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LIDAR-based Robot for Localization and Mapping

Muhamad Shahrizuan Abdul Khair[1], S.A. Abdul Shukor[1,2*] and N.A. Rahim[1,2]

[1]Faculty of Electrical Engineering & Technology, Universiti Malaysia Perlis, 02600 Perlis, Malaysia
[2]Centre of Excellence for Intelligent Robotics & Autonomous Systems, Universiti Malaysia Perlis, 02600 Perlis, Malaysia

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ABSTRACT

This paper presents an application of LIDAR sensor on a robot for 2D mapping construction of an environment and its capability to localize its own location. RP LIDAR is used and computational processing is done by using Robot Operating System (ROS), utilizing one of the prominent LIDAR-based localization and mapping method of Hector SLAM. In this project, mapping of the environment is done in real-time and localization of the robot with respect to static landmarks were also conducted. A typical indoor environment with furniture was chosen to be the testing area. From the results, it can be seen that map of the environment is able to be reconstructed and several locations with respect to marking points are able to be identified with an average of 97% accuracy.

Keywords: Hector SLAM, Robot Localization and Mapping, Robot Operating System (ROS), RP LIDAR

1. INTRODUCTION

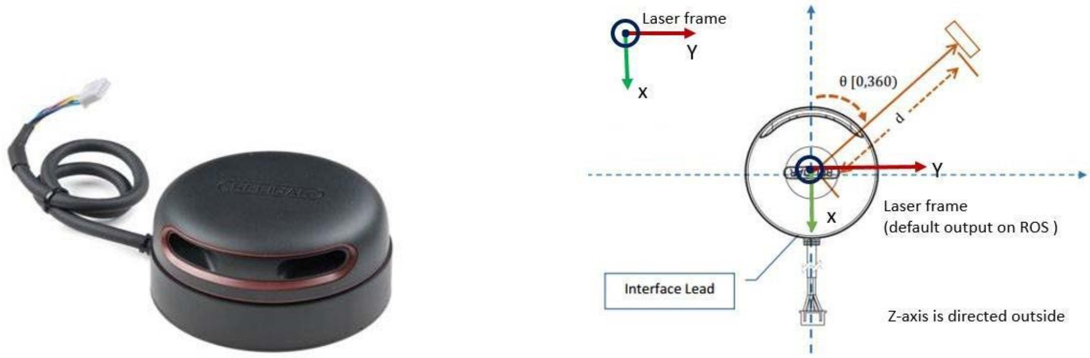
The development of robot-based LIDAR has a long history starting in the 1960s. Since then, LIDAR has evolved significantly, leading to smaller, more efficient and more accurate systems. Autonomous vehicles have benefited greatly from LIDAR, for surveying, mapping and military operations [1].

The RP LIDAR is a compact and lightweight LIDAR sensor developed by RoboPeak. It utilizes a spinning laser scanner to emit laser beams and accurately measure the distance to objects based on their reflections. With a 360-degree field of view and an effective scanning range of up to 8 meters, this sensor is suitable for indoor and outdoor navigations applications [2]. It offers a high scanning frequency of up to 8000 samples per second, enabling real-time mapping and localization. The sensor can be easily integrated into various robotic platforms and systems, thanks to its compact size and lightweight design. It typically communicates through USB or serial interfaces, providing flexibility in data output formats such as point clouds or distance measurements. The RP LIDAR is widely used due to its reliable performance with scanning and mapping capabilities. Figure 1 shows RP LIDAR configurations.

Due to these reasons, it is recommended for RP LIDAR to be tested further for robot localization and mapping. Robot localization and mapping can be defined as a process of establishing correspondence between map coordinate and robot's local coordinate system, with illustrating the environment based on the surrounding information, respectively [3][4]. Hector SLAM is chosen as the main localization and mapping method to test RP LIDAR workability [5]. Previous work utilising LIDAR were tested on either different type of LIDAR [6], with different

*shazmin@unimap.edu.my

environment [7], utilizing different robotic platform [8] with integration of other sensors [9] and some with different algorithm [4][10]. Further, RP LIDAR has only tested virtually in [10], hence tests in real environment will be further investigated here.



(a) (b)

Figure 1. (a) RP LIDAR, (b) RP LIDAR configurations

2. MATERIAL AND METHODS

This section will highlight the hardware and software used for the mobile robot development, specifically for indoor localization and mapping. Figure 2 shows the overall block diagram of the robot. All hardware were placed on the robot, and ROS is used as the main software, specifically utilising Hector SLAM to develop and solve its localization and mapping. In general, Arduino Uno is used to control the robot's movement, utilising Teleop Twist Keyboard application. RP LIDAR will start scanning and the data will be collected by the Raspberry Pi before sending it to ROS (Gazebo, RViz, Hector SLAM) to produce its mapping and localization.

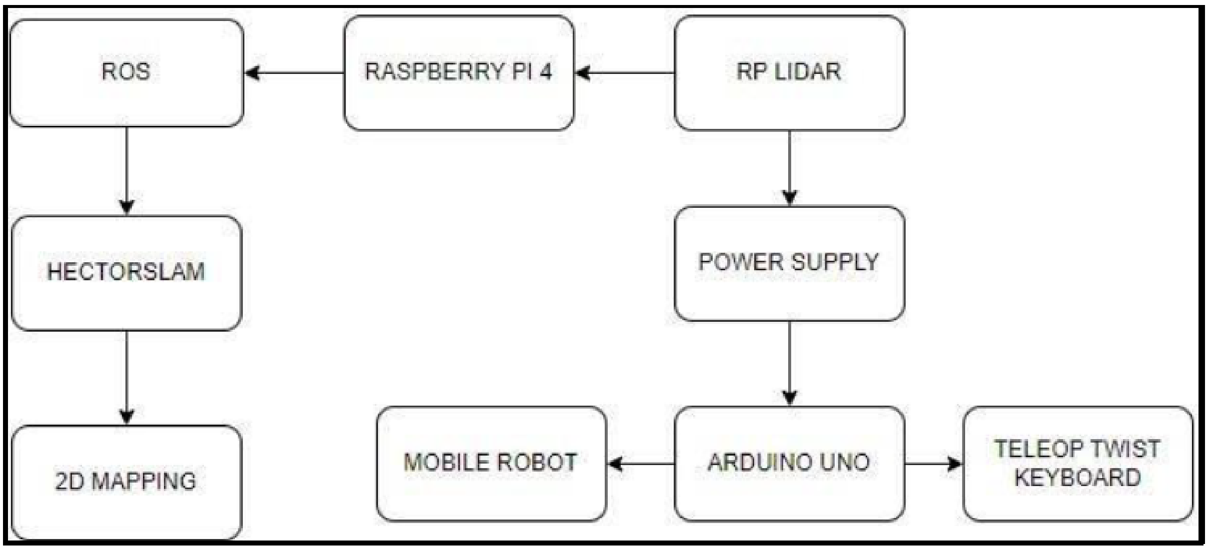
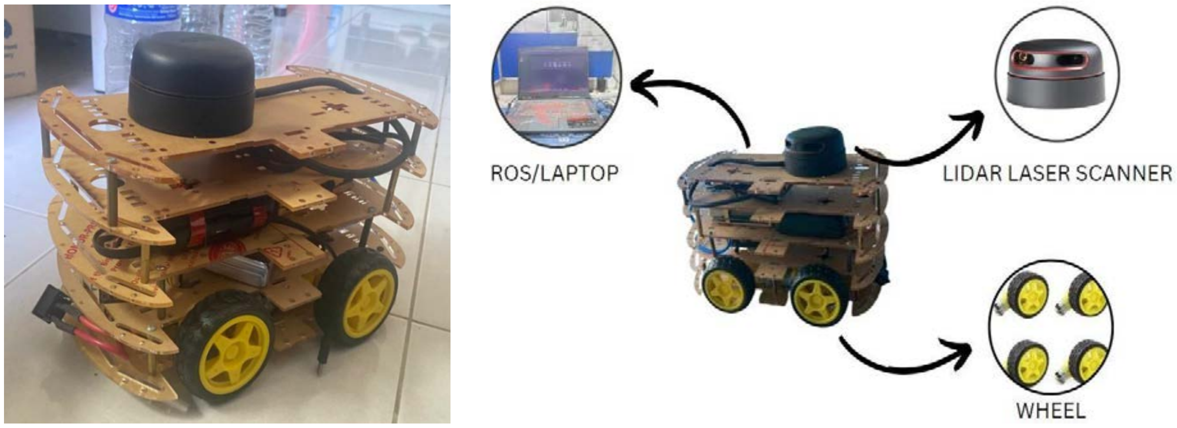


Figure 2. The block diagram of the overall system, consists of both hardware and software

2.1 Hardware Development

Figure 3 shows the robot used in this project. It consists of power supply of LM2596 buck converter to ensure correct voltage is supplied to all the components. Apart from that, 4 DC motors were used for propulsion and navigation, connected to 4 wheels, with L298N motor driver to control the motors. The robot is also equipped with Arduino Uno and Raspberry Pi 4 Model B with a Wi-Fi connection, together with RP LIDAR for scanning its environment. Figure 4 shows the overall hardware configuration of the robot, which highlight the connections of all the hardware used for the robot.



(a) (b)

Figure 3. The robot used for localization and mapping, equipped with RP LIDAR on top

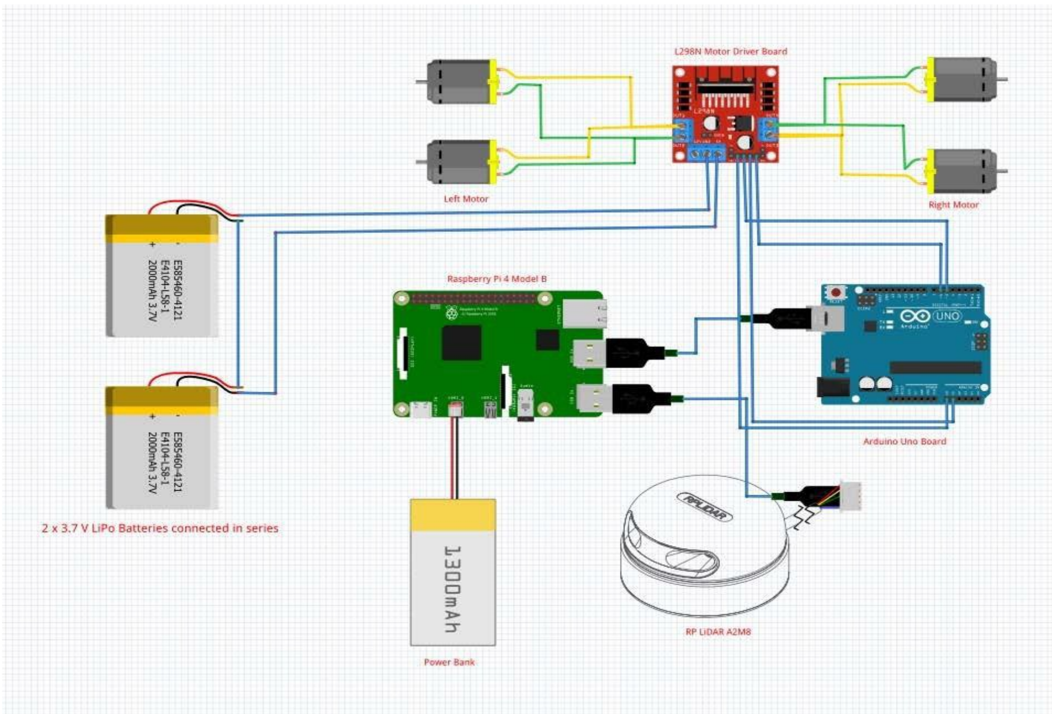


Figure 4. Hardware configuration

2.2 Software Development

This project utilised ROS as the main software. Data from RP LIDAR, which consists of range measurements, will be collected and RViz is used to visualize the data in real-time. Hector SLAM is then used to further process the data and solve the robot mapping and localization.

2.2.1 Hector SLAM

Hector SLAM was developed by [5] which utilised LIDAR data for robot localization and mapping. In here, grid mapping and scan matching are combined to map the first, home position of robot, and LIDAR data is compared with the developed map to know and derive location of the robot. Other method in SLAM might also rely on odometry information to solve for robot's localization and mapping, making Hector SLAM as the suitable method to be utilised in this project.

2.3 Data Collection

In this project, an indoor environment of a room with the dimension of 6m x 5m has been chosen. This represents a typical interior of a living room, with standard dimensions and presence of furniture. The area has been marked with several points of starting point and marking points, which acted as the starting position (0,0) for the robot, as well as the positions for the data collection. The marking points were randomly selected, with the distance between the points to be less than 1 meter, to ensure all important measurements representing the selected area are covered and collected. Angles, ϴ, in radian and distance, *d*, of each point were collected, whereby *X* and *Y*-positions of the points will be determined and calculated by using Equations (1) and (2):

$$X = d \sin(\Theta) \quad (1)$$
$$Y = d \cos(\Theta) \quad (2)$$

to map and localize the robot's position.

To ensure correct position and mapping were obtained, basic measurement of distance, as shown in Equation (3), as well as comparison of distances on the developed map and manual measurements were done to calculate the accuracy of the results, as in Equation (4) and (5):

$$Distance = \sqrt{X^2 + Y^2} \quad (3)$$

$$Error\ (\%) = \frac{(\text{Manual Measurements} - \text{Mapping Measurements})}{\text{Manual Measurements}} \times 100 \quad (4)$$

$$Accuracy\ (\%) = 100\% - Error\ (\%) \quad (5)$$

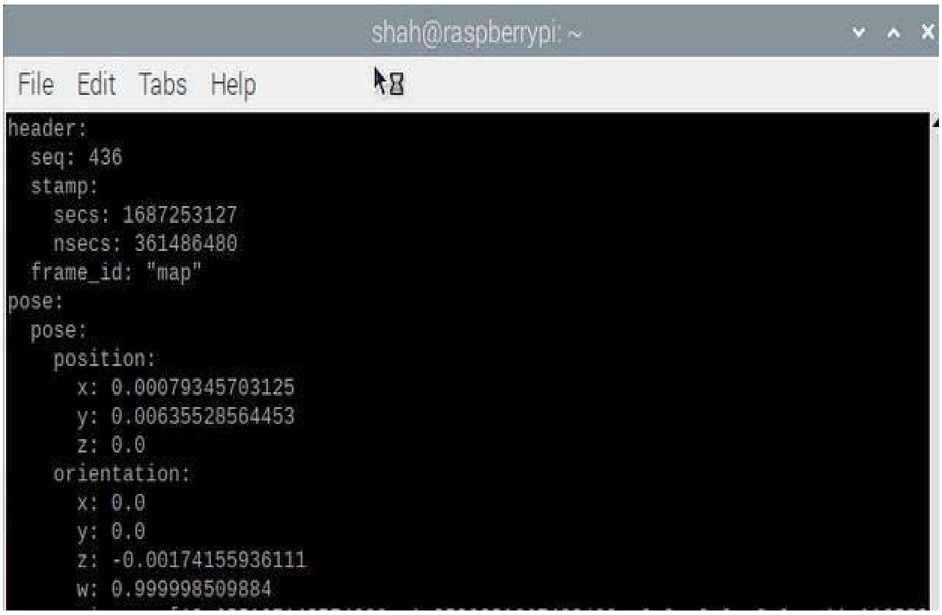
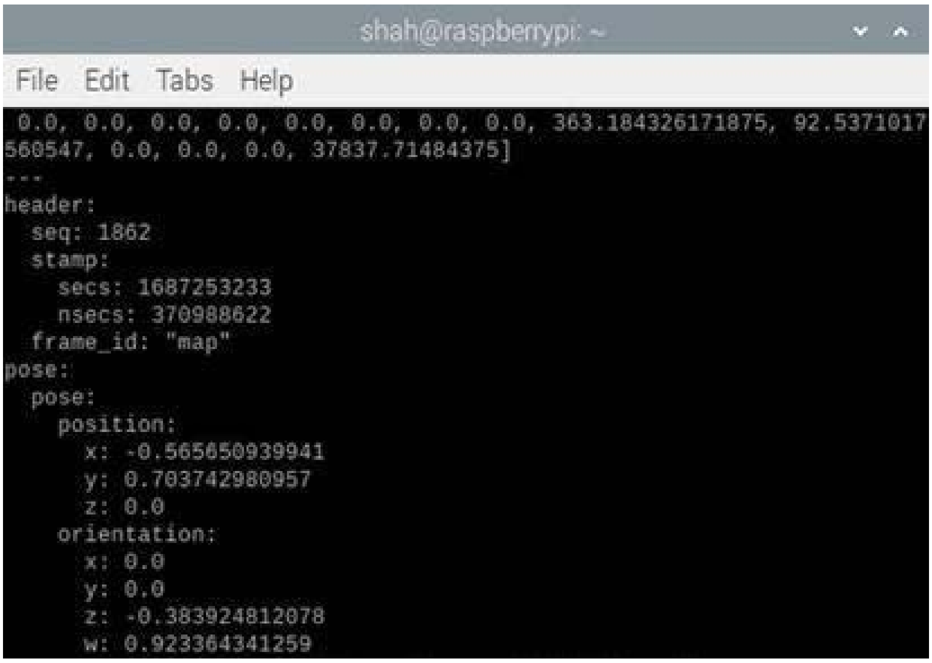
3. RESULTS AND DISCUSSION

Figure 5 shows the chosen indoor area, together with the position of the robot's starting point and its 4 marking points. As mentioned in Section 2, these marking points were selected based on the area and specification of RP LIDAR. Bigger indoor environments may require more marking points to ensure correct and complete scanning of the area.

Figure 5. The chosen indoor area

Table 1 and Table 2 summarizes the pose and localization of the robot with respect to ROS. As can be seen from this table, ROS is able to map and localize the position of the robot accordingly. Meanwhile, Table 3 shows the measurement comparison from ROS and manual reading, to show its accuracy.

Table 1 Summary of location results

<table>
<tr><th>Point</th><th>Location Results</th></tr>
<tr><td>Start Point</td><td>
</td></tr>
<tr><td>Marking Point 1</td><td>
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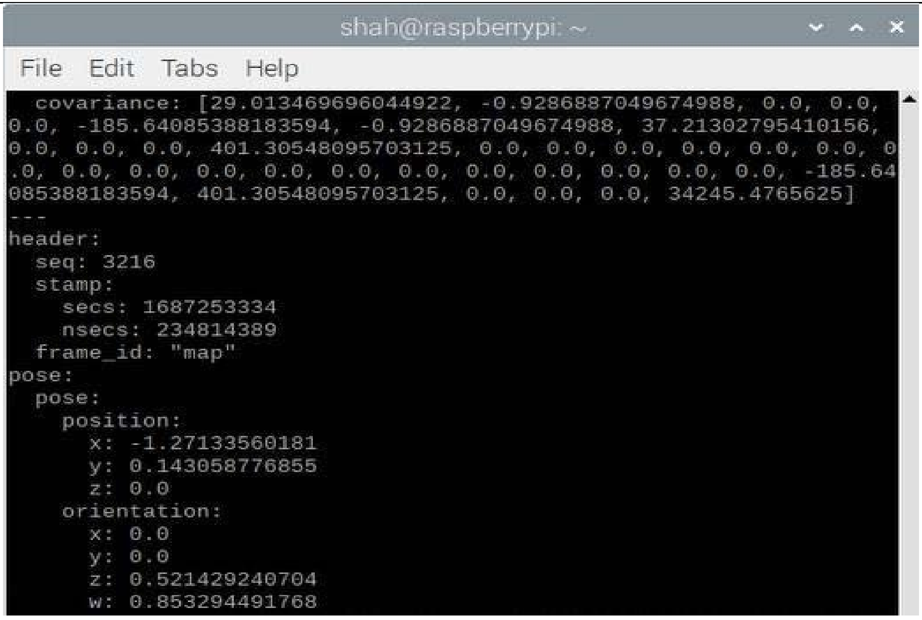
<tr><td>Marking Point 2</td><td>
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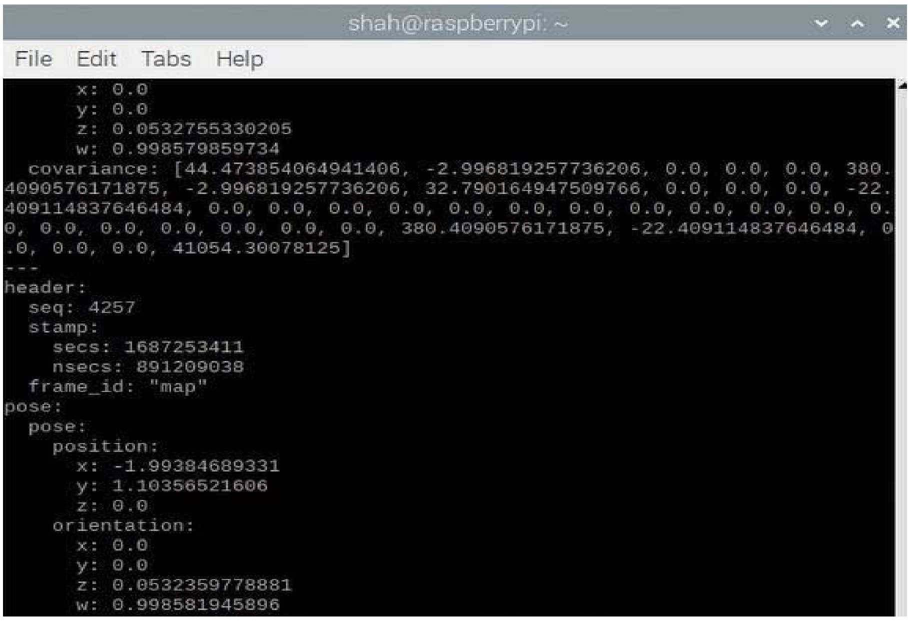
<tr><td>Marking Point 3</td><td>
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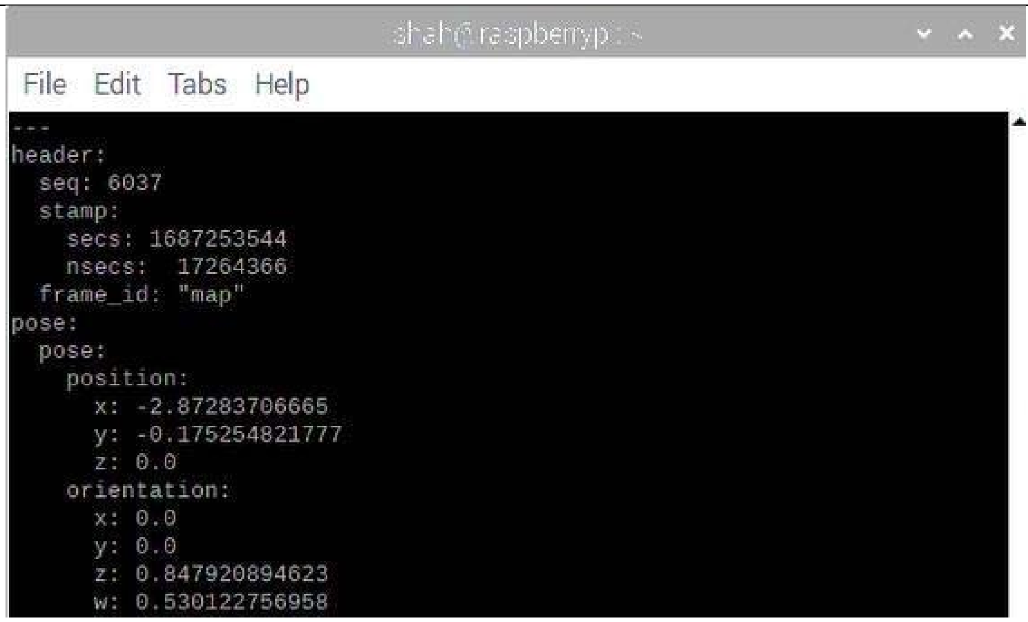
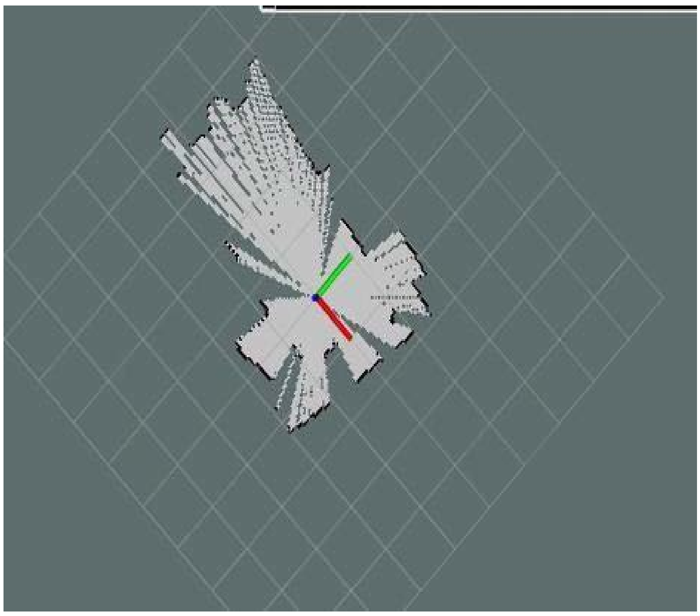
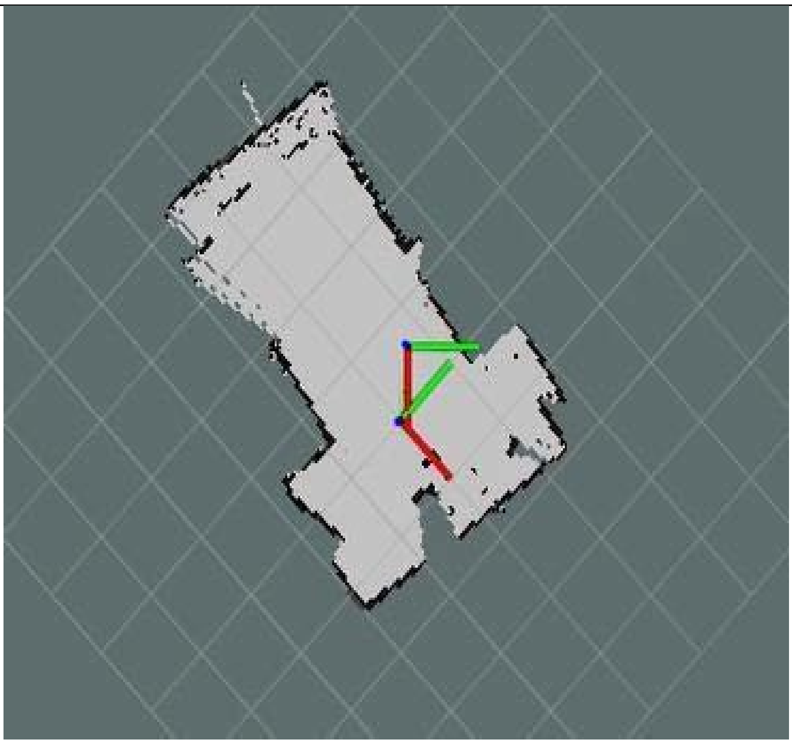
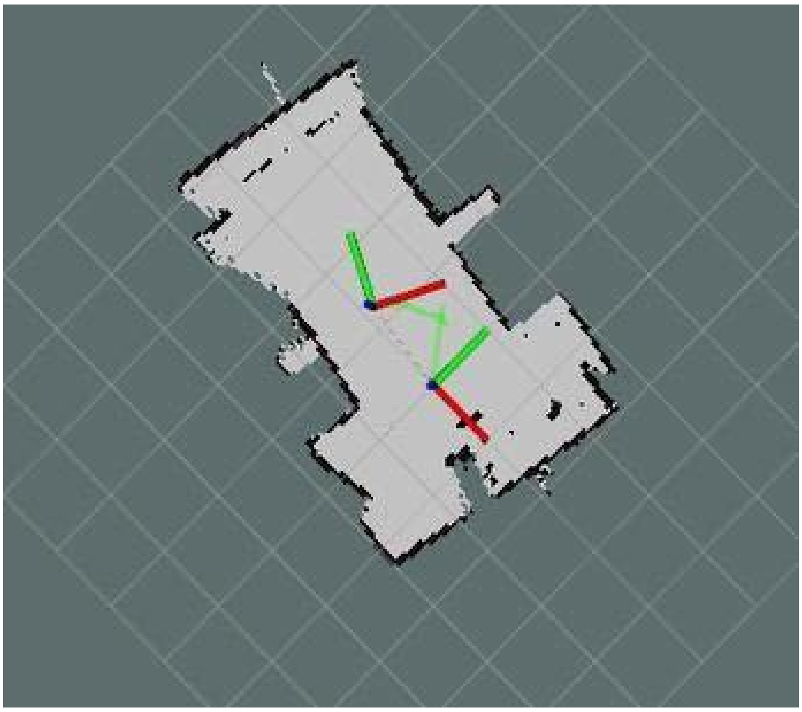
Marking Point 4	

Table 2 Summary of mapping results

Point	Mapping Results
Start Point	

Marking Point 1	
Marking Point 2	

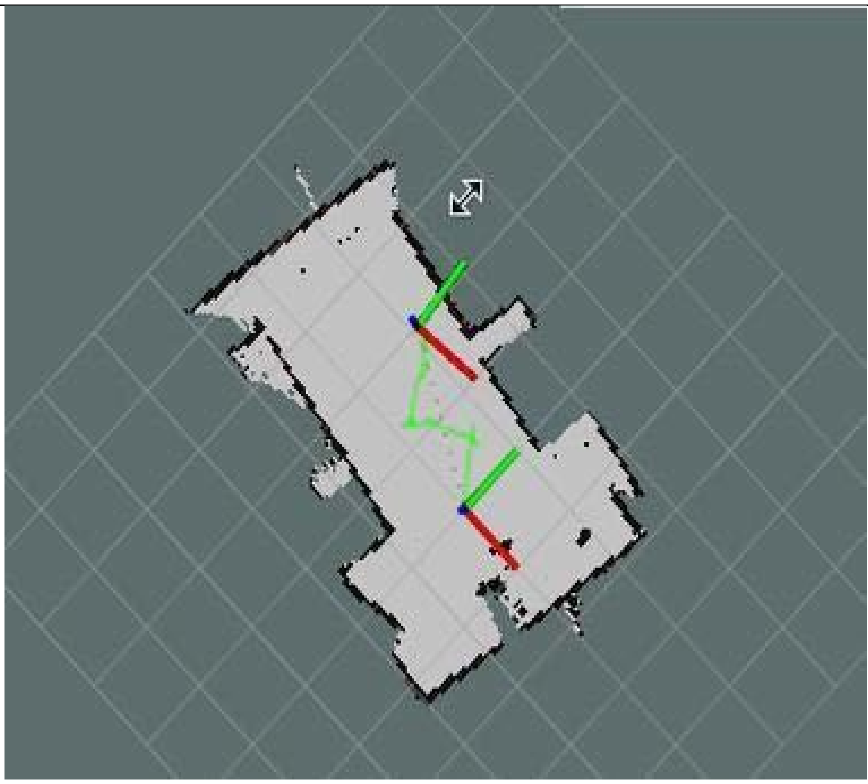
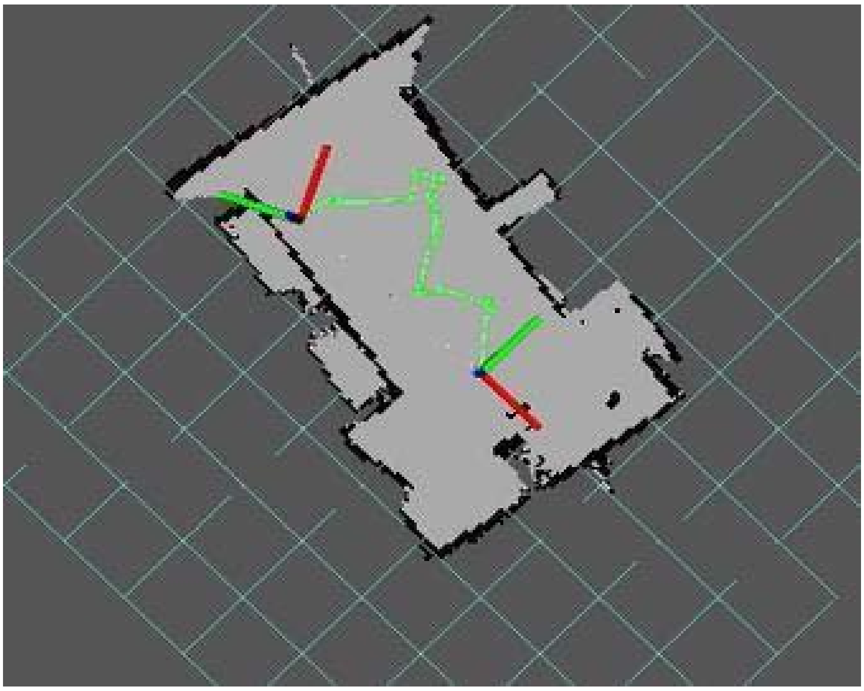
Marking Point 3	
Marking Point 4	

Table 3 Measurement results

Point	Distance from Manual Measurements (cm)	Distance from Mapping Measurements (ROS / Rviz) (cm)	Accuracy	
			Percent Error (%)	Percent Correct (%)
Start – Marking Point 1	85 cm	89 cm	4.8	95.2
Start – Marking Point 2	130 cm	127 cm	2.3	97.7
Start – Marking Point 3	233 cm	227 cm	2.6	97.4
Start – Marking Point 4	294 cm	287 cm	2.4	97.6
AVERAGE			3.3	97.0

As can be seen from the results, RP LIDAR with its associate robotic platform has able to map and localize the robot's position accordingly. However, RP LIDAR has a few limitations, in terms of accessing and scanning small angles and narrow spaces. This can be resulted with uneven and incomplete mapping. However, it is believed that appropriate and suitable algorithm and methods can be applied to encounter these limitations, in acquiring better accuracy results. The robotic platform could also be upgraded by incorporating better hardware for better navigation.

4. CONCLUSION

In conclusion, the usage of RP LIDAR in robot localization and mapping has been successfully tested. Suitable mapping and localization have been produced, with a good, average results of 3.3% error and 97% accuracy. More tests and results can be obtained towards other types of environments, to further discuss and analyse its performance. RP LIDAR could also be paired with a more robust, advanced robotic platform to ensure ability to localize and mapping with more complex indoor environment.

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