

Auto Guided Vehicle (AGV)

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Abstract - This project presents the design and development of an Autonomous Guided Vehicle (AGV) capable of performing autonomous navigation, real-time mapping, localization, and obstacle detection using embedded systems and ROS2-based robotic architecture. The developed AGV integrates hardware components such as Raspberry Pi, ESP32 microcontroller, YDLIDAR S2 Pro, ICM-20948, wheel encoders, BTS7960 motor drivers, and 18V DC planetary geared motors to achieve autonomous robotic operation. The Raspberry Pi acts as the main processing unit responsible for running the ROS 2, SLAM Toolbox, localization, and navigation processes, while the ESP32 performs low-level motor control and encoder processing. Communication between the Raspberry Pi and ESP32 is established using Wi-Fi-based UDP communication for real-time data transfer and motor command execution. The LiDAR sensor is used for environmental scanning and map generation, while the IMU sensor and wheel encoders provide orientation and odometry data for accurate localization and movement estimation. The AGV operates using a differential drive mechanism and is capable of performing forward, reverse, left, and right movements along with autonomous navigation within the mapped environment. The system successfully generated real-time maps, performed localization, visualized sensor data in RViz2, and demonstrated autonomous movement using ROS2-based communication and SLAM techniques. The project provides a low-cost and scalable robotic platform suitable for applications in industrial automation, warehouse material handling, and autonomous indoor transportation systems.

1. INTRODUCTION

An Automated Guided Vehicle (AGV) is a robotic transportation system designed to move materials from one location to another without direct human intervention. AGVs are widely used in industries, warehouses, hospitals, airports, and manufacturing units for carrying raw materials, finished products, tools, and equipment. These systems operate using predefined navigation techniques such as line following, magnetic

guidance, laser guidance, RFID tracking, or vision-based navigation. The primary objective of AGVs is to improve operational efficiency while maintaining safety and consistency in material handling operations. The proposed project focuses on the design and implementation of a line-following Automated Guided Vehicle integrated with obstacle detection and autonomous navigation capabilities. The system is developed using an ESP32 microcontroller, IR sensor array, ultrasonic sensor, motor driver module, and DC geared motors. The AGV follows a predefined path using infrared sensors while continuously monitoring obstacles in its surroundings through ultrasonic sensing technology. Whenever an obstacle is detected within a specific range, the vehicle automatically stops to prevent collision and resumes operation after the path becomes clear.

The ESP32 microcontroller acts as the central control unit of the entire system. It receives input data from the sensors, processes the information, and generates control signals for motor movement. The integration of wireless communication capability through ESP32 also makes the system suitable for future IoT-based industrial automation applications. Compared to traditional transportation methods, the proposed AGV system offers reduced human dependency, improved transportation accuracy, lower operational fatigue, and better adaptability in industrial environments. During the development of this project, special attention was given to system simplicity, low implementation cost, ease of operation, and practical industrial usability. Various testing procedures were performed to evaluate line-following accuracy, motor response, obstacle detection range, and overall system stability. The project also helped in understanding important concepts related to embedded systems, sensor interfacing, motor control, automation logic, and autonomous robotic systems. This AGV project demonstrates how automation and embedded technology can be effectively combined to create intelligent transportation systems for modern industrial applications. The system can further be enhanced using advanced technologies such as artificial intelligence, machine vision, SLAM-based navigation, cloud monitoring, and automatic

charging mechanisms to achieve higher levels of industrial automation and operational intelligence.

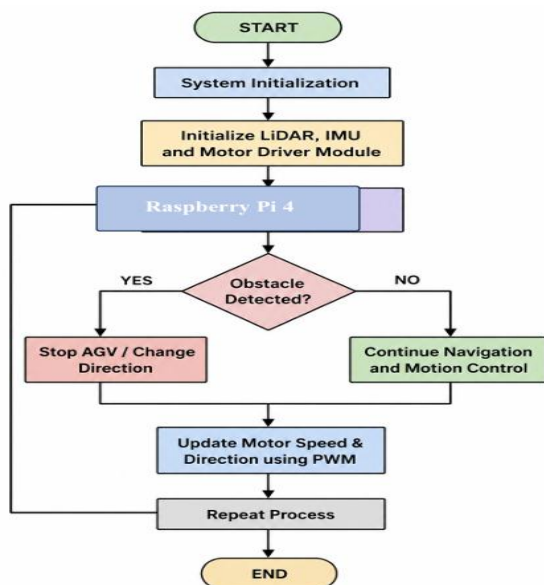
2. METHODOLOGY

Process of Natural Navigation Flow Chart for AGV

1. LiDAR Sensor (Mapping) The LiDAR sensor continuously scans the surrounding environment and measures distances to nearby objects to generate real-time range data.
2. Processor (ROS) The onboard processor (Raspberry Pi running ROS) receives LiDAR data and performs SLAM algorithms to create a map, determine the AGV's position, and plan the movement path.
3. Microcontroller (Feedback Control) The processor sends motion commands to the microcontroller (Arduino Nano), which handles real-time control and interprets the commands for motor operation.
4. Motor Driver The microcontroller sends control signals to the motor driver, which supplies the required voltage and current to the motors.
5. Encoders (Feedback) Encoders attached to the motors measure speed and position and send this feedback to the microcontroller for correction.
6. Motors (Movement) The motors rotate according to the control signals, causing the AGV to move along the planned path.
7. Closed-loop Operation The encoder feedback continuously updates the microcontroller, ensuring accurate speed, direction, and safe navigation throughout the operation.

Flowchart Explanation:

The flowchart represents the operational sequence of the software system implemented in the Automated Guided Vehicle. The process begins with system startup, where the ESP32 microcontroller powers on and initializes all connected hardware modules. During initialization, communication interfaces, sensor modules, GPIO configurations, and motor control pins are activated. This stage ensures that all system components are functioning correctly before autonomous operation begins. After initialization, the LiDAR sensor, IMU sensor, and motor driver module are configured for real-time operation. The LiDAR sensor starts scanning the surrounding environment by continuously measuring distances between the AGV and nearby objects. Simultaneously, the IMU sensor begins monitoring acceleration, angular movement, and directional orientation of the vehicle. These sensors continuously provide real-time information required for autonomous navigation and motion stability. Once sensor initialization is completed, the controller enters a continuous sensor monitoring stage. In this stage, the ESP32 repeatedly collects and processes LiDAR and IMU sensor data. The software analyzes the received information to identify obstacles, determine safe movement directions, and maintain vehicle stability. Real-time monitoring is important because industrial environments may contain dynamic obstacles and continuously changing movement conditions. The obstacle detection stage plays an important role in maintaining operational safety. The controller compares measured LiDAR distance values with predefined safety thresholds. If an obstacle is detected within the danger range, the software immediately interrupts normal movement and generates stopping or directional correction commands. This prevents collisions and protects both the AGV system and surrounding industrial equipment. If no obstacle is detected, the AGV continues normal navigation and movement operations. During this stage, the software continuously updates motor control signals according to navigation requirements and IMU orientation data. PWM-based motor control techniques are used to regulate speed and directional movement. Smooth motor control improves navigation stability and reduces unnecessary vibration during operation. After executing navigation and motor control functions, the controller repeats the entire process continuously in a loop. This continuous monitoring and control mechanism allows the AGV to operate autonomously without human intervention. The flowchart demonstrates how sensing, processing, decision-making, and motor control operations are



Flowchart:
Figure 1: Flowchart.

integrated together to achieve reliable and intelligent AGV movement.

3. MODELING AND ANALYSIS

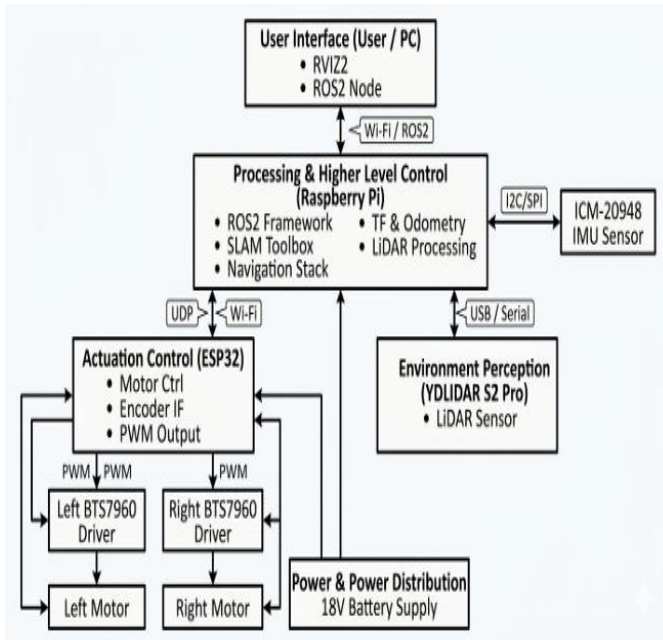


Figure 2: Block Diagram.

Block Diagram Description:

The block diagram of the proposed Automated Guided Vehicle (AGV) system represents the interaction between sensing units, processing units, motor control systems, and power management modules. The ESP32 microcontroller acts as the central control unit responsible for coordinating all system operations. It continuously receives sensor information, processes navigation logic, and generates motor control signals required for autonomous vehicle movement.

The LiDAR sensor is connected to the ESP32 controller for real-time environmental scanning and obstacle detection. It continuously measures the distance between the AGV and surrounding objects using laser-based ranging techniques. The collected distance information helps the AGV identify obstacles and make navigation decisions during movement. Compared to traditional proximity sensing methods, LiDAR provides improved scanning accuracy and better environmental awareness.

The IMU sensor is integrated to monitor acceleration, angular rotation, tilt, and directional movement of the AGV. The sensor provides real-time orientation data that helps maintain vehicle stability and improves movement precision during turning operations and dynamic motion

conditions. The IMU also assists in reducing navigation errors caused by sudden movement disturbances or uneven surfaces.

The ESP32 controller processes all sensor information and sends PWM-based control signals to the motor driver module. The motor driver circuit amplifies these signals and supplies sufficient current to operate the DC geared motors. The motors are responsible for the forward, reverse, and directional movement of the AGV system. The power supply unit provides regulated voltage to all electronic components including sensors, controller, and motor driver circuits. Stable power management is important for maintaining reliable sensor readings and uninterrupted AGV operation. Wireless communication capability through the ESP32 also allows future implementation of remote monitoring and IoT-based industrial automation features.

4. RESULTS AND DISCUSSION

Chart 1. Overall Results

Step No.	Procedure	Results
1	Power On	Power supply was provided to all devices successfully. Raspberry Pi connected to Wi-Fi, ESP32 received power supply to IMU, and motor drivers were initialized successfully for receiving velocity commands.
2	Starting UDP Bridge	Wireless UDP bridge was created successfully between Raspberry Pi and ESP32 using the same Wi-Fi connection for communication.
3	Launching LiDAR Driver	LiDAR scanning started successfully using predefined parameters such as port name, baud rate, frame ID, topic name, and frequency.
4	Starting Velocity Bridge	Velocity command transmission was established successfully using JSON data between Raspberry Pi and ESP32 for AGV movement control.
5	Creating Keyboard Teleop	Manual keyboard teleoperation was achieved successfully for initial AGV movement and testing.
6	Initializing SLAM Toolbox	SLAM Toolbox successfully processed LiDAR and odometry data to determine the current position and heading of the AGV.
7	Visualization on RViz	Clear visualization of the map and real-time AGV location was displayed successfully on the laptop screen using RViz.
8	Initial Manual Control for Generating Map	AGV was manually guided successfully to generate and save the environment map in the software.
9	Autonomous Navigation using Nav2 Software	Autonomous navigation was achieved successfully. The AGV navigated automatically between selected target points on the saved map.

6. REFERENCES

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