AQUAVISION ROV

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ABSTRACT

This study introduces the design and implementation of a Wi-Fi- controlled robot vehicle using the ESP32-CAM module for real-time video streaming. The system incorporates an L298N motor driver, four TT motors, and power source for autonomous mobility. The ESP32-CAM module offers a real-time camera image and allows user control through a web interface. The project is set to provide an economical and portable solution for surveillance and remote monitoring applications, which can be further extended to home security, disaster management, and industrial automation.

1. Introduction

The need for wireless-controlled robotic systems has grown immensely over the last few years as a result of the development of wireless communication technologies like Wi-Fi and the availability of low-cost microcontrollers and sensors. Remote-controlled robots with real-time video streaming features are extremely useful devices in many applications, including surveillance, environmental monitoring, and industrial automation. The capability of controlling a robot from a remote location and having live video feedback is critical in operations where human intervention is impossible, e.g., in risky environments or remote areas.

This paper demonstrates an affordable approach to constructing a remote- controllable and video-streaming robotic vehicle. The system incorporates the ESP32-CAM module, which is a Wi-Fi microcontroller with a camera for real-time video streaming, and the L298N motor driver, which manages the four TT motors for accurate movement. With the help of an easy-to-use web interface, users are able to send commands to the vehicle, allowing for forward, backward, left, right, and stop motion. The real-time video feed from the ESP32-CAM offers users visual feedback in real-time, making control and observation of the vehicle easier.

The main goal of this research is to illustrate how combining low-cost components, like the ESP32-CAM module and L298N motor driver, is possible in order to develop a robust and affordable robotic system. The system proposed in this paper is suitable for use in applications such as home security, remote inspection, surveillance, and emergency response, where permanent monitoring and rapid mobility are needed. The paper also explains the difficulties faced while designing and implementing the system and recommends future improvement areas.

2. Components and Materials

The fabrication of the robot vehicle is based on the use of a number of primary components that play specific roles in the proper function of the system. These components are the ESP32-CAM module, the L298N motor driver, TT motors, a chassis, and a power supply.

2.1 ESP32-CAM Module

The ESP32-CAM module is the core of the system as it offers both video recording and Wi-Fi communication functionality. It is built around the ESP32 microcontroller, which has both Wi-Fi and Bluetooth on board, making it a perfect candidate for IoT applications. The ESP32-CAM module has an onboard camera (OV2640) that can record video and take still images. It also has a microSD card slot to store media, though in this project, real-time video streaming over Wi-Fi is the focus.

The capability of the ESP32-CAM to stream video via Wi-Fi allows remote observation, which can be especially useful in monitoring and surveillance applications. In addition, the ESP32-CAM is programmable with the Arduino IDE, which means it is within reach of a wide variety of developers and hobbyists. The small size and low cost add to the overall cost-effectiveness of the system, making it a good choice for hobby projects and prototypes.

2.2 L298N Motor Driver

The L298N motor driver is a necessary part in managing the movement of the robotic car. It is a dual H-bridge motor driver, as it is able to control two motors individually for direction and speed. The L298N enables bidirectional DC motor control, which is perfectly suited to controlling the movement of the robotic car. It can power motors with high voltage and high current levels, which can be used for bigger robots or heavy applications.

The L298N motor driver is connected to the ESP32-CAM module, which receives control signals from the microcontroller. These control signals regulate the direction and speed of the motors, thus controlling the movement of the vehicle. The L298N also has thermal protection and overload protection capabilities, making the system safe and long-lasting.

2.3 TT Motors

The vehicle has four TT motors, which are low-priced, tiny DC motors that are common in hobbyist robotics. They offer the required torque and speed for the vehicle to travel in any direction. Each motor is linked to the L298N motor driver, responsible for its rotation and speed. The motors are laid out so that the vehicle can travel forward, backward, left, or right, and also halt when needed.

The TT motors are selected based on their price and ease of handling. They are readily available and may easily be interfaced to motor drivers like the L298N. Due to their compact size, they are appropriate for small robotic platforms, and their torque is ideal for the mobility of light robotic cars.

2.4 Power Supply

The robotic vehicle is powered by a rechargeable battery pack. The battery needs to deliver sufficient voltage and current to drive the ESP32- CAM module, the L298N motor driver, and the motors. A 7.4V lithium- ion battery is commonly used, as it offers a good compromise between capacity and size. The battery is plugged into a power distribution board, which distributes the proper voltages to each part of the system.

Apart from the main power supply, a voltage regulator is employed to provide a stable 3.3V supply to the ESP32-CAM module, as demanded by its operating voltage. The power supply is made compact and light to ensure that the robot is portable and efficient in its operation.

2.5 Chassis

The robotic vehicle's chassis gives structural support to all the components. It is usually constructed from light materials like plastic or aluminum, making the robot both strong and manageable. The chassis is meant to support the ESP32-CAM module, the motor driver, the motors, and the power supply firmly in position, such that no component gets dislodged while in use.

In this design, mounting points for the motors are also included in the chassis so they can be placed in a position that maximizes the movement of the robot. The design of the chassis is small and compact so that the robot can be stable even at higher speeds.

3. System Design

3.1 Hardware Design

The robotic vehicle's hardware design incorporates the ESP32-CAM module, L298N motor driver, TT motors, and power supply into a single system. The ESP32-CAM acts as the controller, handling both video streaming and motor control operations. The L298N motor driver is interfaced with the ESP32-CAM, which provides control signals to the driver to regulate the direction and speed of the motors. The TT motors then take care to drive the robot in the desired direction.
The power supply is tasked with delivering the required power to all elements of the system. The battery pack helps the robot run for a long time without having to be recharged. The chassis takes care to support all the elements in place so that the system is kept compact and stable while in operation.

3.2 Software Design

Software design for the robotic car relies on the Arduino IDE, making it simple to program the ESP32-CAM module. The software needs to execute several important tasks:
Video Streaming: The ESP32-CAM records video through its camera module and streams it to a web interface in the MJPEG format. This enables users to see the live video stream from the robot in real-time.
Motor Control: The ESP32-CAM module provides control signals to the L298N motor driver to regulate the robot's movement. Motor control software contains logic to process user inputs (forward, backward, left, right, and stop) and send corresponding signals to the motor driver.
Web Interface: The user interface is implemented in HTML and JavaScript so that users can operate the robot with a browser on any Wi- Fi-enabled device. The interface is responsive and shows the live video feed from the ESP32-CAM module. Users can give instructions to the robot via buttons, and the interface gives real-time feedback on the status of the robot.
The software itself was made modular, so it would be easy to update and make adjustments to in the future. The web interface was also tested to make sure that it gave silky smooth and responsive control of the robot, even when live video streaming was added to it.
The process for the ESP32-CAM-based robot car is implemented using seamless interaction between the user and the robot. To begin with, the ESP32-CAM module is turned on and configured as a Wi-Fi Access Point (AP), which establishes a network connection that can be accessed by a smartphone, laptop, or any other device with Wi-Fi connectivity.
When connected, the user logs in to the web interface of the robot by entering the IP address allocated to the ESP32-CAM.
The live video feed from the robot's camera is shown on the web interface, and the user can see the surroundings of the robot in real-time. The user can give commands from this interface, which are executed by the
ESP32-CAM module. The commands for direction and speed are given by sending proper signals to the L298N motor driver. The driver then engages the motors to propel the robot in the direction desired. As the robot travels, the video feed is refreshed, giving real-time feedback to the user.

4. Methodology

4.1 System Workflow

- Initialization: When the system is powered, the ESP32-CAM boots in Access Point (AP) mode.
- Connection: Users access their devices (smartphone, tablet, or laptop) to the ESP32-CAM Wi-Fi network.
- Control Interface: A browser-based interface is opened by visiting the ESP32-CAM IP address, where users can view the live video stream and send control commands.
- Command Processing: The ESP32-CAM processes the control commands, which then talk to the L298N motor driver to regulate the movement of the vehicle.
- Real-Time Video Display: The real-time video feed from the camera is shown on the web interface so that users can view the environment around the robot in real time.

The robotic vehicle's control commands are:

- Forward: Turns on the motors to propel the robot in a forward direction.

- Backward: Reverts motor direction to drive the robot backwards.
- Left/Right: Operates motors on the left and right side of the robot to turn the robot left or right.
- Stop: Stops the robot's movement by shutting down the motors.

These control commands are transmitted via the web interface and processed in the ESP32-CAM module, which then transmits signals to the L298N motor driver. This driver modifies the speed and direction of the motors to create the required motion.

5. Literature Survey

The domain of robotics and IoT has undergone impressive developments over the past few years due to the accessibility of microcontrollers at an affordable price along with sensors. This literature survey analyzes the important contributions and progress in areas regarding robotic vehicles, live streaming video, and Wi-Fi-based remote control.

- Robotic Vehicles and Control Systems

Robotic cars have been extensively studied for their use in surveillance, disaster relief, and industrial automation. Experiments have proved the efficacy of using microcontrollers like Arduino and Raspberry Pi in controlling robotic systems. Kumar et al. (2019) research indicates the application of Raspberry Pi in autonomous navigation, highlighting its capability in real-time control and data processing.

- ESP32-CAM Module Applications

The ESP32-CAM module has attracted interest based on its low price and onboard camera functionality. Smith et al. (2020) researched its application in home security systems, where live video streams are transmitted to a mobile app. The research highlighted the module's capability to support concurrent video streaming and Wi-Fi connectivity, thus making it appropriate for applications that demand remote surveillance.

- Motor Control Systems

L298N motor driver is a very common motor control component in robotics. Since it can work with both small and big DC motors, it can be applied in a wide range of robotic applications. Singh et al. (2021) states that L298N is usually combined with microcontrollers such as the ESP32 to achieve accurate motor control in robotics.

6. Results and Discussion

6.1 System Performance

The robotic car was able to successfully navigate in every direction (forward, backward, left, right, and stop) smoothly and accurately. The video streaming via live video was smooth, with very little lag between the user interface and camera input. The use of the ESP32-CAM module, where it could operate both motor control and video streaming at the same time, was efficient, with no delay or interruption observed during use.

6.2 Application Scenarios

The design of the robotic vehicle makes it possible to use it in a wide range of real-world applications. For example, it can be used for surveillance in hard-to-reach places by humans, like dangerous environments or disaster areas. The capability of the vehicle to stream live video allows operators to make decisions based on real-time feedback from the environment around the robot.

7. Conclusion and Future Work

This paper outlines the design and development of a Wi-Fi-controllable robotic car with live streaming capabilities. The system was able to integrate the ESP32-CAM module, L298N motor driver, and TT motors to form an operational robotic platform for surveillance and remote monitoring purposes.

Future development will be directed toward expanding the capabilities of the robot by incorporating additional more sophisticated sensors, including ultrasonic sensors for avoidance, and more sophisticated control programs to allow for autonomous movement. In addition, the quality of the video streaming will be improved, and the latency minimized so that the robot can be employed in more demanding environments.

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