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Voice-Controlled Autonomous Robotic Car: Integrating Speech Recognition with Sensor-Based Navigation for Enhanced Human-Machine Interaction

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Abstract

In recent years, the advancement in autonomous vehicle technologies and human-computer interaction has driven the exploration of novel control interfaces. This paper presents a prototype of an autonomous robotic car controlled via voice commands, integrating speech recognition with sensor-based navigation. By enabling intuitive verbal interactions, this system lowers the learning curve for autonomous systems and enhances accessibility. The prototype utilizes an embedded microcontroller, ultrasonic sensors, a speech recognition module, and drive actuators to achieve responsive autonomous behavior. The work aligns with current trends in electric and smart vehicles and aims to contribute toward safer, user-friendly autonomous mobility.

Keywords: Autonomous Vehicles, Voice Command, Robotic Car, Human-Computer Interaction, Speech Recognition, IoT

1. Introduction

With the rapid evolution of electric and autonomous vehicle technologies, enhancing human-machine interaction has become a central challenge. Traditional control interfaces (e.g., steering wheels, buttons) are being augmented or replaced by more

intuitive options, such as voice commands. Voice-enabled interaction has the potential
to improve accessibility, safety, and convenience. Simultaneously, as seen in EV development trends across countries like the USA, Japan, and Germany, there is a growing focus on integrating intelligent systems into vehicles. This paper presents a prototype robotic car that uses voice commands to simulate autonomous vehicle behavior, integrating speech recognition with hardware components for real-time navigation and control.

2. Related Work and Motivation

Research in electric vehicles (EVs) has focused heavily on control theory, battery management, and grid integration. However, the challenge of improving human-machine interaction remains a critical area of study. Voice-command systems have become an increasingly viable solution for enhancing accessibility and usability in autonomous systems.

Recent trends in EVs, especially in countries like the USA, Japan, and Germany, indicate a shift towards incorporating intelligent systems in vehicles. These advancements make it possible to explore intuitive control interfaces such as voice recognition. This paper introduces a prototype of a robotic car that utilizes voice commands for autonomous behavior simulation, integrating speech recognition with sensors and motion control.

3. System Design

The proposed system integrates voice command control into a robotic vehicle, aligning with modern advancements in intelligent transportation systems and human-machine interaction. The vehicle responds to voice commands sent from a mobile device, processed through Bluetooth communication and executed via a microcontroller and motor driver.

3.1 System Overview

In this system, the user issues a command through a voice interface on a smartphone. The spoken command is converted into a text string using voice recognition software and transmitted over a Bluetooth link to the vehicle. The microcontroller on the vehicle receives this data via UART and interprets the command. The control signals are then sent to the motors using a motor driver circuit. The robotic car moves according to the command (forward, backward, left, right, or stop). The system is designed for real-time responsiveness, easy integration, and future scalability.

3.2 Signal Flow and Control Logic

The control architecture begins with voice acquisition on the mobile device. Bluetooth-based serial communication is used to transmit data to the Arduino Uno microcontroller. The Arduino processes the command and activates the motors accordingly, using the L293D motor driver.

For example, when the voice command "forward" is received, the control logic activates both motors in the forward direction. Similarly, "left" and "right" commands drive the motors selectively to turn the vehicle, while "stop" halts the movement. In case of communication failure

or an invalid command, a default stop function is executed for safety.

3.3 Hardware Components

The following components were used in the construction of the prototype:

S.No	Component	Specification
1.	Arduino Uno	ATmega328P MCU, 16 MHz, 14 I/O Pins, UART, Operating Voltage: 5V
2.	HC-05 Bluetooth Module	2.4GHz ISM Band, Bluetooth v2.0+EDR, Range: ~10m, Voltage: 3.3V
3.	L293D Motor Driver	Dual H-Bridge, Max 600 mA per channel, Voltage Range: 4.5–36V
4.	DC Geared Motors	3–12V Operating Voltage, 150 RPM, 3.5kgf•cm Torque, No-load Current: 40-80mA
5.	Power Supply	12V Rechargeable Battery, Voltage Regulation via LM7805 to 5V

3.4 System Reliability and Scalability

The design includes fault-tolerance features. In the absence of a valid command or Bluetooth connectivity loss, the motors automatically stop, ensuring safe operation. The system is scalable, with additional modules such as ultrasonic sensors for obstacle avoidance or a cloud-based dashboard for remote monitoring. These features align with scalable embedded robotic systems, which prioritize modularity and adaptability for future upgrades.

4. Key Technologies and Challenges in Real-Time Systems

Implementing a real-time voice-controlled robotic vehicle involves several key technologies:

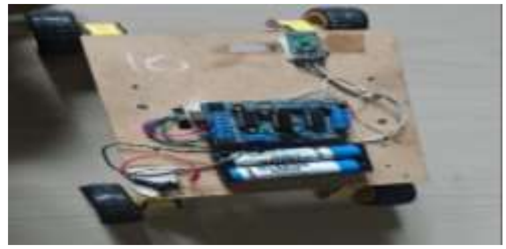
1. **Real-Time Embedded Microcontrollers:** The Arduino Uno is suitable for small-scale real-time applications but larger systems require more powerful microcontrollers with real-time operating systems (RTOS).
2. **Wireless Communication:** Bluetooth provides adequate range and bandwidth for command transmission, but latency and interference can be problematic in real-time systems.
3. **Motor Control Subsystem:** Accurate, low-latency motor control is critical for responsive operation. Any delay in interpreting or executing commands can affect safety and user experience.
4. **Voice Recognition:** Although voice recognition is performed on the smartphone in this prototype, embedding it locally on the robotic vehicle could add significant computational load and energy consumption.
5. **Power Efficiency:** Efficient power management is essential, particularly in mobile systems. Voltage regulation and current handling are crucial for preventing failures during peak loads.
6. **Fail-Safe Mechanisms:** Systems must be robust to failures such as command loss, motor stalls, or communication dropouts. Reliable error-handling routines are essential to maintaining operation.

5. Current Impact on the Electric Vehicle Industry

The rapid expansion of the EV industry has led to significant advances in vehicle technology, including the integration of intelligent systems like voice-command systems. Governments worldwide are incentivizing EV adoption through subsidies and research funding, while technological innovations in battery storage, wireless charging, and V2G systems are redefining mobility.

Voice-command systems are becoming increasingly popular in modern electric vehicles, improving hands-free navigation, infotainment, and safety controls. By integrating speech processing capabilities, manufacturers can enhance user experience and reduce cognitive load on drivers, which is crucial in developing next-generation autonomous vehicles.

7. Hard ware results



Arduino Uno: The Arduino Uno effectively managed real-time processing of voice commands and controlled the motors with minimal delay. It handled the simple control logic well, but for larger-scale systems, a more powerful microcontroller may be needed.

HC-05 Bluetooth Module: This module provided reliable wireless communication, with minimal latency and a range of about 10 meters. However, interference or obstructions occasionally caused minor delays.]

L293D Motor Driver: The motor driver controlled the motors accurately, ensuring smooth movement in all directions based on voice commands. It performed well under the load but is limited to lower-power motors (600 mA per channel).

DC Geared Motors: The motors offered sufficient torque and smooth movement, supporting basic motion commands. They are efficient for lightweight robots but may struggle under heavy loads or on inclined surfaces.

Power Supply: The 12V rechargeable battery, regulated to 5V, powered the system for 1-2 hours. The LM7805 voltage regulator ensured stable operation, though it may need upgrading for better efficiency and thermal management.

Future Expansion (Ultrasonic Sensors): While not yet implemented, adding ultrasonic sensors would enable obstacle avoidance, enhancing the robot's autonomous capabilities.

8. Conclusion:

This paper presented the design and implementation of a voice-command-based robotic vehicle prototype for integrating intelligent interfaces in autonomous electric mobility. The system architecture focused on real-time command execution, Bluetooth-based communication, and safety-aware motion control via an embedded microcontroller. The project demonstrates that low-cost platforms can support advanced human-machine interaction functionalities, which are highly relevant in modern EVs.

As electric vehicles evolve to incorporate more autonomous and AI-driven features, systems like this serve as important building blocks for the future intelligent transportation ecosystem. Continued research in real-time voice processing, low-latency communication, and energy-efficient embedded design will play a pivotal role in shaping this transition.

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