学 位 論 文 内 容 の 要 旨

DISSERTATION ABSTRACT

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学 位 論 文 題 名

Title of dissertation submitted for the degree

Probabilistic Approaches and Algorithms for Indoor Robot Mapping in Structured Environments

(確率論的手法とアルゴリズムに基づく 構造化された環境における屋内ロボットの地図構築)

The work in this thesis addresses an important problem in mobile robot navigation called as the Simultaneous Localization and Mapping (SLAM) problem. Just like we humans perceive the world using our senses and make judgment as how to navigate in the real environment, robots need high level of intelligence and computation to make such judgment using onboard sensors. They also need to consistently update their belief about its position and uncertainty. SLAM is such a fascinating field that it gives any mobile robot intelligence to interact with the environment its operating in and make intelligent decisions on how to navigate inside such environments. To do so, they require an accurate map of the environment (2D or 3D), and autonomously navigate in structured environments. The applications of such kind of robots are many, mainly autonomous navigation, obstacle avoidance, as service robots, search and rescue operation, teleoperation and many more. This thesis aims to find solutions to construct accurate 2D and 3D maps of indoor environments for successful autonomous behavior of a wheeled mobile robot.

The thesis addresses three major solutions to the SLAM problem:

1. *Localization using state of the art filters*: Localization using existing solutions for estimation like the Extended Kalman Filter (EKF), particle filters, and graph theory are presented. The work briefly describes techniques for building maps using Laser Range Finders (LRF) for 2D mapping and localization using 2D features such as corner points and 2D lines.

2. *Clustering approach to build maps*: This work proposes many solutions to make accurate maps by utilizing clustering algorithms for effective noise removal, data segmentation, data extraction and building memory efficient maps for long time mapping of large environments. A novel line extraction methods using clustering of LRF data is briefly presented which is computationally faster and robust to noise produced from cluttered areas.

3. *3D mapping using low cost RGBD sensors*: Finally, 3D mapping solution is presented that uses low cost depth or RGB-D sensors. Vision algorithms are used for fast feature extraction from depth images for constructing accurate maps providing rich information for safe navigation in cluttered areas. The image feature extraction method is combined with 2D localization method to make accurate 3D maps of large areas.

All the above algorithms are presented with results in real environment. The methods can easily be integrated to all kinds of wheeled robots for accurate navigation in indoor environments.

The thesis is divided into the following Chapters:

Chapter 1: Chapter 1 gives a brief introduction to the problem definition and previous works related to the thesis work.

Chapter 2: Chapter 2 gives a brief introduction to different probabilistic filter techniques that are used to address the SLAM problem. The main filtering algorithms like the Extended Kalman Filter, particle filter and Rao-Blackwellized particle filter along with graph based method are discussed in detail that forms the base for the rest of the chapters.

Chapter 3: Chapter 3 introduces different feature extraction methods to extract and segment important features from the LRF data. The chapter gives a comprehensive details of extracting corners and line segments from the laser scans. The chapter also discusses how to generate the covariances of the end points and the corner points that are to be used for the EKF SLAM.

Chapter 4: Chapter 4 forms a major work on a novel clustering techniques for feature extractions and line segment mapping from the LRF data. The major work is on extracting features from the LRF data from noisy environments. The noise from the cluttered environment needs to be removed prior to extracting important features. The contributions of the chapter are: (1) it shows the applicability of density-based clustering methods and mathematical morphological techniques generally used in image processing for noise removal from laser range sensor data; (2) it presents a new algorithm to generate straight-line maps by applying clustering in the spatial domain; (3) it presents a new algorithm for robot mapping using clustering in a Hough domain; and (4) it presents a new framework to load, delete, install or update appropriate kernels in the robot remotely from the server. The framework provides a means to select the most appropriate kernel and fine-tune its parameters remotely from the server based on online feedback, which proves to be very efficient in dynamic environments with noisy conditions.

Chapter 5: Chapter 5 forms the formulation of SLAM algorithm using all the methods described in Chapter 2. The chapter presents the line segment based EKF algorithm for constructing line segment based maps with corner features. Next, the occupancy grid mapping approach using particle filter and Rao-Blackwellized particle filter is discussed with results to real environment. Results using standard scan matching and iterative closest point (ICP) technique are also discussed with results. Graph based theory is used to solve the loop closure and results of long time large scale maps are presented.

Chapter 6: Chapter 6 introduces 3D mapping solution to the SLAM problem using low cost RGBD sensors. This chapter introduces some of the very popular vision algorithms like the Scale Invariant Feature Transpose (SIFT) and Speeded Up Robust Features (SURF) methods to extract 3D features from the depth images. A 3D ICP method is then used along with optimized graph theory to construct robust 3D maps of the environment from the point cloud.

Chapter 7: Chapter 7 concludes the thesis work with possible future works.