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GestureBot: A Smart Robot Powered by ADXL Accelerometer and Hand Gestures

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ABSTRACT

The Versatile Hand Gesture-Controlled Robot with ADXL Accelerometer is designed to offer an intuitive and user-friendly interface for human-robot interaction by recognizing a broad range of hand gestures. At the core of the system is the ADXL MEMS accelerometer, which detects acceleration across three axes (X, Y, and Z), making it an effective sensor for capturing hand movements and improving the functionality and flexibility of robotic control. The robot uses this accelerometer to interpret gesture-based inputs, which are processed by the ESP32 microcontroller. The ESP32 then sends appropriate commands to four motors, managed by an L293D motor driver, to execute various movements. To enable remote and wireless control, the system includes both Bluetooth and Wi-Fi modules, ensuring smooth communication and adaptability in diverse environments. In addition to gesture control, the robot is equipped with a voice recognition module, allowing users to operate it using predefined voice commands—providing an alternative mode of interaction. The robot can perform basic functions such as moving forward, backward, turning left or right, and stopping. It is powered by a rechargeable battery, ensuring portability and longer operational periods. The system's effectiveness is assessed based on gesture recognition accuracy, responsiveness, and practical applicability. Overall, the integration of the ADXL accelerometer significantly enhances the robot's adaptability, precision, and user control through hand gestures.

Keywords: ADXL Accelerometer, ESP32 Microcontroller, L293D Motor Driver, Battery.

1. INTRODUCTION

The versatile hand gesture-controlled robot represents a significant advancement in human-robot interaction, offering intuitive, real-time control through natural hand gestures. The core functionality of this robot lies in its ability to interpret and respond to hand movements using advanced sensors, such as accelerometers, gyroscopes, and cameras, along with machine learning algorithms for gesture recognition. This system processes various hand gestures, such as open and closed hand shapes, pointing, or specific motions, translating them into precise robot actions. The result is a seamless interaction where the robot's response to user commands is both immediate and fluid, making it an ideal solution for diverse applications ranging from industrial automation to healthcare.

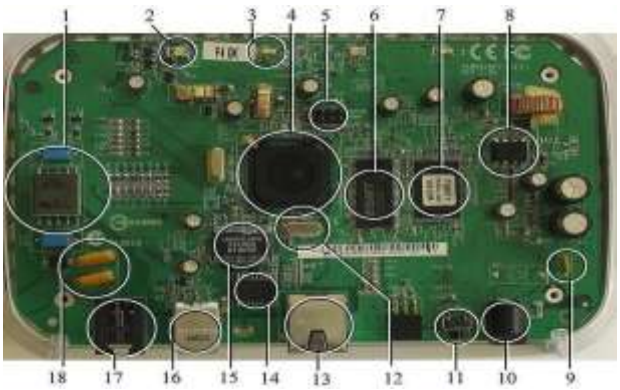

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Fig. 1: A modern example of embedded system

The integration of Bluetooth and Wi-Fi modules facilitates seamless wireless communication, allowing remote operation and adaptability in various environments. The robot is powered by a rechargeable battery, ensuring portability and extended usability. Incorporating gesture recognition technology, the robot is designed to perform a wide variety of tasks, such as object manipulation, navigation, and even complex problem- solving based on the user's hand gestures. This versatility makes it a valuable tool in various sectors, including manufacturing, education, entertainment, and healthcare. One of the major advantages of this robot is its intuitive user interface. Hand gestures are an innate form of communication, making it easy for both beginners and experts to operate the robot without needing extensive training. This makes the technology particularly accessible for individuals with disabilities or those who may struggle with traditional input devices like joysticks or keyboards.

2. LITERATURE SURVEY

Ore-Ofe, et al(2024) proposed a head gesture-controlled robot was designed and developed to assist individuals with disabilities by translating head movements into commands using an accelerometer equipped headgear. Integrated with an Arduino-based system, it enabled precise control for movement and turning. Testing demonstrated over 95% accuracy with minimal latency, highlighting its potential as an affordable and user-friendly assistive technology. [1]

Kaur, et al(2024) designed a Gesture Controlled Bot, a robotic device that was operated through hand gestures to assist individuals with physical disabilities in maneuvering wheelchairs or vehicles. The design incorporated a differential mechanism, which rotated wheels in opposite directions on each side, enabling the wheelchair to turn in place without forward or backward movement. [2]

SatheeshKumar, et al(2024) developed the Advanced Mobility Control Robotic Platform (AMCRP) to enhance adaptability in diverse environments through advanced mobility and modularity. Featuring multiple locomotion modes and an advanced control system, it offered versatility for applications like search and rescue, logistics, and infrastructure inspection. The development process included design, prototyping, testing, and refinement. Further research was needed to maximize its potential across industries. [3]

Jaiswal, et al(2024) presented the design and implementation of a gesture-controlled lawn mower to overcome limitations of traditional and remote-controlled models. Using hand gestures, users could navigate seamlessly, enhancing convenience and safety by operating from a distance. The mower eliminated physical buttons, allowed programmable paths for efficiency, and promoted physical activity, offering a modern, user-friendly solution for lawn maintenance. [4]

Meem, et al(2024) constructed a gesture-controlled car that operated via an accelerometer sensor integrated into a hand glove. The sensor replaced the traditional remote control, allowing the user to steer the vehicle forward, backward, right, or left while using an analogous accelerometer to regulate the throttle position. A pick-and-place robotic arm with 3DoF was mounted on top of the car, controlled by an Android app to perform pick- and-place operations. The combination of these robotic systems assisted in various heavy, hazardous, or surveillance tasks, significantly reducing the risk of human casualties. [5]

Bhavadharini, et al(2024) proposed task involved developing IoT-enabled gadgets and integrating gesture recognition, ultrasonic technology, and fall detection to create a user- friendly, cost-effective, and efficient smart wheelchair. Gesture recognition interpreted human gestures, ultrasonic sensors detected obstacles for safety, and fall detection technology alerted caregivers via messages. By utilizing ultrasonic sensors and accelerometers, this approach provided efficient and secure mobility for users. [6]

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Patil, et al(2024) presented the design and implementation of an intelligent wheelchair system integrating gesture recognition, fall detection, and health monitoring. Developed to enhance mobility and safety for individuals with physical disabilities, it allowed intuitive head gesture control for navigation. Fall detection algorithms monitored movements and alerted caregivers in emergencies, while the health monitoring system tracked vital signs in real time. By combining these technologies, the wheelchair provided a comprehensive solution, promoting independence, safety, and improved quality of life. [7]

Tamilselvi, et al(2024) developed a head gesture-controlled wheelchair using an acceleration sensor to assist individuals with severe disabilities. A microcontroller-driven motor circuit enabled movement in five modes: FRONT, BACK, RIGHT, LEFT, and LOCK. Fabricated with locally sourced components, the device was tested in a lab for functionality, with test results included in this paper. [8]

3. PROPOSED SYSTEM

The versatile hand gesture-controlled robot represents a significant advancement in human- robot interaction, offering intuitive, real-time control through natural hand gestures. The core functionality of this robot lies in its ability to interpret and respond to hand movements using advanced sensors, such as accelerometers, gyroscopes, and cameras, along with machine learning algorithms for gesture recognition. This system processes various hand gestures, such as open and closed hand shapes, pointing, or specific motions, translating them into precise robot actions. The result is a seamless interaction where the robot's response to user commands is both immediate and fluid, making it an ideal solution for diverse applications ranging from industrial automation to healthcare.

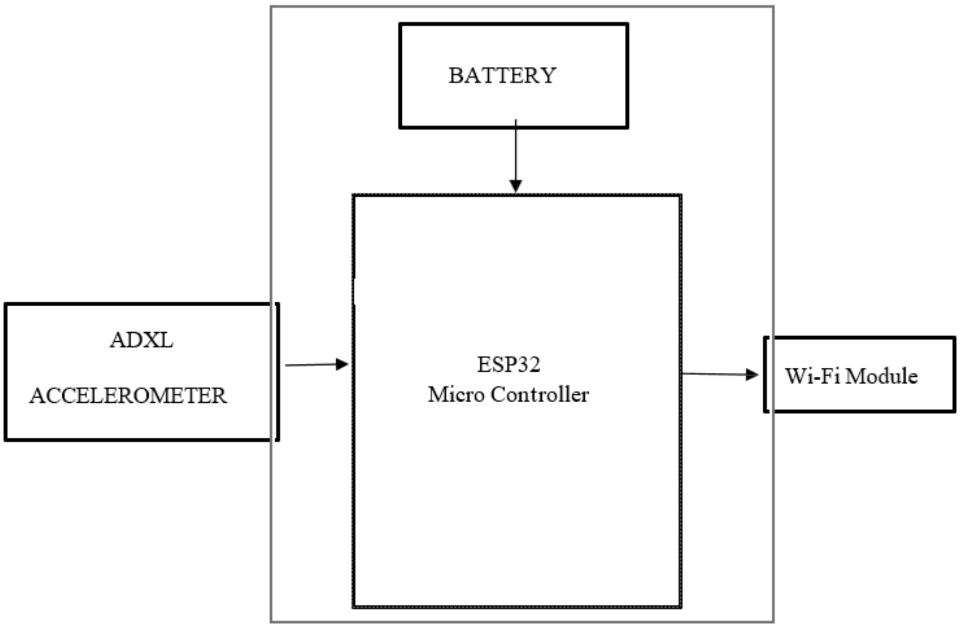

Fig. 2: Transmitter Block Diagram of Hand Gesture Control robot.

The Hand Gesture Controlled Robot using an ADXL accelerometer works by detecting hand movements and converting them into corresponding motions of the robot. The system is powered by a battery, which supplies energy to the ESP32 and the L293D motor driver. The MEMS-based ADXL accelerometer is used as an input device to sense the tilt of the user's hand, sending signals to the ESP32 for processing. Based on these inputs, the ESP32 generates control signals for the L293D motor driver, which then drives the four motors to move the robot in the desired direction—forward, backward, left, or right.

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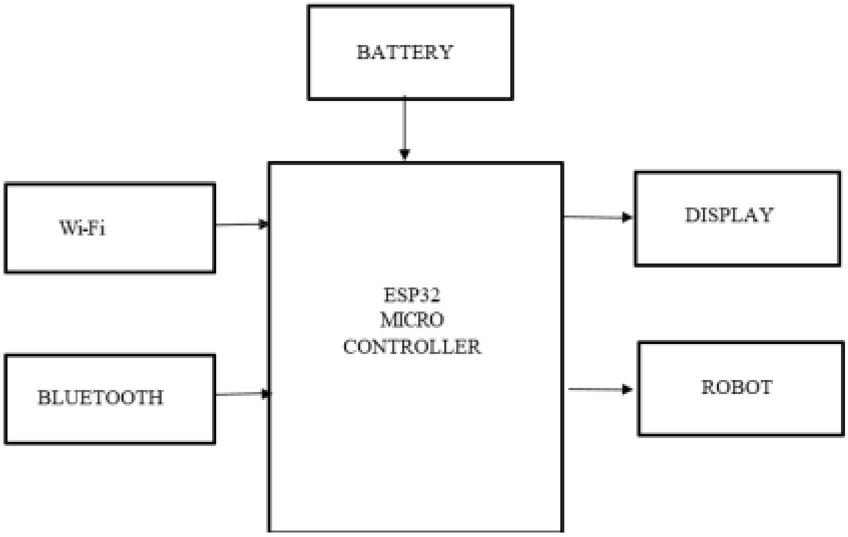

Fig. 3: Receiver Block Diagram of Hand Gesture Control robot

The ESP32's Bluetooth module connects to a smartphone, enabling voice and button control via a Bluetooth app. When the user speaks a command (e.g., "forward", "stop", "left"), the app converts it to text and sends it via Bluetooth. The ESP32 processes the command and moves the robot accordingly. Similarly, on-screen buttons allow manual control by sending directional commands to the ESP32, which drives the L298N motor driver. The ESP32 continuously listens for Bluetooth input, ensuring seamless switching between voice and button control for flexible operation.

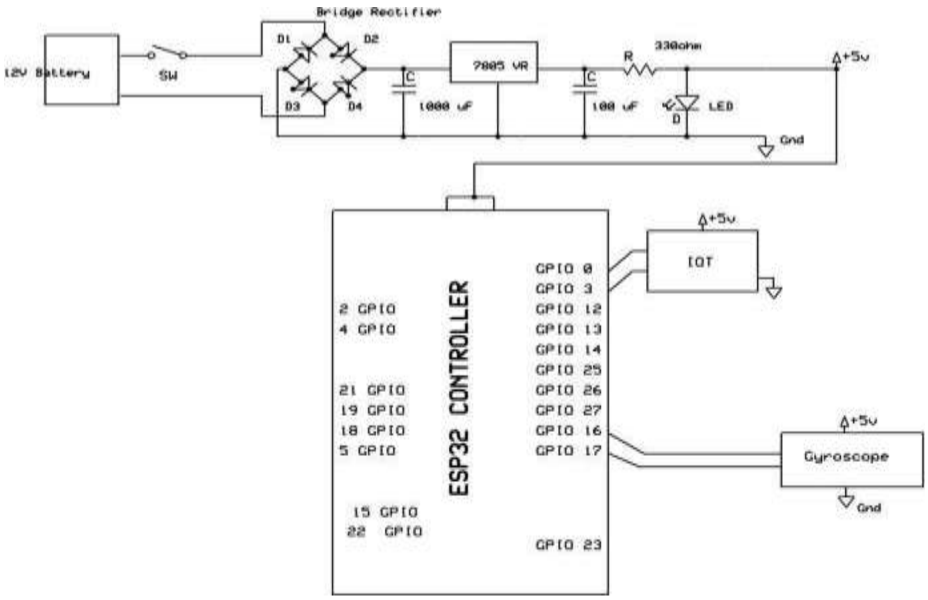

Fig. 4: Transmission circuit of Hand Gesture Control Robot

The circuit consists of a 12V battery, switch, bridge rectifier (4 diodes), capacitors (1000µF and 100µF), 7805 voltage regulator, resistor (330Ω), LED, ESP32 microcontroller, IoT module, and gyroscope sensor. The power supply section includes a 12V battery as the main power source, controlled by a switch. A bridge rectifier (D1, D2, D3, D4) ensures polarity protection, while capacitors (1000µF and 100µF) help in voltage regulation and noise filtering. The 7805 voltage regulator steps down the 12V

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supply to a stable 5V DC output, required for the ESP32 microcontroller and connected peripherals. An LED, in series with a 330Ω resistor, acts as a power indicator.

Advantages

Hand gesture control offers several significant advantages that make it an intuitive and efficient method for operating robots. Firstly, it provides natural and easy-to-learn interaction, as users can control the robot simply by moving their hand, mimicking everyday motions without the need for complex buttons or remote controls. This approach also ensures enhanced precision, especially when using sensors like the ADXL accelerometer, which accurately detects changes in hand orientation and movement across the X, Y, and Z axes. As a result, users can achieve smooth, responsive, and fine-tuned control over the robot's actions. Additionally, when integrated with wireless communication technologies such as Bluetooth or Wi-Fi, this system allows for remote operation, making it ideal for scenarios where direct access to the robot is limited or impractical. The hands-free nature of gesture control is particularly beneficial in environments where manual input is inconvenient or hazardous. Moreover, the system is highly adaptable, as it can be programmed to recognize a variety of custom gestures, enabling tailored control schemes for different tasks or specific applications.

4. RESULTS AND DISCUSSION

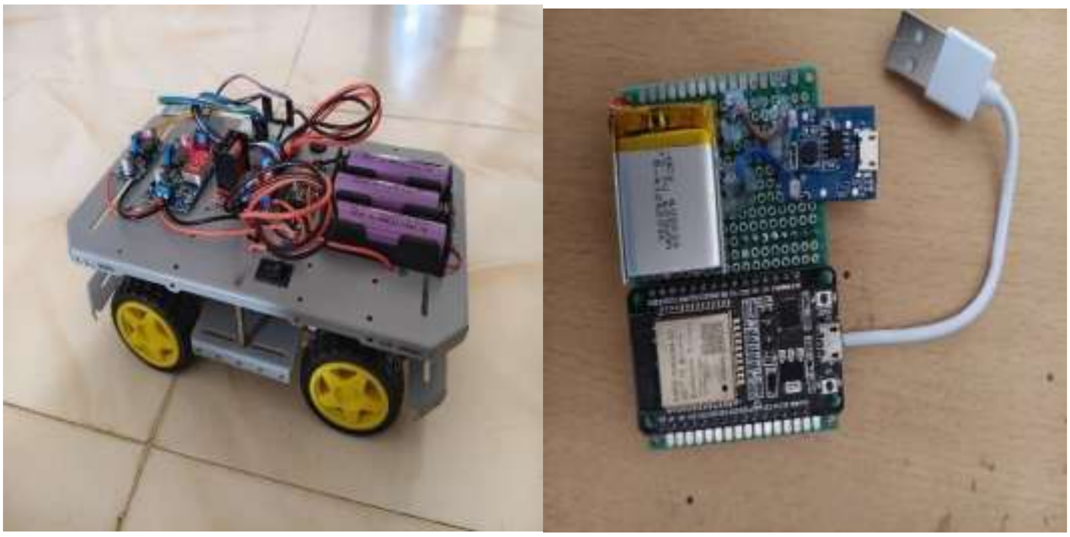

Fig. 5(a) Robot Fig. 5(b) Gesture Control

Fig. 5: Hand Gesture Robot Prototype

The above image shows the Prototype of the project. The kit is turned ON by giving the regulated power supply of 12v which is then converted to 5v dc current. The LED is the indication for 5v current so, if there is 5v current then automatically the LED glows. The generated 5v dc current passes to every hardware co component in the circuit.

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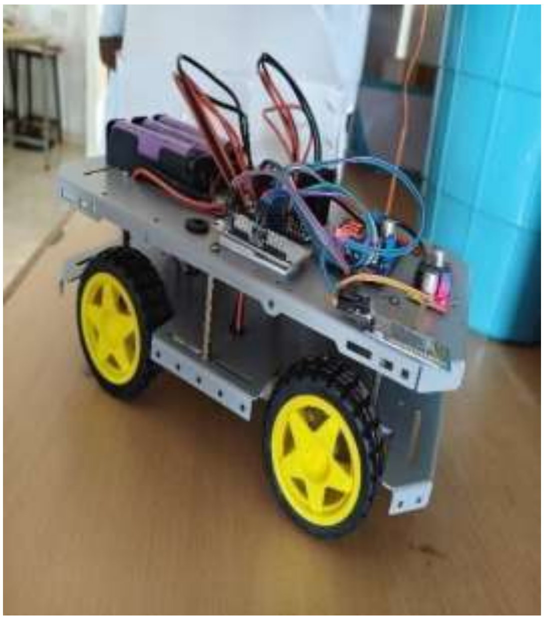
Fig. 6: ADXL Accelerometer

The above image shows the ADXL Accelerometer /MEMS Sensor used in project. This setup features an ESP32 microcontroller connected to a Li-Po battery and a TP4056 charging module, enabling wireless functionality. It likely processes data from a gyroscope sensor to detect hand gestures and transmits signals via Wi-Fi for robot movement control.



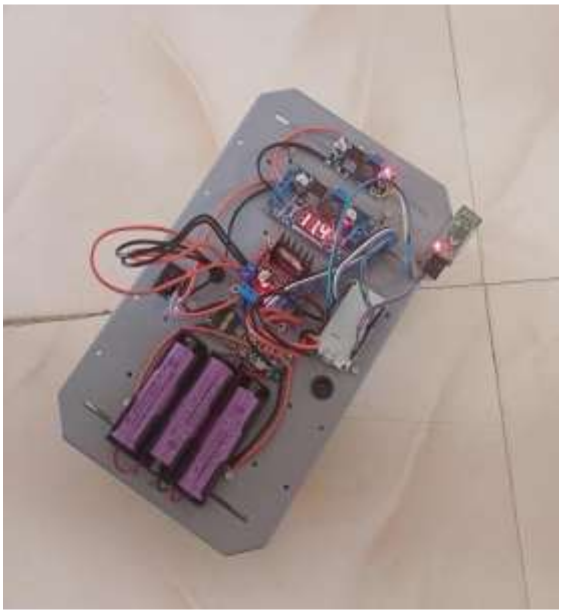


Fig. 7(a) Side view of the robot Fig. 7(b) Side view of the robot

Fig. 7: Robot moving in the right direction

In the above image, the robot receives control command of 'R' right through Wi-Fi and Bluetooth modules. Upon receiving the command, the ESP32 processes the data and sends signals to the motor driver, making the robot move accordingly in the right direction. The lithium-ion batteries provide power, ensuring smooth and efficient movement.

5. CONCLUSION

The Versatile Hand Gesture-Controlled Robot with ADXL Accelerometer effectively enhances human-robot interaction through intuitive gesture and voice-based control. The ADXL accelerometer accurately detects hand movements, while the ESP32 microcontroller processes data to ensure seamless operation. The integration of the L293D motor driver and wireless communication modules (Bluetooth and Wi-Fi) enables reliable and remote-controlled mobility. Additionally, the voice recognition module

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enhances accessibility by offering an alternative control method. Powered by a rechargeable battery, the system ensures portability and extended usability. Performance evaluations confirm its accuracy, responsiveness, and adaptability, making it a promising solution for applications in assistive technology, Healthcare, automation, and interactive robotics.

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