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AI-Based Voice-Controlled Autonomous Robot with Obstacle Avoidance

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Abstract -

This paper presents the design of an AI-based voice-controlled autonomous robot with obstacle avoidance. The proposed system combines speech-based commands with distance sensing so that a user can direct the robot without physical contact while the robot navigates more safely in its surroundings. A microcontroller receives commands from a voice-recognition interface and controls a motor driver connected to the robot's drive motors. An ultrasonic sensor measures the distance to nearby objects. When an obstacle is detected within a predefined safety range, the controller stops the robot and can select a clear direction or wait for a new command. The system is intended to support basic movement commands such as forward, backward, left, right, and stop. The design integrates voice recognition, embedded control, motor actuation, and real-time obstacle detection into a compact prototype. This paper describes the system architecture, hardware and software requirements, working methodology, implementation considerations, potential applications, and limitations. Since measured prototype results have not been supplied, performance figures are not claimed; the system should be validated through repeated tests under different noise, lighting, surface, and obstacle conditions.

Key Words: Artificial Intelligence, Voice Control, Autonomous Robot, Obstacle Avoidance, Ultrasonic Sensor, Embedded System.

1. INTRODUCTION

Robotics is increasingly used to automate repetitive tasks and to assist people in environments where convenient, contactless control is useful. A voice-controlled robot allows a user to issue simple spoken instructions rather than operate switches or a handheld controller. Adding obstacle avoidance makes the robot more capable of moving in an environment where objects may block its path.

The proposed AI-based voice-controlled autonomous robot combines voice-command recognition with sensor-based navigation. A speech-recognition interface converts spoken words into command text. The controller interprets the command and operates the motors through a motor-driver circuit. An ultrasonic sensor continuously checks the distance in front of the robot. If an object is too close, the controller gives priority to safety by stopping or changing the movement according to the programmed logic.

The term artificial intelligence (AI) is used here in the context of speech recognition and command interpretation. The actual capabilities depend on the selected recognition platform and implementation. A basic prototype can use a smartphone or computer for speech recognition and a microcontroller for motor and sensor control.

2. PROBLEM STATEMENT

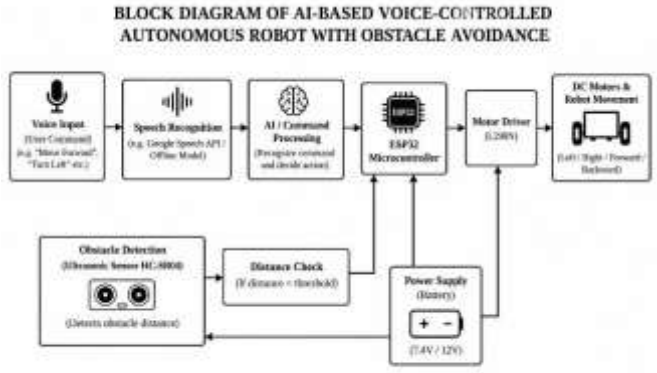
Conventional small robots are often controlled through switches, wired controllers, or mobile applications that require continuous manual input. Such methods may be inconvenient for users who need hands-free interaction. A robot that follows commands without checking for nearby obstacles may collide with objects. Therefore, a low-cost system is needed that combines voice-based movement control with real-time obstacle detection and a safety response.

3. OBJECTIVES

- To develop a robot that responds to basic spoken movement commands.
- To integrate a distance sensor for detecting obstacles in the robot's path.
- To control DC motors through a motor-driver circuit and embedded controller.
- To stop or alter motion when an obstacle is detected within a defined threshold.
- To design a compact, low-cost prototype suitable for educational and assistive applications.

• To evaluate command recognition and obstacle response through structured practical tests.

4. PROPOSED SYSTEM ARCHITECTURE



The system contains a voice input device, a speech-recognition module, a communication link, a microcontroller, an ultrasonic sensor, a motor driver, DC motors, and a battery supply. The voice input device captures the user's speech. The recognition module converts the speech into a text command and sends it to the controller, for example through Bluetooth, Wi-Fi, or a serial connection depending on the selected hardware. The microcontroller reads the command and sensor distance, then produces control signals for the motor driver. The motor driver supplies the current required by the motors.

The obstacle sensor is connected to the controller and is checked during movement. A safety rule should take priority over a forward command: when the measured distance falls below the configured threshold, the controller stops forward motion. The robot may then turn, reverse briefly, or wait for another command, depending on the programmed navigation strategy.

5. HARDWARE COMPONENTS

• Microcontroller (Arduino Uno or ESP32): processes commands and sensor readings and generates motor-control signals.

• Ultrasonic distance sensor (such as HC-SR04): estimates the distance to objects in front of the robot.

• Motor driver (such as L298N or a suitable equivalent): interfaces the controller with the DC motors.

• DC geared motors and wheels: provide movement and traction.

• Robot chassis: supports the controller, sensor, motor driver, and battery.

• Voice input device: a smartphone or computer microphone used by the speech-recognition interface.

• Communication module: Bluetooth, Wi-Fi, or serial communication, selected according to the controller and voice interface.

• Battery and voltage regulation: provide suitable power to the controller and motors.

6. COMPONENTS

6.1. Hardware Componets

i.ESP32

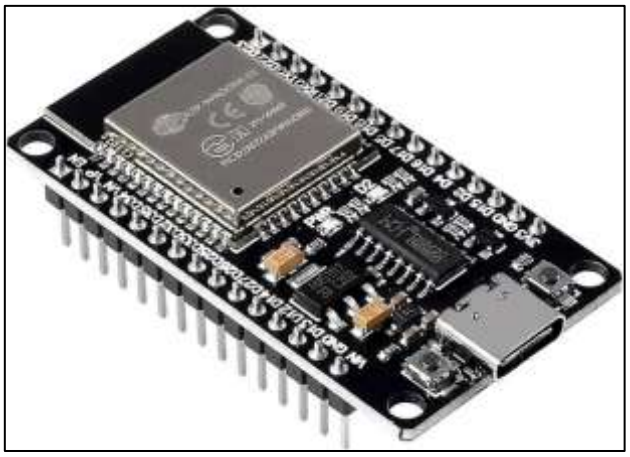


Fig.ESP32

ESP32 is low -cost microcontroller with built -in wi-fi and Bluetooth . it is used to connect sensor ,collect data, and control electronic devices in this project ,it processes input signal and communicates with other components to perform the required operations .

ii. Ultrasonic Sensor (HC-SR04)



Fig. Ultrasonic Sensor (HC-SR04)

Ultrasonic Sensor (HC-SR04): The HC -SR04 is a sensor used to measure the distance between an object and the robot . it sends ultrasonic sound waves and Calculates the distance by measuring the time taken for the echo to return. In this project, it detects obstacles and helps the robot avoid collisions.

Motor Driver Module (L298N)

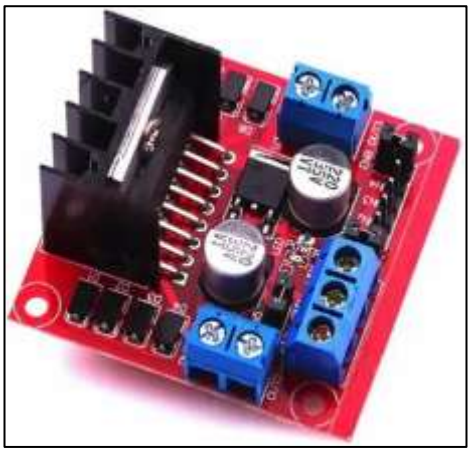


Fig.Motor Driver Module (L298N)

Motor driver module (L298N): The L298N is a motor driver module used to control the speed direction of DC motors . it receives control signals from the ESP32 and supplies the required power to the motors . in this project ,it helps the robot move forward ,backward ,left and right.

iv.Microphone



Fig. Microphone

Microphone: A microphone is an input device used to capture the user's voice commands in this project, it received commands such as forward, backward ,left, and right ,which are processed by the voice recognition system to control the robot .

6.2. Software Components

i. Arduino IDE

Arduino IDE: Arduino IDE is software used to write, compile, and upload programs to microcontrollers such as ESP32. in this project, it is used to program the robot, control the motors, read sensor data, and implement obstacle avoidance

ii. Embedded C/C++

Embedded C/C++: Embedded C/C++ is a programing language used to develop software for microcontrollers such as ESP32. In this project, it is used to control the robot's motors, process sensor data, execute voice commands, and perform obstacles avoidance.

iii. Speech Recognition Software/API

Speech Recognition Software/API: Speech Recognition Software/API converts spoken words into text or commands can understand. In this projects, it recognizes the user's voice commands and help's control the robot's movement, such as forward, backward, left, and right.

iv. ESP32 Libraries

ESP32 Libraries: ESP32 Libraries are pre-written code packages used to simplify programming and controlling hardware components. In this projects they help's the ESP32 communicate with sensors, control motors, connect to wi-fi or Bluetooth, and robot operations efficiently.

7. WORKING PRINCIPLE

Start the controller and initialize the sensor, motor driver, and communication interface.

The user speaks a supported command, such as "forward", "backward", "left", "right", or "stop".

The speech-recognition interface converts the spoken instruction into text and sends the command to the robot.

The controller validates the command and checks the obstacle sensor before allowing forward movement.

If the path is clear, the motor driver operates the motors according to the requested direction.

If an obstacle is detected inside the safety threshold, the controller stops the motors and prevents the robot from continuing forward.

The controller resumes only when the path is considered clear or a safe next action is selected.

8. CONTROL LOGIC AND OBSTACLE AVOIDANCE

A simple control loop can be expressed as follows: read the latest voice command; measure the distance to the nearest obstacle; if the command is STOP, stop both motors; else if the distance is below the safety threshold, stop forward motion and initiate the selected avoidance response; otherwise execute the valid movement command. The distance threshold should be chosen experimentally for the robot's speed, sensor mounting, braking distance, and environment. Sensor readings should be filtered or checked more than once to reduce false triggers.

Voice recognition can fail because of background noise, accents, unsupported words, or communication loss. The system should therefore use a fixed set of supported commands, acknowledge invalid instructions where possible, and stop the robot if communication becomes unavailable. A physical power switch and an accessible emergency-stop method are recommended during testing.

9. IMPLEMENTATION METHODOLOGY

First, assemble the chassis, motors, motor driver, controller, sensor, and power supply. Verify motor direction and confirm that the logic and motor power supplies are appropriate for the selected components. Next, test the ultrasonic sensor independently and compare its distance readings with known distances. Develop the motor-control firmware and verify forward, reverse, left, right, and stop actions using test commands. Integrate the voice-recognition interface and confirm that each recognized phrase maps to the intended command. Finally, add obstacle-priority logic and test the complete system at low speed in a clear, controlled area.

10. TESTING AND EVALUATION

The prototype should be evaluated using a repeatable test plan. Voice-command tests should record the number of correctly recognized commands, incorrect recognitions, and missed commands across quiet and moderately noisy conditions. Obstacle tests should place objects at different distances and verify whether the robot stops before contact. Direction tests should check motor polarity and turning behaviour. Communication tests should verify the robot's response when commands are delayed or the link is disconnected. Battery tests should observe operating time and controller stability.

No measured accuracy, response time, obstacle-detection range, or success rate is asserted in this paper because experimental data were not provided. Such values should be added only after actual prototype measurements, with the test setup and number of trials clearly reported.

11. APPLICATIONS

- Educational demonstrations of robotics, embedded systems, and speech recognition.
- Contactless control of small service or demonstration robots.
- Assistive prototypes for users who find manual controls inconvenient.
- Indoor material movement in simple, controlled environments.
- Research and learning in autonomous navigation and human-robot interaction.

12. ADVANTAGES

- Provides hands-free interaction through spoken commands.
- Combines command-based movement with proximity-based obstacle protection.
- Can be built from commonly available educational electronics components.
- Supports modular upgrades such as additional sensors, wireless control, or improved speech models.
- Offers a practical platform for learning embedded programming and robotics.

13. LIMITATIONS AND FUTURE SCOPE

The system's reliability depends on the speech-recognition platform, ambient noise, sensor placement, surface conditions, and power stability. A single forward-facing ultrasonic sensor cannot identify every obstacle or provide complete environmental understanding; soft, angled, narrow, or sound-absorbing objects may be difficult to detect. A basic command-following robot should not be described as fully autonomous unless its navigation capabilities have been demonstrated.

Future improvements may include multiple distance sensors, wheel encoders, camera-based object detection, mapping and localization, improved noise-robust speech recognition, multilingual commands, feedback through a speaker or display, and a more advanced path-planning algorithm. Testing in progressively more complex environments would help establish the system's practical limits.

14. CONCLUSIONS

This paper describes a proposed AI-based voice-controlled autonomous robot with obstacle avoidance. The design combines speech-command recognition, embedded processing, motor actuation, and ultrasonic distance sensing. Voice commands provide a convenient way to request movement, while obstacle-priority logic reduces the risk of collision by stopping or redirecting the robot when an object is too close. The system is suitable as an educational prototype and can be expanded with better sensing and navigation algorithms. Its actual performance must be established through documented experiments under defined operating conditions; no unverified performance results are claimed here.

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