Real-Time Gesture Controlled Robot Using Mems Accelerometer Sensor

Dr. B.Padmanaban, M.E., Ph.D[1], Mr. P.Vigneshwaran, M.E.,(Ph.D.,)[2], Mrs. K.Padmapriya, M.E.,(Ph.D.,)[3], Harihara Sudhan N[4], Jegannath N[5], Mohamed Al Ashik S[6]

[1]*Head of Department, Department of Electronics and Communication Engineering AAA College of Engineering and Technology*

[2,3]*Assistant professor, Department of electronics and communication engineering AAA College of Engineering and Technology*

[4,5,6]*Department of Electronics and Communication Engineering AAA College of Engineering and Technology*

***Abstract*-This project presents the design and development of a Smart Gesture-Controlled Robot using a MEMS Accelerometer Sensor and Wi-Fi-based communication. The proposed system utilizes an MPU6050 MEMS accelerometer to detect hand gestures such as tilt and motion. These gestures are processed by an ESP32 microcontroller configured as a transmitter, which converts the sensor data into corresponding movement commands. The commands are transmitted wirelessly using the ESP-NOW protocol, a low-latency Wi-Fi communication method that ensures fast, stable, and reliable data transfer over a longer range compared to conventional wireless technologies. At the receiver side, another ESP32 microcontroller receives the gesture commands and controls the robot's movement through an L298N motor driver, which drives the DC motors mounted on the robot chassis. Based on the user's hand gestures, the robot is capable of performing movements such as forward, backward, left, right, and stop in real time. Noise filtering and calibration techniques are implemented to improve gesture recognition accuracy and minimize false detections..**

Keywords - Microcontroller; Bluetooth communication; Embedded Robotics; Servo motors; Gesture control; Accelerometer sensor.

I. INTRODUCTION

Robots are widely used in industrial automation, healthcare, defense, education, and domestic environments to reduce human effort and improve productivity. The performance of a robotic system is largely dependent on the effectiveness of its control mechanism. Gesture-based control systems provide a natural way of interaction by allowing users to control machines using simple hand movements.

Gesture control systems are designed to recognize and interpret human body movements and convert them into meaningful commands for machines or electronic devices. Gesture recognition technology has gained widespread attention due to its applications in robotics, gaming, virtual reality, healthcare, and smart devices.

Sensor-based gesture control systems utilize motion sensors such as accelerometers, gyroscopes, and magnetometers to detect movement, orientation, and tilt. These systems are more reliable, cost-effective, and efficient for real-time applications. MEMS (Micro Electro Mechanical Systems) sensors are commonly used in such systems due to their small size, low power consumption, and high accuracy.

II. RELATED WORK

Robots can be controlled using various techniques depending on their application, complexity, and operational environment. Over the years, several robot control methods have been developed to improve accuracy, reliability, and ease of operation. Each technique has its own advantages as well as certain limitations.

Wired control systems are among the earliest and most commonly used robot control techniques. In this method, robots are controlled using physical connections such as cables, switches, and control panels. Wired systems provide stable and reliable communication with minimal signal loss. However, the presence of physical wires restricts robot movement, reduces flexibility, and limits the operating range. These systems are also inconvenient in dynamic or large-scale environments.

Wireless control systems were introduced to overcome the limitations of wired control. Technologies such as Radio Frequency (RF), Bluetooth, and Wi-Fi are commonly used for wireless robot control. RF-based systems provide moderate range but are susceptible to interference from other electronic devices. Bluetooth-based control systems are easy to implement and suitable for short-range applications, but their limited range and pairing issues reduce reliability. Wi-Fi-based systems offer wider coverage but depend heavily on network availability and stability.

III. SYSTEM ARCHITECTURE

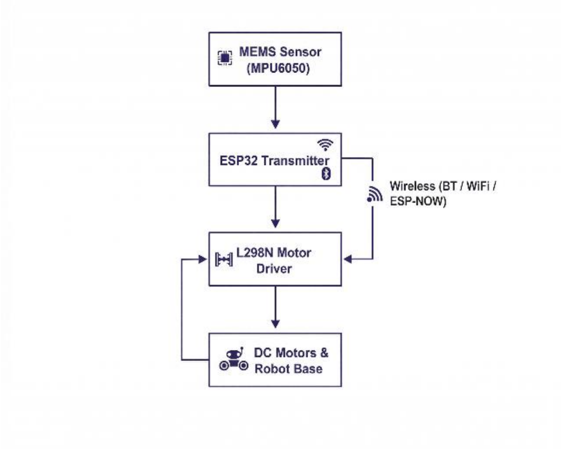

Fig 1. Architecture of the Proposed System

The system architecture consists of two major units: the Transmitter Unit (Gesture Control Unit) and the Receiver Unit (Robot Control Unit). These units communicate wirelessly using Bluetooth, Wi-Fi, or ESP-NOW based on application requirements.
The transmitter unit captures hand movements using MEMS sensors and processes the data through an ESP32 microcontroller. The processed gesture information is encoded into control signals and transmitted wirelessly. The receiver unit decodes the received signals and drives the robot motors accordingly using a motor driver.
The block diagram of the proposed system explains the functional flow of data and control between the main hardware components used in the gesture-controlled robotic system. Overall, the block diagram demonstrates an efficient integration of sensing, processing, wireless communication, and motor control.

IV. PROPOSED SOLUTION

A. Hardware Implementation

Gesture recognition refers to the process of identifying meaningful human movements and interpreting them as control commands for machines or robotic systems. Based on the nature, duration, and complexity of hand movement, gesture recognition systems are broadly classified into static gestures and dynamic gestures.

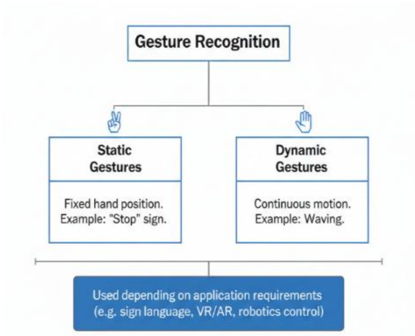

Fig 2 Types of Gesture Recognition

Wireless communication enables remote control of robotic systems. The proposed system uses Bluetooth, Wi-Fi, and ESP-NOW communication protocols depending on range and latency requirements.Bluetooth communication is used in the proposed system for short-range, low-power wireless control of the robot. In this model, the gesture unit transmits control commands directly to the robot unit using Bluetooth connectivity.
Wi-Fi communication enables long-range control of the robot through a wireless network. In this model, gesture data is transmitted from the gesture unit to the robot via a Wi-Fi router. This approach allows remote operation over a wider area and supports IoT-based applications.

B. Software Design

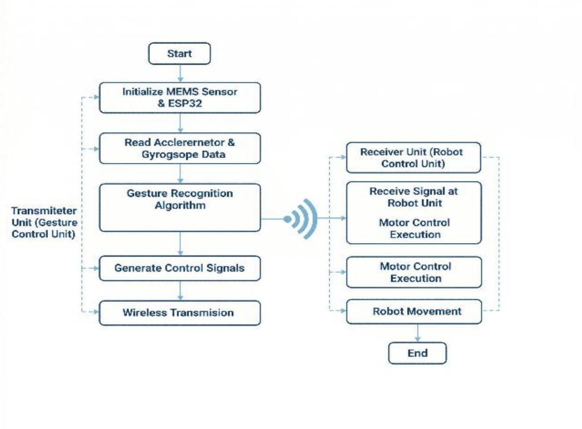

Fig 3 Software Design of the Proposed System

The transmitter module plays a critical role in the proposed gesture-controlled robotic system, as it serves as the primary human–machine interface. This module is designed to capture, interpret, and transmit user hand gestures in real time.

The MPU6050 integrates both an accelerometer and a gyroscope, allowing it to measure linear acceleration and angular velocity along the X, Y, and Z axes. As the user moves their hand, the sensor continuously captures motion data. These raw sensor values are transmitted to the ESP32 through the I²C communication interface.

The receiver module forms the execution unit of the proposed gesture-controlled robotic system and plays a critical role in converting wireless gesture commands into precise mechanical motion. This module is physically mounted on the robotic platform and consists of an ESP32 microcontroller, an L298N motor driver circuit, and DC motors attached to a rigid robot chassis. The integration of these components ensures accurate, responsive, and reliable robot movement.

The ESP32 microcontroller in the receiver module is responsible for continuously monitoring the wireless communication interface for incoming control commands transmitted by the gesture unit.

V. RESULTS AND DISCUSSION

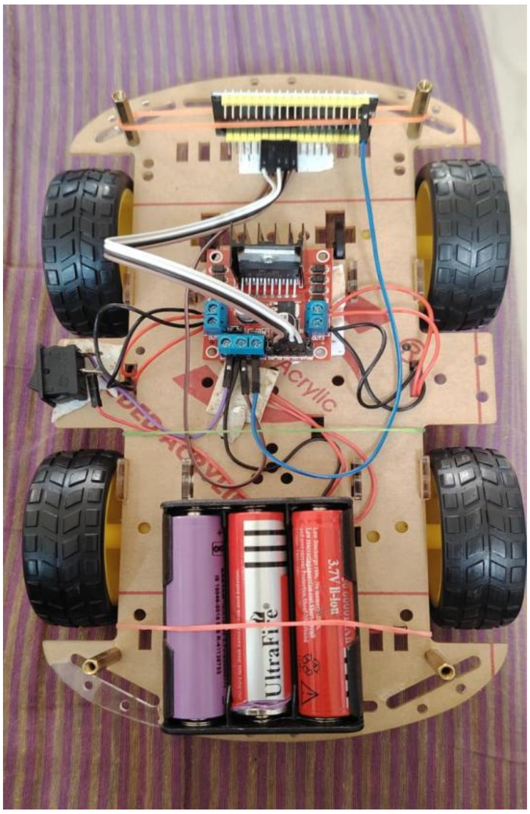

Fig 4 Overall prototype of the Proposed System

The experimental setup of the proposed gesture-controlled robotic system was designed to evaluate the performance, reliability, and responsiveness of the developed prototype under real-time operating conditions. The complete system consists of two major units: the gesture control unit (transmitter) and the robotic unit (receiver).

During experimentation, the MEMS sensor was securely attached to the user's hand to accurately capture hand orientation and movement. The ESP32 transmitter continuously read accelerometer data through I²C communication and processed it using a threshold-based gesture detection algorithm. Identified gestures were transmitted wirelessly to the receiver ESP32 in real time.

The robotic unit was powered using a battery-based power supply to ensure portability and uninterrupted operation. The L298N motor driver interfaced between the ESP32 and the DC motors, enabling direction and speed control. The prototype was tested on flat surfaces to observe movement accuracy, response time, and stability.

Multiple test cases were performed by executing various gestures such as forward, backward, left, and right hand tilts. The experimental setup allowed validation of system functionality, wireless communication reliability, and motor control accuracy, thereby confirming the effectiveness of the proposed design..

The results obtained from the experimental evaluation demonstrate that the gesture-controlled robotic system performs effectively and reliably in real-time conditions. The robot successfully responded to hand gestures with minimal delay, indicating efficient gesture detection and wireless communication. The use of threshold-based decision logic helped eliminate false triggers caused by minor hand movements or sensor noise.

Forward and backward movements were executed smoothly when the hand was tilted along the Y-axis, while left and right turns were accurately controlled using X-axis tilts. The response time between gesture execution and robot movement was observed to be low, making the system suitable for real-time applications. The PWM-based motor control ensured smooth acceleration and deceleration, reducing mechanical stress on the motors.

VI. CONCLUSION

This project successfully presents the design, development, and implementation of a gesture-controlled robotic system that enables intuitive, touchless, and real-time control using MEMS sensors and wireless communication technologies. The L298N motor driver efficiently interfaced between the low-power control signals and high-current DC motors, enabling precise control over direction and speed.

The integration of the MPU6050 MEMS accelerometer with the ESP32 microcontroller accurately capturing and interpreting hand gestures. The use of a threshold-based gesture detection algorithm ensured reliable recognition while minimizing false triggers caused by noise or unintentional hand movements. Real-time processing and wireless data transmission enabled smooth and responsive robot control, demonstrating the effectiveness of the selected hardware and software architecture.

Overall, the proposed gesture-controlled robotic system provides a strong foundation for advanced human–machine interaction applications. It is well suited for use in hazardous environments, assistive technologies, educational platforms, and industrial automation. The project demonstrates a practical and cost-effective approach to intuitive robotic control and contributes meaningfully to the field of embedded systems and robotics.

The L298N motor driver efficiently interfaced between the low-power control signals and high-current DC motors, enabling precise control over direction and speed. PWM-based motor control further improved movement smoothness and reduced mechanical stress.

VII. FUTURE WORK

The scope of this project encompasses the design, development, and implementation of a gesture-controlled robotic system that operates based on hand movements detected using MEMS sensors. The primary focus of the project is to demonstrate an effective and intuitive method of robot control without the use of physical contact or conventional input devices.

This project covers the integration of various hardware components, including MEMS accelerometer sensors, the ESP32 microcontroller, motor drivers, DC motors, and wireless communication modules. The scope includes sensor data acquisition, processing of motion signals, gesture recognition logic, and real-time command transmission. Through this integration, the project provides practical insight into embedded system design, sensor-based control, and robotic motion control.

From a software perspective, the project scope includes programming the microcontroller to interpret sensor data, implement control algorithms, and manage wireless communication.

Overall, the scope of this project is limited to basic gesture recognition and robot movement control, but it provides a scalable platform for further research and development in the field of human–machine interaction and intelligent robotic systems.

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