学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Lidar-based Localization and Pose Estimation Approaches in the Map Built by Monocular SLAM
(単眼カメラ SLAM による地図における Lidar に基づく自己位置と姿勢の推定)

Nowadays, the autonomous navigation of mobile robots and vehicles is a promising technology. For a mobile robot, self-localization in its work area is an essential requirement for practical applications. The Simultaneous Localization and Mapping (SLAM) is a widely used algorithm to reconstruct the environment and provide a map to other robots to perform self-localization and navigation. There is a large amount of SLAM solutions based on various types of sensors used for environmental perception. Among them, the monocular SLAM, in which only a single camera is employed, attracts plenty of interest in the robotic community because of its simple structure and low cost. However, since the distances between the camera and obstacles are not observable in a single image, the monocular SLAM suffers from an inherent problem that the
estimated motion is determined without an absolute scale factor. Additionally, in case that there is no fixed baseline between two frames, the map reconstructed by monocular SLAM is also prone to be scale drifted over time.

This natural drawback makes it very difficult for other types of sensors to reuse the map built by monocular SLAM, since the distance information is of key importance to the range sensors such as sonar and laser range finder. Nonetheless, it should be noticed that the geometrical structure of the obtained map is still available for performing localization. Using the geometrical features without scale information, it is still possible to match the perception from range sensors and the map.

This thesis mainly focuses on solving the localization problem against the map from monocular SLAM. The structure of this thesis is listed as follows:

Chapter 1: The motivation of this study is demonstrated. Additionally, this chapter also gives a brief review of the technologies that are relevant to this study, including the localization methods, state-of-the-art monocular SLAM frameworks, and the solutions for dealing with the monocular scale drift.

Chapter 2: A scale-aware Monte Carlo localization (MCL) is proposed to localize a robot with 2D laser scanner in the map from monocular SLAM. Through Monte Carlo sampling, the proposed method can estimate the pose of robot in the target environment as well as the local scale factor of the map. The proposed method can also achieve global localization on the real time with the help of Kullback-Leibler Divergence (KLD) sampling. The performance of the method is first tested on a public dataset to evaluate the accuracy and then carried out on a real robot in practical environment.

Chapter 3: A novel scan registration algorithm with stretching the scale is presented. Although MCL can estimate the robot pose efficiently, it is expensive in computational cost and therefore can hardly solve the 6DoF pose estimation. Scan registration is another widely utilized technique which can directly estimate the relative pose of the sensor by matching the scan and reference point cloud. In this chapter, a novel point scan registration method named Scaled Normal Distribution Transform (sNDT) is proposed to handle the alignment between two-point clouds with different size. Both the run-time and convergence performance of sNDT are analyzed by comparing with the ICP-based solutions. Furthermore, this study proposes to combine a UKF (unscented Kalman filter)-based back-end with the sNDT to verify whether it is able to handle the 6D Lidar-based localization in an incomplete and scale-drifted map from the monocular SLAM.

Chapter 4: Conclusions are presented in this chapter. The defects and further improvement of this study are pointed out as well.