TEST Engineering & Management

March - April 2020
ISSN: 0193-4120 Page No. 223 - 227

Design and Develop Automated Guided Vehicle (AGV) Base for Mapping and Navigation Task

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Article Info
Volume 83
Page Number: 223 - 227
Publication Issue:
March - April 2020

Article History

***Article Received**: 24 July 2019*
***Revised**: 12 September 2019*
***Accepted**: 15 February 2020*
***Publication**: 12 March 2020*

Abstract
The environment scanning has been important in mobile robot studies and applications that may help people to investigate, monitor and study a variety of environments such as unexplored or hazardous surroundings. The main issue regarding this research is the efficiency of the mobile robot system and the accuracy of the laser sensor. This project presents designing and developing of an Autonomous Guided Vehicle (AGV) with indoor mapping capability only using a LIDAR as primary sensor and without odometry information of the AGV base. Hector mapping SLAM algorithm is adopted for building the map around the robot which is equipped with single 1D laser range finder in ROS platform and viewed through ROS visualization Rviz. To evaluate the performance of the sensor and the AGV base, usability testing was carried out in multiple experiments. The Lidar results for object distance measurement show over 97% accuracy for targets within 9 meter radius of the AGV base and the mapping accuracy is 83% for areas larger than 34sq.m and over 94% for areas smaller. Arduino Uno is used to communicate and control the motors. The AGV is remotely controlled via wireless communication. It is also designed to transport load in closed areas such as labs or libraries therefore, the design base is capable of carrying upto 20 kilograms at a speed of 0.6 m/s. Discussion of errors and troubleshooting methods are presented after the experiment results.

Keywords: *Robotic Operating System (ROS), SLAM, 2D mapping, Lidar, HectorSLAM, AGV.*

I. INTRODUCTION

Automated Guided Vehicles (AGVs) have advanced into an established source for organizing modern intralogistics. One of the first industries to initiate the usage of AGVs were the automotive industry. However, today all the industries use AGVs in their factories to optimize work flow. The utilization of automation in industries as opposed to human workforce has allowed the automotive industry to guarantee that tasks are being performed according to expectations. Speed and accuracy that comes along with industrial automation is unmatched when compared to human workers

A. Research Problem

To improve workplaces that rely mainly on logistics, AGVs are introduced. AGVs were mostly popular in factory floor spaces but now they can also operate in offices, hospitals and even in malls. Moreover, AGVs work both in indoor and outdoor environments and around the clock, day or night. The environment scanning has been important in mobile robot studies and applications that may help people to investigate, monitor and study a variety of environments such as unexplored or hazardous surroundings.

B. Justification for the Research

Area mapping is important and is widely being used in the field of archeology, geographic, geodetic and atmospheric surveys. Other areas that are benefited is the area of robotics. The sensor mainly used for mapping is Lidar and has increasingly become popular for autonomous robots. Implementation of AGVs in factories can reduce the physical burden

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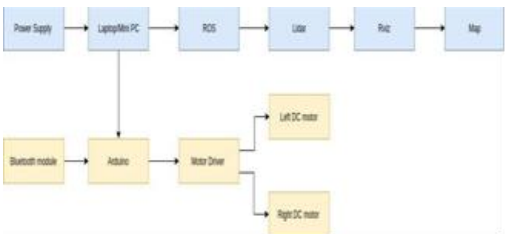
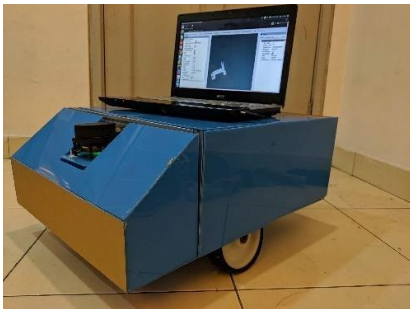
on human staff by doing the repetitive or tiring work such as pick and place of materials, lifting and moving heavy items across the factory.

II. METHODOLOGY

ROS (Robot Operating System) is used as the main platform to implement the whole system. Since ROS is a distributed framework of nodes that allows programs to separately be designed. ROS is operated on the laptop/ mini PC and this in turn is used to run Lidar sensor which is connected to the laptop by serial port. After establish communication with ROS, lidar begins to scan the environment to map the area using the Hector mapping SLAM algorithm. The scan data that is being recorded by the lidar is transformed into a 2D map and visualized in Rviz. Rviz is a ROS visualization GUI that can be used to view the AGVs 2D reconstruction of the environment. The main purpose of Rviz is to allow user to see ROS messages in 3D to let user to visually verify data. The lidar setup is built on a moving AGV base that can be controlled using a bluetooth module. The AGV base is controlled by the input data from the Bluetooth module. This data is sent to the motor driver that controls the geared motors that allows the AGV to navigate. The speed of the motors can be controlled depending on the load the AGV is carrying.



Block diagram of the system Hardware



Final prototype

The prototype built was 45cm x 45cm This is an ideal size for indoor navigation. When the AGV base is activated the lidar mounted in the front is able to map its surroundings and it can also navigate by established wireless communication between the base and the smartphone. The AGV moves around till the surrounding area is completely mapped. It is only required to go once around the space to build a finished 2D map. The top of the AGV is built flat so that it can carry load upto 20 kilos without any difficulties. The geared DC motors are capable of traversing the base without loads at low torque and with loads at high torque. The programming done allows the speed of the AGV to be controlled. The app to control the AGV has designated buttons for different movements. It also has speed adjuster programmed to control the motor speed from only 20% output to maximum speed.

The design has 2 wheels that will be controlled by DC motors and a third wheel in the front that will help the bot with maneuverability. The reason why servo- controlled wheels are placed in the inside of the body rather than the outside is to avoid any collision with objects while navigation through tight spaces. The rpLidar is placed on the front end of the AGV. The AGV body will be made from aluminum sheets as aluminum is lightweight and durable. The body is hollow on the inside. In here the servo motors will be connected to the robot wheels, the microcontroller and the mini PC will be placed inside, and all the circuit connections made will also be inside the AGV body. This will ensure the AGV have any exposed electrical wires.

Lidar sensor was programmed in python as ROS is an UNIX platform for operating robotic systems. The working of the sensor is such that it should be able to laser scan environments and create a 2D map of its surroundings. This is done by implementing Hector mapping algorithm.

A. Flowchart of the system

When the AGV and the lidar are powered the lidar begins to scan the environment. The first scans from the sensor are registered as the initial map, simultaneously the AGV also navigates when it is powered on. When the AGV moves the following scans done will be different. Therefore, it uses a scan matching algorithm to estimate pose change from the new laser scan. This is done by applying the Hector mapping SLAM algorithm in the

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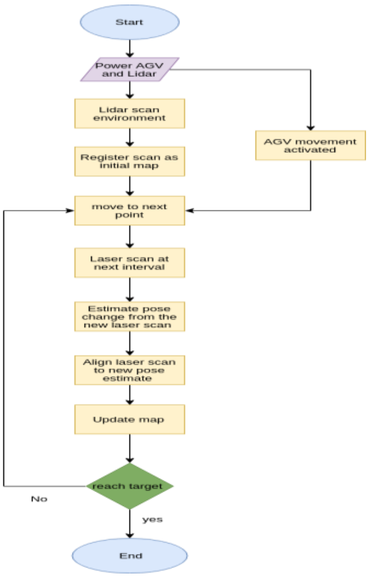
system. The laser scan is aligned to the new pose estimate and the map is updated. If the AGV reaches the target it will stop or else, it will move to the next point and repeat the process until its destination is reached.

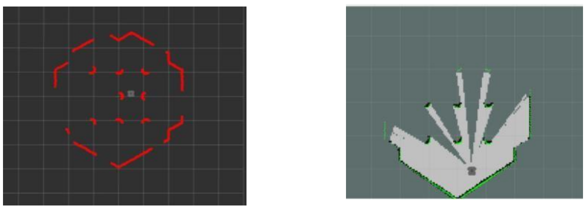


System flowchart

III. Results and Testing

Simulation

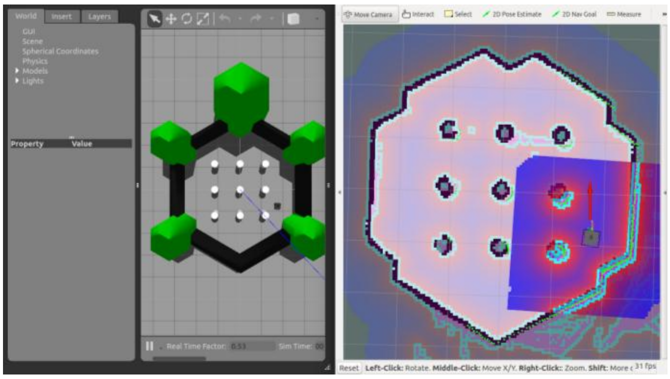
Before testing the AGV in real environment scenario, simulations were carried out to find out how the AGV behaves in a situation by mapping its surroundings. In the simulations autonomous navigation was also carried out after laser scanning and mapping. The simulations were performed in Gazebo and the 2D mapping was viewed in Rviz. The robot begins to laser scan the environment to detect objects. This laser scan data is then converted into a 2D map by running the Hector mapping algorithm in the lidar sensor. As the robot moves around the area, the 2D map gets build.



(a) (b)

Laser scanned map (a) converted to 2D map (b) using Hector SLAM

The navigation algorithm then makes a path for the robot to reach its goal position and the robot follows the path therefore, completing autonomous navigation while avoiding obstacles.



(a) (b)

AGV moving in environment(a) and using navigation SLAM algorithm (b)

Hardware results

The results from the mapping can be seen in Rviz. As the AGV base moved around the area it mapped it. The map on the left is the actual drawing of the room and the one on the right is obtained from the lidar scanner. The final map acquired from the lidar is comparable with the actual map.

Testing

Lidar is the only and primary sensor in the prototype. It is used to laser scan the surroundings and re-create a 2D map of its environment. The distance measured with the lidar sensor has to be very accurate to the real value

Exp No.	Measured Distance (m)	Avg Sensor Value(m)	Efficiency (%)
1	0.5	0.501	99.80%
2	1	1.004	99.60%
3	2	2.017	99.15%
4	3	3.034	98.87%
5	4	4.049	98.78%
6	5	5.066	98.69%

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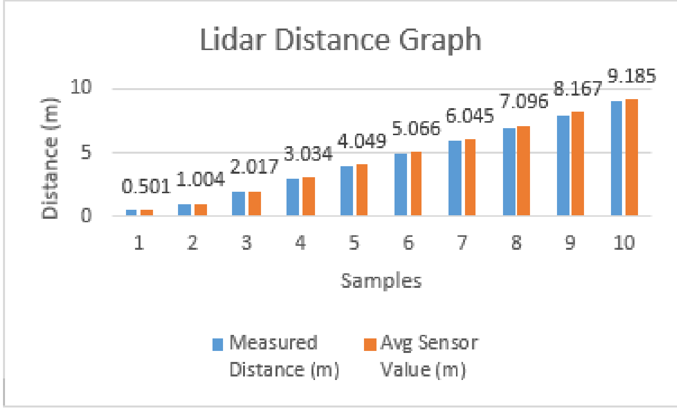
7	6	6.045	99.25%
8	7	7.096	98.64%
9	8	8.167	97.95%
10	9	9.185	97.98%

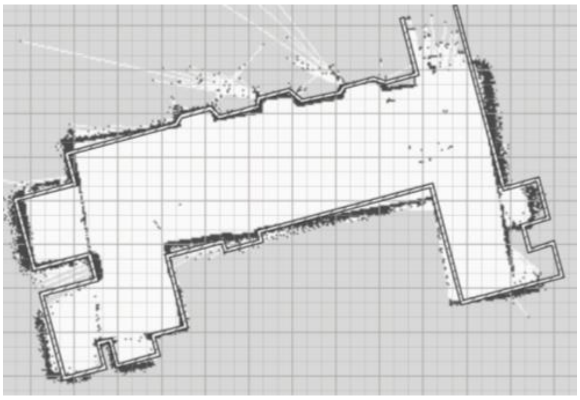


Lidar distance vs measured graph

As for this test the maximum distance measured with the lidar sensor was 9 meters and the acquired value was 9.185 meters, 18.5 centimeters difference with the truth value. This is however very small change when compared to the actual as the efficiency of the lidar still over 97%.

Hector vs Gmapping test

After a map construction the next important part is to evaluate the results of the map. Since SLAM has multiple algorithms to create maps, it is difficult to choose the best and suitable for evaluating certain problems. In this test two SLAM algorithms will be compared with each other to find out the best suitable mapping algorithm for the environment.

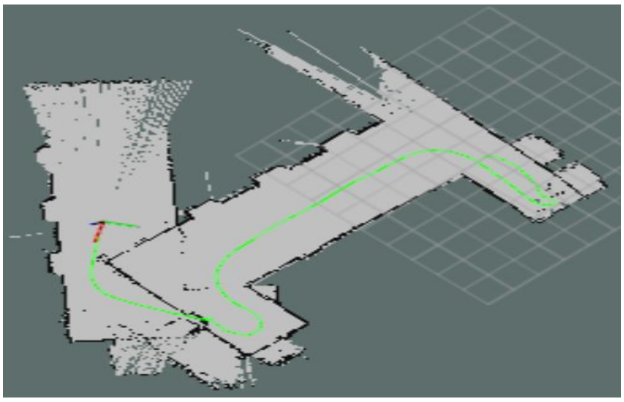


Hector mapping vs ground map

Gmapping vs Ground Map

Throughout the samples taken with Hector mapping the results remained similar to one another. This is because Hector only uses Lidar data and not odometry. Therefore, for this setup Hector mapping is more suitable than Gmapping SLAM algorithm. However, for larger maps Hector is less accurate and does not produce quality maps. Gmapping algorithm works by analyzing the data from the lidar sensor and an odometry sensor such as Inertial Measurement Unit (IMU) for localization and map rectification. Since there were no IMU sensors in the prototype, Gmapping Algorithm is not suitable for this setup.

The ground map is compared with one of the maps generated from the Gmapping algorithm. The map is accurate in the beginning but when the AGV makes a turn at one end it loses its position and orientation and continues mapping in the wrong direction. The path the AGV in green while navigating. It continues to proceed straight and turns later than it was expected to.



AGV path in Gmapping

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IV. CONCLUSION AND FUTURE RECOMMENDATION

The aim of this project was to design and develop an Autonomous Guided Vehicle that can perform mapping and navigation tasks. The developed system achieved all the objectives. Limitations of lidar is that it does not work accurately in presence of glass or reflective walls. Scans in horizontal plane therefore only 2D maps are achievable. For future work IMU sensor can be used for further enhancement in navigation capabilities. For 3D maps 2 lidars to scan both horizontal and vertical plane and combine using mapping algorithm.

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