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Vision Sense Rover

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Abstract

This paper presents the design and implementation of an autonomous obstacle-avoiding robotic system utilizing an Arduino Uno microcontroller, an ultrasonic distance measurement module, a servo-based scanning mechanism, an L298N motor driver module, and an ESP32-CAM for real-time visual monitoring. The proposed system is developed to operate without human intervention, using sensor-driven decision-making for navigation. The ultrasonic sensor continuously measures the distance to adjacent obstacles, while the servo motor rotates the sensor across left and right directions to obtain multi-directional environmental information. Based on the collected distance data, the Arduino executes a decision algorithm to determine robot movement: moving forward when the path is clear, stopping when an obstacle is detected, and turning left or right depending on which side offers a free path. The L298N motor provides turning and power control to the motors for smooth and stable mobility. Additionally, the ESP32-CAM module delivers live video streaming and remote visual supervision of the robot's surroundings. The system includes an ESP32-CAM module to allow for real-time visual observation of the robot's working environment in addition to autonomous movement. This feature increases situational awareness and broadens the system's applicability to surveillance and monitoring jobs by enabling remote users to view the robot's surroundings via live video streaming. Because of the general design's emphasis on affordability, energy efficiency, modularity, and ease of fabrication, it is especially well-suited for research experimentation, teaching, and simple autonomous navigation applications. The usefulness of the suggested autonomous robotic system is validated by experimental results, which show that the robot functions dependably in real-world situations, successfully identifying barriers, choosing the best routes, and keeping constant video surveillance. The overall system is low cost, energy-efficient, and easy-to-construct, making it highly suitable for educational, surveillance, and self-directed navigation applications. Experimental results reveal that the robot performs reliably in real-time environments, showcasing active obstacle detection, path choice, and continuous video monitoring.

Keywords: Electrical appliances, ESP32-CAM, home automation, microcontroller, user interface device

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INTRODUCTION

Autonomous mobile robots have attracted significant attention in recent years owing to their wide range of applications in surveillance, environmental monitoring, smart transportation, and educational robotics. With improvements in low-cost microcontrollers and sensor technology, the design of efficient and smart robotic platforms for real-time navigation and obstacle avoidance has become increasingly feasible. Such systems rely on the combination of sensing, decision-making, and actuation to interact effectively with their location. In this study, an autonomous obstacle-avoiding robot was developed by using an Arduino Uno microcontroller as the primary processing unit. The robot employs an ultrasonic sensor to spot obstacles and measure the distance in real time. A servo motor was used to swap the ultrasonic sensor left and right, enabling the system to scan multiple directions and gather environmental information. Based on sensor data, Arduino performs a result algorithm to determine whether the robot should move forward, stop, or turn left or right.

For motor actuation, an L298N motor driver module was used to control the speed and direction of DC motors. This ensures the smooth signaling of the robot, even under shifting environmental conditions. Furthermore, an ESP32-CAM module was integrated into the system to provide live video streaming, qualify remote monitoring, and educate situational awareness. This project aimed to design a cost-effective and intelligent robotic system capable of autonomous navigation without human involvement. The proposed robot is simple to construct, easy to program, and suitable for educational and practical applications. This study presents the system design, hardware integration, working principles, and performance analysis of the developed robot.

RELATED WORK

Several studies have explored the development of self-sufficient mobile robots by using low-cost microcontrollers and common sensor modules. Obstacle avoidance is one of the most widely implemented functionalities in robotic platforms, and numerous scientists have proposed different strategies for improving detection accuracy and navigation efficiency.

Previous studies have utilized ultrasonic sensors for distance measurements owing to their simplicity, low cost, and reliability. Researchers demonstrated an Arduino-based obstacle-avoiding robot that uses a solo ultrasonic sensor to stop and change direction when an obstacle is detected [1].

Similar designs incorporated servomotors to sweep the sensor across numerous angles, enabling the robot to gather directional marks and make more informed decisions [2].

Other studies have focused on improving motor control and navigation accuracy using motor driver modules such as L298N. For example, the implemented speed and direction control using L298N to ensure stable motion across different terrains [3]. Several studies have explored the mixing of wireless camera modules for real-time monitoring. ESP32-CAM has gained popularity in the plans [4] owing to its compact design, built-in Wi-Fi capability, and ability to capture and stream video at low power consumption.

More advanced research has inspected multisensor fusion, machine vision, and AI-based navigation. However, these systems often require more computational resources and higher-cost technologies. In contrast, the system proposed in this paper focuses on a practical and affordable key using normally available equipment, such as the Arduino Uno, ultrasonic sensor, servo motor, L298N motor driver, and ESP32-CAM. This approach allows the robot to be accessible for educational use and small-scale applications [5–9].

Overall, previous studies in this field offer a foundation for designing efficient and cost-effective autonomous robots. The gifts of this project build upon these lessons by participating in real-time video monitoring with autonomous navigation while maintaining simplicity and low hardware cost [10, 11].

AIM AND OBJECTIVE

Aim

This project aims to design and develop a low cost, self-governing obstacle-avoiding robot equipped with real-time video monitoring. The procedure focuses on reliable navigation, efficient sensing, and smooth motor control using existing components such as the Arduino Uno, Ultrasonic Sensor, Servo Motor, L298N Motor Driver, and ESP32-CAM, as shown in Figure 1.

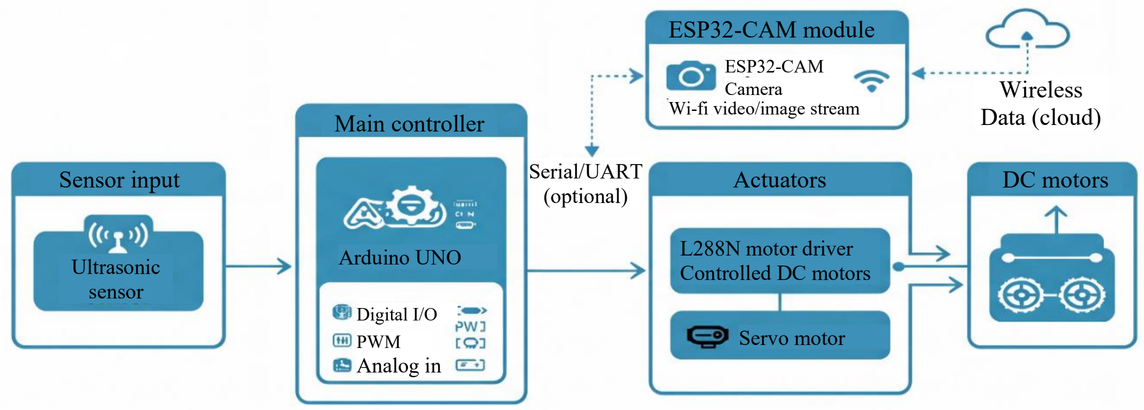

Figure 1. Block diagram of the proposed model.

Objective

- To build a self-directed mobile robot capable of autonomous navigation without human intervention.
- To integrate an ultrasonic sensor for obstacle detection and exact distance measurement.
- To use a servo motor for left-right scanning to augment environmental awareness.
- Implementing a decision-making algorithm via the Arduino Uno to control forward, stop, and turning activities.
- Utilize the L298N motor driver for the effective control of DC motors and even movement.
- To unite the ESP32-CAM for real-time video streaming and monitor the surroundings of the robot.
- Developing a low-cost and easy-to-construct system suitable for students, learners, and research applications.
- To test the robot's performance in obstacle-rich situations and scrutinize its accuracy, response time, and stability.

KEY COMPONENTS

Various key components of the autonomous robot system are listed below.

Arduino Uno

The Arduino Uno is a widely used open-source microcontroller board intended to construct digital devices and interactive items. Arduino boards are equipped with a variety of digital and analog input/output (I/O) pins, allowing them to interface with diverse sensors, modules, and devices. This makes the Arduino Uno an ideal option for prototyping in projects, such as home automation, where control over many devices is required. It is the core processor of the system, receiving incoming orders from the smartphone and controlling linked devices. The simplicity, affordability, and wide community support of Arduino make it a versatile tool for home automation and many other internet of things (IoT) applications.

Ultrasonic Sensor

Ultrasonic radar is a non-contact distance-measuring sensor used to sense hindrances in front of a robot. This is accomplished by releasing high-frequency sound waves and controlling the time taken for the reflected echo to return. This distance data enables the robot to draw informed navigation conclusions and avoid collisions effectively. Owing to its high accuracy, wide coverage range, and low cost, it is generally used in self-governing robotic classifications for reliable hindrance sensing.

Servo Motor

The servo motor was used to rotate the ultrasonic sensor left and right, allowing the robot to scan its surroundings. It operates with accurate angle control, permitting precise turning perception for obstacle detection. By providing a controlled revolving motion, the servo increases the environmental awareness and decision ability of the robot. Its high precision, fast response, and ease of interfacing make it indispensable for autonomous robotic navigation.

L298N Motor Driver

The L298N motor driver acted as an interface between the Arduino and DC motors, providing the required current and voltage. It allows bidirectional control, which allows the robot to move forward, backward, left, and right. The driver ensured a stable motor process even under varying load conditions. Its dual H-bridge formation makes it ideal for governing the two motors simultaneously in robotic applications.

DC Motors

The DC motors offer the robot's physical movement by driving the wheels according to the motor driver's commands. They generated sufficient torque to move the chassis smoothly across different surfaces. Each motor operated independently, enabling differential steering for precise turning. Their simplicity, effectiveness, and reliability have made them widely used in self-directed mobile robots.

ESP32-CAM Module

The ESP32-CAM module offers real-time video streaming and wireless monitoring capabilities. It integrates a camera with Wi-Fi functionality, making remote observations easy and efficient. This module allows users to perceive the robot's environment from a distance using a live video feed. Its compact design and low power consumption make it suitable for lightweight robotic systems [12–14].

Robot Chassis

The robot chassis provides a stable mechanical structure to securely mount all components. It supports motors, sensors, batteries, and electronic components while ensuring overall stability. A durable and lightweight chassis ensures smooth movement and durability across different terrains. It forms the backbone of the robot and contributes to structural integrity and proper component alignment [15, 16].

SYSTEM MODEL

The organizational model of an autonomous robot integrates multiple hardware components that work together to accomplish obstacle detection, navigation, and real-time monitoring. The ultrasonic sensor mounted on a servo motor performs continuous left-right scanning to collect distance data from the adjacent environment.

This scanned information was transmitted to the Arduino Uno, which acted as the main processing unit. Based on predefined algorithms, Arduino decides whether the robot should move forward, stop, or turn left or right, as shown in Figure 2.

The L298N motor driver accepts control signals from the Arduino and regulates the DC motors to create the physical movement of the robot. Differential motor control enables smooth course plotting and quick response to dynamic obstacles. In addition, the ESP32-CAM module operates independently to provide real-time video streaming, allowing the remote monitoring of the robot's path and surroundings through a wireless network.

The entire arrangement is mounted on a robust chassis that holds all components and ensures mechanical stability. The power supply unit transports the regulated current to the microcontroller, sensors, motors, and video camera module. Collectively, these components form a coordinated and dependable system capable of autonomous operation and remote visual supervision [17, 18].

Figure 2. Smart vision sense rover.

RESULTS

The autonomous robot was tested in various indoor environments to evaluate its sensing accuracy, navigation stability, and monitoring capability. During the tests, the ultrasonic sensor provided accurate distance measurements, thereby enabling the robot to recognize obstacles with high reliability. The servo-based scanning mechanism expands the robot's detection range by allowing it to sense objects on the left and right margins. The Arduino Uno efficiently processed the incoming sensor data, resulting in smooth and timely navigation decisions. The L298N motor driver carried stable power to the DC motors, which confirmed smooth motion, sufficient torque, and reliable performance, even during continuous operation. The ESP32-CAM module successfully transmitted a clear and stable live video with minimal delay, thereby ensuring effective remote monitoring throughout the tests. The machine maintained stable navigation across different surfaces, including tiles and wooden floors, with almost no collisions. Overall, the system performed reliably, signifying the successful integration of the sensing, control, and monitoring components, and fully achieved the planned objectives of autonomous navigation and immediate visual feedback.

CONCLUSIONS

The autonomous obstacle-avoiding robot developed in this project successfully integrated sensing, control, and monitoring technologies into a compact and efficient system. The ultrasonic sensor, paired with a servo-based scanning mechanism, permitted the precise detection of neighboring obstacles, allowing the robot to make intelligent navigation decisions. The Arduino Uno and L298N motor drivers worked reliably together to provide smooth and responsive movements across various indoor surfaces. Furthermore, the ESP32-CAM module delivers stable real-time video streaming, enhancing the monitoring and surveillance capabilities of the system. The experimental results verify that the robot meets the primary objectives of self-directed movement, effective obstacle avoidance, and live video transmission. The overall performance demonstrated that low-cost components can be combined to create an efficient and practical robotic system suitable for learning, research, and small-scale automation applications. The project also establishes a strong foundation for adding advanced features such as gesture control, AI-based vision, and wireless remote control to future enhancements.

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