

Intelligent IoT-Based Hand Gesture Controlled Robot

Prof. Sanjay M. Malode¹, Vaishnavi Rajesh Gahlod², Nikita Vijay Yende³, Pooja Pradip Naikwade⁴

¹U.G. Professor, Department of Artificial Intelligence and Data Science Engineering, K.D.K.College of Engineering, Nagpur, Maharashtra, India

^{2,3,4}Student, Department of Artificial Intelligence and Data Science Engineering, K.D.K. College of Engineering, Nagpur, Maharashtra, India

Abstract - The paper focuses on an IoT-based robot that users can control with hand gestures. The primary objective of the project is to develop a smart robotic system that recognizes and responds to hand gestures in real-time. The algorithm is based on control with the help of C++, and recognizing gestures, thereby enabling quick and efficient processing. Accelerators or a vision module detect movement of the hands with the sensors. The data is processed by a microcontroller, such as an ESP32. Wireless modules like Bluetooth or Wi-Fi transmit the data, allowing the hand to communicate with and control the robot. It connects to an Internet of Things (IoT) platform for remote monitoring, control, and analysis. Here, we propose a new and natural control interface for these robotic systems based on gesture recognition, IoT connectivity, and AI-based intelligence.

Keywords: Hand gesture recognition; Data transmission, Omnidirectional; Human-computer interaction. Signal recognition.

1. INTRODUCTION

Our project involves building an IoT-based hand gesture-controlled robot. The IoT and AI technologies are integrated into this mini four-wheeler, enabling it to move in all directions without manual control, eliminating the need for manual controls. The system is built on a mini four-wheeled robotic platform, which is capable of moving forward, backward, left, right, as well as stopping, all with specific hand gestures. The robot's IoT connectivity allows for remote monitoring and control, making it easy, simple, and convenient to operate. This real-time gesture recognition, combined with wireless IoT communication, makes robotics smarter, quicker, more responsive, and more interactive. Such an approach is employed to improve usability and give rise to new applications in assistive technology, healthcare, industrial automation, smart homes, and defense systems.

2. LITERATURE SURVEY

The author explains about the [1] "an IoT system that allows users to control devices by using simple hand gestures. The model uses a camera to detect movements and switches the appliances on or off without the need to touch a thing". It is a good example of how gesture control can make everyday device use easier and more natural.

The author in [2] introduces LEXIBOT, a miniature personal assistant robot controlled with hand gestures. An accelerometer detects the user's hand movements and turns them into commands for the robot. The results show that simple gestures can be used instead of buttons or voice control, making it easier and natural to use.

In [3], the authors design an Arduino-based robot that moves according to hand gestures. An accelerometer senses the hand gestures by users and translates this movement into commands that are sent to the robot. Tests showed that the robot responds quickly and correctly to different gestures. The work shows how basic sensors and IoT technology can make gesture-controlled robots easy to build and use.

In [4], the authors build a basic Arduino-based robot that operates by hand gesture, hand-tilt. An RF transmitter sends the gesture signals to the robot, removing the need for buttons or joysticks. With separate transmitter and receiver sections, the system provides an easy and natural way to control the robot and can be improved further for advanced purposes.

The author in [5] develops a gesture-controlled robotic car that moves based on hand gestures detected by an accelerometer sensor. Motor drivers control the car's four gear motors, allowing it to respond smoothly to each gesture. The study shows that the use of gesture control simplifies the use of robotic vehicles more easily and naturally, which gives rise to new applications.

In [6], the authors create a novel web-based hand gesture recognition model to implement a gesture-controlled system for every directional autonomous vehicle. By removing the need for systems, wearable technology, specialized hardware, or complicated setups, this is applicable for future works that expand the potential for deploying intuitive, touch-free control systems across real-world domains.

3. DESCRIPTION OF PROJECT

This project includes an invention of a gesture-controlled robotic vehicle that is capable of moving in any direction. It is a mecamum, and it is controlled by an ESP32 microcontroller. The hand gesture controller is commanded by the MPU6050 sensor to follow the positioning and the tilt of the user's hand. A transmitter module based on the ESP32 will act upon the sensor data and will transmit wireless input to the ESP-NOW protocol to the robot, as the control signals required. The ESP32 receiver installed on the robot deciphers these and drives the robot with four separate DC motors with the help of motor drivers. In this design, all directions are capable of movement in every direction, including forward, backward, sideways, and even diagonal directions. The mecamum wheels together with ESP-NOW communication form a system that creates a system that provides quick control and manoeuvrability, which can be applicable in robotics and human interaction.

4. WORKING

It is controlled by the wireless control of hand gestures using ESP-NOW and real-time control. Gesture Detection: It is a sensor that is an MPU6050 accelerometer and a gyro sensor on a glove, and is able to measure the tilt angles of the hand in a sequence of directions.

1. Data Transmission: ESP32 on the glove issues the translation of the sensor data; the sensor data is transmitted using the wireless ESP-NOW protocol. This allows the devices to interact amongst themselves with or without Wi-Fi and the internet.
2. Signal Reception: The ESP32 module, which has been attached to the robot, receives the information about the gesture per se and processes it to understand the direction, as well as the speed.
3. Motor Control: Two-channel motor drivers are used to drive the four DC motors with the channel-decoded signals. Contributions made by the motors to motion are inseparable. These mecamum wheels can move the robot without turning in different directions, but with the assistance of special rollers that provide the wheels with an angle of 45 degrees.
4. The Omnidirectional Movement: The hand gesture varies, which is based on the hand gesture:
 - Forward tilt – moves forward
 - Backward tilt – moves backward
 - Left tilt – moves left (strafing)
 - Right tilt – moves right
 - Diagonal tilt combination – diagonal movement or rotation

5. PROPOSED METHODOLOGY

The system comprises an accelerator and a microcontroller to detect hand gestures. C++ interprets such gestures and transmits the information wirelessly to the robot through IoT (Wi-Fi/Bluetooth). The motor control converts the motor control commands into a transducer that drives the robot. The system is also tested in terms of accuracy, speed, and reliability before its actual implementation. The following steps are included in the methodology:

1. Component Selection: Select appropriate hardware, such as ESP32, accelerator (MPU6050), motor driver, DC motors, and IoT module.
2. System Design: Assemble the hardware and software control of the robot using gestures and combine IoT and AI.
3. Gesture Detection: Monitor the motion of the hands using the accelerometer and transmit the motion data to the microcontroller.
4. Signal Processing: Using C++ algorithms, process the raw sensor data and identify the specific gestures, e.g., forward, backward, left, right, as well as stop.
5. IoT Communication: Transmit the identified gesture commands wirelessly using Wi-Fi / Bluetooth to the robot.

6. Movement Control: The robot moves forward, backward, left, right, and stops depending on the received commands.
7. Testing & Optimization: Test the system in terms of accuracy, latency, and reliability.
8. Deployment: Implement the system in the actual field where remote and contactless applications of controlled robots are to be accomplished.

6. OBJECTIVES

- To design a hand-gesture-controlled robot that responds to hand gestures.
- To integrate IoT for remote control.
- To develop hand gesture recognition.
- To implement robot navigation that allows the robot to move in different directions based on hand gestures.
- To create a user-friendly interface that helps users easily control the robot.
- To improve the accuracy and reliability of the hand gesture recognition system.

7. BENEFITS

- Innovative control method: Hand gesture control provides a unique and easy way to interact with the robot.
- Increased accessibility.
- Improved safety: The robot can be controlled from a distance, which lowers the chance of accidents or injuries.
- The hand gesture control system offers an enjoyable and engaging way to interact with the robot.
- The technology can work in many fields, like healthcare, education, and entertainment.
- Scalability.

8.1. Software Components:

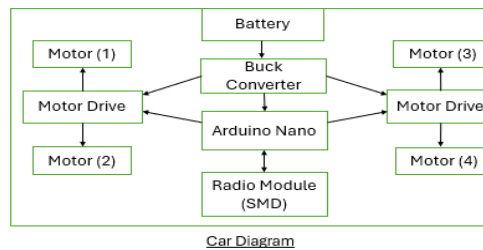
- C++: It is a high-level programming language that is used to drive the microcontroller and the motor drivers.
- Arduino IDE: It is the primary software tool that is used to write, compile, and upload code to the Arduino microcontroller embedded in the hand-gesture-controlled robot.

8.2. Hardware Components:

- ESP32: ESP32 is the primary microcontroller unit that interprets the data of the gesture and implements wireless communication via ESP-NOW or Wi-Fi.
- N20 Gear Motor (100 RPM): This motor is a powerful motor needed to provide the power necessary to give the torque and speed to rotate all the Mecanum wheels.
- Motor driver (HR8833): This is a component that controls the DC motors regarding the direction they should move and their speed.
- MPU6050 Sensor: This sensor is employed to detect movements in a hand via reading of the accelerometers as well as gyroscopes used in giving the robot directions to move.
- PCB Circuit Board (6x4): This serves as the initial point in building as well as affixing all the electronic components within a well-structured positioning.
- Mecanum wheels (4x): These are special wheels that enable the robot to move in any direction, including forward, backward, sideways, and diagonal.
- Lithium Battery (18650): This battery is used to provide the robot with the power to power the motors and electrical components.
- Battery Holder (2S): This is used to provide a secure connection of the Li-ion batteries with the circuit.
- Battery Charging Module: This module provides the ability to safely charge the Li-ion batteries without removing them from the system.
- Male/Female Header Pins: These connectors allow removable connections between the ESP32 module, the sensor module, and the motor driver module.

- On/Off Switch: This is a switch that is employed in switching the main power supply to the robot on or off, to avoid awkward operation.
- 2-Pin Pitch Screw Terminal: This screw consists of simple components of 4 conductors with certain power lines and motor links to the PCB.
- Jumper Wires: These are wire-fed wires connecting the different components on the PCB with one another and with modules.
- Gloves: The users should be capable of working with these gloves, and using them, they can attach the gesture sensor (MPU6050) and thus be capable of.
- Other Components: They are miscellaneous minor components, i.e., screws, connectors, and reinforcement materials that are used during assembly.
- Model Structure: It refers to the body and physical chassis, which are utilized to ensure that the electronic and mechanical components are held in place.

FLOWCHART



PROTOTYPE

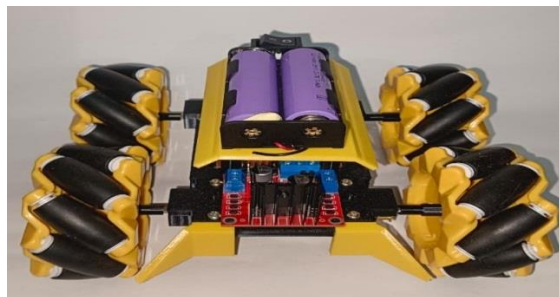
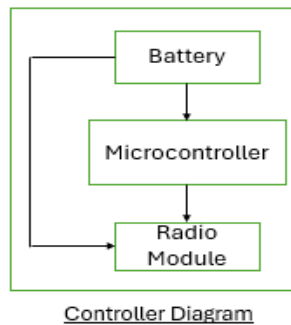


Fig.1: IoT-Based Hand Gesture Controlled Robot

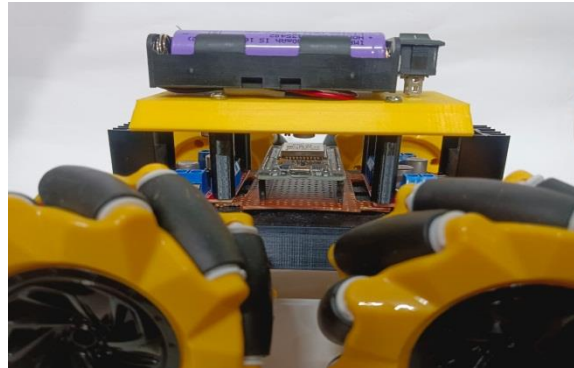


Fig.2: Side view of IoT-Based Hand Gesture Controlled Robot

9. CONCLUSION

The IoT-Based Hand Gesture-Controlled Robot proves that the process of human-robot communication can be easier, in addition to being improved by technology. The buttons or remotes are not used in interacting with the robot; rather, the hands are moved by the users. This type of robot has been used in the real world, e.g., assisting the disabled, contaminating robots in unsafe areas, and on occasions doing work that does not allow the presence of a human being. It is a cheap system that is not hard to install. Wireless connectivity and AI can also be improved. Therefore, a large potential of this technology is expected in actual practice in smart industries and daily life in the near future.

10. FUTURE SCOPE

In the future, the AI-based gesture learning technology will enable these robots to use gesture learning, which means that they are user-friendly since they can know the single gestures of different users. Having the thematics connected to the IoT systems, their users will be able to monitor and remotely control the robots via a smartphone or a cloud dashboard. This will add more applications for them in home automation, surveillance, and warehouses. The usage of 5G or Wi-Fi 6 will allow real-time control without the delays. Old or physically challenged people can also be facilitated with this technology since it is also possible to touch the smart mobility tool without charge.

REFERENCES

- [1] D. Balazh, Vasyly Mrak, A. Sydor, V. Andrushchak, Bohdan Rusyn, Taras Maksymyuk, "Intelligent IoT Control System based on Hand Gesture Recognition", Advanced Industrial Conference on Telecommunications, 2023.
- [2] T. Rajasekar, P. Mohanraj, P. Madhumitha, S. Nanthitha, S. Naveena, "LEXIBOT: Gesture Controlled Personal Assistant Companion", 5th International Conference on Smart Electronics and Communication (ICOSEC), 2024.
- [3] M. Muqet, Bushra Raahat, Narjis Begum, Mohammad Abul Nabeel Hasnain, Afreen Mohammed, "IoT-Based Implementation of Gesture-Controlled Robot", International Conference on Advances in Electronics, Computers and Communications, 2023.
- [4] B Devi Sree, K. S. Varsha, D. Subbulekshmi, S. Angalaeswari, T. Deepa, "Design of Hand Gesture Controlled Robot using Arduino", International Conference on Electrical Energy Systems, 2024.
- [5] Patel Kathan, Ronak Makwana, Dhruvil Bhavsar, Sandeep Chauhan, Shriji Gandhi, "IoT-Based Hand Gesture Control Robot", International Journal of Engineering Research & Technology (IJERT), 2278-0181 Vol. 12 Issue 09, September 2023.
- [6] Huma Zia, Bara Fteiha, Maha Abdunnasser, Tafleh Saleh, Fatima Suliemn, "Gesture-controlled omnidirectional autonomous vehicle: A web-based approach for gesture recognition", volume 26, July 2025.

[7] IJ Ding, JL Su, "Designs of human-robot interaction using depth sensor-based hand gesture communication for smart material-handling robot operations", Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 237 (3) (2023), pp. 392-413, 2023.

[8] R. Swarup, K. Banerjee, S. Sehgal, "Hand gesture controlled smart car using image recognition", ir.juit.ac.in, J Electr Syst, 20(7s)(2024), pp. 2349-2355, 2024.

BIOGRAPHIES



Vaishnavi Rajesh Gahlod,
Currently studying in
Artificial
Intelligence and Data
Science
Engineering, RTMNU,
Nagpur.



Nikita Vijay Yende,
Currently studying in
Artificial
Intelligence and Data Science
Engineering, RTMNU, Nagpur.



Pooja Pradip Naikwade,
Currently studying in
Artificial
Intelligence and Data
Science
Engineering, RTMNU,
Nagpur.



Dr. Sanjay M. Malode,
Working as a Professor in
Artificial
Intelligence and Data Science
Engineering, RTMNU, Nagpur.