

HAND GESTURE CONTROLLED ROBOTIC CAR USING ESP32

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Abstract— This project presents the design and implementation of a gesture-controlled robotic car using ESP32 and MPU6050 for wireless and real-time control. Traditional robotic systems rely on joysticks, remote controls, or mobile applications, which require manual effort and lack intuitive interaction. The proposed system uses a motion sensor (MPU6050) to detect hand gestures and convert them into control signals. An ESP32 microcontroller processes these signals and transmits them wirelessly using the ESP-NOW protocol. The receiver module mounted on the robotic car interprets the signals and controls the motors through an L298N motor driver. This enables smooth movement in multiple directions such as forward, backward, left, and right based on hand gestures. The system eliminates the need for physical controllers and reduces dependency on internet connectivity. It provides low latency, fast response, and improved user experience. The design is cost-effective, portable, and easy to implement using readily available components. The system is suitable for applications in robotics, automation, assistive technologies, and surveillance. Future enhancements include integrating camera modules, AI-based gesture recognition, and IoT-based remote monitoring for improved functionality.

Index Terms— Gesture Control, ESP32, MPU6050, Robotics, Wireless Communication, ESP-NOW, Automation, Microcontroller.

I. INTRODUCTION

Surveillance has become an essential part of modern security. Surveillance and robotic control systems have become an essential part of modern technology, especially in areas such as industries, automation, and smart environments. However, most traditional robotic control methods rely on devices such as joysticks, remote controllers, or mobile applications. These approaches often require manual effort, continuous user attention, and sometimes internet connectivity, making them less efficient and not user-friendly. In certain situations, especially in hazardous or restricted environments, these traditional control methods can be inconvenient and slow to respond.

With the rapid development of embedded systems, wireless communication, and IoT technologies, there is a growing interest in designing intelligent and intuitive control systems. These systems aim to reduce human effort while improving efficiency, flexibility, and real-time responsiveness. One of the key advancements in this field is gesture-based control, which allows users to interact with machines using natural hand movements instead of physical controllers.

In this project, we propose a gesture-controlled robotic car that uses hand gestures to control movement wirelessly. The system is designed using an ESP32 microcontroller and an MPU6050 motion sensor.



Fig. 1. A general view of Gesture Control Car

The motion sensor detects hand movements and sends the data to the ESP32 transmitter. This data is then transmitted wirelessly using the ESP-NOW protocol to the receiver module mounted on the robotic car.

Based on the received signals, the microcontroller controls the motors of the car through a motor driver, enabling movement in different directions such as forward, backward, left, and right. This ensures smooth, real-time, and intuitive navigation without the need for traditional control devices.

The proposed system offers a low-cost, portable, and efficient solution for robotic control applications. It eliminates the dependency on physical controllers and internet connectivity while providing fast response and ease of use.

An intelligent gesture-controlled robotic system is being developed that integrates motion sensing, wireless communication, and embedded control to enhance modern automation and robotics applications. This system provides a user-friendly and real-time control mechanism, making it suitable for applications such as robotics, assistive technologies, automation systems, and educational projects.

System Design and Development: The entire flow of the proposed system is divided into a few steps as follows.

- **Gesture-Based Control System:** The system is designed to detect hand movements using an MPU6050 motion sensor. The sensor captures acceleration and orientation data, which is processed by the ESP32 microcontroller to identify different gestures corresponding to movement directions.
- **Wireless Communication:** The processed gesture data

the movement of motors accordingly. This enables the car to make quick decisions such as moving forward, stopping, or changing direction.

- **Real-Time Navigation Control:** The receiver ESP32 module interprets the incoming signals and controls the motors through an L298N motor driver. Based on the detected gesture, the car performs actions such as moving forward, backward, turning left, or turning right, ensuring smooth and responsive control.

The rest of the paper is organized as follows: Section II presents a review of existing robotic control systems and their limitations. Section III describes the proposed system design and methodology for gesture-based control and wireless communication. Section IV discusses the implementation details and working of the ESP32 and MPU6050-based system. Section V presents the results and performance evaluation of the proposed system. Finally, Section VI concludes the paper and highlights the future scope of the project.

II. RELATED WORK

In recent years, several researchers have explored the development of intelligent robotic systems using embedded technologies and wireless communication. Traditional robotic control systems such as joysticks, remote controllers, and mobile applications are widely used; however, they are limited in terms of user interaction, flexibility, and real-time responsiveness. These systems often require continuous manual input and are not always intuitive, which restricts their effectiveness in dynamic environments.

The work proposed by J. Borenstein and Y. Koren focused on real-time navigation techniques for mobile robots, where sensor data is used to make movement decisions. Their research laid the foundation for modern robotic systems by introducing efficient control mechanisms for real-time applications. Another study by S. R. Kumar and P. K. Singh demonstrated the implementation of microcontroller-based robotic systems using simple hardware components. Their work showed that low-cost embedded systems can effectively control robotic movement and perform basic automation tasks.

With the advancement of wireless communication technologies, researchers have focused on improving interaction between users and robotic systems. Studies involving wireless protocols such as Wi-Fi, Bluetooth, and ESP-NOW have demonstrated how real-time data transmission can be achieved with minimal latency. In particular, ESP32-based systems have gained popularity due to their built-in wireless capabilities and processing efficiency, making them suitable for real-time control applications.

Gesture-based control systems have also been widely researched as an alternative to traditional control methods. Researchers have used sensors such as accelerometers and gyroscopes (e.g., MPU6050) to capture hand movements and convert them into control signals. These systems provide a more natural and intuitive way of interacting with machines, improving user experience and reducing dependency on physical controllers. However, challenges such as sensor calibration, noise, and gesture accuracy need to be addressed for reliable performance.

Microcontroller-based systems using platforms like Arduino and ESP32 are commonly used for robotic control. Arduino is preferred for its simplicity and low cost, while ESP32 offers enhanced processing power along with integrated wireless communication features. The use of ESP32 enables faster data transmission and real-time responsiveness, making it more suitable for gesture-controlled applications. However, improper configuration or signal interference can affect communication performance.

Motor control using PWM (Pulse Width Modulation) is widely used to regulate the speed and direction of robotic vehicles. Motor driver modules such as L298N allow efficient control of DC motors based on input signals from the microcontroller. While PWM ensures smooth movement, incorrect tuning or delays in signal processing may affect system performance.

Overall, the proposed system combines gesture sensing using MPU6050, ESP32-based wireless communication, and motor control to provide a simple, low-cost, and efficient solution for real-time robotic control. Gesture-controlled robotic systems offer several advantages in terms of ease of use, flexibility, and real-time interaction. However, they also face challenges such as sensor accuracy, communication reliability, and power management. Factors such as signal interference, calibration errors, and hardware limitations can impact overall system performance.

Therefore, developers or users planning to implement such systems should carefully consider these limitations and ensure proper system design, reliable components, and effective calibration techniques. A balanced approach between performance, cost, and reliability is essential for successful implementation and long-term usability of gesture-controlled robotic systems.

III.METHODOLOGY: GESTURE-BASED CONTROL AND WIRELESS COMMUNICATION USING ESP32 AND MPU6050

The methodology of the proposed gesture-controlled robotic car system focuses on integrating gesture sensing with real-time wireless communication using embedded system components. The system is designed to operate based on human hand movements, enabling intuitive and controller-free interaction. The overall approach involves sensing hand gestures, processing the acquired data, transmitting it wirelessly, and executing actions through motor control.



Fig. 2. Overview of detection and recognition process

This system eliminates the need for traditional controllers and provides a faster and more user-friendly control mechanism. To achieve this functionality, the system is divided into different functional modules that work together in a coordinated manner. Each module is responsible for a specific task, and their integration ensures smooth and efficient operation of the system.

A. Method-1: Sensing Unit (Gesture Detection)

The sensing unit is responsible for detecting hand gestures. It uses an MPU6050 motion sensor, which consists of an accelerometer and a gyroscope.

The sensor measures acceleration and orientation of the hand in different directions. These values are continuously read by the ESP32 microcontroller.



Based on the tilt of the hand, gesture values are obtained and used to determine the direction of movement. This continuous sensing allows the system to capture gestures in real time.

B. Method-2: Processing Unit (Decision Making)

The processing unit acts as the brain of the system and is implemented using an ESP32 microcontroller. It receives sensor data from the MPU6050 and processes it to generate control commands.



The logic used by the system is simple and efficient:

- IF tilt forward → move forward
- IF tilt backward → move backward
- IF tilt left → turn left
- IF tilt right → turn right
- ELSE → stop

This decision-making process occurs continuously, ensuring real-time response and smooth control of the robotic car.

C. Method-3: Communication Unit (Wireless Transmission)

The communication unit is responsible for transmitting the processed gesture data from the transmitter to the receiver.

The system uses the ESP-NOW protocol for wireless communication. This protocol enables fast, low-latency data transmission between ESP32 devices without requiring internet connectivity.

The transmitter ESP32 sends gesture commands to the receiver ESP32, ensuring real-time control of the robotic system.

In the transmitter unit, the ESP32 reads gesture data from the MPU6050 sensor and converts it into predefined control commands such as forward, backward, left, right, or stop. These commands are encoded into small data packets and transmitted wirelessly using ESP-NOW.

At the receiver side, another ESP32 is configured in receiving mode. It continuously listens for incoming data packets from the transmitter. Upon receiving the data, the ESP32 decodes the command and forwards it to the motor control unit for execution.

The communication process follows these steps:

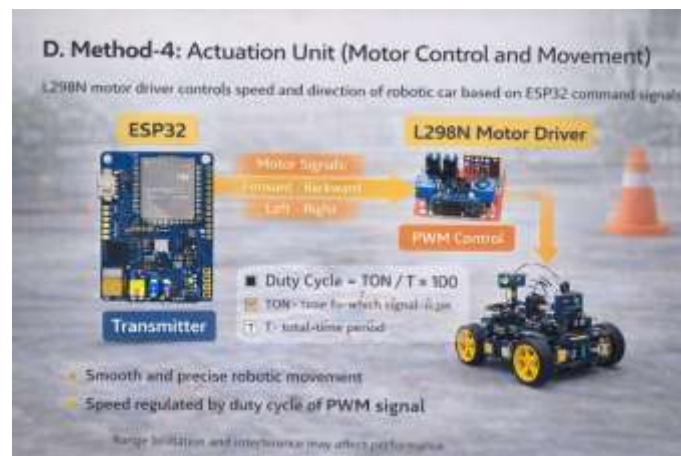
- Initialization of ESP-NOW protocol on both transmitter and receiver
- Configuration of peer-to-peer communication using MAC addresses
- Continuous transmission of gesture-based command packets
- Real-time reception and decoding of commands at the receiver
- Immediate forwarding of commands to the motor driver



D. Method-4: Actuation Unit (Motor Control And Movement)

The actuation unit is responsible for controlling the movement of the robotic car. It consists of an L298N motor driver and DC motors.

The motor driver acts as an interface between the ESP32 and the motors. It receives control signals and drives the motors accordingly.



Based on the received signals, the car performs the following movements:

- Move forward
- Move backward
- Turn left
- Turn right

Motor speed control is achieved using Pulse Width Modulation

Duty Cycle Formula

$$\text{Duty Cycle (\%)} = \frac{T_{\text{ON}}}{T} \times 100$$

Where:

T_{ON} = Time for which the signal is ON

T = Total time period

(PWM).

This ensures smooth and controlled movement of the robotic car.

IV.CONCLUSION

In conclusion, the gesture-controlled robotic car developed in this project successfully integrates intuitive human interaction with real-time wireless control into a single system. The use of the MPU6050 motion sensor enables accurate detection of hand gestures, while the ESP32 microcontroller processes this data efficiently to generate control commands.

The implementation of ESP-NOW communication ensures fast and reliable wireless transmission without the need for internet connectivity. The motor driver and PWM-based control enable smooth and responsive movement of the robotic car in multiple directions.

The system is low-cost, easy to implement, and suitable for various applications such as robotics learning, automation systems, and assistive technologies. This project highlights the potential of embedded systems and wireless communication technologies for developing user-friendly and efficient control mechanisms.

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