Analysis of Mobile Robot Indoor Mapping using GMapping Based SLAM with Different Parameter

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Abstract. Mapping is one of the elemental application of the mobile robot. The map is created using the mobile robot by employing sensors such as camera, sonar and laser sensor. One of the most popular mapping methods is the Simultaneous Localization and Mapping (SLAM). SLAM allows the map to be created while localizing the robot location in the map at the same time. GMapping is one of the widely used algorithms in SLAM which will be used in this project. The mobile robot is equipped with a Hokuyo Laser Range Finder sensor and netbook. The router is used for wireless communication between the mobile robot and the user. The GMapping is done in two different locations of different lab size and amount of features in the area. Three trial is conducted to investigate the effects of different parameters such as robot speed, mapping delay and particle filter on the mapping quality. The results show a significant difference in terms of mapping accuracy and the time taken to complete the process as the parameter changed from the three trial. As a result, the parameter used in the second trial, robot speed 0.1333m/s, mapping delay 1s and particle filter 30 is considered as the best based on the time taken and the map accuracy.

1. Introduction

Mobile Robot is a type of robot that can move around in the environment freely either using the wheel-based or foot-based system. These robots are developed in order to help solve the problems that usually arise because the task is harmful to human. Tasks like repetitive movement would cause ergonomic risk or deal with something unknown, like the exploration of the unmapped area. In the exploration of an unknown area, the mobile robot can be sent first to check the condition and mapping of the area for any danger or hazard that may exist. The mobile robot continuously receiving the attention of many researchers as one of the ways to solve problems arising and continuous research done in order to explore more on mobile robot capability.

Mapping is the process of creating a map that is readable by both human and mobile robot. These maps created using a mobile robot with suitable sensors like visual (camera), sonar and laser sensor. Mapping is considered as one of the interesting contributions of mobile robot since the map can be used for various application. For example, mobile robot autonomous navigation which requires the map of the area in order to navigate safely [1]. Other application includes being able to be used in search and rescue robot which requires the robot to create the map while searching and mapped the location of the potential victim [2]. As such, mapping has become one of the important research in the mobile robotic area with various mapping technique currently available.
One of the most popular mapping methods is Simultaneous Localization and Mapping (SLAM). SLAM is the mapping method that is available in the Robotic Operating Software (ROS) platform. It is able to construct or update the map while at the same time keeping track of the location of the mobile robot [3]. This will reduce the errors in terms of mapping accuracy by taking into account the robot location while mapping. As such, many algorithms of SLAM method is developed and used with the mobile robot in other research [4]. There are many algorithms that are available under SLAM, for example, GMapping, Core SLAM, Graph SLAM, and Hector SLAM.

However, most of the study done by others are comparing the algorithms to see which able to construct the most accurate map. Each of the algorithms also has its own parameters which can be changed based on the environment the robot is working. Using different parameters like robot speed and mapping update delay not only able to cause changes in the time taken but also the accuracy of the map. Hence, it is important to know the effect of how different parameter of the algorithm can change the quality of the map which is the focus of this paper.

This paper is organized as follows. Section II discusses other researcher works on SLAM topic. Section III shows the mobile robot setup which is used in this research. Section IV explains the algorithm used for SLAM and the mapping flow process. Section V shows the results and discussion of this research. Section VI is the conclusion of the paper.

2. Related Works

SLAM is continuously being researched in order to create or improve on the algorithm available to create a better quality map. As mapping is considered as crucial especially for navigation purpose which is considered as the beginning of the process many research had been conducted in the past.

The research by Kohlbrecher et al [5] uses Hector open source modules for the map generation using their robot. Their research is to do the mapping and navigation for the rescue robot. Using the Robotic Operating System (ROS) as the platform, they used Hector SLAM in order to solve the SLAM problem and generate a highly accurate metric map for exploration of uneven environment for rescue. Figure 1 shows the hector SLAM used with Hector UGV robot and the quadrotor. The researcher used the proposed method in RoboCup 2012 for a rescue operation, which is the autonomous exploration of the robot in the arena to locate all the four victims.

![Figure 1](image1.png)

Figure 1. Map learned using Hector modules, (a) mapping results using hector_slam and hector_exploration_planner with Hector UGV robot, (b) hector SLAM application on ccny quadrotor [5].

Balasuriya et al [6] research on outdoor robot navigation uses the GMapping based SLAM algorithm to generate the map. The robot equipped with a laser scanner with a combination of sonar sensor as the backup. Using the slam_gmapping algorithm will create the grid-based map. Figure 2 shows the results of the GMapping for an indoor and outdoor environment. It can be seen that the walls which should have been a straight line but are not updated in the map as straight. This is due to slippage between the
tracks and robot wheel occurring constantly during the mapping. From the results the GMapping algorithm able to cope with both stationary and dynamic landmarks. It keeps the stationary and removed the dynamic landmarks from the created map as the map is updated.

![GMapping mapping results](image)

**Figure 2.** GMapping mapping results, (a) Indoor, (b) outdoor [6].

Li et al [7] propose the use of FastSLAM with new jacobian free Neural Network (NN). FastSLAM suffers from the limitation on error accumulation when it is introduced with incorrect odometry model and inaccurate linearization of the SLAM. Using the multilayer of NN able to compensate the odometry error and the NN is trained online during the SLAM. The researcher also used the third-degree Cubature rule for Gaussian weighted integral to calculates nonlinear transition density of Gaussian to estimate correctly the SLAM state. The researcher simulated the proposed algorithm using the MATLAB simulator with Ackermann vehicle model. Their algorithm was able to outperform the traditional FastSLAM 2.0.

Based on the works by others, it can be seen all the algorithm GMapping, Hector SLAM and FastSLAM able to provide a good mapping quality. GMapping is also used by other researchers [8-10] in their research making it one of the popular choices for SLAM mapping algorithm. However, besides the differences in the algorithm, there are also parameters in each mapping technique that would be able to affect the mapping quality. Hence, in this research, it is decided to focus on different parameters effect of the GMapping technique.

### 3. Mobile Robot Setup

The mobile robot used for this research is the IRobot Create. The robot has the total max speed of 500mm/s is equipped with a Hokuyo Laser Range Finder (LRF) and netbook on top of it. The netbook is connected with the robot through serial port wire communication. Figure 3 shows the mobile robot together with the Hokuyo LRF and netbook. The LRF sensor is able to sense the surrounding in range of 0.02m to 5.6m and covering up to 240° angle. The laptop or remote station called as a base station while the robot with the netbook is the workstation. Both of these stations communicated using wireless communication of the Router as shown in figure 4.
4. Simultaneous Localization and Mapping (SLAM)
SLAM is one of the methods available for the mobile robot mapping using the platform Robot Operating System (ROS) that are available in Ubuntu. The algorithm chosen for this research is GMapping. GMapping used the Rao-Blackwellized Particle Filter (RBPF) and take data from both laser sensor and robot pose to create a 2D grid map [9]. Figure 5 shows the mapping flow process which is used for this research.

![SLAM mapping flow process diagram](image-url)
The base station and workstation is connected wirelessly using a router based on the network configuration of [11]. Once the connection is established then the corresponding node for the mapping process is run on the remote pc which able to access the netbook on the robot through ssh command. The robot will move in a spiral path pattern as shown in figure 6.

![Robot mapping path](image)

The map accuracy is calculated when the robot finished the mapping. The equation (1) is used to determine the accuracy of the map based on the size of the real map layout. The $x$ represents the total length of the map created by the robot while $y$ is the total length of the real map. If the accuracy is high or more than 85% then the map will be saved if it is not then the robot will do one more loop to fill any missing parts of the map.

\[
\text{Accuracy} \, (\%) = \frac{x}{y} \times 100
\]  

5. Result and Discussion

The result is obtained from the SLAM mapping of two different indoor areas. The first mapping location is in Lab A and the second location is Lab B. Both are located indoors. Each of the area mappings is done in three trials with the different parameter of mobile robot speed, mapping delay and particle filter as shown in table 1.

| Trial | 1   | 2    | 3    |
|-------|-----|------|------|
| Robot speed (m/s) | 0.1 | 0.133 | 0.161 |
| Map update interval (s) | 5   | 1    | 0.1  |
| Particle filter    | 30  | 30   | 15   |

The mapping for Lab A is done in three trial as mentioned before. The map area of characterization lab is 108m$^2$ and the total length is 41.8m. The robot starting area is the same for all three trial of the mapping process. Figure 7 shows the real map layout and three trial mapping of Lab A. Comparing the three results with the real map in visual alone it can be seen that as the trial goes the maps become more incomplete (increasing empty unmapped area). The results of the mapping are shown in table 2. The mapping accuracy decreases even though the time taken for mapping becomes shorter. For Lab A the
best map is the second trial. This is due to the time taken to complete the map is almost two times shorter than the first trial even if the accuracy lower by 1%.

![Figure 7](image)

**Figure 7.** The Lab A mapping, (a) real map layout, (b) first trial, (c) second trial (d) third trial

| Trial | 1       | 2       | 3       |
|-------|---------|---------|---------|
| Map size perimeter (m) | 38.8592 | 38.1266 | 36.1965 |
| Time taken to complete mapping (min : s) | 24 : 33 | 12 : 19 | 6 : 14 |
| Map accuracy (%) | 92.96 | 91.21 | 86.59 |

Table 2. Mapping result for Lab A.

Lab B map area is 184m² and the total length is 55.6m. The lab consists of two rooms separated by wall and open door in the middle. The notable difference with Lab A is that this lab B is bigger in size but the fewer amount of feature presents in the area. Fig. 8 shows the real map layout and three trial of Lab B mapping. The results of Lab B mapping is shown in table 3.
The first and second trial is quite similar in terms of the accuracy of the map. However, the first trial took quite a long time to finish the mapping which is 40min compared to the second trial ends at 19min. This is due to the lower speed and long mapping delay causing it takes some time to finish the mapping. Since not only the map size is bigger but also the number of features which is comparatively lesser than in Lab A, it also contributes to the longer time it takes to finish the map. Unlike the first and second trial which shows high-quality map in terms of visual and high accuracy, the third trial, however, the second room on the left becomes slanted. This is due to the shorter map update delay and low particle filter causes high computational load for the robot causing some data loss giving an inaccurate representation of the map. This also causes the robot movement to occasionally move and stop a few times even with the manual command being sent from the base station. Finally, from the results in Table 3, the second trial is considered as the best map with the highest accuracy.

Based on the result from both lab mapping the time taken for mapping decreases as the robot speed increases, map update delay and particle filter decreases. However, it can be seen that the mapping quality also decreases especially in the third trial. This is due to the higher robot speed and much lower mapping delay that resulted in the increases of computational load for the mobile robot. As a result, some of the new data are being sent to the workstation are lost in the process. Not to mention that the

| Trial | 1      | 2      | 3      |
|-------|--------|--------|--------|
| Map size perimeter (m) | 54.5963 | 54.0231 | 51.8253 |
| Time taken to complete mapping (min : s) | 40 : 22 | 19 : 35 | 15 : 01 |
| Map accuracy (%) | 98.19 | 97.16 | 93.21 |
faster robot speed means the sensor will not have enough time to scan every area in the lab. Thus, this will induce more holes and errors in generating the map.

6. Conclusion
The SLAM method is used with the GMapping algorithm for the mapping process in this research. Three trials of the different parameter of robot speed, map update interval, and particle filter are set to investigate its effect on the mapping quality. The results show the significant differences in the map quality and time taken as the changes take effect. The robot speed needs to be complemented with the map update delay as the speed increase the delay also should be lower. This is due to faster speed will give not enough time for the map update if the delay is high causing some parts of the map to remain unexplored. The same can be said on the particle filter if too high will cause heavy computational process effect while too low will affects the map accuracy.

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