Autonomous Navigation Mobile Robot using ROS, Raspberry Pi, RP Lidar, and Differential Drive Kinematics

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***Abstract*— Robots have transformed logistics, manufacturing, and exploration by automating tasks like mapping, navigation, or exploring the world. Additionally. The project is focused on creating an autonomous navigation robot that incorporates the latest technologies, including the Robot Operating System (ROS), Rapberry Pi 4 for computation, and RP Lidar for environmental scanning. Using differential drive (included in the robot) kinematics, it will be capable of real-time decision making and precise movement.**

Path planning and obstacle avoidance. By utilizing Simultaneous Localization and Mapping (SLAM) to navigate through unfamiliar terrain, the robot will ensure safe and reliable navigation without collisions.

***Keywords*— Autonomous Navigation Mobile Robot (ANMR),ROS, RPLidar, Raspberry Pi 4, Differential Drive Mechanics**

I. INTRODUCTION

Robotics Technology has been evolving at a greater pace in these recent years, with the development of Autonomous Robots using Mobile. The non-interaction and noninvolvement of human supervision may lead to the creation of new industries in logistics, farming, healthcare, automation. Tasks like mapping, navigation and moving are performed efficiently and with reliability. By using these new advanced technologies like Robot Operating System(ROS), Raspberry Pi, RP Lidar, and the differential drive mechanics, builds a solid foundation in developing more versatile and flexible autonomous systems that can interact and make decisions in real-time. The main aspect of this project is to create a robot which can be handled using a mobile and can navigate through taxing environments by utilizing these technologies. The robot's ROS, sensor data processing, and RP Lidar scanning capabilities enable it to avoid obstacles with accuracy and speed. SLAM is utilized by the robot to navigate through unfamiliar terrain and map its surroundings without any risks, while also maintaining safety. This project has broad potential applications in various industries, where automating navigation tasks can improve efficiency, safety, and operational costs. By developing a functional prototype, the project seeks to expand the research on autonomous robotics and investigate practical applications that can be developed in the future.

II. METHODOLOGY

BLOCK DIAGRAM

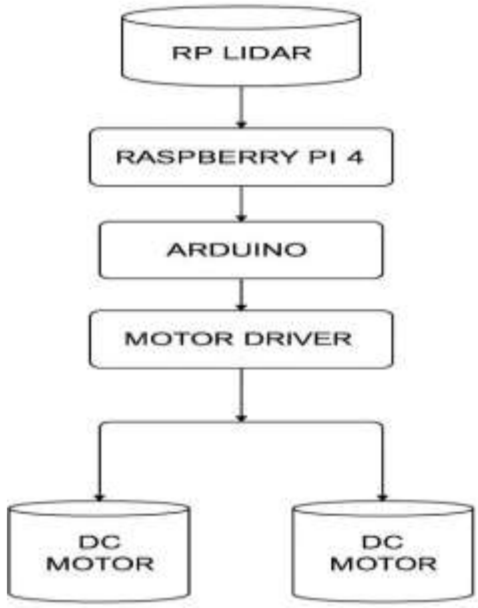


Fig 1.0 Block Diagram of Autonomous Navigation Mobile Robot

The presented a block diagram that illustrates the workings of an autonomous mobile robot. This provides a human-readable account of how the components work:

1. RP Lidar: The RP LIDAR system is designed to provide enhanced light detection and range. The robot's environment is first scanned by the RP LIDAR sensor, which takes a complete 360-degree picture of the robot. Lasers are fired by the device,

which measures the time it takes for reflection to return and distances from surrounding objects to be measured. A 2D map of the surroundings is produced, which aids in identifying obstacles, open areas, and structural boundaries in real time.

2. Raspberry Pi 4: The robot's brain is formed by the Raspberry Pi 4 which receives raw scan data from a LIDAR sensor via serial or USB communication. The Pi's quad-core processor and ample RAM are paired with the Robot Operating System (ROS) to process data. The algorithms used to detect obstacles, localize them, implement SLAM (Simultaneous Localization and Mapping), and plan routes are implemented. Based on the LIDAR input, the Pi determines the most efficient motion strategy and sends movement commands to the Arduino controller.

3. The Robot Operating System (ROS): The Raspberry Pi 4 features ROS, an open-source middleware that runs on its board. The framework is based on tools, libraries, and communication infrastructure that enable seamless interaction between modules (sensors, control logic, mapping, etc.). Module development is made possible by the use of nodes and topics for message passing. From subscribing to sensor data, publishing velocity commands, logging system data and real-time visualization via tools like Rviz, ROS is the primary handling of this.

4. Arduino Microcontroller: A low-level control unit is provided by the Arduino board.It is able to process high-level motion commands, usually sent over serial communication from the Raspberry Pi, into an electrical signal that control the motor driver. By ensuring real-time response and actuation, it serves as a bridge between high-level planning and low-dimensional hardware control.

5. Motor Driver Module: A motor driver, such as L298N or other similar devices, is used to interface with the motors in the Arduino. The motors are powered by the device, which accepts PWM and directional inputs from the Arduino and supplies the required voltage and current. The robot can move forward, reverse, or make precise turns due to the ability to control the speed of both motors and perform bidirectional motion.

6. Two DC Motors: The robot's operation is based on the use of two DC motors in a differential drive setup. Depending on how the motor driver is energized, these motors control the robot's movement by providing direction and speed. Depending on the speed at which each motor operates, the robot can rotate in place, move along a track (e.g, turning left or right), or spin vertically. By incorporating feedback for closed-loop control, motion accuracy can be improved by adding encoders. Two DC Motors: The robot's operation is based on the use of two DC motors in a differential drive setup. Depending on how the motor driver is energized, these motors control the robot's movement by providing direction and speed. Depending on the speed at which each motor operates, the robot can rotate in place, move along a track (e.g, turning left or right), or spin vertically. By incorporating feedback for closed-loop control, motion accuracy can be improved by adding encoders.

Summary: The RP LIDAR collects environmental data that is sent to the Raspberry Pi 4 by ROS, which uses real-time algorithms to generate control commands. The Arduino receives and interprets these commands as signals that can be used to drive the motor. The robot's ability to navigate, avoid obstacles, and reach designated targets is dependent on the two DC motors powered by a motor driver. In addition to facilitating integration and debugging, this well-organized and modular setup provides room for future improvements such as GPS navigation, object recognition, or voice control.

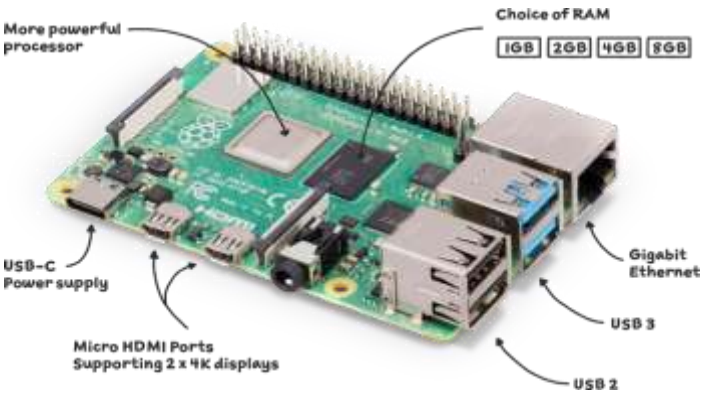
Listed Below are the key Components:

1) RP Lidar A1-M8

.Designed for 2D mapping and obstacle detection, the new RP Lidar A1-M8 is a powerful LiSAR sensor that also consumes less power. It has a 360-degree scanning range that allows it to measure measurements from 0.15 to 12 meters and an impressive accuracy of 1% in 0.5m to 6 meters.

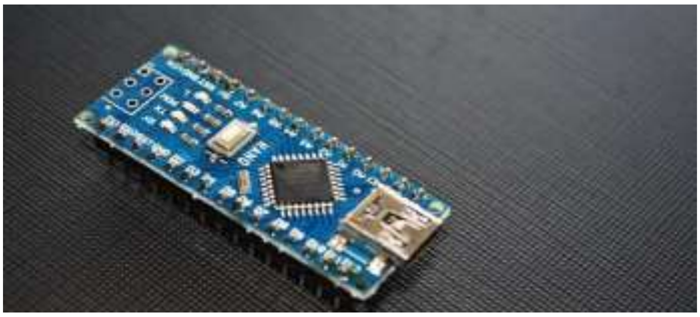
The sensor's real-time environmental mapping and localization capabilities make it a popular choice for robotics, autonomous vehicles, and drone navigation. By using a serial interface, the A1-M8 is easily able to communicate with various microcontrollers and computing platforms. This makes it ideal for integration into robotic systems.

2) Raspberry Pi 4 Model B



The Raspberry Pi 4 Model B is utilized to execute the ROS framework, sensor communication, and SLAM and navigation algorithm processing. It has a quad-core processor with accessible 2 GB/4 GB RAM that guarantees real-time data processing efficiency. GPIO, I2C, SPI, and UART interfaces provide interfaces to communicate with Arduino and other sensors. It is connected to peripherals through USB and Ethernet, and is powered by a 5V/3A USB-C power supply, and is ideal for effective robotic control in a small package.

3) Arduino Nano.

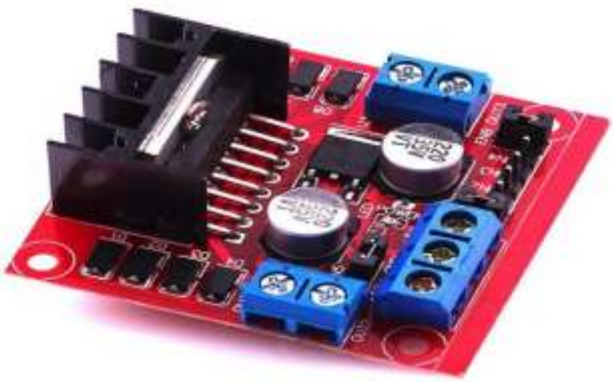


Using the ATmega328P microchip, the Arduino Nano is a small and easily breadboard-compatible microcontroller board that uses circuit breakers.

With 14 digital input/output pins, 8 analog inputs and a USB connection for easy power programming, the device is versatile. Both hobbyists and professionals favor the Nano due to its compact size, ease of use, and compatibility with the extensive Arduino ecosystem.

Small form factors are the determining factor for projects like robotics, wearables and home automation systems. Prototype and development of various kinds can be easily achieved by users with the help of a wide range of libraries and community support.

4) L298N 2A Based Motor Driver Module.



With the L298N motor driver module, a dual H-bridge driver is available that can handle up to two DC motors or one stepper motor with an output current of 2A per channel. It has built-in diodes for back EMF protection and operates at voltages of 5V–35V. By enabling forward and reverse movement, the L298N motors can be controlled in both directions, making it a key element in robotics/automation projects. Interface: The module is easy to use with microcontrollers like Arduino and Raspberry Pi, and speed control via PWM signals.

5) DC Motor

The DC gear motor that is utilized by the autonomous mobile robot is in its best condition when operated over a voltage level of 6V to 12V with the optimal functioning at 12V. The motor gives a no-load speed of around 300 RPM and offers a rated torque of around 2.5 kg·cm, thereby being well fit for powering lightweight robotic platforms. Its small size, along with a reasonable gear ratio, provides controlled movement and sufficient torque output for navigation and obstacle avoidance. The motor consumes low current during no-load operation, adding to overall energy efficiency, while its robust shaft and standard mounting dimensions facilitate ease of integration into robotic chassis designs.

6) Wheels.

Mobility: Wheels are used in mobile robotic systems, which enable them to move around different terrains. The robot's size and material choice are determined by its intended application. Typically, wheels are constructed to decrease friction and increase traction in robotic applications.

Choosing the right type of wheels for the robot is crucial to its desired outcome, as these wheels will impact its mobility, balance, and control characteristics. Combined motor drivers with wheels allow for precise control of the vehicle's motion.

7) Ball Caster Wheel.

Essentially, it's the equivalent of a ball in tyres that is mounted inside an otherwise stationary object to move smoothly through its surroundings.

This wheel is often used in robotics and automation systems because it can pivot freely in any direction.

This design also helps mobile robots navigate around tight spaces or sharp turns. Ball caster wheels offer greater stability, reduced weight, and resistance, making them ideal for balancing and mobility applications in robotic systems.

III. FINDING FROM LITERATURE SURVEY

From the literature survey following gaps are identified:

1) SLAM algorithm and LIDAR sensors enable the robot to map out and detect obstacles in areas it has not been exposed to before, providing real-time obstacle detection. It is effective even in

chaotic and active settings.

2) The use of differential drive kinematics is effective for autonomous robots in controlled environments, such as warehouses or hospitals, but extra sensors or balance mechanisms are necessary for rough terrain or outdoor applications.

3 Raspberry Pi 4 is featured as an emerging embedded platform because of its ability to handle real-time sensor data processing and utilize light-weight navigation algorithms. Since the device lacks special AI hardware and is susceptible to thermal throttling under heavy loads, its efficiency and flexibility make it appropriate for utilization on mobile robotic systems provided there are effective cooling mechanisms.

4) An open-source and modular framework called ROS Framework, it is widely used to incorporate a variety of sensors and actuators. This allows for flexibility in experimentation with different robotic systems and navigation issues.

5) Research stresses the need for effective integration of hardware and software parts. The integration of RP Lidar, Raspberry Pi 4, differential drive mechanisms, and ROS results in agile, low-cost autonomous robots. Optimal performance across various environments, though, demands power constraints, computational overheads, and physical terrain difficulties to be addressed.

IV. GAP IDENTIFICATION

1) The sensitivity of differential drive kinematics is optimal for indoor environments with smooth surfaces, but not as effective in outdoor terrains with uneven surfaces. To overcome this issue, additional balance systems or alternative methods of locomotion like omnidirectional wheels or advanced suspension systems are necessary, as it can aid in navigation on uneven terrain.

2) Raspberry Pi 4 has sufficient processing for light AI processing and sensor fusion; however, execution of heavy computation algorithms like SLAM real-time may produce substantial processing delay. As a task or complexity of the environment increases, it may introduce latencies into the system, making the robot responsive and impacting performance overall.

3) Discrimination and miscommunication may occur in environments where surfaces are reflective, transparent, or absorptive, making it difficult to use RP Lidar. Although the RP Lidar is suitable for many applications, adding complementary sensors (such as cameras or depth sensors) may make it more capable of handling these limitations and providing greater accuracy when used with other materials.

4) Power and Heat Management: The Raspberry Pi 4 Model B, though optimized for embedded use, may still witness heat accumulation and moderate power consumption during extended periods of computational use. For this project, good thermal management—like applying heat sinks or active cooling—along with efficient code execution, becomes necessary to promote stable operation. These precautions assist in ensuring unbroken, stand-alone operation without the necessity of manual resets or interruptions.

5) Scalability is crucial for complex and dynamic tasks, as the system is designed to function autonomously in structured environments, but scalability becomes problematic when applied to more dynamic and unstructured environments. Changing conditions, such as those caused by multiple moving obstacles, may pose challenges for the adaptive algorithms and sensor systems required to accommodate real-world scaling.

Managing Real-Time Decisions: The robot's real-time path planning and obstacle avoidance mechanisms may face challenges or delays when working in highly active or dense environments. This may have to do with limitations on algorithms or computational resources at present.? Accuracy and speed of decision-making could be enhanced by implementing more efficient algorithms, such as predictive modeling or machine learning.

Integrated Data Fusion: The current system relies on navigation (Lidar) but accuracy could be greatly improved by using data from various sensors (cameras, IMUs etc.). Better decision-making and overall robustness would be achieved by utilizing advanced sensor fusion techniques that enable the robot to operate more efficiently in complex environments or when visibility is reduced.

V. FUTURE SCOPE

With the rapid growth of Artificial Intelligence and robotics, this project has many promising futures. The use of a Raspberry Pi 4 as the primary computational unit in this system highlights the potential of small and capable embedded platforms to drive autonomous robotics. As AI and Machine Learning progress, these robots will become more capable of performing tasks that necessitate complex decision-making, object manipulation coordination that typically requires human effort. The energy-saving Raspberry Pi 4's flexible architecture and real-time processing make it a perfect fit for applications such as disaster response and agricultural monitoring. The advancement of battery technology has enabled these isolated systems to operate over long distances, resulting in greatly extended range. Also, the implementation of 5G networks and edge computing will significantly enhance the real-time communication capabilities of mobile robots. The auxiliary node in these interconnected systems is a Raspberry Pi 4, which facilitates data exchange and communication with centralized control units. Industries like logistics, healthcare systems or urban management now have the potential for collaborative robotics and efficient large-scale automation. Additionally, this platform aligns with emerging technologies such as autonomous vehicles, smart city infrastructure and the IoT where mobile robot will serve as intelligent agents interacting with various components of an interconnected environment.

CONCLUSION

1) Autonomous navigation mobile robot was implemented through ROS, Raspberry Pi 4, RP Lidar, and Differential Drive Kinematics. Its integration represents an important step in intelligent robotic automation since it equips the robot with the capacity to navigate and perform in varying environments with lesser human interference.

2) SLAM (Simultaneous Localization and Mapping) utilization enables the robot to build real-time maps of unknown environments and detect and avoid obstacles. The RP Lidar sensor is central in delivering precise 360° scanning of the environment, ensuring solid performance

in crowded environments.

3) Built with practical use in mind, the robot finds ready application in logistics, healthcare, agriculture, and disaster relief. Autonomous working makes operations more efficient and minimizes the need for direct human intervention in adverse or hostile conditions.

4) Raspberry Pi 4 acts as the core processing unit and performs SLAM algorithms as well as sensor processing at an efficient pace. With the quad-core processor and generous memory, it handles real-time operation at low power consumption.

5) ROS offers the system's software foundation, facilitating easy communication among various hardware and software elements. Modularity and openness make it possible to execute tasks in parallel, integrate sensors, and easily experiment or scale.

6) The project further exhibits great potential for the future. With improvements in AI, sensor accuracy, SLAM technology, and energy-efficient processing, such systems will become increasingly dependable and effective in real-world applications. Finally, the project is a working prototype and proof-of-concept of the increasing application of intelligent robotics in both formal and informal environments. It exhibits the revolutionary effect of smart automation and the scalability of such systems for applications in the future.

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