

Raspberry Pi-Based Automated Robot Car with an AI Assistant

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Abstract- Autonomous vehicle research often requires expensive hardware platforms equipped with multiple sensors, which limits accessibility for students and early-stage researchers. To address this challenge, this paper presents the design and implementation of a low-cost autonomous robot car using a Raspberry Pi integrated with an AI-based voice assistant. The proposed system enables autonomous navigation, obstacle detection, fog-aware vehicle detection, multilingual voice control, and automatic parking. Sensor fusion is achieved using ultrasonic sensors, camera modules, and optional thermal sensing to ensure safe operation in low-visibility conditions. Voice commands primarily in English are processed using a cloud-based speech recognition service, allowing natural human-vehicle interaction. The system architecture is modular, enabling gradual sensor integration and future scalability. Experimental results demonstrate reliable obstacle avoidance, accurate voice command execution, and successful autonomous parking, validating the effectiveness of the proposed platform as a practical testbed for intelligent transportation research. The rapid development of autonomous driving technologies has emphasized the need for affordable and scalable experimental platforms capable of validating perception, decision-making, and control algorithms in real-world conditions.

Index Terms- Autonomous Robot Car, Raspberry Pi, AI Assistant, Voice Control, Speech Recognition, Auto Parking.

I. INTRODUCTION

Autonomous vehicles are intelligent systems capable of perceiving their environment, making decisions, and navigating without continuous human intervention. With increasing interest from academic institutions and industries, autonomous driving technologies are being actively researched for applications ranging from intelligent transportation to

service robotics. However, the development of real-world autonomous vehicles typically requires costly hardware platforms and complex system integration, which poses a barrier for small-scale research and student projects.

To overcome these limitations, miniature robotic platforms such as robot cars provide an effective alternative for experimenting with autonomous driving concepts. These platforms allow researchers to validate perception, decision-making, and control algorithms in real-world conditions at a significantly lower cost. Additionally, integrating artificial intelligence and natural language interaction further enhances usability and system intelligence.

In this paper, we present an AI-enabled autonomous robot car built using a Raspberry Pi, designed to support both autonomous operation and voice-based manual control. The system incorporates obstacle detection, fog-aware sensing, automatic parking, and a multilingual AI assistant capable of understanding spoken commands. Unlike simulator-based approaches, the proposed system operates in real environments, enabling identification of practical challenges such as sensor noise, lighting variation, and communication delays.

II. RELATED WORKS

Autonomous driving research spans a wide range of platforms, from full-scale vehicles to simulated environments. According to SAE standards, autonomous driving is classified into six levels, ranging from driver assistance to full automation. Most commercial and research implementations focus on higher levels of automation using advanced sensors such as LiDAR, radar, and high-resolution

cameras. Simulation environments like Gazebo, CARLA, and AirSim are commonly used to test autonomous driving algorithms due to their safety and flexibility. However, simulators often fail capture real-world uncertainties such as sensor misalignment, lighting variations, and unpredictable obstacles. As a result, there is a growing interest in low-cost physical platforms that can bridge the gap between simulation and real-world deployment.

Previous studies have demonstrated the feasibility of using Raspberry Pi-based robot cars for lane detection, obstacle avoidance, and basic navigation. Some systems employ remote AI servers for computation, while others implement onboard intelligence. However, limited research has focused on integrating voice-based AI assistants and multilingual interaction into autonomous robot cars. The proposed system extends existing work by combining autonomous navigation with natural language voice control and modular sensor integration.

III. SYSTEM DESIGN

This section describes the overall hardware and software architecture of the proposed autonomous robot car system.

1) Hardware Architecture

The developed system consists of a four-wheel robotic car chassis equipped with a Raspberry Pi as the main controller. Ultrasonic sensors are mounted at the front and sides of the vehicle for real-time obstacle detection. A camera module provides visual input for navigation and parking operations. Optionally, a thermal sensor or camera can be integrated to detect nearby vehicles or obstacles in foggy or low-light conditions. A motor driver module interfaces between the Raspberry Pi and the DC motors to control vehicle movement. A microphone is connected to capture voice commands, while a speaker provides audio feedback from the AI assistant. All components are powered using a rechargeable battery pack, making the system fully mobile. A motor driver module interfaces between the Raspberry Pi and the DC motors to control vehicle movement. A microphone is connected to capture voice commands, while a speaker provides audio

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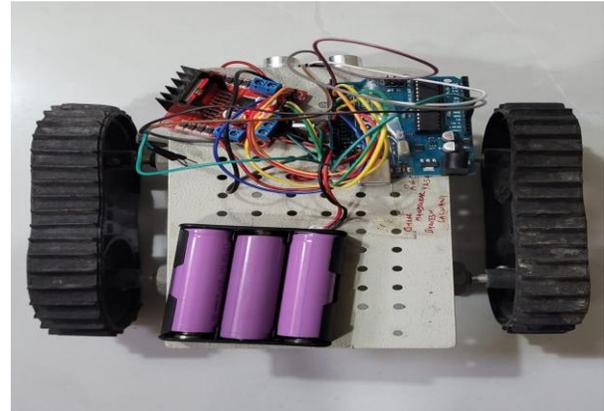


Figure 1 Automated Car

A motor driver module interfaces the Raspberry Pi with DC motors to enable precise control of vehicle movement. Voice interaction is supported through an external microphone and speaker, allowing the AI assistant to receive user commands and provide audio feedback. All components are powered by a rechargeable battery pack, resulting in a compact, low-cost, and modular hardware platform suitable for autonomous vehicle experimentation.

Table 1 Hardware Specification

Automated car	AI Server
1 Raspberry Pi 4 32 GB Micro-SD Card Four wheel robotic car chassis 2 DC geared motors 4 Ultrasonic sensors Thermal camera / thermal sensor Li-ion battery pack	HP Laptop Intel i5 CPU, 512 GB RAM Intel Arc GPU

2) Software Architecture

The software architecture follows a modular design approach, where each functional component is implemented as an independent module. The main controller coordinates sensor data acquisition, voice command processing, decision-making, and motor control. The software architecture follows a modular

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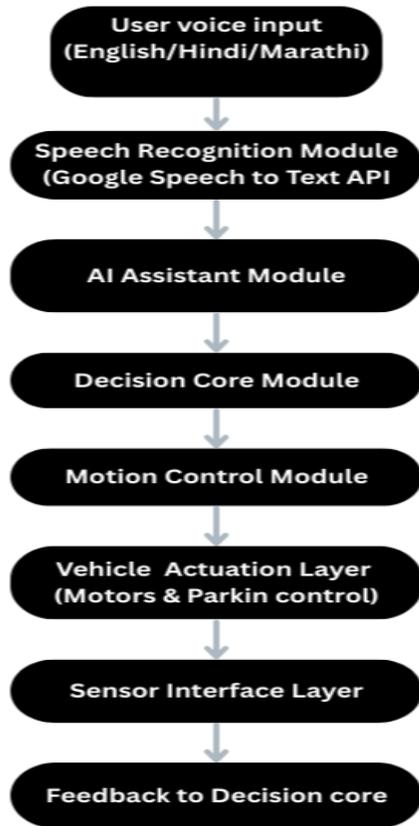


Figure 2 Block Diagram for Software Architecture

The AI assistant module handles speech recognition using a cloud-based speech-to-text API and converts voice commands into structured control intents. A decision core module evaluates sensor data and voice commands to determine the appropriate vehicle action. A safety management module continuously monitors obstacle distance and overrides unsafe actions when necessary. This separation of concerns improves system reliability, scalability, and ease of debugging.

Sensor processing is handled by dedicated Python modules that interface with ultrasonic sensors, the camera module, and optional thermal sensors. These modules continuously acquire environmental data and provide structured input to the decision core. The

decision core implements a state-based control mechanism that determines the vehicle's operating mode, such as forward motion, turning, stopping, or automatic parking. This state-based approach allows the vehicle to maintain continuous motion until a new command or safety constraint is detected.

IV. IMPLEMENTATION OF AUTONOMOUS FUNCTIONS

Voice Command Recognition

The AI assistant enables hands-free vehicle control using spoken commands such as “move forward,” “turn left,” and “stop.” To support multilingual interaction, the speech recognition engine is configured for Indian languages, including English, Hindi, and Marathi. Recognized text is processed using keyword-based intent extraction to ensure reliable command interpretation even with accent variations.

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Once the speech signal is converted into text, the recognized sentence is forwarded to the AI assistant module for semantic interpretation. Instead of relying on strict command matching, the system uses a keyword-based intent extraction approach. This method identifies key action words such as “forward,” “backward,” “stop,” or their linguistic equivalents in Hindi and Marathi. By focusing on semantic keywords rather than exact phrases, the system remains robust against variations in sentence structure, accent, and informal speech. To enable continuous vehicle operation, a state-based control mechanism is integrated with the voice recognition module. When a valid command is detected, the corresponding vehicle state is updated and maintained until a new command or safety constraint overrides it. This design allows commands such as

“move forward” to result in sustained motion, closely mimicking real vehicle behavior. In cases where speech recognition fails or ambiguous input is detected, the system safely defaults to an idle state, preventing unintended vehicle movement.

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Listening...  
You said: move forward  
Action: moving forward
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Obstacle Detection and Safety Control

Ultrasonic sensors continuously measure the distance between the vehicle and nearby obstacles. If an obstacle is detected within a predefined safety threshold, the safety manager immediately halts vehicle movement, regardless of the issued command. This ensures collision-free operation and enhances system robustness.

Low-Visibility and Fog Awareness

To address reduced visibility conditions such as fog, the system supports integration of thermal sensing. Thermal data complements visual input by detecting heat signatures of nearby vehicles or objects, enabling safer navigation when camera-based perception becomes unreliable.

The primary obstacle detection system relies on ultrasonic sensors mounted at the front of the vehicle. These sensors operate using high-frequency acoustic waves and measure the time required for the reflected signal to return from nearby objects. Since ultrasonic sensing is based on sound propagation rather than optical visibility, it remains effective even in foggy or low-light environments. This makes it a reliable method for detecting nearby obstacles and preventing collisions when visual sensing is degraded.

Automatic Parking

Automatic parking is an important capability in autonomous vehicle systems, allowing the vehicle to detect a suitable parking space and maneuver into it without direct human control. In the proposed AI-enabled robot car, an automatic parking mechanism is implemented using sensor-based distance measurement combined with camera-assisted

alignment. The objective of this module is to demonstrate intelligent vehicle maneuvering using a low-cost embedded platform.

The camera module further assists the parking process by providing visual feedback that helps the system maintain proper alignment during the maneuver. The decision core integrates both sensor readings and visual input to dynamically adjust motor speeds and steering directions. Through this feedback-based control approach, the vehicle gradually positions itself within the parking space while maintaining safe clearance from surrounding objects.

The automatic parking algorithm follows a state-based sequence consisting of four main stages: parking space detection, vehicle alignment, controlled reverse maneuvering, and final position adjustment. Each stage is executed only when the previous stage is completed successfully, ensuring stable and predictable operation.

V. EXPERIMENTAL SETUP

The proposed AI-enabled robotic vehicle was experimentally evaluated in a controlled indoor environment to assess its performance in voice command recognition, obstacle detection, and navigation control. The robotic platform consists of a Raspberry Pi 4 Model B connected to ultrasonic sensors, DC motors through a motor driver module, and a microphone for capturing voice commands.

The system was powered using a rechargeable Li-ion battery pack, allowing fully mobile operation. Voice commands were issued by users in English, Hindi, and Marathi languages to evaluate the multilingual capability of the AI assistant.

Multiple test scenarios were conducted including forward motion, directional turning, stopping commands, and obstacle avoidance. During each test, system response time, command recognition accuracy, and obstacle detection performance were recorded.

VI. RESULTS AND PERFORMANCE EVALUATION

Experimental results demonstrate that the system can accurately interpret user commands, detect obstacles, and execute vehicle movements effectively. The modular hardware and software architecture allows further expansion for advanced autonomous driving capabilities.

The proposed platform provides a low-cost experimental framework for research in autonomous vehicles, robotics, and intelligent transportation systems.

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