IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 1, April 2026
Impact Factor: 8.2

Mobile Controlled Robotic Vehicle with Robotic Arm

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Abstract: *This project focuses on designing and developing a mobile-controlled robotic car equipped with a six- degree-of-freedom (6DOF) robotic arm mounted on top. The system allows users to remotely control both the movement of the car and the robotic arm using a mobile interface, providing real-time interaction and precise manipulation. The robotic arm can perform tasks such as picking, placing, and handling objects of varying shapes and sizes while the car navigates different terrains. The integration of wireless communication, robotics, and automation makes this system highly versatile and adaptable for applications in industrial automation, hazardous environment handling, surveillance, and educational demonstrations. The mobile interface ensures a user- friendly experience, allowing easy control and operation.*

Keywords: Robotic Vehicle, 6DOF Robotic Arm, ESP32, Wireless Teleoperation, Mobile Interface, Mechatronics, Automation

I. INTRODUCTION

In modern robotics, the combination of mobility and manipulation represents a significant leap forward from traditional, stationary robotic systems. While static robotic arms are highly effective in fixed assembly lines, they lack the ability to traverse environments. Conversely, simple mobile robots can navigate but cannot interact with or manipulate objects in their surroundings.

This project bridges that gap by developing a mobile-controlled robotic vehicle equipped with an articulated 6DOF robotic arm. By leveraging an embedded microcontroller (ESP32) and wireless communication protocols, the system allows an operator to remotely pilot the rover to a specific location and seamlessly transition to controlling the arm to pick, place, or rotate objects. This teleoperated approach is highly valuable for scenarios where human presence is unsafe or impossible.

II. LITERATURE SURVEY

The development of mobile manipulators has evolved rapidly alongside advancements in wireless technology and microcontrollers:

1. Tethered and RF Systems: Early mobile manipulators relied on tethered cables or basic Radio Frequency (RF) remotes, which severely limited their operational range and data bandwidth.
2. Bluetooth-Controlled Systems: The shift to Bluetooth (e.g., HC-05 modules) allowed for smartphone control, but the range was typically limited to 10 meters, making it unsuitable for long-range industrial or hazardous operations.
3. Wi-Fi and IoT-Enabled Platforms: Modern research utilizes Wi-Fi-enabled microcontrollers like the ESP32. This allows the robot to be controlled via local Web Servers or IoT platforms over extensive ranges, providing the bandwidth necessary for complex multi- axis control and future camera integration.

III. PLATFORM TECHNOLOGY USED

This system integrates mobile locomotion, articulated manipulation, and wireless telemetry into a single cohesive platform.

• Microcontroller (ESP32): Serves as the central processing unit, chosen for its powerful dual-core processor, high number of PWM outputs (for servos and motors), and native Wi-Fi/Bluetooth capabilities.
• Wireless Communication: Utilizes Wi- Fi to establish a connection between the robotic platform and the mobile application interface.
• Kinematic Actuation (6DOF): Employs precise servo-driven articulation to control the six degrees of freedom of the robotic arm, mimicking human joint movements.
• Differential Drive Locomotion:
Utilizes DC gear motors paired with a high-current motor driver to provide skid-steering and omnidirectional rotation for the vehicle base.

IV. PROBLEM STATEMENT

Many industrial, research, and emergency operations require interacting with objects in environments that are hazardous to humans (e.g., toxic chemical spills, bomb disposal, or structurally unstable disaster zones). Traditional static robots cannot reach these areas, and standard surveillance drones cannot physically manipulate the environment. There is a critical need for an affordable, scalable, and highly interactive robotic solution that provides both agile ground mobility and precise object manipulation, completely controlled from a safe, remote distance via a user-friendly interface.

V. AIM AND OBJECTIVES

The primary aim is to design and develop a cohesive mobile robotic platform capable of remote navigation and environmental interaction. Objectives:
1. To design a robust mobile vehicle chassis capable of traversing varied terrains while supporting the weight of a robotic arm.
2. To develop and mount a 6-Degree-of- Freedom (6DOF) robotic arm for precise picking, placing, and rotating of objects.
3. To implement wireless communication using an ESP32 microcontroller for remote teleoperation.
4. To create a user-friendly mobile interface that allows intuitive, real-time control of both the wheels and the arm's joints.
5. To evaluate the system's payload capacity, workspace range, and teleoperation latency.

VI. DIAGRAM

A) Block Diagram

The block diagram maps the signal flow from the User's Smartphone to the ESP32. The microcontroller then splits its control signals: sending digital logic to the Motor Driver (for the DC wheels) and PWM signals directly to the servo motors (for the 6DOF arm).

DOI: 10.48175/568

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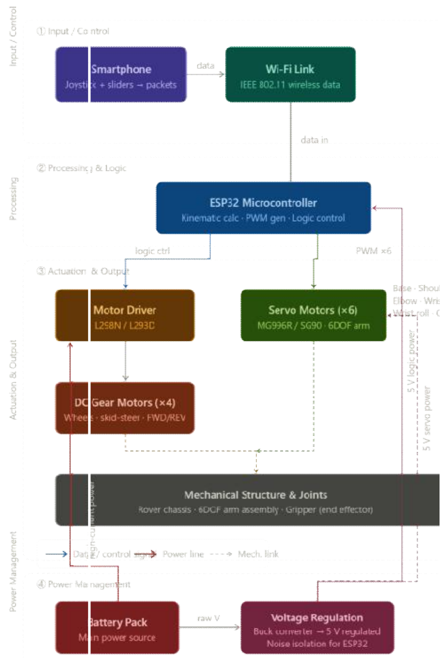
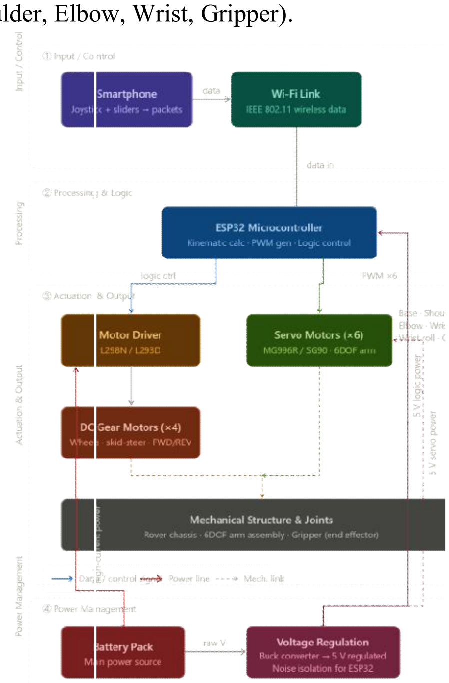


Fig. 1. System Block Diagram.

B) Flow Chart

The software flow chart illustrates the continuous listening loop. The ESP32 waits for a wireless command. If a navigation command is received, it actuates the DC wheels. If an articulation command is received, it adjusts the specific servo angles (Base, Shoulder, Elbow, Wrist, Gripper).



.Fig. 2. Software Flow Chart.

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c) Circuit Diagram

The circuit diagram details the power distribution and GPIO connections. It highlights the use of step-down buck converters to supply stable 5V power to the servos, isolating them from the ESP32 logic circuit to prevent brownouts, while the high-power battery connects directly to the L298N motor driver.

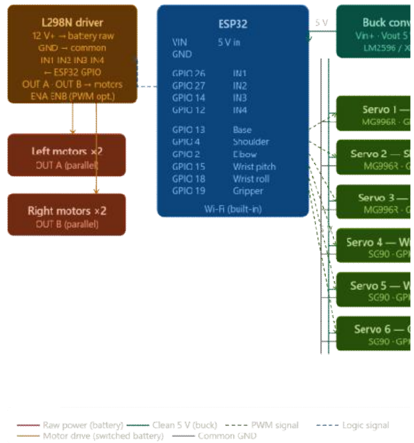

Fig. 3. Circuit Diagram.

VII. COMPONENTS / MATERIALS

The system is constructed using carefully selected mechatronic components to balance weight, torque, and power efficiency.

• ESP32 Development Board (Microcontroller): The brain of the robot. It receives remote commands via its built-in Wi-Fi antenna, processes the kinematics, and generates the exact PWM signals required for both locomotion and arm articulation.

• DC Gear Motors & Wheels: Provide the physical locomotion for the rover. These motors offer high torque to navigate over uneven surfaces while carrying the weight of the robotic arm and power supply.

• L298N / L293D Motor Driver: Acts as an H-Bridge amplifier. Because the ESP32 cannot directly supply the high current needed by the DC motors, the motor driver takes low-voltage logic signals and safely switches the high- current battery power to drive the wheels forward or backward.

• Servo Motors (MG996R & SG90): These closed-loop actuators drive the 6DOF arm. High-torque metal gear servos (MG996R) are utilized for the base and shoulder joints to lift the arm's weight, while lighter micro-servos (SG90) are used for the wrist and gripper to minimize the payload at the end of the lever arm.

• Mechanical Chassis & Arm Structure: Fabricated using lightweight but rigid materials (such as aluminum brackets or 3D-printed PLA) to provide a stable foundation that resists tipping when the arm is fully extended.

• Power Supply (Li-Po Battery): A high- discharge Lithium-Polymer battery provides the significant amperage required to simultaneously run four DC motors and up to six servo motors without causing voltage drops.

• Mobile Interface / Application: A smartphone application (custom-built or using platforms like Blynk) that provides a graphical interface with joysticks and sliders, translating user input into wireless data packets sent to the ESP32.

VIII. WORKING

The operational logic is highly responsive, executing commands in real-time:

• System Initialization: Upon powering up, the ESP32 establishes a Wi-Fi Access Point (AP) or connects to a local network. The robotic arm automatically resets to a safe "Home" folded position.

• Wireless Pairing: The user opens the mobile interface on their smartphone and connects to the ESP32 via IP address or Bluetooth.

DOI: 10.48175/568

• Locomotion Control (Navigation): When the user utilizes the on-screen joystick, the app sends directional characters (e.g., 'F' for forward, 'L' for left). The ESP32 translates these into logic signals for the motor driver, applying differential steering to move the rover to the target location.
• Arm Articulation (Manipulation): Once in position, the user switches to the arm control interface, which utilizes sliders. Sliding a UI element sends a specific angle value (0-180°) to the ESP32, which immediately adjusts the PWM duty cycle of the corresponding joint servo (Base, Shoulder, Elbow, or Wrist).
• Task Execution: The user aligns the arm, commands the gripper servo to close, grasps the object, and navigates the rover back to the drop-off zone before releasing the gripper.

IX. RESULTS

The developed prototype was rigorously tested under varied operational scenarios.
• Teleoperation Latency: The Wi-Fi- based control system exhibited near-zero latency, allowing for smooth, real-time interaction without lag between the mobile interface input and the mechanical response.
• Kinematic Stability: The 6DOF arm successfully demonstrated the ability to pick, place, and rotate small objects reliably. The weight distribution of the chassis prevented tipping during maximum arm extension.
• Locomotion: The robotic vehicle navigated successfully over flat and mildly uneven terrains while carrying the full payload of the arm and battery systems.

X. ADVANTAGES & APPLICATIONS

ADVANTAGES
• High Versatility: Combines the benefits of a mobile rover with the precision of an industrial manipulator.
• User-Friendly: The mobile interface makes the system intuitive to control without requiring extensive operator training.
• Safe Teleoperation: Allows users to interact with objects from a safe, remote distance.
APPLICATIONS
• Hazardous Environments: Handling toxic chemicals, radioactive materials, or performing bomb disposal operations.
• Industrial Automation: Transporting components across warehouse floors and loading/unloading them automatically.
• Search and Rescue: Delivering medical supplies or clearing small debris in disaster-stricken areas.
• Educational Research: Serving as a foundational platform for students learning mechatronics, kinematics, and embedded programming.

XI. FUTURE SCOPE

The mobile-controlled robotic car with a robotic arm has significant potential for further development. Future enhancements may include:
• Obstacle Detection & Autonomous Navigation: Integrating ultrasonic or LiDAR sensors to allow the rover to map its environment and navigate autonomously.
• Computer Vision & Camera Feedback: Adding an ESP32-CAM or Raspberry Pi to enable live video streaming to the mobile app, and using object recognition (OpenCV) to allow the arm to automatically identify and grab specific items.
• Heavier Payloads: Scaling up the mechanical chassis and replacing standard servos with high-torque industrial stepper motors to handle heavier industrial loads.
• AI & Machine Learning: Incorporating AI algorithms for predictive control, path optimization, and intelligent task execution to increase overall system autonomy.

XII. CONCLUSION

The project successfully demonstrates a highly interactive, mobile-controlled robotic vehicle integrated with a 6DOF robotic arm. By synergizing wireless communication, microcontroller-based ESP32 logic, and servo- driven articulation, the system creates a user- friendly and highly adaptable teleoperation platform. While current prototypes are constrained by payload capacity and battery life, the fundamental design provides a robust foundation for modern remote manipulation. With future integrations of computer vision and AI, this architecture stands as a highly promising approach for advancing industrial automation and hazardous environment robotics.

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