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A Review on Autonomous Navigation Robot Using Map-Based Guidance

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Abstract

This project presents the development of a Map-Guided Automated Guided Robot (AGV) designed for document delivery within a college campus. The robot is powered by an Arduino Uno microcontroller and integrates key components including IR sensors for obstacle detection, rotary encoders for position tracking, and motor drivers for movement control. The robot autonomously follows a predefined route to transport documents between designated locations on campus, avoiding obstacles and ensuring timely deliveries. The system utilizes an LCD display for destination selection, allowing users to specify delivery points. In the case of obstacle detection, the robot halts and alerts the user through a buzzer. The primary aim of this project is to enhance operational efficiency by automating the document delivery process, reducing the need for manual intervention, and minimizing the risk of delays and human error. The proposed solution offers a scalable, cost-effective method to automate routine tasks within educational institutions, providing a foundation for future advancements in robotics and automation. The integration of simple yet effective navigation algorithms and user interaction mechanisms in this system demonstrates the potential of autonomous vehicles for enhancing administrative workflows in academic environments.

INTRODUCTION

The growing demand for automation in various industries has led to the development of innovative solutions for routine tasks, particularly in educational environments. One such task is the delivery of documents within a college campus, which traditionally relies on human labor, leading to inefficiencies and delays. The proposed Map-Guided Automated Guided Robot (AGV) aims to address this challenge by automating the delivery process. Using an Arduino Uno microcontroller, IR sensors for obstacle detection, and rotary encoders for position tracking, the robot navigates predefined paths to transport documents between various locations on campus. It features an LCD display for user input, allowing destination selection, and incorporates a buzzer to alert users to obstacles in the robot's path. By automating the document delivery system, the proposed robot can improve efficiency, reduce manual labour, and optimize resource utilization on campus. This project represents a step towards integrating automation into educational settings, showcasing the potential of robotic systems to enhance administrative processes while reducing operational costs and human error.

Background

The application of automation and robotics has seen significant growth across various industries, with notable advancements in fields such as manufacturing, logistics, and healthcare. In educational institutions, however, the potential for automation has largely been underexplored, particularly in administrative tasks. One such task is the transportation of documents across a college campus, a process typically handled manually by staff or students. This conventional method is not only time-consuming but also prone to delays, human error, and inefficiencies. The need for a more efficient, reliable, and cost-effective solution to this problem has grown with the increasing complexity of campus operations and the demand for quicker administrative processes. Automated Guided Vehicles (AGVs) have long been employed in industrial settings to transport goods and materials. These systems utilize sensors, motors, and controllers to navigate predefined paths, ensuring efficient and accurate delivery. However, the adaptation of AGVs in academic environments, specifically for document delivery within campuses, remains a relatively unexplored area. The use of simple microcontroller-based systems, such as the **Arduino Uno**, combined with basic components like **IR sensors** and **rotary encoders**, offers a promising approach to develop a low-cost yet functional robot capable of autonomous navigation and delivery.[4]

In recent years, there has been a growing interest in leveraging automation to streamline campus operations. The integration of robotics into document handling can help minimize human workload, reduce operational costs, and enhance the overall efficiency of administrative functions. By employing AGVs for campus document delivery, educational institutions can benefit from faster processing times, improved resource utilization, and an overall reduction in manual tasks, leading to more streamlined operations and a reduction in operational bottlenecks.

Problem Statement

In the existing document delivery systems, manual intervention is often required to transport documents across campuses. This results in inefficiency, delays, human error, and resource waste. Additionally, traditional delivery methods lack automation and require significant human resources for routine tasks. While there have been advancements in AGV systems for industrial applications, implementing such systems in a college environment, particularly for document delivery, remains underexplored.[3] This gap in the existing systems creates an opportunity for improvement, particularly in automating routine administrative tasks in academic institutions.

Proposed System

The proposed system consists of an **Automated Robot** designed for document delivery within a college campus. The robot will be equipped with an **Arduino Uno** microcontroller, an **LCD display** for user interface, **IR sensors** for obstacle detection, and **rotary encoders** for position tracking.[4] The robot follows a predefined route from its home location to the selected destination using motor control and encoder feedback. The system incorporates basic obstacle avoidance mechanisms, where the robot halts and alerts the user with a **buzzer** in case of obstacles. The system is designed to be simple, scalable, and energy-efficient, providing an automated solution to streamline document delivery.

Aim and Objectives

The aim of this project is to design and develop a **Map-Guided Automated Robot** that autonomously delivers documents across a college campus. The specific objectives include:

- To develop an AGV that can navigate predefined routes using an **Arduino Uno microcontroller**.
- To implement **IR sensors** for detecting obstacles and ensuring safe navigation.
- To integrate an **LCD display** for destination selection and user interaction.
- To design a **motor control system** using **motor drivers** and **rotary encoders** to control movement and track position.
- To create a system that can handle basic obstacle avoidance and alert users to potential issues through a **buzzer**.
- To test and evaluate the system's effectiveness in real-world campus environments.

LITERATURE REVIEW

The use of Automated Guided Vehicles (AGVs) has significantly advanced in various fields, including logistics, manufacturing, and healthcare. However, in educational settings, their adoption remains limited, with most systems still being developed for larger industrial applications. The primary goal of AGVs is to provide autonomous navigation and material transport, and their development has been facilitated by advancements in microcontrollers, sensor technologies, and robotic systems. This section explores the existing literature on AGVs, their components, and their applications, especially in campus settings, and identifies gaps that this study seeks to address.

1. Navigation Control of Autonomous Guide Robot (Sadeghi Nam, 2020)

This work explored navigation control for an autonomous mobile guide robot designed for indoor environments. The behavior-based mapless navigation system enabled functions like localization, obstacle avoidance, and wall following. The research compared behavior-based and map-based navigation, emphasizing the former's advantages in dynamic environments. Mechanical deficiencies, such as wheel alignment and structural symmetry, were identified as major challenges. Despite these issues, the robot demonstrated efficient navigation without requiring pre-mapped environments. Future improvements aim to address mechanical limitations and enhance the robot's performance in real-world applications.[1]

2. RFID and Ultrasonic Sensor-Based Document Delivery Robot (Yingthawornsuk et al., 2021)

This research focused on the development of a document delivery robot tailored for office environments. The robot integrated an RFID-based security system and ultrasonic sensors for obstacle and line detection. It was capable of transporting documents securely by verifying the receiver's identity through card scanning. The system achieved a 70% task completion accuracy, with errors mainly attributed to hardware issues like card scanning failures. Despite its limitations, the prototype demonstrated potential in reducing manual labor and enhancing efficiency in document circulation within organizational setups. Planned improvements include refining hardware components to improve overall performance.[2]

3. Intelligent Autonomous Document Delivery Robot (Ganokratanaa & Ketcham, 2022)

This study introduces an intelligent document delivery robot powered by deep learning techniques. A convolutional neural network (CNN) was employed to recognize traffic lanes and stop signs using data from a monocular camera. The system demonstrated adaptability to diverse floor surfaces, such as terrazzo, canvas, and wood. The robot achieved an impressive accuracy of 96.31% during testing, making it highly effective in navigating structured environments. The innovation lies in its ability to move autonomously without additional lane reconstructions, requiring only modifications to stop sign placements. Future work aims to integrate sensors for simultaneous localization and mapping (SLAM), enhancing environmental recognition and movement precision.[3]

4. Arduino-Based Smart Delivery Robot (Manjula et al., 2022)

This paper proposed a line-following robot designed for autonomous load transport applications. The system utilized IR sensors and Arduino microcontrollers to navigate predefined tracks, supporting both visible and magnetic field-based paths. The robot included an IoT-enabled communication module for remote operations, making it suitable for industrial and domestic environments. The study highlighted the robot's ability to securely transport small loads using a delivery tray that unlocks only after user verification. Applications ranged from industrial automation to home tasks, such as floor cleaning and guiding paths in public spaces. The research underlines the potential of automation in addressing challenges related to traditional manual transport systems.[4]

5. LiDAR and Ultrasonic Sensor-Based Intelligent Obstacle Detection Systems for E-Vehicles. (Warule et al., 2024)

This study presented an advanced framework for integrating LiDAR sensors in autonomous electric vehicles (AEVs). The focus was on enhancing safety through data fusion, redundancy, and real-time environmental perception. With an accuracy of 99.02%, the model demonstrated high reliability in hazard detection and collision avoidance. The research emphasized the importance of cybersecurity protocols to protect sensor data and highlighted the potential of combining LiDAR with 360-degree binaural cameras for future applications. This innovative approach aims to advance autonomous driving technology while prioritizing safety for passengers and pedestrians.[5]

METHODOLOGY AND WORKING PRINCIPLE

The Map-Guided Automated Guided Robot (AGV) operates based on a simple yet effective methodology that integrates sensors, controllers, and actuators to autonomously navigate a predefined path and deliver documents. The robot is powered by an Arduino Uno microcontroller, which acts as the central controller to process inputs from various sensors and control the robot's movement. At the start of the process, the robot is placed at its home location, and the user selects the desired destination via an LCD display. The LCD display serves as the user interface, allowing easy selection from predefined destinations using buttons or switches.

Once the destination is set, the robot begins its journey by activating its motors through motor drivers, which control the movement of the robot along the predefined path. The robot relies on rotary encoders to track its movement, ensuring it stays on course by providing feedback on its position and movement accuracy. The robot also incorporates IR sensors that detect obstacles in its path. If an obstacle is detected, the robot halts and triggers a buzzer to alert the user. After the alert, the robot may either take an alternate route or remain stationary until the obstacle is cleared

As the robot progresses along its route, it continuously monitors its position and surrounding environment to navigate safely and efficiently. The use of rotary encoders ensures that the robot can maintain an accurate path, while IR sensors prevent collisions, enhancing the system's reliability. Upon reaching the destination, the robot stops, and the user is notified via the LCD display, signalling the completion of the document delivery. This method enables the robot to autonomously navigate a college campus, providing a practical solution for automated document delivery.

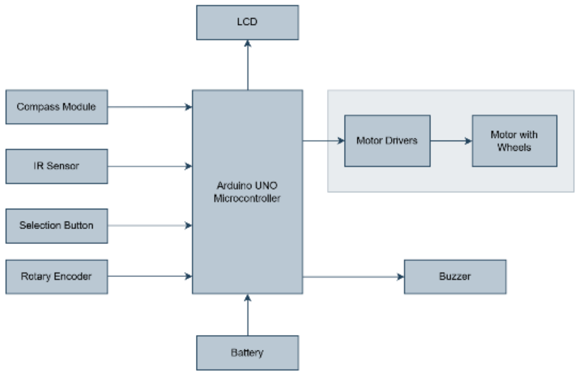

Fig1 Block Diagram

PROJECT REQUIREMENT

Hardware Requirements

1. **Arduino Uno Microcontroller**
   The **Arduino Uno** serves as the central control unit, processing sensor inputs and managing the actuators. It coordinates the robot's movement and obstacle detection.
2. **DC Motors with Motor Driver (L298N)**
   These motors drive the wheels of the robot, allowing it to move along the predefined path. The **L298N motor driver** controls the direction and speed of the motors.
3. **IR Sensors**
   The **IR sensors** are used for obstacle detection. They emit infrared light and detect its reflection from obstacles, helping the robot avoid collisions by halting or rerouting when an obstacle is detected.
4. **Rotary Encoders**
   Rotary encoders track the movement of the robot, providing feedback on the wheel's rotation to ensure precise navigation and positioning along the predefined route.
5. **LCD Display**
   The **16x2 LCD display** serves as the user interface for selecting the destination. It allows the user to input the destination room number or location, displaying relevant information for the user during the robot's operation.
6. **Push Buttons/Switches**
   These buttons are used to allow users to select the desired destination for document delivery. Each button corresponds to a different destination, enabling easy route selection.
7. **Buzzer**
   A **buzzer** is used to alert the user in case of an obstacle or any malfunction during the robot's operation, ensuring effective communication with the user.
8. **Chassis**
   A mobile robot chassis is required to hold all components (motors, sensors, microcontroller) and provide the robot with structural support. It should have wheels, a power source, and mounting positions for the components.
9. **Power Supply**
   A suitable **battery pack** (e.g., Li-ion or Li-poly) is required to power the robot's motors, sensors, and microcontroller, ensuring the system remains operational throughout its journey.
10. **Wires and Connectors**
    Various wires and connectors are necessary to make connections between the components (e.g., sensors, motors, Arduino).

Software Requirements

1. **Arduino IDE**
   The **Arduino Integrated Development Environment (IDE)** is required for writing and uploading the control program to the Arduino microcontroller. It is used to develop the logic for sensor input processing, motor control, and obstacle detection.
2. **C/C++ Programming Language**
   The robot's control program will be written in **C/C++**, which is compatible with the Arduino IDE. This will manage sensor data acquisition, motor control, user interface interactions, and obstacle detection.
3. **Arduino Libraries**
   Various Arduino libraries will be needed to interface with hardware components such as the **LCD display**, **IR sensors**, **motors**, and **buzzer**. Examples include:
   - **Liquid Crystal Library** (for the LCD display)
   - **Motor Driver Library** (for controlling motor speed and direction)
   - **IR Sensor Library** (for obstacle detection)
4. **Serial Monitor**
   The **Serial Monitor** in the Arduino IDE will be used for debugging and monitoring the robot's operations. It can display real-time data such as position tracking, sensor status, and motor commands.

5. **Route Mapping Software (optional)** In some cases, additional software may be required to design the path for the robot within the campus, though this can also be hardcoded into the Arduino program if predefined routes are used

Together, these hardware and software components enable the design and operation of the **Map-Guided Automated Robot**, allowing it to autonomously navigate and deliver documents within a college campus

APPLICATIONS AND ADVANTAGES

The Map-Guided Automated Robot provides numerous benefits and has diverse applications in various environments. The integration of automation and map-based navigation enhances operational efficiency, reduces costs, and offers significant educational and practical value. Below is a detailed discussion of its applications and advantages:

1. Campus Document Delivery : One of the primary applications of the Map-Guided Automated Robot is automating document delivery within a campus environment, such as universities, corporate offices, and research institutions. Traditionally, document transportation requires human effort, leading to delays and inefficiencies. This robot can autonomously navigate through predefined routes, ensuring:Reliable delivery of documents between administrative offices, departments, and faculty members.Reduced workload on office assistants, allowing them to focus on more important administrative tasks. Minimized human errors, such as misplaced or lost documents, improving the accuracy of the delivery process. Continuous operation, functioning even during non-working hours, thereby enhancing workflow efficiency.

2. Resource Optimization: By reducing the need for human intervention in routine transportation tasks, the robot enables organizations to optimize resource allocation. This is particularly useful in environments where: Staff members can focus on more critical and complex tasks, rather than spending time on mundane activities like document transportation. It eliminates dependence on human messengers, reducing delays caused by availability issues. It improves workforce efficiency by automating repetitive processes, allowing personnel to engage in higher-value tasks.

3. Educational Value: The Map-Guided Automated Robot serves as an excellent learning tool for students and researchers in the fields of robotics, automation, and artificial intelligence. Key educational benefits include: Hands-on learning experience in robotics, embedded systems, and autonomous navigation. Encourages research in areas such as motion planning, sensor fusion, and real-time mapping. Enhances programming and engineering skills, as students can modify and improve the robot's functionality. Facilitates interdisciplinary collaboration, enabling students from different domains (mechanical, electrical, and computer science) to work together on real-world applications.

4. Cost-Effectiveness: Implementing an autonomous delivery robot can significantly reduce operational costs in institutions and organizations. The cost benefits include:Reduction in manpower expenses, as fewer staff members are required for routine delivery tasks. Lower maintenance costs, as automated robots are more durable and require minimal servicing compared to employing multiple human couriers. Increased longevity of operations, as the robot can function continuously without additional costs for overtime work. Scalability, allowing organizations to deploy multiple robots for larger campuses or more extensive delivery networks without significant cost increases.

5. Time Efficiency: Time is a crucial factor in any operational environment, and the Map-Guided Automated Robot ensures timely and efficient task execution. The following points highlight how it improves time management: Predefined navigation routes allow the robot to take the shortest and most efficient path to its destination, reducing transit time. Eliminates human delays such as breaks, distractions, or fatigue, ensuring uninterrupted workflow. Optimized scheduling, allowing for automatic prioritization of urgent document deliveries. Consistent performance, as the robot can operate 24/7 without downtime, leading to improved overall productivity.

ADVANTAGES

The Map-Guided Automated Robot introduces numerous advantages in automation, efficiency, safety, and cost-effectiveness. By integrating smart navigation and autonomous control, it enhances productivity while reducing manual effort. The following sections provide a comprehensive explanation of these advantages:

1. Automation: Reduces Reliance on Human Labor for Routine Tasks One of the primary advantages of the Map-Guided Automated Robot is its ability to automate repetitive and labor-intensive tasks, reducing the dependence on human resources for document delivery. This automation provides the following benefits: Eliminates the need for human couriers, allowing staff to focus on more complex and value-driven responsibilities. Minimizes fatigue and human limitations, as the robot can function continuously without breaks, improving workflow consistency. Enhances accuracy and consistency, as automated systems follow predefined routes and schedules without deviation or forgetfulness. Increases reliability, as robots do not experience absenteeism or human-related inefficiencies such as miscommunication, delays, or errors. By leveraging automation, institutions and businesses can streamline operations, leading to improved productivity and optimal workforce utilization.

2. Efficiency: Improves the Speed and Reliability of Document Delivery The efficiency of document transportation is crucial in time-sensitive environments such as academic institutions, corporate offices, and research facilities. The robot's map-guided navigation system ensures fast and accurate deliveries, which leads to: Optimized route planning, allowing the robot to take the shortest and most efficient path, reducing delivery time. Consistent operational speed, ensuring that documents are delivered at a predictable rate without unnecessary delays. No dependency on human availability, as the robot can function 24/7, providing an uninterrupted workflow. Reduction in misplacements or lost documents, as the robot follows a structured delivery system, ensuring that every package reaches its intended destination. By automating deliveries, the system ensures that important documents reach their recipients in a timely manner, leading to improved organizational workflow and communication.

3. Safety: Reduces the Risk of Human Error in Document Handling Human errors in document transportation can lead to misplaced, delayed, or lost paperwork, potentially affecting critical operations. The Map-Guided Automated Robot enhances safety through: Accurate document handling, ensuring that items reach the right location as per the programmed instructions. Elimination of human-related mishandling, such as dropping, misplacing, or delivering documents to the wrong recipient. Secure and controlled access, as the robot can be designed to restrict unauthorized access to sensitive documents. Minimized risk of accidents, particularly in high-traffic environments where manual couriers might encounter obstacles or distractions. With a structured and autonomous approach, sensitive documents can be delivered securely and reliably, reducing administrative errors and inefficiencies.

4. Cost-Effective: Lowers Operational Costs Compared to Manual Delivery Methods Cost efficiency is a significant consideration for organizations looking to reduce expenses while maintaining high productivity. The Map-Guided Automated Robot provides a financially viable alternative to traditional delivery methods in the following ways: Reduces labor costs, as fewer personnel are required for document transportation. Minimizes overhead expenses, such as wages, benefits, and training costs associated with hiring human couriers. Requires minimal maintenance, as modern autonomous robots are built for durability and can operate with minimal servicing. Long-term investment benefits, as the robot's ability to function continuously leads to savings over time.

CONCLUSION

The **Map-Guided Automated Robot** presents an innovative solution to automate document delivery across a college campus. By leveraging **Arduino-based control**, **IR sensors**, **rotary encoders**, and other basic components, this system offers a practical and cost-effective alternative to traditional delivery methods. The proposed solution demonstrates the potential of autonomous systems in educational environments, providing a basis for further research and development in the field of robotics and automation. Future enhancements may include adding more sophisticated navigation algorithms, integrating wireless communication for remote control, and extending the system to handle more complex tasks.

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