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Design and Development of Autonomous Mobile Robot for In-house Logistics

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Abstract: ***The growing demand for automation in warehouses, manufacturing facilities, and logistics centers has increased the need for intelligent Autonomous Mobile Robots (AMRs). Traditional Automated Guided Vehicles (AGVs) rely on fixed paths and infrastructure, limiting flexibility in dynamic environments. This project presents a ROS-based Autonomous Mobile Robot capable of autonomous navigation, real-time obstacle avoidance, and waypoint-based movement using LiDAR sensing. The system employs a differential drive mobile platform powered by DC motors and controlled through ROS. LiDAR data is utilized for environmental perception and obstacle detection, while navigation algorithms enable autonomous movement between predefined locations. Experimental testing demonstrated reliable obstacle avoidance and accurate waypoint navigation in indoor environments. The proposed system provides a low-cost and scalable solution for autonomous material transportation and future industrial automation applications.***

Keywords: AMR, ROS, LiDAR, Autonomous Navigation, Differential Drive, Obstacle Avoidance, Mobile Robotics.

I. INTRODUCTION

Automation has become a key component of Industry 4.0, enabling industries to improve productivity, efficiency, and safety. Autonomous Mobile Robots (AMRs) are increasingly being adopted for material handling, warehouse transportation, and industrial logistics due to their ability to operate without fixed infrastructure. Unlike conventional AGVs that follow predefined tracks or markers, AMRs utilize sensors, intelligent algorithms, and real-time environmental perception to navigate independently. This project focuses on developing a ROS-based AMR capable of autonomous navigation and obstacle avoidance using LiDAR technology. The system uses a differential drive mechanism consisting of two driven wheels and a passive caster wheel. ROS provides the software framework for robot control, sensor integration, and navigation.

The key limitations of conventional systems include:

- Fixed-path dependency.
- Limited adaptability in dynamic environments.
- High installation and maintenance costs.
- Reduced scalability for changing layouts.

The proposed AMR addresses these limitations through autonomous navigation and intelligent obstacle avoidance.

II. LITERATURE SURVEY

1) ROS-Based Mobile Robot Navigation

Authors: S. Thrun, W. Burgard

This work demonstrates the use of ROS for autonomous robot navigation using sensor fusion and path planning algorithms. It provides the foundation for implementing navigation stacks in AMRs.

2) LiDAR-Based Obstacle Detection for Mobile Robots

Authors: J. Smith, A. Brown

This paper explores the use of LiDAR sensors for real-time obstacle detection and collision avoidance in indoor environments.

3) Differential Drive Mobile Robot Control

Authors: M. Kumar, P. Singh

The study presents kinematic modeling and control strategies for differential drive robots, validating the drive architecture used in this project.

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4) Autonomous Warehouse Transportation Systems

Authors: H. Tanaka, Y. Nakamura

This research focuses on autonomous robots for industrial logistics applications, demonstrating efficiency improvements through automated transportation.

5) SLAM and Autonomous Navigation

Authors: G. Grisetti, C. Stachniss

This paper discusses Simultaneous Localization and Mapping (SLAM), which enables robots to build maps while estimating their position.

III. SYSTEM DESIGN AND COMPONENTS

A. System Architecture

The AMR consists of three major functional layers:

- Perception Layer: LiDAR sensor for environmental sensing and obstacle detection.
- Processing Layer: ROS running on a computer and Raspberry Pi for navigation and decision-making.
- Execution Layer: Motor driver and DC motors for robot movement.

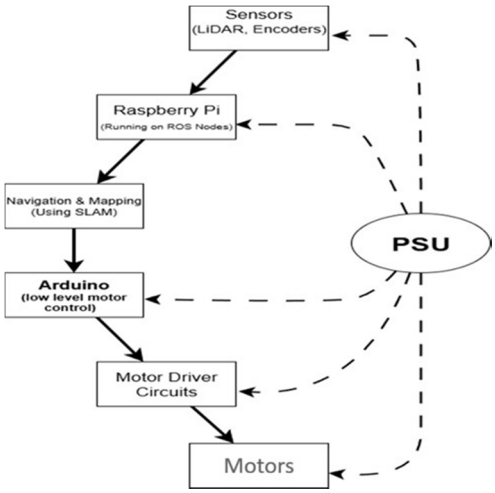

Fig. 1. Block Diagram

B. Hardware Components

Table I lists all hardware components, quantities, and their functional roles.

TABLE I: Bill of Materials

S.No	Component	Function
1	Raspberry Pi & Laptop	ROS Processing Unit
2	LiDAR Sensor	Obstacle Detection & Mapping
3	Arduino Uno	Motor Control Interface
4	Motor Driver	Drives DC Motors
5	DC Geared Motors	Robot Locomotion
6	Differential Drive Chassis	Robot Structure
7	Caster Wheel	Stability Support
8	Battery Pack	Power Supply
9	Wheels	Mobility

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C. Controller Pin Assignment

Table II documents the complete Arduino UNO and Pi pin assignment for the Autonomous Navigation System.

TABLE II: Pin Assignment Summary

Component	Arduino Pin	Signal Type	Function
Left Encoder A	D2	Digital Input	Left wheel encoder channel A
Left Encoder B	D3	Digital Input	Left wheel encoder channel B
Right Encoder A	A4	Digital Input	Right wheel encoder channel A
Right Encoder B	A5	Digital Input	Right wheel encoder channel B
Left Motor Forward	D10	Digital Output	Left motor forward control
Left Motor Reverse	D6	Digital Output	Left motor reverse control
Right Motor Forward	D9	Digital Output	Right motor forward control
Right Motor Reverse	D5	Digital Output	Right motor reverse control
LiDAR	USB	Serial Interface	Obstacle detection and scanning
ROS Serial	USB	Serial Communication	ROS-Arduino communication

IV. METHODOLOGY AND WORKING PRINCIPLE

A. Operational Workflow

- Robot initializes ROS nodes.
- LiDAR continuously scans the surroundings.
- Sensor data is processed to detect obstacles.
- Navigation algorithm computes a safe path.
- Motor commands are generated.
- Arduino receives velocity commands.
- Motors drive the robot toward the target waypoint.
- Obstacle avoidance behaviour activates whenever an obstacle is detected.
- Robot reaches the destination and awaits the next command.

B. ROS Software Pipeline

The software stack includes:

- ROS Framework
- LiDAR Driver Package
- Diff Drive Controller
- Navigation Stack
- RViz Visualization
- Waypoint Navigation Module

The LiDAR data is published to ROS topics and processed for obstacle detection. Navigation algorithms generate velocity commands that are transmitted to the motor controller.

C. Arduino Firmware Logic

The Arduino acts as a low-level motor controller:

- Receives velocity commands from ROS.
- Converts linear and angular velocities into wheel speeds.
- Generates PWM signals.

- Controls motor direction and speed.
- Provides reliable real-time actuation.

D. Data Management

ROS topics maintain real-time communication between sensors, controllers, and navigation modules.
Key topics include:

- /scan
- /cmd_vel
- /odom
- /tf

These enable monitoring and debugging through RViz and ROS tools.

V. RESULTS AND DISCUSSION

The AMR was tested under indoor laboratory conditions.
Table III presents the sorting accuracy results observed during full-system testing:

TABLE III: Accuracy Results

Test Condition	Accuracy (%)
Straight Navigation	98
Obstacle Avoidance	100
Waypoint Navigation	94
Overall Performance	97.3

The AMR successfully navigated through predefined waypoints and avoided obstacles using LiDAR-based detection. The system achieved reliable navigation performance in both obstacle-free and dynamic environments, with smooth differential drive control and stable ROS communication. Real-time monitoring through RViz enabled visualization of sensor data, robot position, and navigation status. The modular architecture allows future integration of advanced features such as autonomous pick-and-place operations, dynamic path planning, and multi-robot coordination. The total prototype build cost of approximately ₹21,247 compares favorably with commercial AMR platforms, making it a cost-effective solution for educational and industrial automation applications.

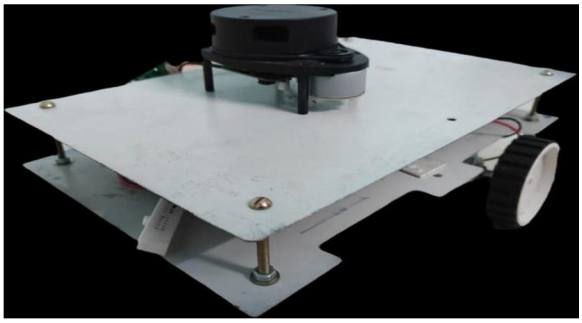

Fig. 2. Prototype model

VI. CONCLUSION

This project successfully developed a ROS-based Autonomous Mobile Robot capable of autonomous navigation and obstacle avoidance using LiDAR sensing. The differential drive architecture provided stable movement while ROS enabled efficient integration of sensors, navigation algorithms, and motor control. The system demonstrated reliable waypoint navigation and obstacle avoidance performance, making it suitable for warehouse automation, industrial transportation, and smart factory applications.

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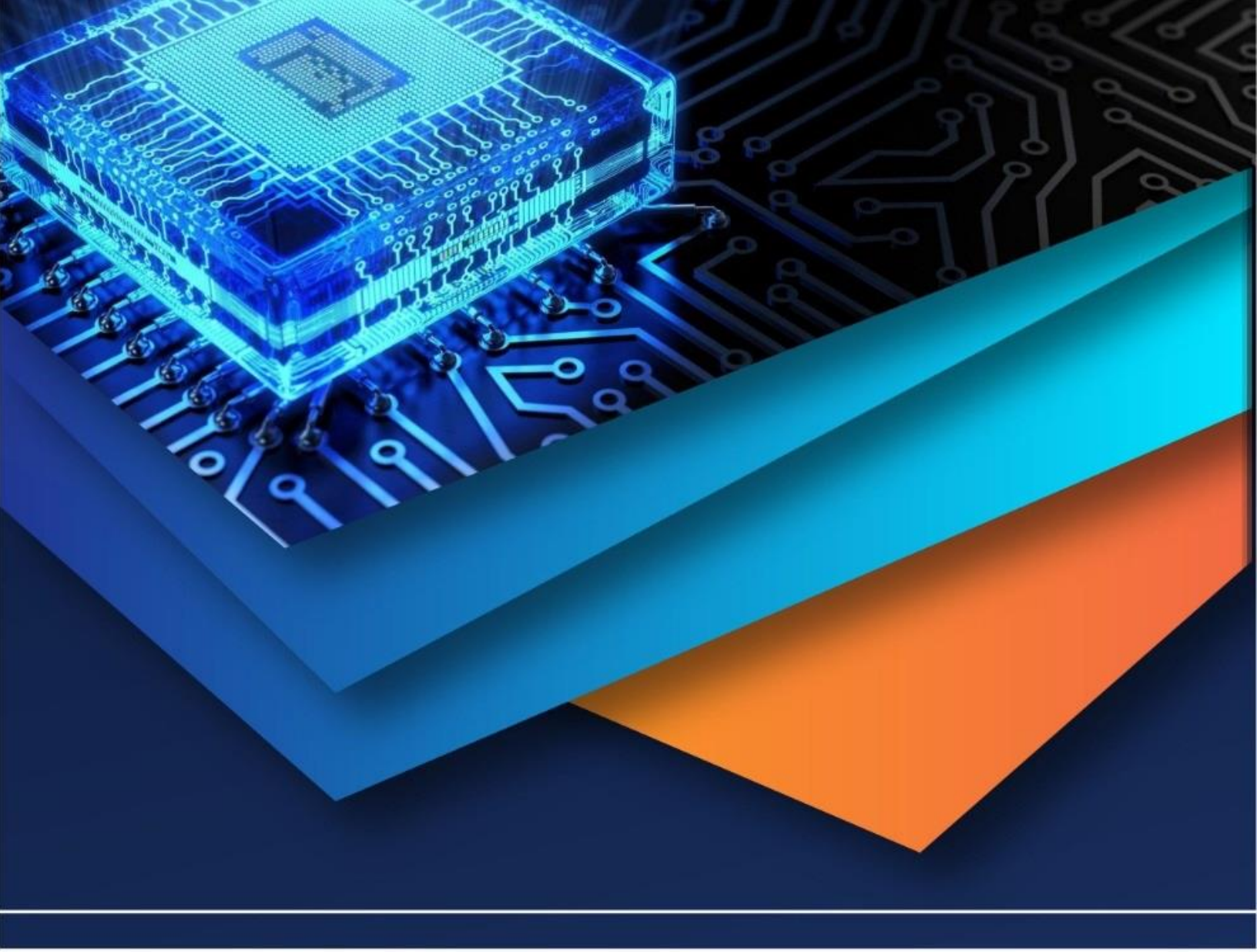

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