Algorithms for Mobile Robot Localization and Mapping, Incorporating Detailed Noise Modeling and Multi-Scale Feature Extraction

Thesis by

Samuel T. Pfister

Advisor: Joel W. Burdick

In Partial Fulfillment of the Requirements

for the Degree of

Doctor of Philosophy

California Institute of Technology

Pasadena, California

2006

(Defended April 14, 2006)

Abstract

Mobile robot localization and mapping in unknown environments is a fundamental requirement for effective autonomous navigation. Three different approaches to localization and mapping are presented. Each is based on data collected from a robot using a dense range scanner to generate a planar representation of the surrounding environment. This externally sensed range data is then overlayed and correlated to estimate the robot's position and build a map.

The three approaches differ in the choice of representation of the range data, but all achieve improvements over prior work using detailed sensor modeling and rigorous bookkeeping of the modeled uncertainty in the estimation processes. In the first approach, the raw range data points collected from two different positions are individually weighted and aligned to estimate the relative robot displacement. In the second approach, line segment features are extracted from the raw point data and are used as the basis for efficient and robust global map construction and localization. In the third approach, a new multi-scale data representation is introduced. New methods of localization and mapping are developed, taking advantage of this multi-scale representation to achieve significant improvements in computational complexity. A central focus of all three approaches is the determination of accurate and robust solutions to the data association problem, which is critical to the accuracy of any sensor-based localization and mapping method.

Experiments using data collected from a Sick LMS-200 laser scanner illustrate the effectiveness of the algorithms and improvements over prior work. All methods are capable of being run in real time on a mobile robot, and can be used to support fully autonomous navigation applications.