Indoor Localization of a Mobile Robot Using Sensor Fusion

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Abstract

Reliable indoor navigation of mobile robots has been a popular research topic in recent years. GPS systems used for outdoor mobile robot navigation can not be used indoor (warehouse, hospital or other buildings) because it requires an unobstructed view of the sky. Therefore a specially designed indoor localization system for mobile robot is needed. This project aims to develop a reliable position and heading angle estimator for real time indoor localization of mobile robots. Two different techniques have been developed and each consisted of three different sensor modules based on infrared sensing, calibrated odometry and calibrated gyroscope. Integration of these three sensor modules is achieved by applying the real time Kalman filter which provides filtered and reliable information of a mobile robot's current location and orientation relative to its environment. Extensive experimental results are provided to demonstrate its improvement over conventional methods like dead reckoning. In addition, a control strategy is developed to control the mobile robot to move along the planned trajectory. The techniques developed in this project have potentials for the application for mobile robots in medical service, health care, surveillances, search and rescue in indoor environments.

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I would like to acknowledge my Supervisor Dr. Loulin Huang, for his consistent support throughout the duration of my master degree. Thanks are also given to those people from the University, who has helped me a lot during the development process of this project. I would also like to express my deep gratitude to my family, especially to my parents for their constant encouragement, their tolerance and for their assistance in many ways for the successful completion of this thesis. Last but not least, I would like to thank those who always stood by me throughout my life and for their sacrifice and tolerance during the writing of this thesis.

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1 Introduction

This section introduces the aims of this project and why indoor localization of mobile robots is important. And a brief overview of the developed indoor localization method for mobile robots is presented. Also the structure of the entire thesis is explained.

1.1 Aims

The main research aim is to develop a reliable indoor localization system for mobile robots. This research was also done to achieve an understanding of the specific topic that is covered in this project. The secondary aim of the research was to identify new research topics for continuations of research study.

1.2 Indoor localization of mobile robots

For a long time, accurate and reliable indoor localization of mobile robots have been a challenging research topic. This is due to common localization methods such as odometry which based on encoder readings have problems with accumulated errors. Other modern localization systems such as GPS (Global Positioning System) have several limitations. Most significantly, direct line of sight is required between the receiver and the satellites. Any objects obstructing this path can block the signal from a satellite making GPS suitable only for outdoor environment purposes. Therefore severely limiting its applications with mobile robots as a large proportion are designed for indoor use.

Figure 1: A mobile robot navigating in an indoor environment

Many different methods have been developed in an attempt to solve the problems of robot localization [1 - 18]. These can be classified into the following two main categories:

Relative Localization: The robot's position and orientation are determined relative to objects that are either stationary or moving in the environment. Pose coordinates are evaluated using data information provided by different on-board sensors, such as encoders, gyroscopes and accelerometers.

Absolute Localization: The robot's absolute position and orientation are evaluated using data information provided by external sensors such as visual landmarks, navigation beacons or GPS. However, such technique required expensive installation of sensors, high maintenance and computational costs.

Although the techniques described above can achieve localization for mobile robots, however they still face further physical limitations specific to the indoor environment. One of the ways to overcome this is to combine multiple sensory data from different sensor modules to provide better, reliable and accurate information of the robot's current location and orientation relative to its environment. Thus, in most mobile robot applications the relative and absolute positioning estimation methods have been employed together as one system to improve the localization performance [1 - 15].

1.3 Overview of the developed indoor localization system

In this project, a new solution for reliable indoor localization of mobile robots has been developed. The proposed localization system combines the absolute and relative position measurement obtained from three different sensor modules based on infrared sensing, calibrated odometry and calibrated gyroscope. Integration of the three sensor modules is achieved by implementing the Kalman filter technique in conjunction with a conditional algorithm created to analyze and to provide position measurement and heading angle data collected from the three different sensor modules. The Kalman filter technique is selected due to its ease of implementation and its ability to update multiple pose data continuously. Throughout the development process, two different approaches in our proposed method for localization have been developed and these can be represented by Figure 2 and Figure 3 respectively.

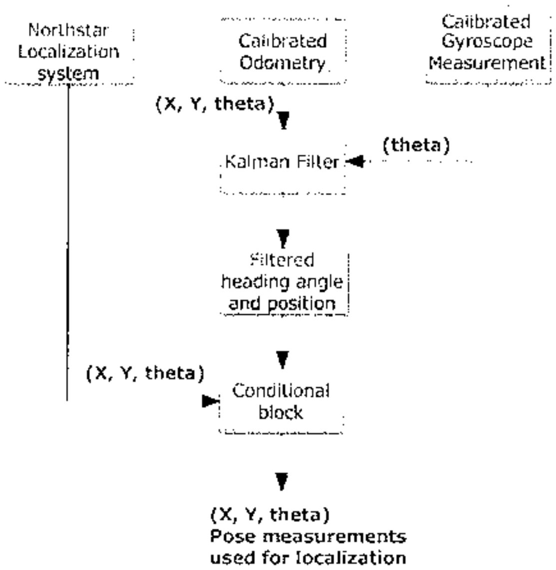

Figure 2: Overall structure of method one used for localization

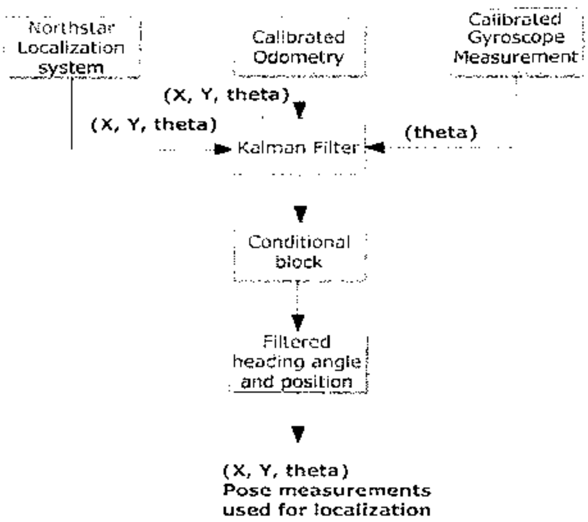

Figure 3: Overall structure of method two used for localization

Figure 2 and 3 shows the overall structure of the two different approaches of the developed indoor localization system. Essentially, each approach consists of the relative position measurement from the calibrated odometry and calibrated gyroscope and absolute position measurement from the optical beacon device known as the Northstar system [21]. The pose measurement collected from the three sensors modules are used to provide the information of the mobile robot's current location and orientation relative to its environment. The effectiveness of the two presented techniques and full description of the developed indoor localization system are explained in details in section 4.

1.4 Structure of the thesis

Section 2 presents an introduction to the field of mobile robot localization and the fundamental problems of localization. Also different localization techniques and calibration methods used to improve localization performance will be discussed and explained in details.

Section 3 presents the background of the robot model and details the software development process for robot control.

Section 4 presents testing and calibrations methods used and experiments results are explained in details.

In section 5, the conclusion of the thesis is presented and further development of the localization system and related work is discussed.