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(Research Article)

Simultaneous Localization and Mapping (SLAM) for warehouse applications

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Abstract

The ravaging impacts of the COVID-19 pandemic on global supply chains and its exposures of the vulnerabilities of the This research paper describes the development and implementation of a practical SLAM model for warehouse application. SLAM technology allows autonomous systems to map unknown environments while estimating their own position. The model combines hardware (mobile robot platform with sensors) and software (SLAM algorithms and real-time data processing) components. The project involved reviewing SLAM algorithms, assembling the hardware, developing software modules, and testing the model's performance. The experiments showed that the model successfully mapped unknown environments and accurately estimated its position in real-time. The project has practical implications for robotics, autonomous vehicles, and augmented reality. Overall, this research contributes to the advancement of SLAM technology and provides insights for further exploration in the field.

Keywords: SLAM; Autonomous vehicle; Navigation and Mapping; Raspberry Pi; ROS2; Ubuntu; Gazebo; Rviz

1. Introduction

This research paper presents the development and evaluation of a working model that utilizes SLAM (Simultaneous Localization and Mapping) technology. It incorporates hardware components such as sensors and cameras, as well as SLAM algorithms and real-time data processing techniques in its software implementation [1-8]. SLAM for autonomous robots by the fusion of WiFi fingerprint sequence and LiDAR laser scans can also be done using trajectories [2]. The model aims to autonomously map unknown environments while accurately localizing itself within those environments [8].

Overall, the model demonstrates the simultaneous mapping and localization capabilities of SLAM, making it a valuable resource for researchers and practitioners in the field.

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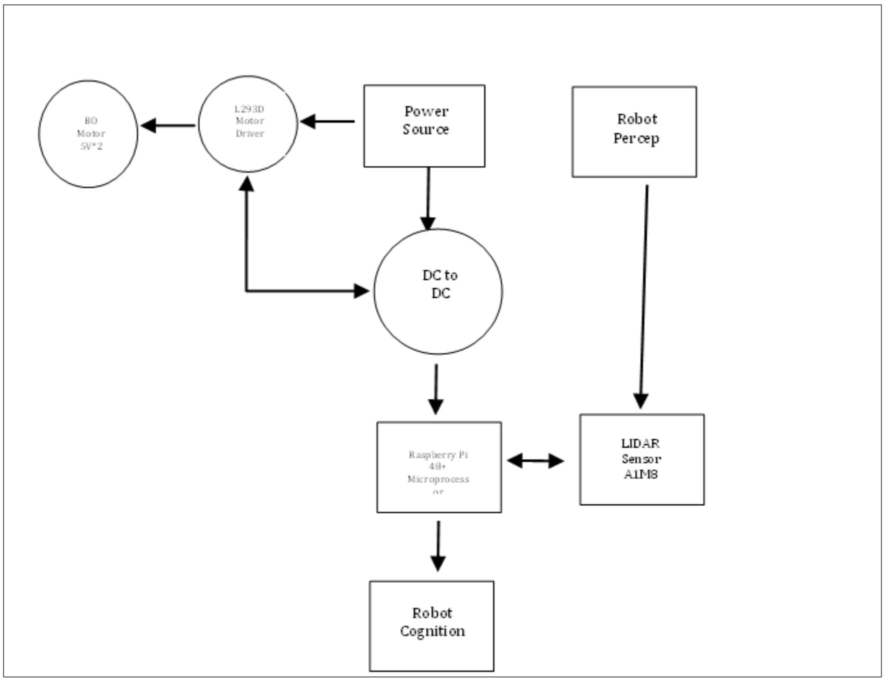

Figure 1 Connection Diagram

Table 1 Components used for vehicle

Components	**Quantity**
Lidar SensorA1M8	1
Raspberry Pi 4b	1
Arduino Boarad Uno	1
LN293	1
LiPo Battery	2
Motors	2
Vehicle chassis	1
Wheels	4
Battery holder	1
Connecting wires	15
Power banks	1

2. Methodology

2.1. Procedure for connections

- Identify the communication interface supported by LiDAR sensor, such as UART (Universal Asynchronous Receiver-Transmitter) or USB.
- LiDAR sensor uses USB, simply connect the USB port of the sensor to an available USB port on the Raspberry Pi.
- Establish serial communication between the Raspberry Pi and Arduino.
- A communication protocol supported by both the Raspberry Pi and Arduino, such as UART is selected.
- The baud rate and communication settings on both devices (Raspberry Pi and Arduino) are properly configured to match each other.

- Connect the Arduino to the motor driver:
- Appropriate pins on the Arduino that will be used for motor control are selected. These are typically digital output pins.
- Connect the Arduino's digital output pins to the input pins of the motor driver, which controls the motors. The specific wiring will depend on the motor driver.
- Connect the motor driver's ground (GND) pin to the Arduino's ground to establish a common ground reference.
- Power the Raspberry Pi and Arduino.
- Power source such as a battery and power bank are used to provide power to both the Raspberry Pi, motors and Arduino.
- Ensure that the voltage levels from the power source are compatible with the input voltage requirements of both devices.

2.2. Software

Ubuntu 22.4 version was installed on both the onboard computer Raspberry pi and the main computer. Followed by ROS2 humble installation on both as well by giving commands in the ubuntu terminal. Arduino IDE was installed on the main computer to upload the code on the UNO board. Firstly the overall environment was simulated on Gazebo an ROS2 extension by creating a differential drive in Gazebo by using links and co-ordinates. Designing of vehicle chassis was done in Gazebo by adding its body, wheels and Lidar on to it. A world was simulated in gazebo to navigate the robot in the simulated world. Slam toolbox and Nav toolbox were installed as well on both computers to implement SLAM. Rviz2 is used to display the real time Lidar data collected by the Lidar mounted on the vehicle by installing the rplidar package. The entire project was developed using ros2 packages.

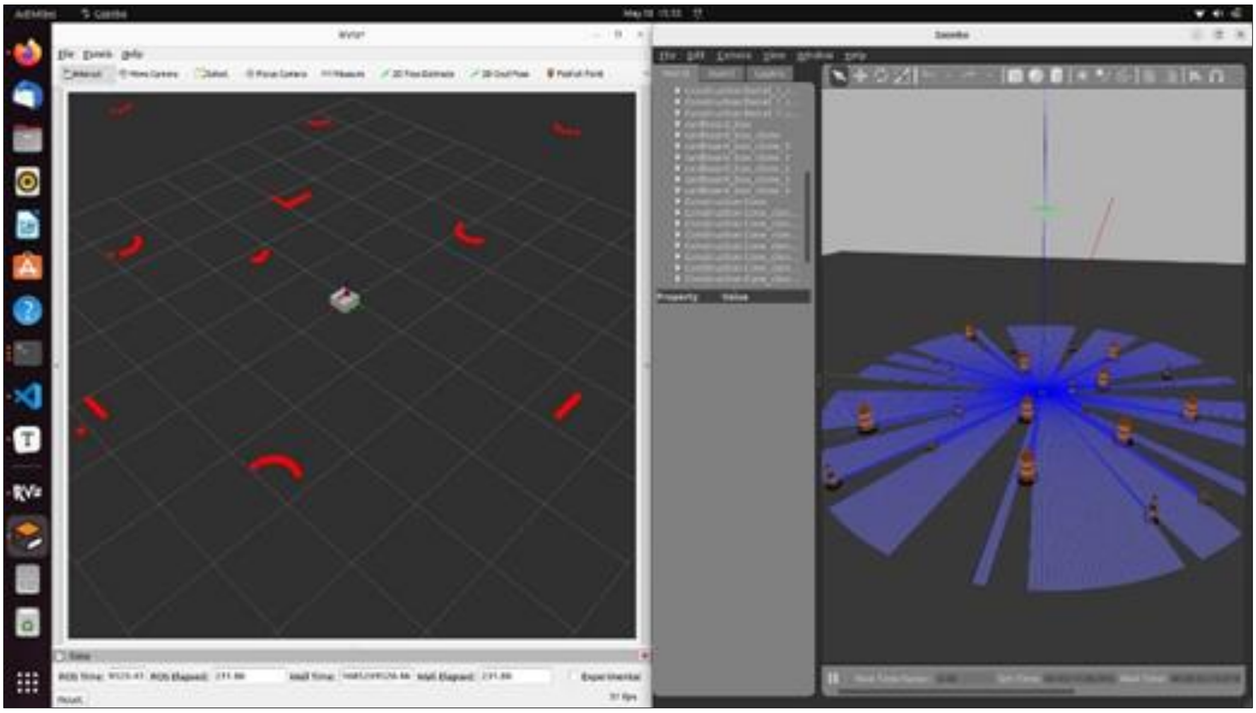

Figure 2 Lidar data in Rviz and Gazebo

The vehicle was tested in an environment of 10 x 10 sq ft room and figure 3 shows the real time results.

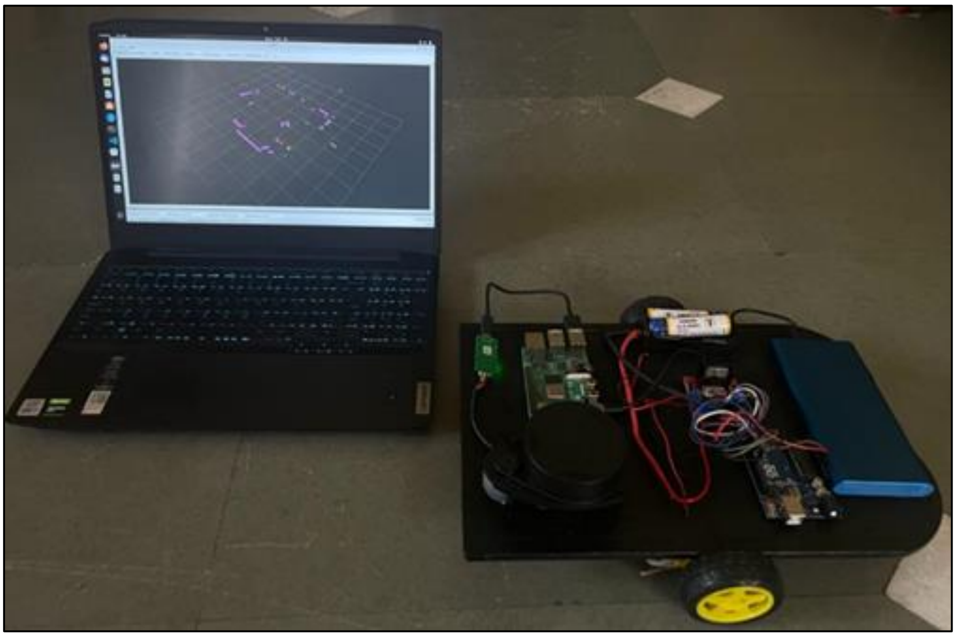

Figure 2 Real time Lidar data on rviz and vehicle

3. Working of simultaneous localization and mapping

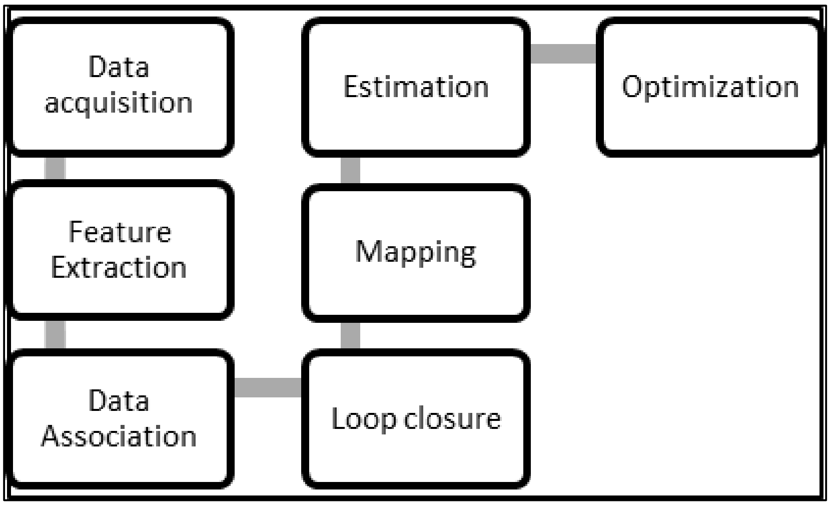

Figure 3 Workflow of SLAM

- Data Acquisition: The robot collects data from various sensors, such as cameras, LIDAR (Light Detection and Ranging), or depth sensors. These sensors capture information about the environment, including visual features, distances to objects, or depth measurements.
- Feature Extraction: The collected sensor data is processed to extract relevant features, such as keypoints or distinctive landmarks. These features can be edges, corners, or unique patterns in the sensor data.
- Data Association: In this step, the SLAM system matches the extracted features across different sensor readings to establish correspondences. It aims to identify the same feature or landmark observed in multiple frames of sensor data. This association helps in building consistent maps and estimating the robot's motion.
- Estimation: SLAM uses probabilistic estimation techniques, such as the Extended Kalman Filter (EKF) or Particle Filter, to estimate the robot's pose (position and orientation) and the locations of the mapped features. The estimation is done iteratively, updating the belief about the robot's state and the map as new data becomes available.

- Mapping: As the robot moves through the environment, the SLAM system builds a map by integrating the estimated positions of the features observed at different time steps. The map can be represented as a 2D or 3D representation, depending on the type of environment and sensors used.
- Loop Closure: Over time, the SLAM system looks for opportunities to close loops in the robot's trajectory. Loop closure occurs when the system recognizes a previously visited location and adjusts the estimated poses and maps to ensure consistency. Loop closure helps in reducing drift and improving the accuracy of the map and robot's localization.
- Optimization: Once loop closures are detected, SLAM systems typically perform a global optimization step, such as Graph-based Optimization or Bundle Adjustment. These techniques refine the estimated poses and landmarks, ensuring a consistent and accurate map representation.

4. Conclusion

In this paper, we presented a method for performing SLAM for autonomous robots by using laser maps obtained from LIDAR which is further used by the robot to navigate autonomously in the deployed area. SLAM (Simultaneous Localization and Mapping) is a technique used in robotics and computer vision to create a map of an unknown environment while simultaneously determining the robot's location within that environment. It allows a robot or a system to navigate autonomously and understand its surroundings. The SLAM process is typically performed in real-time, with the robot continuously updating its estimate of its position and the environment. SLAM has numerous applications, including autonomous navigation, augmented reality, robotic mapping, and more.

Future scope

SLAM can be used to develop advanced navigation systems for AMRs, allowing them to move autonomously and safely within the warehouse environment. By accurately mapping the surroundings and localizing themselves in real-time, AMRs can optimize their paths, avoid obstacles, and perform tasks such as picking, sorting, and transporting items SLAM can play a crucial role in inventory management by providing accurate and up-to-date information about the location and quantity of items within the warehouse. By integrating SLAM with RFID or barcode scanning technologies, warehouses can automate inventory tracking, reduce errors, and improve the overall efficiency of stock management processes.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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