LiDBot (Autonomous Bot for 2D mapping)

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***Abstract*—This paper introduces an autonomous robotic system that employs LiDAR (Light Detection and Ranging) technology, driven by a Raspberry Pi 4 single-board computer, and seamlessly integrated with the Robot Operating System 2 (ROS2) for the purpose of 2D mapping and Simultaneous Localization and Mapping (SLAM) in indoor environments. The Raspberry Pi 4 serves as the onboard computer, responsible for processing LiDAR data, sensor fusion, control algorithms, and communication with external devices. ROS2 acts as the middleware, ensuring a seamless use of sensors, control algorithms, and visualization tools. The implementation of SLAM algorithms is an important aspect of this project, allowing the robot to construct an intricate 2D map of its environment while concurrently determining its own position within that map. This information proves indispensable for secure and efficient navigation within dynamic indoor surroundings. Furthermore, the autonomous robot adeptly maneuvers through these environments while continually updating its map and self-localization estimations. The paper showcases performance metrics such as map precision, navigation speed and computational efficiency within the provided resources. This research contributes substantively to the domain of robotics by furnishing a practical implementation of an autonomous robot system utilizing LiDAR, Raspberry Pi 4, and ROS2, underscoring its efficiency in 2D mapping and SLAM.**

Key Words: LiDBot, Simultaneous Localization and Mapping (SLAM), Light Detection and Ranging(LiDAR), Robot Operating System 2(ROS2), Raspberry Pi4, 2D Mapping.

I. INTRODUCTION

With the advancement of intelligent manufacturing and the expansion of the industrial logistics industry, logistics robot technology has been continuously developed. As a member of the industrial logistics robots, autonomous mobile robots are developing in the direction of intelligent control, multi- machine collaboration, and design mode, and people's requirements for its functions are getting higher and higher. Therefore, accelerating the development of autonomous mobile robot technology is of great significance for promoting the development of the intelligent equipment manufacturing industry. At present, industrial robots at home and abroad are mainly oriented to tasks such as handling and distribution. Such robots are mainly produced by traditional large-scale equipment manufacturers and are controlled by special software and programming languages.

Through a series of experiments and performance evaluations, we will demonstrate the effectiveness of our autonomous robot system in creating precise 2D maps of complex indoor environments, showcasing its ability to adapt and navigate dynamically changing surroundings. In applications such as industrial automation, indoor navigation, and robotics, these bots excel at obstacle detection, collision avoidance, and mapping of the environment.

In summary, the integration of 2D LiDAR into autonomous bots opens opportunities for safer and more efficient navigation and automation in a wide range of industries. As technology continues to evolve, bots will likely become even more versatile and capable, contributing to advancements in mobility, safety, and productivity across various domains.

II. OBJECTIVE

The goal of such project a LiDAR (Light Detection and Ranging) robot is a robotic system equipped with LiDAR sensors for navigation, mapping, and obstacle detection. LiDAR technology uses laser beams. to measure distances to objects in its surroundings, allowing the robot to create detailed 3D maps and perceive its environment with high precision.

These robots are commonly used in various applications such as autonomous vehicles, unmanned aerial vehicles (UAVs), agricultural robots, warehouse automation, and search and rescue operations. They leverage LiDAR data to make real-time decisions, avoid obstacles, and navigate complex environments safely and efficiently.

The LiDAR robot typically consists of a mobile base or platform, LiDAR sensors mounted on the robot's body or rotating turret, and onboard processing units such as microcontrollers or computers. By continuously scanning its surroundings and analyzing the LiDAR data, the robot can plan optimal paths, detect obstacles, and execute tasks autonomously or under remote control.

The objectives of the project are as follows

A. Autonomous Navigation: Lidar robots are essential for autonomous vehicles, drones, and robots as they provide precise 3D mapping of the environment, allowing these machines to navigate safely and effectively.

B. Mapping and Surveying: Lidar robots are used for creating detailed maps of terrains, buildings, and infrastructure. They are invaluable in urban planning, construction, archaeology, and environmental monitoring.

C. Search and Rescue Operations: Lidar-equipped robots are used in search and rescue missions to quickly scan large

III. Block Diagram

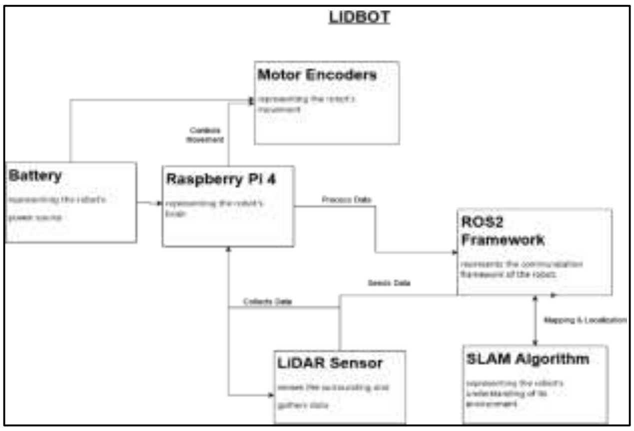


Figure 1: Block Diagram of LiDBot

Working:

areas and detect survivors or hazards in disaster zones, such as collapsed buildings or natural disaster sites.

D. Industrial Automation: Lidar robots are employed in factories and warehouses for tasks such as inventory management, object detection, and quality control. They can efficiently scan shelves, track inventory, and detect anomalies in production lines.

E. Agriculture: In agriculture, Lidar robots are used for crop monitoring, yield estimation, and precision farming. They can provide detailed information about plant health, soil conditions, and topography, helping farmers optimize their operations.

F. Environmental Monitoring: Lidar robots play a crucial role in environmental research and monitoring by assessing vegetation, tracking changes in landscapes, and studying ecosystems. They are used in forestry, wildlife conservation, and climate studies.

G. Security and Surveillance: Lidar robots enhance security systems by providing real-time monitoring and detection of intruders or unusual activities in restricted areas. They are used in perimeter surveillance, border control, and facility security.

H. Infrastructure Inspection: Lidar robots are employed for inspecting critical infrastructure such as bridges, pipelines, and power lines. They can detect structural defects, measure dimensions, and assess the condition of assets, reducing the need for manual inspections and improving safety.

The process of constructing an autonomous robot, equipped with a LiDAR sensor for 2D mapping and integrated within the ROS 2 framework, this requires a method that includes hardware configuration, software engineering, and seamless integration within the ROS 2 ecosystem.

Initialization: The robot is powered on and the Raspberry Pi 4, which serves as the robot's brain, is booted up.

ROS2 Setup: The Robot Operating System 2 (ROS2) is initialized on the Raspberry Pi. ROS2 is a flexible framework that allows for communication between various parts of a robot's system.

Sensor Integration: The LiDAR sensor, attached to the robot, is activated. This sensor will be used to map the environment.

Data Acquisition**:** As the robot moves, the LiDAR sensor collects data by sending out laser beams and measuring how long it takes for them to bounce back after hitting an object.

Data Processing: The Raspberry Pi 4 processes this data in real-time to create a 2D or 3D map of the environment.

SLAM Algorithm**:** The Simultaneous Localization and Mapping (SLAM) algorithm is applied to this data. SLAM helps the robot understand its location within the environment while also mapping the environment.

ROS2 Communication: The processed data and SLAM output are communicated across the system using ROS2, allowing for real-time adjustments and decision-making.

Path Planning**:** Using the map created by the SLAM algorithm, the robot plans its path, avoiding obstacles and efficiently reaching its target destination.

Movement Execution: The robot executes the planned path, constantly collecting data and updating its map and path as needed through ROS2 communication.

IV. METHODOLOGY

The methodology of the design and development of the LiDBot(Autonomous Robot using LiDAR Sensor) is divided into the following stages

A. Sensors*:*

- 2D LiDAR Sensors: Provide precise environmental mapping data.
- Inertial Measurement Unit (IMU): Measures accelerations and angular velocities for motion and orientation estimation.

B. Perception and Mapping*:*

- SLAM Algorithm*:* Utilizes data from LiDAR, IMU, and cameras to perform Simultaneous Localization and Mapping, creating a map of the robot's environment while estimating its position.
- Localization*:* Determines the robot's precise location in real-time, using the SLAM-generated map.
- Odometry Estimation: Calculates robot motion and position based on wheel encoders or other motion sensors.
- Object Detection: Identifies and tracks objects in the environment.

C. Decision and Control:

- Path Planning and Navigation Module: Uses the map and localization information to generate obstacle- aware paths and trajectories.
- Autonomous Behavior Module: Implements higher-level decision-making algorithms, enabling the robot to perform tasks autonomously.
- ROS 2 Middleware: Manages communication and data exchange between various software modules and robot components.

D. Motor Encoders:

- Motor Drives: Control the robot's wheel or track movement for propulsion.
- Wheels/Tracks: Provide mobility and locomotion.
- Manipulators: If applicable, robotic arms or manipulators can be used for object manipulation.
- Grippers/Tools: Attachments to the manipulators for grasping and performing specific tasks.

This illustrates the key components and their interactions within an autonomous 2D LiDAR robot that utilizes ROS
2 and SLAM for accurate mapping, localization, and autonomous operation. It highlights the sensor data flow, perception and mapping, decision-making processes, and the control of actuators.

V. SOFTWARE/ HARDWARE TOOLS AND FRAMEWORKS

In the following section, the various software and hardware tools and frameworks used in the development and implementation process are introduced and explained.

A. Raspberry Pi 4 :

Figure 2: Raspberry Pi 4

A single board computer which is a brain of a robot, 4 GB variant is used for ease of handling multiple process simultaneously.

B. LiDAR Sensor :

Figure 3: LiDAR Sensor

2D LiDAR sensor used for mapping and simultaneously.

C. DC motors:

Figure 4: DC motors with Encoders

Used for speed control feedback in DC motors.

D. Motor driver:

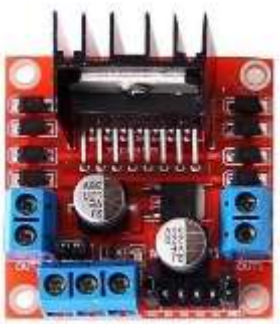


Figure 4: Motor Driver

To provide essential interface between board and motors and to drive power from battery to high power motors.

E. Battery pack :

Figure 5: Battery Pack

To power motors and other components.

F. PC with Ubuntu*:*

Ubuntu is a free and open-source distribution of Linux. It is an OS for cloud computing to support Open Stack. Ubuntu is integrated by the Canonical Community and it's freely available. It is designed for network servers, smartphones, and computers. Every principle used for developing the Ubuntu software is based on open-source software development principles.

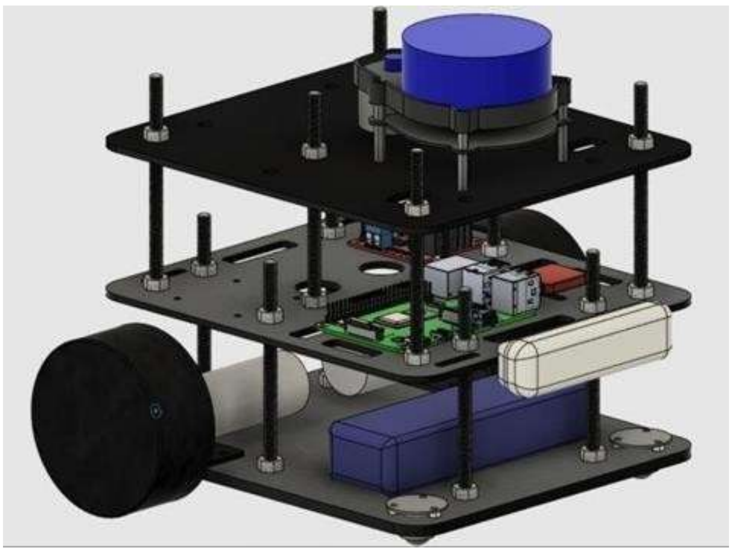
G. Robot Operating System 2 (ROS2):

ROS 2 (Robot Operating System 2) is an open source software development kit for robotics applications. The purpose of ROS 2 is to offer a standard software platform to developers across industries that will carry them from research and prototyping through to deployment and production. ROS 2 builds on the success of ROS 1, which is used today in myriad robotics applications around the world.

H. SLAM Algorithm:

SLAM (simultaneous localization and mapping) is a method used for autonomous vehicles that lets you build a map and localize your vehicle in that map at the same time. SLAM algorithms allow the vehicle to map out unknown environments. Engineers use the map information to carry out tasks such as path planning and obstacle avoidance.

VI. RESULT



Above is the 3D design on our product. The advancements in LiDAR technology and the development of sophisticated algorithms for data processing and interpretation have significantly enhanced the capabilities of these robots. As a result, they are becoming increasingly prevalent in our daily lives, improving efficiency and productivity in numerous sectors. However, there are still challenges to be addressed, such as improving the robustness and reliability of these systems, particularly in dynamic and unpredictable environments. Ongoing research and development in this field are expected to lead to even more advanced autonomous robots in the future. In conclusion, autonomous robots equipped with LiDAR sensors represent a significant technological advancement with wide-ranging applications and immense potential for future growth.

VII .FUTURE SCOPE

Advanced 3D LiDAR: The utilization of more advanced sensor and software technologies, such as advanced 3D LiDAR, will increase autonomous mobile robots' (AMRs) abilities to monitor and respond to their changing surroundings in both indoor and outdoor applications. This will allow AMRs to perform increasingly complex tasks, improving worker safety and efficiency.

Enhanced Navigation and Situational Awareness: LiDAR systems are key to enhancing the capabilities of future autonomous vehicles in terms of navigation and situational awareness3. Significant advancements are needed by terrestrial, marine, aerial, and space vehicles to meet the levels of safety and performance required within present and future application scenarios.

Long-Term Robot Autonomy: Research is being conducted into long-term robot autonomy, LiDAR data processing under adverse weather conditions, as well as sensor fusion4. This could lead to more robust and adaptable autonomous robots.

CONCLUSION

Autonomous robots using LiDAR sensors have shown great potential in a variety of fields, from logistics and manufacturing to healthcare and security. The use of LiDAR sensors allows these robots to perceive their environment in real-time, enabling them to navigate complex environments and perform tasks with a high degree of autonomy.

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