

Autonomous Rover for Medical Requirements with Web-based Geospatial Path Planning using GPS

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ABSTRACT

The **Autonomous Rover for Medical Requirements with Web-Based Geospatial Path Planning Using GPS** is an intelligent robotic system designed to automate the transportation of medicines, medical equipment, and emergency healthcare supplies. The project aims to improve the efficiency, accuracy, and safety of medical logistics while reducing human effort and delivery time. The rover utilizes **Global Positioning System (GPS)** technology for real-time location tracking and **Web-Based Geospatial Path Planning** to determine the shortest and safest route to the destination. The system consists of a **microcontroller, GPS module, motor driver, DC motors, ultrasonic sensors**, and a **wireless communication module**. A web application enables users to assign destinations, monitor the rover's movement, and track deliveries in real time. The integrated **Obstacle Detection** mechanism ensures safe navigation by identifying and avoiding obstacles encountered along the route. This solution is particularly beneficial for hospitals, healthcare campuses, rural medical centers, and disaster-affected areas where timely delivery of medicines is critical. By combining **Robotics, Internet of Things (IoT), GPS Navigation, and Geospatial Technologies**, the proposed system provides a reliable, cost-effective, and scalable platform for autonomous medical delivery. The project contributes to the advancement of **Healthcare Automation**, improving operational efficiency and supporting faster emergency response while minimizing manual intervention.

Keywords: Global Positioning System (GPS), Web-Based Geospatial Path Planning, Robotics, Internet of Things (IoT), Obstacle Detection, Healthcare Automation, Real-Time Tracking, Embedded Systems.

INTRODUCTION

The rapid advancement of robotics, embedded systems, and Internet of Things (IoT) technologies has significantly transformed various industries, particularly the healthcare sector. Hospitals and medical institutions are continuously adopting smart technologies to improve operational efficiency, reduce human workload, and enhance patient care [1]

The Autonomous Medicine Bot is an intelligent robotic vehicle designed to automate the transportation of medicines within hospitals and healthcare facilities[2]. The robot combines embedded electronics, wireless communication, real-time monitoring, and autonomous navigation into a single integrated system. It is capable of operating in both manual mode, where a user remotely controls the robot through a web application, and autonomous mode, where it follows a predefined route without continuous human intervention[3]. This dual-mode functionality makes the system flexible enough to adapt to different operational requirements while demonstrating the practical application of robotics in healthcare[4].

The hardware of the robot is built around the ESP32 microcontroller, which acts as the central processing unit of the system. The ESP32 was selected due to its powerful dual-core processor, integrated Wi-Fi capability, low

power consumption, and compatibility with numerous sensors and communication modules[5-6]. It receives movement commands from the web application, controls the motors through the motor driver, processes GPS data, and continuously communicates with the server. This wireless communication eliminates the need for wired control systems, making the robot highly portable and easy to operate.

Robot movement is achieved using four 12V DC geared motors controlled through an L298N Motor Driver Module [7]. The motor driver receives digital signals from the ESP32 and supplies the required current to the motors for forward, backward, left, right, and stop movements. Motor speed is controlled using Pulse Width Modulation (PWM), allowing smooth acceleration and adjustable movement speed according to user requirements. The entire system is powered by a rechargeable Lithium-Ion battery pack, providing sufficient energy for extended operation while maintaining portability. An ON/OFF switch ensures safe power control, and connecting wires establish reliable electrical connections among all components.

One of the important features of the Autonomous Medicine Bot is its real-time location tracking capability. The robot incorporates a NEO-6M GPS module, which continuously receives signals from GPS satellites to determine its geographical position[8]. The GPS data, including latitude, longitude, speed, altitude, satellite count, and signal quality, is transmitted to the control application, allowing users to monitor the robot's live location through an interactive digital map. This feature is particularly useful for outdoor demonstrations and future applications where real-time tracking of the robot is required.

Communication between the robot and the control interface is established using WebSocket communication, a protocol that enables full-duplex, low-latency communication between the ESP32 and the server [9-10]. Unlike traditional HTTP communication, WebSockets maintain a persistent connection, allowing commands and telemetry data to be exchanged instantly[11]. Whenever a user issues a movement command or changes the robot's speed, the command is immediately transmitted to the ESP32[12]. Similarly, the robot continuously sends status information and GPS data back to the server, enabling real-time monitoring and control.

Working Principle

An autonomous rover for medical requirements operates by integrating GPS navigation, web-based geospatial path planning, and onboard sensing technologies to deliver medicines, vaccines, blood samples, and emergency medical supplies with minimal human intervention. The process begins when a destination is selected through a web application, which uses geospatial mapping and path-planning algorithms such as A* or Dijkstra's algorithm to determine the safest and shortest route. The optimized path is then transmitted to the rover, which continuously uses GPS to determine its location and navigate through predefined waypoints. Sensors such as ultrasonic sensors, LiDAR, or cameras detect obstacles in real time, enabling the rover to stop or reroute safely when necessary. Throughout the journey, the rover sends its live location, battery status, and delivery progress to the web server for remote monitoring. Upon reaching the destination, it securely delivers the medical supplies and updates the server with the delivery status, ensuring efficient, reliable, and contactless medical logistics.

Hardware Implementation

ESP32 Microcontroller



Fig 1: ESP32 Microcontroller

It features built-in Wi-Fi and Bluetooth connectivity, eliminating the need for additional communication modules. The ESP32 offers multiple General Purpose Input/Output (GPIO) pins, Analog-to-Digital Converters

(ADC), Pulse Width Modulation (PWM), UART, SPI, and I2C interfaces, making it highly versatile for robotics and automation. In this project, the ESP32 acts as the brain of the Autonomous Medicine Bot by controlling motor movement, processing GPS data, and communicating with the web application as shown in Fig. 1.

L298N Motor Driver Module

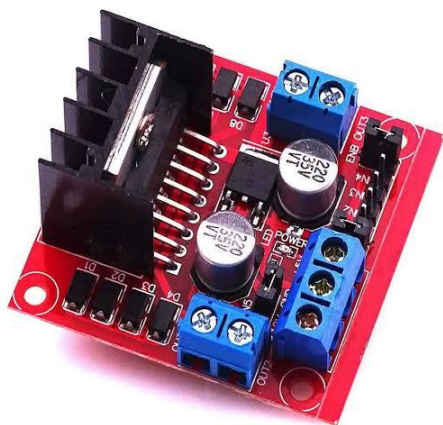


Fig 2: L298N Motor Driver Module

The L298N Motor Driver Module as shown in Fig. 2 is a high-current dual H-Bridge motor driver designed to control the direction and speed of DC motors and stepper motors. Since the ESP32 operates at a low voltage and cannot supply sufficient current to drive motors directly, the L298N acts as an interface between the ESP32 and the DC motors.

The module allows independent control of two motor channels, each capable of controlling one or more motors connected in parallel. It supports bidirectional motor rotation by changing the polarity of the supplied voltage through logic signals received from the ESP32. The L298N also supports Pulse Width Modulation (PWM), enabling smooth speed control of the motors. Due to its simple interface, high reliability, and compatibility with most microcontrollers, it is widely used in robotic vehicles, automation projects, and mobile robotic platforms.

12V DC Geared Motors

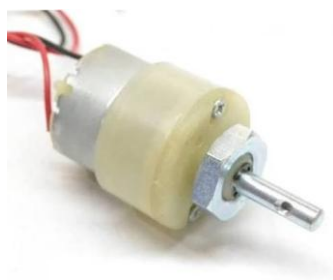


Fig. 3: 12V DC Geared Motors

The 12V DC Geared Motor as shown in Fig. 3 is a compact electric motor integrated with a reduction gearbox to provide high torque and controlled rotational speed. Unlike standard DC motors, geared motors reduce the motor's output speed while significantly increasing torque, making them ideal for robotic applications that require stable and controlled movement. In the Autonomous Medicine Bot, four 12V DC geared motors are used to drive the robot's wheels, enabling smooth navigation while carrying medicines. These motors are well suited for indoor robotic platforms because they provide sufficient pulling power, better speed control, and reliable performance under varying load conditions. The motors receive power from the L298N Motor Driver Module, while their direction and speed are controlled by the ESP32 microcontroller using digital signals and Pulse Width Modulation (PWM).

NEO-6M GPS Module



Fig. 4: 12V DC GEARED MOTORS

The NEO-6M GPS Module as shown in Fig.4 is a high-performance Global Positioning System (GPS) receiver designed to provide accurate real-time location information for embedded systems and IoT applications. It receives signals from multiple GPS satellites orbiting the Earth and calculates the device's geographical coordinates, including latitude, longitude, altitude, speed, and time. The module communicates with the ESP32 using **UART (Universal Asynchronous Receiver/Transmitter)** serial communication, making it easy to integrate into robotic systems. Due to its compact size, low power consumption, and reliable positioning capability, the NEO-6M is widely used in autonomous vehicles, drones, navigation systems, fleet tracking, and robotics.

Lithium-Ion Battery Pack



Fig. 5: **Lithium-Ion Battery Pack**

The Lithium-Ion (Li-Ion) Battery Pack as shown in Fig. 5 is the primary power source of the Autonomous Medicine Bot, supplying electrical energy to all electronic and mechanical components. Lithium-Ion batteries are widely used in portable electronic devices and robotic systems due to their high energy density, lightweight construction, long cycle life, and rechargeable nature. Unlike conventional lead-acid batteries, Li-Ion batteries provide higher efficiency while occupying less space, making them ideal for mobile robotic applications. The battery pack powers the ESP32 microcontroller, L298N motor driver, DC motors, and GPS module, allowing the robot to operate independently without requiring an external power supply. Its compact design improves the portability of the robot and enables continuous operation during medicine transportation tasks.

Power On/Off Switch



Fig. 6 : Power On/Off Switch

The Power ON/OFF Switch as shown in Fig. 6 is a simple but essential electrical component used to control the power supply of the Autonomous Medicine Bot. It allows the user to safely turn the robot ON before operation and OFF after completing its tasks without disconnecting the battery. The switch is connected in series with the positive terminal of the Lithium-Ion battery, enabling or interrupting the flow of electrical current to the robot's electronic components. Although mechanically simple, the power switch plays an important role in ensuring operational safety, preventing accidental motor movement, and conserving battery power when the robot is not in use. The use of a dedicated power switch also protects the electronic components from unnecessary power consumption during storage or maintenance.

7. Robot Wheels



Fig. 7: Robot Wheels

The robot wheels as shown in Fig. 7 are the primary mechanical components responsible for converting the rotational motion of the DC geared motors into the linear movement of the Autonomous Medicine Bot. Four wheels are mounted directly onto the shafts of the 12V DC geared motors, providing stability, balance, and smooth movement across flat indoor surfaces. The wheels are designed using durable rubber or plastic material with adequate grip to prevent slipping during movement and turning. Proper wheel selection is essential for maintaining accurate navigation, balanced weight distribution, and efficient power utilization. In this project, the wheels enable the robot to carry medicines safely while moving through hospital corridors, laboratories, and healthcare facilities.

8. CONNECTING WIRES

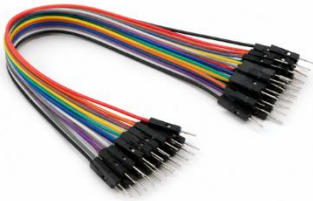


Fig. 8 : Connecting Wires

The Connecting wires as shown in Fig. 8 are the fundamental electrical components used to establish secure connections between the various hardware modules of the Autonomous Medicine Bot. They serve as the medium for transmitting electrical power and control signals between the ESP32 microcontroller, L298N motor driver, GPS module, battery, motors, and other electronic components. Depending on the connection requirements, both jumper wires and power cables are used in the project. Jumper wires are mainly employed for low-current signal connections, while thicker power wires are used for supplying current to the motor driver and DC motors. Proper wiring is essential to ensure reliable communication, stable power distribution, and safe operation of the robot. Organized wiring also simplifies troubleshooting, maintenance, and future hardware upgrades while reducing the chances of loose connections or short circuits.

Software Implementation

Arduino IDE

The Arduino Integrated Development Environment (Arduino IDE) is an open-source software platform used to write, compile, debug, and upload programs to microcontrollers such as the ESP32. It provides a simple and user-friendly interface, making embedded system programming accessible for both beginners and professionals. The Arduino IDE supports multiple programming languages based on C and C++ along with a vast collection of built-in and third-party libraries that simplify hardware interfacing. In the Autonomous Medicine Bot project, the Arduino IDE is used to develop and upload the firmware responsible for controlling robot movement, processing GPS data, managing Wi-Fi connectivity, and enabling WebSocket communication. The IDE also includes a Serial Monitor, which is extremely useful for debugging, monitoring GPS data, verifying Wi-Fi connectivity, and testing communication between the ESP32 and the backend server.

Purpose in this Project:

- Used to develop the firmware for the ESP32 microcontroller.
- Compiles and uploads the control program to the ESP32.
- Integrates external libraries such as:
 - **WiFi.h** for wireless connectivity.
 - **WebSocketsClient.h** for real-time communication.
 - **ArduinoJson.h** for JSON data handling.
 - **TinyGPS++.h** for GPS data processing.

FUSION 360

Fusion 360 is a cloud-based Computer-Aided Design (CAD), Computer-Aided Engineering (CAE), and Computer-Aided Manufacturing (CAM) software developed by Autodesk. It is widely used for designing mechanical components, 3D models, product prototypes, and engineering assemblies. Fusion 360 combines design, simulation, rendering, and manufacturing tools into a single platform, enabling engineers to visualize and refine their designs before fabrication. In the Autonomous Medicine Bot project, Fusion 360 is used to design the robot's chassis, arrange hardware components, and ensure proper placement of motors, battery, ESP32, GPS module, and medicine storage compartment. Using CAD software before hardware fabrication minimizes design errors, improves structural stability, and reduces development time.

Purpose in this Project:

- Fusion 360 was used during the initial design phase of the Autonomous Medicine Bot to create a detailed 3D model of the robot.
- The software enabled the proper positioning of the four DC geared motors and wheels, ensuring balanced weight distribution and smooth movement.
- Mounting holes and support structures were incorporated into the design for secure installation of electronic components.
- The medicine storage compartment was also designed to provide stability during transportation and prevent medicines from shifting while the robot was in motion.

React Web Application

React is an open-source JavaScript library developed by Meta (formerly Facebook) for building fast, responsive, and interactive user interfaces. It is based on a component-based architecture, allowing developers to build reusable UI components that improve code organization and maintainability. React efficiently updates only the necessary parts of a webpage using a Virtual DOM, resulting in faster rendering and better user experience. In the Autonomous Medicine Bot project, React is used to develop the web-based control dashboard that enables users to manually control the robot, monitor its live GPS location, and manage autonomous navigation. The dashboard communicates with the FastAPI backend through WebSocket connections, providing real-time interaction with the ESP32 microcontroller.

Purpose in This Project:

- Provides a graphical user interface (GUI) for controlling the Autonomous Medicine Bot.
- Enables manual control using Forward, Backward, Left, Right, and Stop buttons.
- Allows users to adjust the robot's speed using an interactive speed slider.
- Displays the robot's connection status with the backend server.
- Shows the robot's live GPS location on an interactive map.
- Provides an autonomous route planning interface where users can define navigation paths.

1. Fast API Backend

FastAPI is a modern, high-performance Python web framework used for building APIs and real-time web applications. It is designed to be fast, lightweight, and easy to develop, making it suitable for IoT, robotics, and embedded system applications. FastAPI supports both HTTP APIs and WebSocket communication, allowing real-time bidirectional data exchange between connected devices. In the Autonomous Medicine Bot project, FastAPI acts as the central communication server between the React web dashboard and the ESP32

microcontroller. It receives movement commands from the web application, forwards them to the ESP32, and simultaneously receives GPS and robot telemetry data from the ESP32 to update the dashboard in real time.

Purpose in This Project:

- Acts as the communication bridge between the React dashboard and the ESP32 microcontroller.
- Receives robot movement commands from the web application.
- Forwards control commands to the ESP32 through WebSocket communication.
- Receives GPS coordinates and telemetry data from the ESP32.
- Broadcasts live robot status updates to all connected dashboard clients.

2. Websocket Communication

WebSocket is a communication protocol that enables full-duplex (two-way) communication between a client and a server over a single, persistent connection. Unlike traditional HTTP communication, where a new connection is established for every request and response, WebSocket maintains a continuous connection, allowing data to be exchanged instantly without repeated connection overhead. This protocol is widely used in applications requiring real-time data transmission, such as robotics, IoT systems, online gaming, live chat applications, stock trading platforms, and remote monitoring systems. In the project, WebSocket communication is used to establish a real-time connection between the This enables immediate transmission of movement commands from the user to the robot and continuous streaming of GPS and robot status information back to the dashboard.

Purpose in This Project:

- Establishes continuous communication between the ESP32 and the FastAPI server.
- Enables real-time transmission of robot movement commands.
- Sends speed adjustment values instantly from the dashboard to the robot.
- Continuously transmits GPS coordinates to the web application.
- Updates robot movement status without refreshing the webpage.

METHODOLOGY

During manual operation, the user accesses the web dashboard through a browser. The dashboard provides directional buttons for Forward, Backward, Left, Right, and Stop, along with a speed adjustment slider. When a movement button is pressed, the command is transmitted to the FastAPI server through a WebSocket connection. The server immediately forwards the command to the ESP32 in JSON format. The ESP32 processes the received command and controls the L298N Motor Driver Module, which supplies the necessary current to the four 12V DC geared motors. Depending on the received command, the motors rotate in the appropriate direction, causing the robot to move accordingly. The motor speed is regulated using Pulse Width Modulation (PWM) signals generated by the ESP32.

The robot also supports autonomous navigation through the route planning interface available in the web dashboard. Users can create a predefined route by selecting waypoints on a virtual grid. Once the autonomous mode is activated, the planned route is transmitted to the ESP32 through the FastAPI server. Based on the received navigation instructions, the ESP32 executes the movement sequence automatically without requiring

continuous user intervention. This enables the robot to perform medicine delivery tasks independently, making it suitable for repetitive transportation within healthcare facilities.

Another important feature of the system is real-time location tracking. The NEO-6M GPS module continuously receives satellite signals and determines the robot's current geographical position. The GPS module provides information such as latitude, longitude, altitude, speed, satellite count, and signal quality. The ESP32 reads this data through UART communication using the TinyGPS++ library. The collected information is converted into JSON format and transmitted to the FastAPI backend through the active WebSocket connection. The backend forwards this data to the React dashboard, where users can monitor the robot's live location on an interactive digital map.

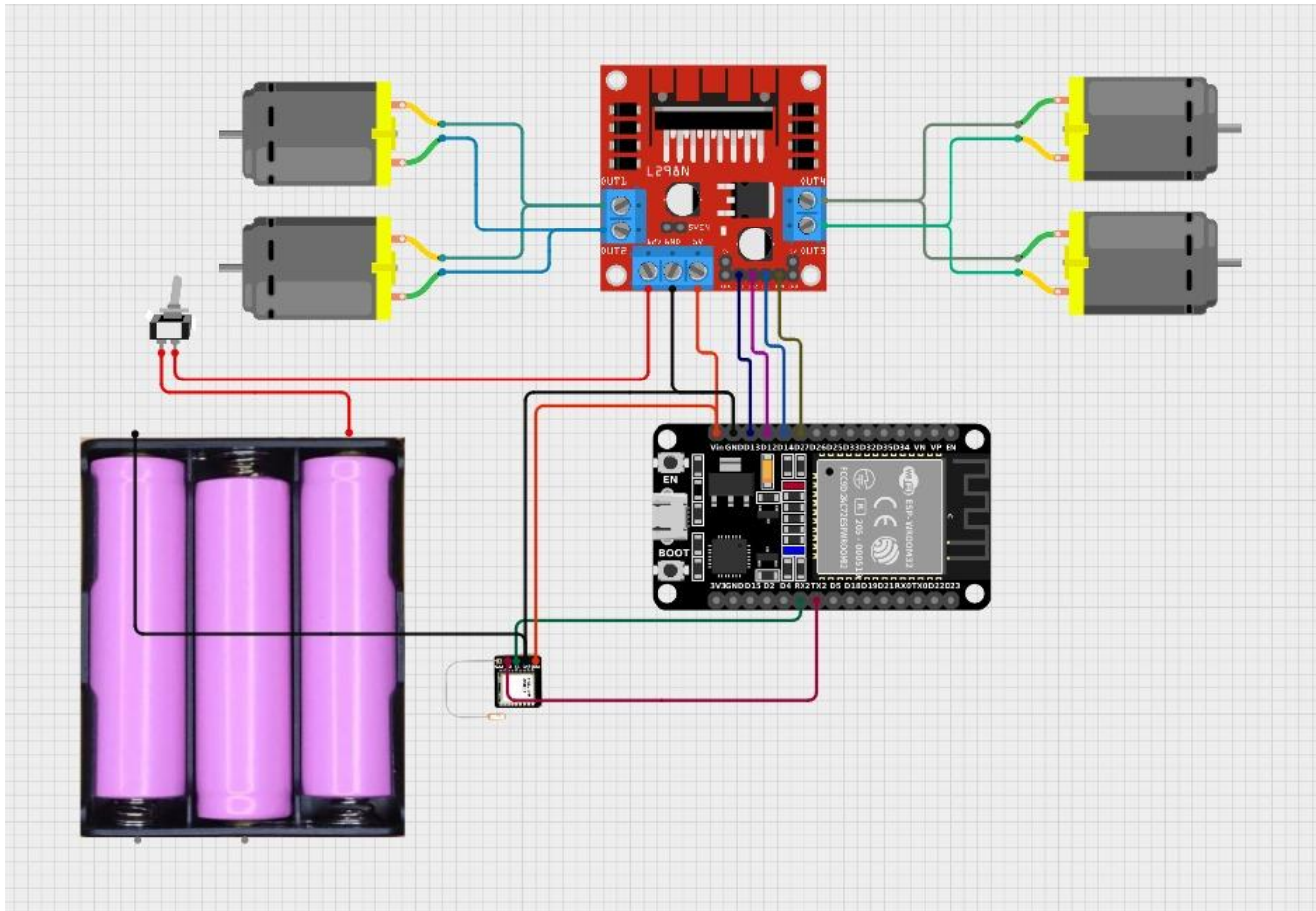


Fig. 9: Circuit Diagram of an Autonomous Rover

The circuit diagram as shown in Fig. 9 of the Autonomous Medicine Bot illustrates the electrical connections between the ESP32 microcontroller, L298N Motor Driver Module, DC geared motors, NEO-6M GPS module, Lithium-Ion battery, and other supporting components. The ESP32 serves as the central controller of the entire system, receiving commands from the web application through Wi-Fi and controlling the movement of the robot.

The L298N Motor Driver Module acts as an interface between the low-power ESP32 and the high-current DC motors, while the GPS module provides real-time location information. The Lithium-Ion battery supplies power to all components, making the robot completely portable.

The circuit is designed to ensure efficient communication between hardware modules while maintaining stable power distribution and reliable operation.

1. Power Supply Section

The power supply section provides electrical energy to the complete robotic system.

2. ESP32 Microcontroller Section

The ESP32 acts as the central processing and communication unit.

3. L298N Motor Driver Section

The motor driver receives logic signals from the ESP32 and supplies sufficient current to the motors as Shown in Table-1.

Table -1: **Motor Driver Pins connected to ESP32**

Motor Driver Pin	Connected To
IN1	ESP32 GPIO 18
IN2	ESP32 GPIO 19
IN3	ESP32 GPIO 21
IN4	ESP32 GPIO 22
ENA	ESP32 PWM Pin 26
ENB	ESP32 PWM Pin 25
Motor Output A	Left Side Motors
Motor Output B	Right Side Motors
12V Input	Battery Positive
GND	Battery Ground & ESP32 Ground

DC Motor Section

The robot uses four 12V DC geared motors for movement.

GPS Module Section

The NEO-6M GPS Module continuously provides location information as shown in Table -2.

Table -2 : **GPS Pins connection in ESP32.**

GPS Pin	Connected To ESP32
VCC	3.3V / 5V
GND	GND
TX	GPIO16 (RX2)
RX	GPIO17 (TX2)

Wi-Fi Communication Section

The ESP32 contains an integrated Wi-Fi module.

WebSocket Communication

The communication architecture consists of three devices:

React Dashboard $\longleftrightarrow$ FastAPI Server $\longleftrightarrow$ ESP32 Robot

RESULTS

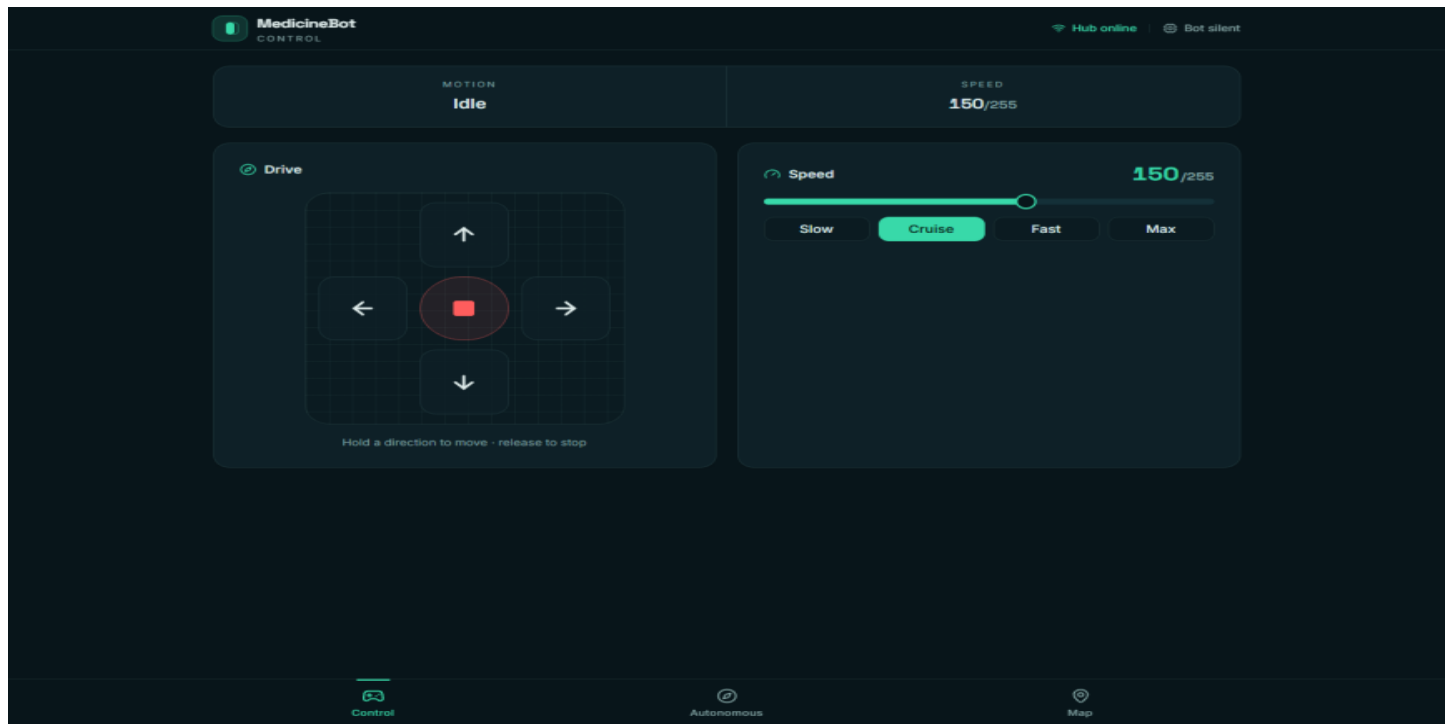


Fig. 10: Manual Operation of an Autonomous Rover

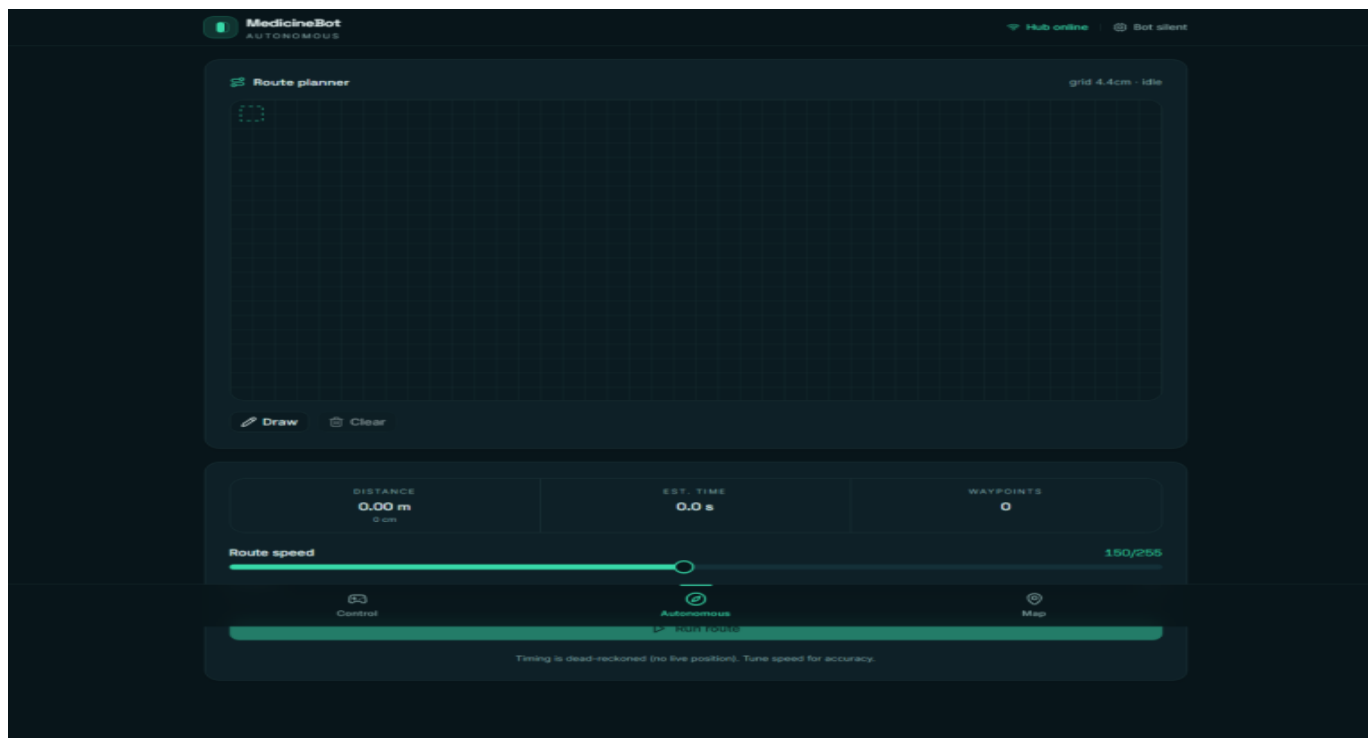


Fig.11 : Mapping the path to an Autonomous Rover for an Automatic Operation

The Autonomous Medicine Bot as shown in Fig.10 was successfully designed, developed, and tested to evaluate its movement accuracy, communication reliability, GPS tracking capability, and overall system performance. The integration of the ESP32 microcontroller, L298N Motor Driver Module, NEO-6M GPS module, React web dashboard, FastAPI backend, and WebSocket communication resulted in a stable and efficient robotic platform as shown in Fig. 11. During testing, the robot demonstrated smooth manual control, successful autonomous navigation, reliable real-time communication, and continuous GPS monitoring.

The following observations summarize the overall performance of the proposed system.

1. Successful Manual Robot Control

The robot successfully responded to all movement commands sent through the React web dashboard. Commands such as Forward, Backward, Left, Right, and Stop were executed almost instantly through WebSocket communication.

2. Smooth Motor Speed Control

The speed control feature functioned efficiently using Pulse Width Modulation (PWM). Users were able to increase or decrease the robot's speed directly from the dashboard, and the robot adjusted its movement accordingly.

3. Successful Autonomous Navigation

The autonomous navigation feature was tested using predefined routes created through the web dashboard. Once a route was selected, the robot successfully followed the specified movement sequence without requiring continuous user intervention.

4. Real-Time GPS Tracking

The NEO-6M GPS module successfully obtained location information and continuously transmitted GPS data to the FastAPI server through the ESP32. The robot's live location was displayed on the React dashboard in real time.

5. Reliable WebSocket Communication

The WebSocket communication system remained stable throughout the testing process. The persistent connection allowed continuous exchange of movement commands and telemetry data without requiring repeated requests.

6. Efficient Remote Monitoring

The React dashboard successfully displayed all important robot information during operation. Users could remotely monitor robot movement, connection status, speed, and GPS location through an intuitive graphical interface.

7. Stable Battery Performance

The Lithium-Ion battery powered the robot throughout the testing process without requiring an external power source. The robot operated continuously while maintaining stable voltage for both the electronic components and the motors.

8. Successful Hardware and Software Integration

The hardware and software modules were successfully integrated into a single functional system. Communication between the ESP32, GPS module, motor driver, FastAPI backend, and React dashboard remained stable during the entire testing period.

CONCLUSION

The Autonomous Medicine Bot developed in this project successfully demonstrates an intelligent and efficient solution for automating medicine transportation within hospitals and healthcare facilities. By integrating the ESP32 microcontroller, L298N Motor Driver Module, 12V DC geared motors, and the NEO-6M GPS module, the system is capable of performing both manual and autonomous navigation while providing reliable real-time

control and monitoring. The robot effectively receives movement commands from the web dashboard, executes them accurately, and continuously transmits its live GPS location and operational status. The implementation of WebSocket communication ensures low-latency data exchange, enabling smooth and responsive interaction between the user and the robot.

The software architecture, consisting of a FastAPI backend and a React-based web dashboard, provides a modern and user-friendly platform for remote robot operation. The dashboard allows users to manually control the robot, adjust its movement speed, monitor live GPS location, and execute predefined autonomous routes. Throughout the testing phase, the system demonstrated stable wireless communication, accurate motor control, reliable GPS tracking, and smooth execution of movement commands. The integration of embedded hardware with IoT technologies successfully created a centralized platform for intelligent robot control and monitoring, making the system practical for real-world healthcare environments.

Overall, this project successfully combines robotics, embedded systems, wireless communication, IoT, and modern web technologies to create a reliable medicine delivery platform.

The system is cost-effective, scalable, and designed using readily available hardware and open-source software technologies, making it suitable for further research and commercial deployment. Future enhancements such as obstacle detection, computer vision, indoor localization, robotic arm integration, voice control, and artificial intelligence-based navigation can significantly improve the robot's autonomy, safety, and decision-making capabilities, making it an even more effective solution for next-generation healthcare automation.

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