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# Fast SLAM using Polar Scan Matching and Particle Weight based Occupancy Grid Map for Mobile Robot

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***Abstract* - Simultaneous Localization and Mapping is the one of essential techniques for mobile robot navigation. In this paper, we propose a fast SLAM method that uses particle weight based occupancy grid map, and also works well with in indoor environment. In addition, in the prediction step, our method that uses the polar scan matching and wheel odometry information improves the accuracy of prediction pose. In order to evaluate our proposed method, we use a simulation and the 2-wheeled mobile robot that is able to move in large-scale indoor environment. The experimental results show that our method is suitable for fast and accurate mapping and localization algorithm for mobile robot.**

***Keywords* – Fast SLAM, Polar Scan Matching, Particle Filter, Occupancy Grid Map**

## 1. Introduction

To navigate a mobile robot autonomously, some fundamental techniques are required. These are motion control, localization, path planning, path following and mapping. Among these techniques, localization and mapping are the very important and basic techniques.

When a mobile robot is in an unknown environment, it requires to create a map of its surroundings while simultaneously estimate its position on the created map. This problem is called simultaneous localization and mapping (SLAM)[1]. Several previous researches to SLAM is related to our work[5].

To estimate the map of the environment, we use a highly efficient variant of the fast SLAM algorithm[2], which itself is an extension of the Rao-Blackwellized particle filter for simultaneous localization and mapping proposed by Grisetti et al. [4]

In this paper, we propose a fast SLAM[2] method that uses polar scan matching[3] and particle weight based occupancy grid map, and also works well with in indoor environment. The rest of this paper organized as follows. Section 2 describes the proposed fast SLAM. Experimental environment and results are analyzed in section 3, while conclusions and further work are drawn in section 4.

## 2. The Proposed fast SLAM

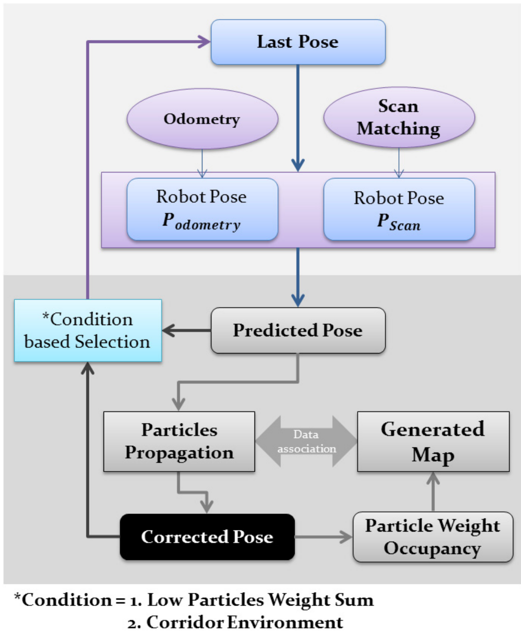


Fig. 1. Overall Structure of our proposed fast SLAM

Fig. 1 shows an overview of our method. Our method is divided into two steps which are prediction step and correction step. In the prediction stage, we use encoder information and polar scan matching result as a following Eq.(1). Here, $X_k$ is robot pose, $\bar{X}_o$ and $\bar{X}_s$ are odometry pose and polar scan matching result pose, respectively, where $e_{psm}$ is polar scan matching error and $w_s$ is scan matching weight.

$$\begin{aligned} X_k &= ((1-w_{s,k})\Delta\bar{X}_o + w_{s,k}\Delta\bar{X}_s) + X_{k-1} \\ w_s &= K_p e_{psm}{}^{-1} + \Delta\theta_o \end{aligned} \tag{1}$$

Particle weight based occupancy grid map formulated as Eq.(2). Here $w_p$ is weight of particle.

$$\begin{aligned} Map_{\{x,y\}} &= K_m \sum w_p + \text{current\_intensity\_of}(x, y) \\ w_p &= e^{-cE} \\ \textit{where, } E &= e_{psm} + K_T e_{position} + K_R e_{rotation} \end{aligned} \tag{2}$$



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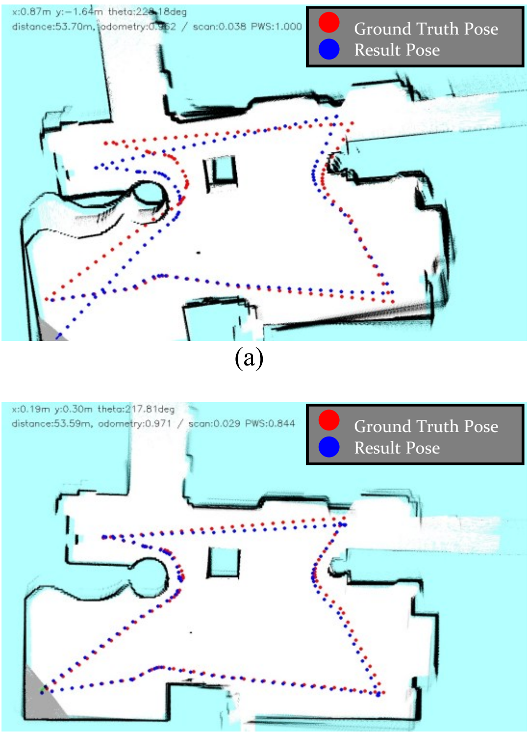
## 3. Experimental Results

### 3.1 Simulation

In the simulation experiment, we used virtual image map whose size is 30m × 20m under +10% encoder offset error in left wheel. Fig. 2(b) shows that despite of encoder error, the state of walls are clear and result pose of robot dose not deviate much from the ground truth while (a) is not.




(a)

(b)

Fig. 2. Simulation Results. (a) Using only erroneous odometry information (b) Result of our proposed fast SLAM with erroneous odometry information

### 3.2 Real Mobile Robot

We have tested on the inside of KAIST electrical engineering building to validate our proposed method using real mobile robot as seen in Fig. 3.

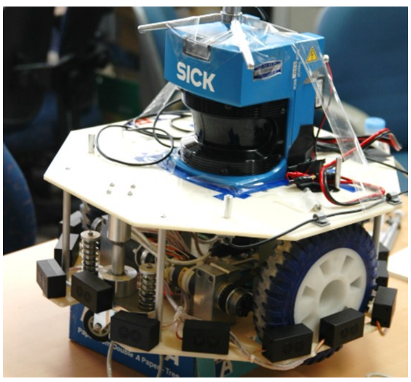



Fig. 3. Mobile robot used in experiment

Our algorithm in written in standard C++, and runs at 2GHz CPU with 50 particles and the mobile robot used SICK LMS200 LiDAR. Under these conditions, the computational time was approximately under 100ms per frame.

Fig. 4 shows that localization and mapping result of our method in large scale environment nearly 340m long movement, while the final positional error is approximately 7m.

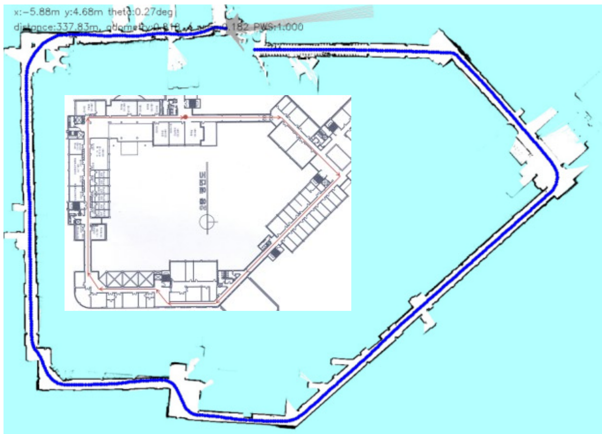


Fig. 4. Localization and mapping result of our method in large scale environment.

## 4. Conclusion

A new fast SLAM using polar scan matching and particle weight based occupancy grid map is proposed in this paper. The algorithm is suitable for fast and accurate mapping and localization for mobile robot in large-scale indoor environment. Furthermore, we will focus on a method for operating more complicated environment.

## Acknowledgement

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## References

[1] H. F. Durrant-Whyte and T. Bailey, "Simultaneous localization and mapping: part I, " IEEE Robotics & Automation Magazine, vol. 13, no.2, pp. 99-110, 2006.

[2] Michael Montemerlo, "FastSLAM: A Factored Solution to the Simultaneous Localization and Mapping Problem with Unknown Data Association," doctoral dissertation, tech. report CMU-RI-TR-03-28, Robotics Institute, Carnegie Mellon University, July, 2003.

[3] A. Diosi and L. Kleeman, "Fast Laser Scan Matching using Polar Coordinates", presented at I. J. Robotic Res., pp.1125-1153, 2007.

[4] Grisetti, G., Stachniss, C. and Burgard, W., "Improved techniques for grid mapping with rao-blackwellized particle filters", Robotics, IEEE Transactions on, vol. 23, no.1, pp. 34-46, 2007.

[5] Kaess. M, Ranganathan. A, Dellaert. F., "iSAM: Incremental Smoothing and Mapping", Robotics, IEEE Transactions on, On page(s): 1365 - 1378, Volume: 24 Issue: 6, Dec. 2008