022.00050.

4 A. Kaur, A. Jadli, A. Sadhu, S. Goyal, A. Mehra and Rahul, ”Cloud Based Surveillance using ESP32 CAM,” 2021 International Conference on Intelligent Technology, System and Service for Internet of Everything (ITSS-IoE), Sana’a, Yemen, 2021, pp. 1-5, doi: 10.1109/ITSS-IoE53029.2021.9615334.

5 F. Constantin, G. Suciu, S. Bosoc and R. Craciunescu, ”Internet Controlled Car,” 2020 13th International Conference on Communications (COMM), Bucharest, Romania, 2020, pp. 261-264, doi: 10.1109/COMM48946.2020.9141988.

6 Kambli, R., et al. ”Implementation of a wireless surveillance robot using ESP32-CAM.” International Journal of Advanced Research in Computer Engineering Technology, vol. 7, no. 5, 2018, pp. 93-96.

7 Chen, W., et al. ”Design of a mobile robot for environmental monitoring.” IEEE Transactions on Instrumentation and Measurement, vol. 67, no. 8, 2018, pp. 1899-1908.

8 Yarlagadda, P., et al. ”Design and implementation of a wireless robot for industrial monitoring.” Journal of Robotics and Mechatronics, vol. 33, no. 2, 2021, pp. 399-404.

9 Liu, C., et al. ”Design and implementation of a wireless surveillance robot based on ESP32-CAM.” IEEE Access, vol. 9, 2021, pp. 14582-14591.

10 Noh, J., et al. ”Development of a surveillance robot with obstacle avoidance capability.” International Journal of Advanced Robotic Systems, vol. 15, no. 1, 2018, pp. 1-8.

11 Waghmare, D. ”Implementation of a low-cost security robot using ESP32-CAM.” International Journal of Engineering Research and Applications, vol. 10, no. 2, 2020, pp. 34-38.

12 Zou, J., et al. ”A novel design of wireless monitoring robot.” Journal of Physics: Conference Series, vol. 1749, 2021, p. 012015.

13 H. Deshpande, D. Zite, S. Bagul, and V. Philip, ”Research Paper on Surveillance Robot Using ESP32 CAM,” International Journal of Creative Research Thoughts (IJCRT), vol. 12, no. 4, pp. 70–78, Apr. 2024. [Online]. https://www.ijcrt.org/papers/IJCRT24A4148.pdf.

14 B. A. Kumar, ”Robot Vehicle with ESP32 CAM,” International Journal for Research in Applied Science and Engineering Technology (IJRASET), vol. 12, no. 3, pp. 1–5, Mar. 2024, doi: 10.22214/ijraset.2024.64054.

15 K. Patel, M. Gadaria, and K. Kansagra, ”Surveillance Robo Car Using ESP32 CAM Module,” International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), vol. 12, no. 2, pp. 559–571, Apr. 2025, doi: 10.32628/IJSRSET25122176.

16 A. Nayyar, V. Puri, N. G. Nguyen, and D. N. Le, ”Smart Surveillance Robot for Real-Time Monitoring and Control System in Environment and Industrial Applications,” in Information Systems Design and Intelligent Applications, Springer, Singapore, 2018, pp. 229–243.

17 T. Akilan, P. Kumari, S. Chaudhary, and U. Pandey, ”A Survey on Surveillance Robot in Hazardous Place Using IoT Technology,” International Journal of Research in Engineering, Science and Management, vol. 3, no. 6, pp. 310–315, 2020.

18 C. V. Mahamuni and Z. M. Jalauddin, ”Intrusion Monitoring in Military Surveillance Applications Using Wireless Sensor Networks (WSNs) with Deep Learning for Multiple Object Detection and Tracking,” in 2021 International Conference on Control, Automation, Power and Signal Processing (CAPS), pp. 1–6, IEEE, 2021.

19 N. Popli, K. Masiwal, S. Batra, and C. Mamgain, ”Surveillance Car Bot: Future of Surveillance Car Bot,” International Journal of Engineering Research n Technology, vol. 9, no. 3, pp. 1–5, 2020.

20 M. M. Menaka, S. K. Ramya, D. R. Sakthi Sri, and M. Thirisha, ”Surveillance Robot Using ESP32 CAM,” International Journal of Advanced Research in Science, Communication and Technology, vol. 3, no. 2, pp. 1–5, 2022.

21 A. Aalase, P. Bandgar, K. Kamble, S. Bhosale, and A. A. Udgave, ”Surveillance Monitoring Using ESP32-CAM Module,” International Journal of Research Publication and Reviews, vol. 3, no. 5, pp. 1–5, 2021.

22 H. Deshpande, D. Zite, S. Bagul, and V. Philip, ”Research Paper on Surveillance Robot Using ESP32 CAM,” International Journal of Creative Research Thoughts (IJCRT), vol. 12, no. 4, pp. 70–78, Apr. 2024.