DESIGN AND IMPLEMENTATION OF A BLUETOOTH-CONTROLLED ROBOTIC CAR USING ARDUINO

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ABSTRACT

This work presents the design and construction of a Bluetooth-controlled robotic car using an Arduino Uno, HC-05 Bluetooth module, and L293D motor driver. The vehicle responds to directional commands—forward, reverse, left, and right—sent from a smartphone application. The Arduino processes the received Bluetooth data and generates motor control signals to drive two DC motors mounted on a four-wheel chassis. The prototype demonstrates stable wireless connectivity, smooth motor control, and low-cost implementation, making it suitable for educational use, beginner-level robotics, and remote-operation experiments.

Keyword: - *Bluetooth-controlled car, Arduino Uno, HC-05 module, L293D driver, wireless control, robotic vehicle.*

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1. INTRODUCTION

Advancements in embedded systems and wireless communication have enabled the development of low-cost robotic platforms that can be remotely operated using compact hardware and consumer devices. Bluetooth technology is widely adopted in such systems due to its simplicity, reliability, and compatibility with most smartphones. These characteristics make it ideal for short-range robotic applications and instructional projects [1].

A Bluetooth-driven robotic car integrates wireless communication with microcontroller-based motor control. In this configuration, the Arduino Uno serves as the system controller, receiving instructions via the HC-05 Bluetooth module and translating them into motor control signals through the L293D driver. The driver regulates both the direction and speed of the DC motors, enabling smooth navigation on the chassis [2].

This project provides practical exposure to serial communication, hardware interfacing, and mobile-based control. The design also forms a foundation for more advanced robotic applications, such as autonomous navigation, sensor-supported decision-making, and IoT-enabled control systems.

1.1 Hardware Components

- **Arduino Uno:** A microcontroller board based on the ATmega328P, offering multiple digital and analog I/O pins for interfacing with peripheral components. Its ease of programming and wide community support make it ideal for prototyping.
- **Motor Driver (L293D):** A dual H-bridge driver IC capable of controlling the direction and power supplied to the motors. It operates across standard voltage ranges suitable for small robotic vehicles.
- **Bluetooth Module (HC-05):** A UART-based wireless module that enables serial communication between the robot and a smartphone.
- **DC Gear Motors:** Motors integrated with gear reduction to increase torque and ensure controlled motion of the vehicle.

- **Battery:** A 9V battery used to supply power to the electronics and motors.

1.2 Software Components

- **Arduino IDE:** The platform used to write, compile, and upload programs to the Arduino Uno. The IDE enables development of control logic that interprets Bluetooth commands and generates motor-driving outputs.

2. LITERATURE REVIEW

Prior research on Bluetooth-controlled robotic systems has explored various approaches to enhancing mobility, communication, and automation. Kundu and Sanyal (2023) demonstrated a reliable Arduino-based vehicle utilizing an HC-05 module for wireless control. Ali et al. (2023) extended Bluetooth control by integrating voice commands and obstacle detection, showing how multi-modal inputs can enhance versatility.

Tomar and Choubey (2024) analysed performance metrics such as signal latency and response time, emphasizing the importance of optimized communication in real-time applications. Earlier work by Rai et al. (2016) introduced fundamental methods of Bluetooth-based control for educational robotics. Later, Nipun and Biswas (2023) incorporated sensors to facilitate color-based navigation, enhancing the functional autonomy of robotic platforms. Additionally, Yadav et al. explored the blend of Bluetooth and voice control in obstacle-avoiding robots, highlighting the utility of sensor integration for safer navigation.

These studies collectively show the progressive evolution of Bluetooth-based robotic systems and underline the importance of sensor integration, communication optimization, and algorithmic enhancements for future development.

3. METHODOLOGY

3.1 System Overview

The robotic car consists of a chassis equipped with two DC gear motors, an Arduino Uno, an L293D motor driver, a Bluetooth module, and a battery pack. The Bluetooth module establishes a wireless link between the smartphone controller and the robot, while the Arduino processes received commands and generates appropriate motor control outputs. Power supplied from the battery drives both the electronics and the motors [3].

3.2 Working Principle

A mobile application transmits directional commands via Bluetooth. Once the smartphone pairs with the HC-05 module, the app sends characters that represent specific movement instructions [4]. The Arduino continuously monitors incoming serial data and interprets each received character according to a predefined command map. Based on the instruction, the Arduino sets the necessary output signals on the L293D driver, which in turn controls the rotation direction and activation of the DC motors.

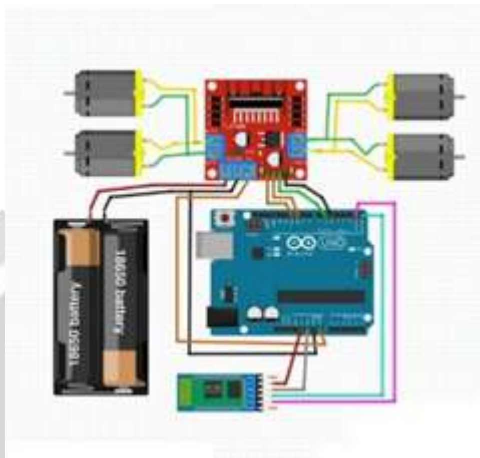

Fig. 1 Circuit Diagram

Forward motion is achieved by driving both motors in the same direction, while reverse motion uses the opposite polarity. Turning is performed by varying the rotation of the motors—either by slowing one motor or reversing its direction relative to the other.

3.3 Software Workflow

The Arduino program includes initialization of serial communication, command recognition logic, and motor control functions. Once uploaded through the Arduino IDE, the board operates independently. No additional wired connection is required after programming [5]. The modular code structure ensures easy modification for adding new features such as speed control or obstacle detection.

3.4 User Interface

The smartphone application presents directional buttons that generate corresponding Bluetooth signals. Its two-step interface—device pairing followed by command control—enables intuitive operation even for beginners.

Fig. 2 User Interface

The Bluetooth range (typically 10–20 meters) allows comfortable remote handling of the vehicle within indoor or controlled outdoor environments [6].

4. RESULT

The developed Bluetooth-controlled robotic car successfully responds to directional commands transmitted from the mobile application. Once paired with the HC-05 module, the control signals reach the Arduino without noticeable delay, allowing smooth transitions between forward, reverse, and turning operations. The L293D motor driver accurately executes the control signals, ensuring stable rotation of the DC motors and consistent vehicle movement.

Fig. 3 Actual Model

The mechanical structure and electronic components function cohesively, resulting in a compact prototype capable of reliable wireless navigation within the effective Bluetooth range. The system demonstrates the feasibility of integrating low-cost components to achieve real-time remote control of a robotic platform.

5. ADVANTAGES, DISADVATAGES, AND APPLICATIONS

5.1 Advantages

- **Wireless Operation:** The Bluetooth interface enables remote control of the car without the need for physical connections, allowing flexible and convenient operation from a distance.
- **Moderate Communication Range:** Bluetooth technology provides a practical communication range, typically extending up to several meters, which permits effective control of the car within a reasonable distance.
- **User-Friendly Interface:** The system leverages an Android smartphone as the remote control. Since most users are familiar with mobile devices, the control process is intuitive and requires minimal training.
- **Cost Efficiency:** The project uses affordable components, such as Arduino microcontrollers and Bluetooth modules, making it an accessible and economical option for students, hobbyists, and educational purposes.

5.2 Disadvantages

- **Limited Communication Range:** Although Bluetooth enables wireless control, its effective range is restricted. Physical barriers, interference from other devices, and environmental factors can reduce signal quality, limiting long-distance operation.
- **Latency Issues:** Bluetooth communication may introduce slight delays due to data processing and signal transmission, which can affect real-time responsiveness in certain applications.

- **Power Consumption:** The Bluetooth module requires continuous power, which can impact the overall battery life of the robotic car. Efficient energy management is essential to maintain prolonged operation.
- **Complex Pairing Process:** Establishing a connection between the Bluetooth module and the controlling device can sometimes be challenging, particularly for beginners or non-technical users, affecting the ease of setup.

5.3 Applications

- **Educational Purposes:** Bluetooth-operated cars serve as practical tools for teaching robotics, embedded systems, and wireless communication concepts to students and hobbyists. They provide hands-on experience in programming, electronics, and system integration.
- **Robotics Research and Prototyping:** Such cars are used as prototypes in research for developing advanced robotic control systems, including autonomous navigation, path planning, and human-machine interaction experiments.
- **Remote Surveillance and Monitoring:** Bluetooth-controlled vehicles can be equipped with cameras or sensors for short-range monitoring in laboratories, classrooms, or indoor environments.
- **Entertainment and Recreational Projects:** These cars are widely used for hobby projects, competitions, and interactive demonstrations, offering an engaging platform for STEM learning.
- **Testing Wireless Communication Systems:** The Bluetooth interface allows developers to experiment with wireless data transmission, device pairing, and mobile-to-embedded system communication in real-world scenarios.

6. CONCLUSIONS

This project demonstrates the effective use of Bluetooth communication and microcontroller-based control to build a functional robotic vehicle. The system performs essential movements—forward, backward, and directional turns—with stable response and consistent motor output. Its simplicity, low cost, and modular structure make it a strong candidate for educational use and entry-level robotics research. The completed prototype validates the practicality of using Bluetooth for short-range robotic control and highlights how readily available components can be combined to develop a reliable and interactive robotic platform.

7. FUTURE SCOPE

Several enhancements can significantly extend the capabilities of the current system. Integrating sensors such as ultrasonic or infrared modules would enable obstacle detection and semi-autonomous navigation. Upgrading the communication module to Wi-Fi or Bluetooth Low Energy (BLE) could increase range and improve overall responsiveness.

Additional features—such as speed control, camera modules for real-time video streaming, or artificial intelligence-based decision-making—can transform the car into a versatile research platform. Improvements in power management and motor efficiency could further enhance battery life and performance. Overall, the prototype provides a solid foundation for building more sophisticated robotic systems suitable for advanced academic and industrial applications.

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