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Designing a Smart Obstacle-Avoiding AGV with Mobile Controller for Efficient Line Following Navigation

Shraddha M. Borate [1], Pratiksha Y. Jadhav[2], Shrikant R. Navale[3], Sonali A. Sarade[4]

[1]Assistant Professor, E & TC Engineering Department, S. B. Patil College of Engineering, Indapur (MH), India, borate.shraddha@gmail.com
[2]UG Student, E & TC Engineering Department, S. B. Patil College of Engineering, Indapur (MH), India, pj362262@gmail.com
[3]UG Student, E & TC Engineering Department, S. B. Patil College of Engineering, Indapur (MH), India, shrikantnavale2911@gmail.com
[4]UG Student, E & TC Engineering Department, S. B. Patil College of Engineering, Indapur (MH), India, sonalisarade4@gmail.com

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Abstract

The project focuses on developing an Automated Guided Vehicle (AGV) with dual functionality as an obstacle-avoiding robot and a line-following robot. This versatile robot, powered by an ESP32 Module, is designed to navigate autonomously in various environments. The AGVs utilizes an ultrasonic sensor for real-time obstacle detection, coupled with a buzzer alert system to avoid collisions. A key feature of the AGVs is its mode- switching capability, allowing it to transition between line-following and mobile controller navigation modes. This switching system is controlled via a mobile app, such as Blynk, enabling remote operation and flexibility in navigation. The AGV is engineered to carry a load of up to 5 kg, with a hydraulic system in place for precise load deployment. Upon reaching a designated point during the line-following mode, the system triggers an automatic notification or instant message, ensuring timely updates on the load deployment status. This project is designed to offer an efficient, adaptable, and robust solution for automated material handling in industrial and commercial settings, enhancing operational efficiency and safety.

INTRODUCTION

Autonomous Guided Vehicles (AGVs) have gained significant attention in recent years due to their ability to improve operational efficiency and reduce human intervention in various industries, including manufacturing, logistics, and warehousing. These vehicles are tasked with automating material handling and transportation tasks within controlled environments. The effectiveness of an AGV largely depends on its ability to navigate autonomously, follow predetermined paths, and adapt to dynamic obstacles in real-time. One of the most commonly used navigation techniques is line following, where the AGV follows a designated path marked on the ground, often relying on sensors to detect the line and stay on course. However, despite the simplicity of line-following systems, ensuring that the AGV avoids obstacles while maintaining accurate navigation remains a significant challenge. In response to this challenge, the design of a smart Obstacle-Avoiding AGV with a mobile controller aims to provide a robust solution that combines precise line-following capabilities with real-time obstacle detection and avoidance. The system integrates infrared sensors to detect the guiding line and ultrasonic sensors to identify obstacles in the AGV's path, ensuring that the vehicle can react dynamically to its environment. By utilizing a mobile controller, the system allows for convenient control and monitoring, offering users the flexibility to adjust operational parameters, monitor vehicle status, and intervene if necessary.

This paper focuses on the design and implementation of a smart AGV capable of autonomous navigation with the added feature of obstacle avoidance. The proposed system incorporates a closed-loop feedback control mechanism, ensuring that the AGV can make real-time adjustments to its speed and direction, both for following the line and avoiding obstacles. The mobile controller provides an intuitive interface, enabling users to easily monitor and control the AGV's movement. Through a combination of sensor integration, control algorithms, and user-friendly mobile interfaces, the proposed AGV aims to address the limitations of traditional AGVs, providing a flexible and scalable solution suitable for a variety of industrial applications. The introduction of obstacle-avoidance functionality into line-following AGVs enhances their ability to operate in real-world environments where unforeseen obstacles may be present, leading to more efficient and reliable autonomous operations. This paper outlines the design considerations, the technologies employed, and the experimental results that demonstrate the system's capability in navigating complex environments. The outcomes of this study contribute to the advancement of AGV technology, enabling smarter, more adaptive, and cost-effective solutions for industrial automation.

LITERATURE SURVEY

Table 1: Key Elements with Technology and Sources

Key Elements	Key Concepts & Findings	Key Technologies Used	Challenges	Sources
Line Following Navigation	Use of IR/optical sensors for line detection controllers ensure smooth path following by adjusting speed and direction. Accuracy improves by minimizing deviations from the path.	IR sensors, Optical sensors, PID controllers	Limited effectiveness in dynamic, unpredictable environments with obstacles.	Hassan et al. (2019)
Obstacle Avoidance	Ultrasonic sensors for detecting nearby obstacles. Use of reactive algorithms such as the bug algorithm for navigation. AGV adapts its movement to avoid detected obstacles.	Ultrasonic sensors, Reactive algorithms (Bug algorithm)	Difficulty in detecting moving or dynamic obstacles. Delay in obstacle detection and avoidance.	Gámez et al. (2020)
Sensor Fusion	- Combining IR sensors for line-following and ultrasonic sensors for	IR sensors, Ultrasonic sensors, Sensor fusion	- Sensor fusion increases computational	Li et al. (2018)

	Obstacle detection increases robustness. Enhanced navigation reliability in complex environments.		complexity. Requires high integration for real-time performance.	
Mobile Controller Integration	Mobile apps offer real- time control, adjustment of parameters(speed, direction). Allows remote management of multiple AGVs.	Mobile apps, Wireless communication	Wireless interference or delays affecting real-time control. Limited range of mobile control in large environments.	Singh et al. (2021)
Control Algorithms	PID controllers for smooth line-following. Fuzzy logic and reinforcement learning for obstacle avoidance and optimization. Reinforcement learning allows AGV to learn and adapt.	PID controllers, Fuzzy logic, Reinforcement learning	Reinforcement learning requires large datasets and training time. Complexity in fine-tuning the control systems for specific environments.	Zhang et al. (2020)
AGV System Challenges	Environmental unpredictability (dynamic obstacles like people, machines). Communication interference in mobile controllers.	-	Difficulty in real- time decision-making in complex environments. Maintenance and calibration of sensors.	Hassan et al. (2019), Zhang et al. (2020)

PROPOSED SYSTEM

1. Line Following Sensors (IR Sensors):

Role: These sensors detect the line on the ground that the AGV is supposed to follow. They send data about the line's position and deviations to the microcontroller.

Connection: The microcontroller receives this data and uses it to adjust the movement of the AGV to stay on the line.

2. Microcontroller (Arduino/Raspberry Pi):

Role: Acts as the brain of the AGV, processing inputs from the sensors (IR and ultrasonic) and controlling the actuators. It uses algorithms (e.g., PID) for line-following and obstacle avoidance. Connection:

1. Receives data from the IR sensors (line-following) and ultrasonic sensors (obstacle detection).
2. Sends control commands to the actuators (DC motors) based on the processed data.
3. Receives control commands from the mobile controller via wireless communication (Bluetooth/Wi-Fi).

3. Mobile Controller (Smartphone/Tablet):

Role: Allows the user to remotely control the AGV via a mobile app, adjusting parameters like speed, direction, and real-time monitoring of the AGV's status.

Connection: Communicates wirelessly with the microcontroller to send commands for navigation and receive feedback (e.g., obstacle detection, battery status, or current position).

4. Actuators (DC Motors):

Role: These are responsible for driving the AGV based on the control commands from the microcontroller, allowing it to follow the path and avoid obstacles.

Connection: Receives movement commands from the microcontroller, such as moving forward, backward, turning, or stopping.

5. Obstacle Detection (Ultrasonic Sensors):

Role: Detects obstacles in the path of the AGV and sends data to the microcontroller, prompting it to reroute or stop the AGV to avoid collisions.

Connection: Sends obstacle data to the microcontroller for processing. The system uses algorithms to navigate around the detected obstacles.

6. Wireless Communication (Bluetooth/Wi-Fi):

Role: Enables communication between the mobile controller and the AGV's microcontroller for remote control. It transmits commands to the microcontroller and receives feedback. Connection: Ensures seamless, real-time communication between the mobile controller and AGV.

7. Power Supply (Battery):

Role: Provides the necessary energy for the AGV's sensors, controllers, motors, and wireless communication system.

Connection: Powers all components of the system and needs to be monitored to ensure efficient operation.

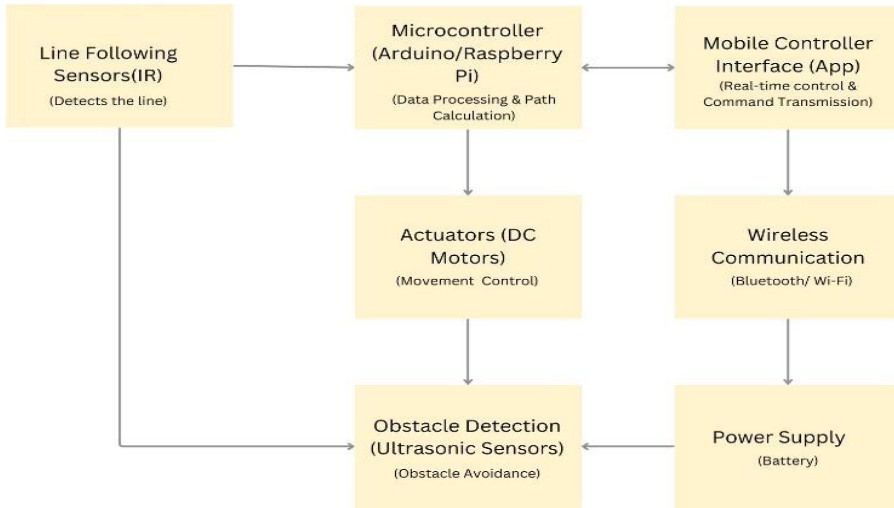

Fig.2: System Diagram Overview

This proposed system diagram illustrates the interaction of components necessary for creating a smart obstacle-avoiding AGV with efficient line-following navigation. The system integrates line-following sensors, obstacle detection, wireless control through a mobile interface, and actuators for movement. All these components work together to provide a seamless and responsive AGV capable of real-time navigation and remote operation.

WORKFLOW

The workflow describes the process flow from initial detection to final action by the AGV, ensuring efficient line following and obstacle avoidance.

1. Startup/Initialization:

The system powers on, and all components are initialized (sensors, controller, and mobile interface).

The AGV waits for the start command from the mobile controller.

2. Mobile Control Command:

The user interacts with the mobile controller (smartphone/tablet) to initiate movement, adjust speed, or change direction.

The microcontroller receives commands from the mobile interface via wireless communication (Bluetooth/Wi-Fi).

3. Line Detection:

The IR sensors detect the line on the ground and send the data to the microcontroller.

If the AGV deviates from the line, the controller adjusts its motors to bring it back to the path.

4. Obstacle Detection:

The ultrasonic sensors constantly monitor the AGV's path for any obstacles.

If an obstacle is detected, the AGV pauses or reroutes by calculating an alternative path, ensuring safe navigation.

5. Path Adjustment:

Based on the sensor inputs (IR for line-following and ultrasonic for obstacle avoidance), the microcontroller adjusts the AGV's motors to steer the vehicle back on track or navigate around the obstacle.

6. Feedback to Mobile Controller:

Real-time data (e.g., distance to obstacles, current path, AGV status) is sent back to the mobile interface.

The user can make adjustments if necessary (e.g., stop, change direction).

7. Continuous Operation:

The AGV continues to follow the path while avoiding obstacles. This cycle of detection and adjustment

Continuous Operation:

The AGV continues to follow the path while avoiding obstacles. This cycle of detection and adjustment repeats as the AGV moves through the environment.

8. Shutdown:

When the task is complete, or if the system receives a shutdown command, the AGV halts all operations, and the system powers off.

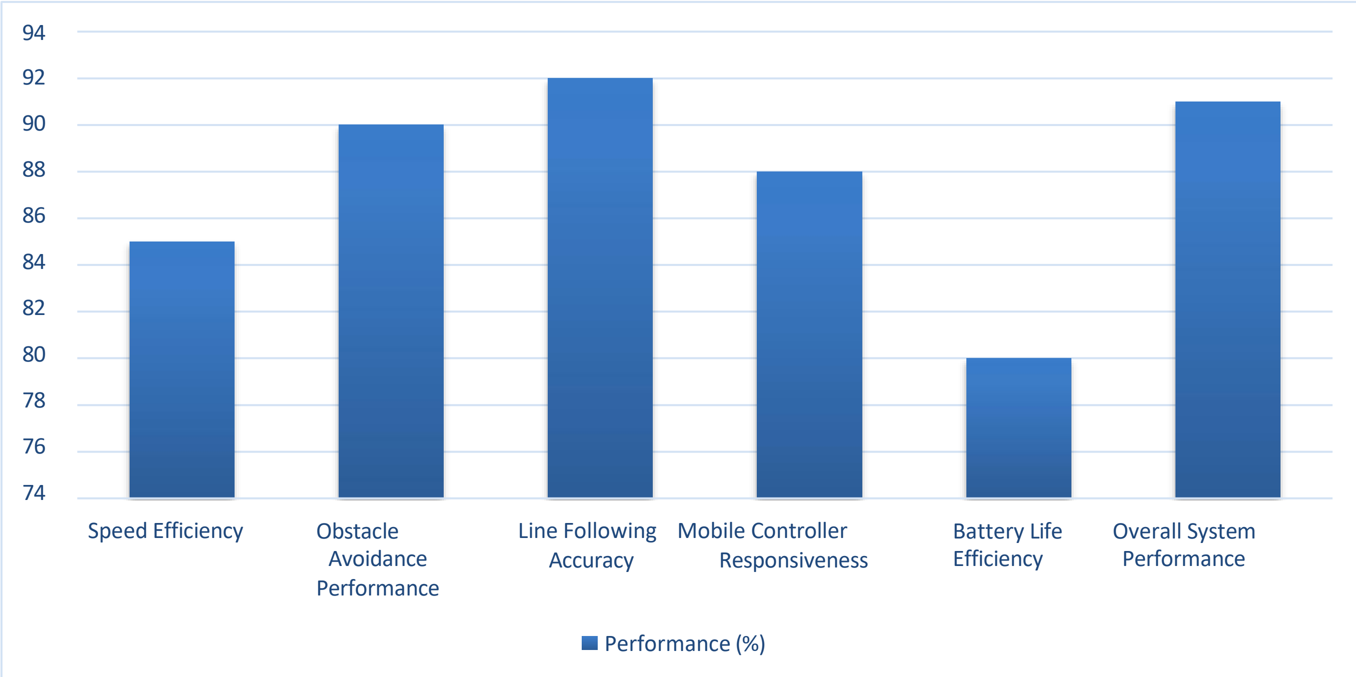

Fig.2: Performance Evaluation of the Automated Guided Vehicle (AGV)

APPLICATIONS

Autonomous Guided Vehicles (AGVs) have diverse applications across multiple industries:

1. Warehouse and Material Handling: AGVs automate goods transport and inventory management, improving efficiency.
2. Manufacturing: AGVs streamline assembly lines by transporting materials and finished goods.
3. Logistics and Distribution: AGVs help in package sorting and freight movement, optimizing logistics operations.
4. Healthcare: AGVs deliver medical supplies and assist with sanitization in hospitals.
5. Agriculture: AGVs monitor crops, collect data, and perform tasks like irrigation and fertilization.
6. Retail: AGVs assist with stock replenishment and customer guidance in large stores.
7. Hospitality: AGVs deliver room service and perform cleaning tasks in hotels.
8. Military: AGVs support surveillance, reconnaissance, and transport of supplies in military settings.
9. Construction: AGVs transport materials and monitor site safety on construction sites.
10. Education: AGVs are used for teaching robotics and testing autonomous systems.
11. Energy and Mining: AGVs inspect and maintain infrastructure and transport materials in energy and mining industries.

These applications demonstrate the growing importance of AGVs in improving operational efficiency, safety, and automation across sectors.

CONCLUSION

The design of a Smart Obstacle-Avoiding AGV with Mobile Controller for Efficient Line Following Navigation provides an innovative solution for enhancing autonomous vehicle navigation in dynamic environments. By integrating key technologies such as IR sensors for line detection, ultrasonic sensors for obstacle avoidance, and a mobile controller interface, the system demonstrates the ability to perform efficient and reliable navigation while overcoming challenges such as obstacles and path deviations.

The use of a microcontroller to process sensor data and control the actuators ensures smooth and adaptive operation, while the mobile controller allows for real-time remote monitoring and control, providing flexibility and ease of use for operators. Wireless communication via Bluetooth or Wi-Fi further enhances the system's usability, enabling remote adjustments and feedback.

This system's intelligent navigation approach, combining autonomous decision-making with human control through a mobile interface, makes it highly versatile for a range of applications, from industrial automation to logistics and warehouse management. The ability to follow lines accurately while avoiding obstacles in real time showcases the practical potential of this design.

Moving forward, further optimizations can be made to enhance the system's efficiency, scalability, and reliability. Improvements in sensor fusion, path-planning algorithms, and power management will continue to refine the AGV's performance, ultimately contributing to the broader adoption of autonomous systems in various industries. This design represents a significant step toward more intelligent and efficient AGV systems that can seamlessly navigate and adapt to real-world environments.

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