学 位 論 文 内 容 の 要 旨

DISSERTATION ABSTRACT

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Scan Matching and SLAM for Mobile Robot in Indoor Environment

(屋内移動ロボットのスキャンマッチングと SLAM)

Autonomous indoor mobile robots are very promising application of robotics. In order to realize autonomous navigation, a robot that enters an unknown environment needs to reconstruct a consistent map of the environment and estimate its pose with respect to the map simultaneously. This problem is well known as the Simultaneous Localization And Mapping (SLAM) problem, which has attracted a lot of interest from researchers in past few decades. The most popular approaches towards SLAM problem are usually developed based on the probabilistic methods, such as Extended Kalman Filter (EKF) SLAM, particle filter SLAM, and maximum likelihood SLAM. In recent years, a robust technology named “Scan Matching” plays a very important role in solving the SLAM problem. By matching sensor scans that are taken from different poses, the scan matching method can efficiently estimated the rigid transformation of the robot between two poses. Due to the fact that the exploring sensors are usually very accurate and robust, scan matching is very efficient for mobile robot to localize itself with respect to the given reference scans or maps.

Although vision based approaches are getting more and more popular in SLAM research field, vision sensors are sensitive to the unpredictable variations of environment, such as the change of the lighting condition. Besides, most vision based solutions construct sparse feature points based maps which are not sufficient for robot autonomous navigation. Therefore Laser Range Finder (LRF) based scan matching method and fast indoor SLAM framework are still widely desired in consideration of the robustness of LRF towards environment changes. Another widely adopted sensor is Inertial Measurement Unit (IMU) which provides measurements of accelerations and rotating rates at the same time. In consideration of cost efficiency, Micro Electrical Mechanical Systems (MEMS) technology based IMU is preferable in consuming grade applications as well as robotic researches. However, the measurements of low-cost MEMS-IMUs are usually corrupted by various types of noises. Thus a calibration work to compress noises is nessary before the usage of MEMS-IMU.

The contributions of this study are consisted of three main parts. In the first part, various scan matching methods have been introduced. And the most widely used methods, Iterative Closest Point (ICP) and its variants, have been investigated and modified to obtain better performance. Second, a line-segment based EKF-SLAM approach is proposed for the application in structured indoor environment. In addition to fulfilling planar SLAM task with line-segment based maps, this method can efficiently detect the slope and edge that locate in structured indoor environment. Third, taking advantage of the proposed robust scan matching solution, a straightforward and efficient calibration method

toward MEMS-IMU has been developed. This thesis is organized in the following six chapters:

Chapter 1 introduces the research background of this study. And the motivation and contributions of this research as well as the outlines of the thesis were also provided.

Chapter 2 firstly introduces various algorithms of scan matching and then details the ICP variants. Several famous ICP variants have been introduced and compared. The reason why ICP is prone to failure when scans have large angular displacement has been explained. And a new iterative method to eliminate large angular displacement between scans has been proposed.

Chapter 3 firstly demonstrates the methods to speed up the process of ICP variants. And then two fast and robust association approaches for ICP association process have been proposed. The last part of this chapter introduces a framework of an incremental scan matching solution that is able to build sparse point maps and localize robot simultaneously.

Chapter 4 firstly introduces the method that extracts line-segments from LRF scans. Then, the line-segment based EKF-SLAM which adopts optional prediction process has been detailed. After the modeling processes of slope and edge have been presented, the vital information of slope and edge has been merged into EKF-SLAM framework.

Chapter 5 presents a straightforward way to calibrate the low-cost MEMS-IMU. A plastic cube that is made by 3D printer is introduced as the carrier of IMU. The proposed approach firstly calibrates accelerometer with multi-orientation method. By using a reformed swivel chair as an easy turntable, smooth rotation is obtained for gyroscope calibration. The angular displacement is estimated by using proposed scan matching method and the gyroscope is calibrated by comparing raw readings' integrations with scan matching results.

Chapter 6 firstly concludes the works that have been explained in the thesis. Based on the summary, several future works that intend to improve current achievements have been proposed.