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Line Follower Robot

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Abstract: *In the realm of autonomous robotics, line following robots represent an essential stepping stone toward advanced automated systems. This paper introduces a smart line follower robot enhanced with adaptive path correction using ultrasonic sensors. Unlike traditional line followers that rely solely on infrared (IR) sensors for navigation, our approach incorporates a multi-sensor fusion strategy that enables real-time obstacle detection and dynamic rerouting. By integrating an Arduino-based control system, pulse width modulation (PWM) motor drivers, and an ultrasonic sensor array, the robot not only follows a predefined path but also adapts to unforeseen changes in its environment. This enhancement significantly improves performance in cluttered or dynamic spaces. The proposed design is low-cost, scalable, and well-suited for applications in warehouse automation, hospital logistics, and educational environments. Experimental evaluation demonstrates the robot's capability to detect obstacles with over 90% accuracy and reroute effectively with minimal deviation from its original path.*

Keywords: IR sensors, embedded systems, automation, path detection

I. INTRODUCTION

Autonomous navigation is a rapidly evolving field that plays a pivotal role in modern robotics, especially in logistics, surveillance, and service industries. Line following robots serve as a foundational prototype in this space, typically programmed to track a visual line on the floor using infrared sensors. While effective in controlled environments, these robots face limitations in dynamic or unpredictable settings where sudden obstacles or route changes occur.

To overcome these challenges, researchers and developers have started integrating more sophisticated sensing and control mechanisms into traditional platforms. This paper focuses on enhancing the traditional line follower with the incorporation of ultrasonic sensors, which provide real-time distance measurements, enabling the robot to detect and avoid obstacles without human intervention. The result is a smart, flexible system that maintains line-following accuracy while adapting to changes in its surroundings. Our work also explores the use of sensor fusion, pulse-width modulation for smoother motor control, and efficient path correction algorithms.

The proposed robot is built on a modular, low-cost hardware framework using an Arduino Uno microcontroller and widely available components, making it ideal for both research and educational purposes. This paper documents the design, development, and testing ofthe system, demonstrating significant improvements in obstacle response time and navigation accuracy.

II. METHODOLOGY

The design and implementation of the smart line follower robot involved both hardware and software integration. The core components include an Arduino Uno microcontroller, IR sensors for line detection, an ultrasonic sensor for obstacle avoidance, a motor driver (L298N), and two DC motors.

1. Hardware Setup

IR sensors were positioned at the front to continuously detect the black line on a white surface.

An HC-SR04 ultrasonic sensor was mounted on the front to measure distances from obstacles.

The system was powered by a rechargeable 12V battery.

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2. Software Logic

The robot continuously reads values from the IR sensors.

If the IR sensors detect deviation from the line, the Arduino sends corrective PWM signals to steer the robotback. Simultaneously, the ultrasonic sensor checks for obstacles within a predefined threshold (e.g., 20 cm). If an obstacle is detected, the robot halts, calculates an alternative path by checking side clearance, and attempts a reroute to resume line-following.

3. Path Correction Algorithm

A state machine approach was used where the robot shifts between line-following mode and obstacle-avoidance mode. A PID control logic was partially integrated to ensure smooth navigation, especially around curves.

This hybrid design provides robust performance under various lighting and surface conditions and allows dynamic rerouting in real-time.

III. PROPOSED METHOD

The system includes three ultrasonic sensors placed at the front, left, and right of the robot. Each sensor constantly emits pulses and calculates the distance to nearby objects. Based on sensor feedback, the microcontroller makes movement decisions:

- **All paths clear**: Move forward.
- **Front blocked**: Check sides.
- **Side clear**: Turn in that direction.
- **All blocked**: Stop or reverse briefly.

Components Used

- Ultrasonic sensors (HC-SR04)
- Arduino Uno
- Servo motors
- L293D Motor Driver
- Rechargeable battery
- Chassis with wheels

IV. RESULTS

The smart line follower robot was tested in different indoor environments with varied floor textures and obstacle placements. The performance metrics were focused on line-following accuracy, obstacle detection efficiency, and rerouting success rate.

Line-following accuracy: 96% on straight paths and 89% on curves.

Obstacle detection range: Consistent detection within 18–22 cm.

Obstacle avoidance success rate: 92% over 50 test runs.

Rerouting time: Average time to detect, stop, and reroute was approximately 3.8 seconds.

The robot successfully demonstrated real-time adaptation to obstacles while maintaining reliable line tracking. Minor inaccuracies were noted when obstacle spacing was minimal or when sensor calibration was misaligned, which can be improved with fine-tuning.

V. CONCLUSIONS

This project successfully developed a smart line follower robot with adaptive obstacle avoidance using ultrasonic sensors. By merging IR-based navigation with ultrasonic sensing and intelligent control logic, the robot is capable of dynamic rerouting and efficient path-following even in complex environments. The implementation demonstrated a

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scalable, low-cost design suitable for real-world applications like warehouse logistics, hospital automation, and educational robotics.

Future work could explore the integration of image recognition, wireless communication for coordinated multi-robot systems, and deep learning models for more advanced decision-making. With such enhancements, the robot can evolve from a line follower into a versatile mobile autonomous system.

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