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Microcontroller-based mobile robot positioning and obstacle avoidance

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Abstract

The use of mobile robots is growing in manufacturing facilities, hazardous materials handling, etc. Usually, several sensor systems are used in combination. The task of combining the information into a usable form, suitable for making navigation decisions, is known as sensor fusion. In this paper, the navigation system built on a mobile robot operating in a warehouse is presented focusing on the sensory system used. Hybrid navigation system that combines the perception and dead reckoning is used and gives satisfactory operation. A microcontroller system is designed to control the navigation of a mobile robot while avoiding obstacles. A system of 24 ultrasonic sensors was designed and the operation algorithms were described. The encoder and the ultrasonic sensors used are presented in detail together with the navigation system designed based on their operation.

Keywords: Mobile robot; Navigation control; Odometry; Ultrasonic sensors; Microcontroller

1. Introduction

Robot navigation means the ability to wonder in the environment without colliding with obstacles, the ability to determine one's own position, and the ability to reach certain goal locations. So, navigation system may imply the following components: robot positioning system, path planning and map building. These are four popular positioning systems:

1. Odometry (dead reckoning)-based navigation.
2. Active beacons-based navigation system.
3. Landmark-based navigation system.
4. Map-based navigation system.

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Most autonomous robotic systems will have multiple sensors (Brooks, 1986; Mogensen, 2006). Usually several sensor systems are used in combination. These are sometimes complementary, sometimes redundant. In almost all robot systems, multiple sensors from the same type or different types are used to give complete coverage, for example a ring of 24 ultrasonic sensors in 15° increments around a vehicle, mobile robot CARMEL (Computer-Aided Robot for Maintenance, Emergency and Life support) (Borenstein and Koren, 1991). Another example is the Nomad Supper Scout II which carries 16 ultrasonic sensors separated by 22.5° around the vehicle (Yi, 2001). The task of combining the information into a usable form, suitable for making navigation decisions, is known as sensor fusion.

Mobile robots generally carry dead reckoning sensors such as wheel encoders and inertial sensors and also landmark and obstacle detecting and map making sensors such as time of flight (TOF) ultrasonic sensors. Sensors measurements in this case are to be fused to estimate the robot's position.

Vision sensors are used in many applications to build an image of the space confronting the mobile robot in order to detect any obstacle and avoid collisions. Vision systems are usually computationally expensive as image formation is too complicated for many applications.

In this paper, the navigation system built on a mobile robot operating in a warehouse is presented. Hybrid navigation system that combines the perception and dead reckoning was found to be complementary and gives a satisfactory operation of the mobile robot. If environment contains confusing information or few perceptually distinguishable landmarks, the performance of these systems decline. The perceptual aliasing problem can be solved by including the odometry data to discriminate between the similar places. The use of ultrasonic sensors in most applications is easier, cheaper and computationally simpler. Ultrasonic transducers are preferably used to obtain three-dimensional information of the environment (Bak, 2002; Everett, 1995; Borenstein and Koren, 1988; Benitz-Read and Rojas-Ramirez, 2010). They measure and detect distances to moving objects, are impervious to target materials, surface and color, solid-state units have virtually unlimited maintenance-free lifespan. Ultrasonic sensors are not affected by dust, dirt or high-moisture environment.

In Section 2 of this work, the odometry and the odometry errors were presented. Section 3 presents ultrasonic systems, the source of errors that could be encountered and the sensors type specially the sensor used in this work. Section 4 presents the robot description and the sensors, decoders and encoders built on the robot while Section 5 describes the robot controller designed for robot operation with the ultrasonic sensors used clustering and the controller hardware and software. Section 6 details the proposed robot navigation inside and outside the warehouse while Section 7 presents the experimental testing together with the interface board used. Sections 8 and 9 give the results discussion and conclusions.

2. Odometry and odometry errors

Odometry is the most widely used navigation method for mobile robot positioning. It is well known that odometry provides good short term accuracy, is inexpensive and allows very high sampling rates. However, the fundamental idea of odometry is the integration of incremental motion information over time, which leads inevitably to the accumulation of errors. Odometry is used in almost all mobile robots for various reasons: Odometry data can be fused with absolute position measurements to provide better and more reliable position estimation (Chenavier and Crowley, in press; Evans, 1994). Odometry can be used in between absolute position updates with landmarks.

Odometry is based on simple equations that are easily implemented and that utilize data from inexpensive incremental wheel encoders. However, odometry is also based on the assumption that wheel revolutions can be translated into linear displacement relative to the floor. This assumption is of limited validity. One extreme example is wheel slippage: – if one wheel was to slip on, say an oil spill, then the associated encoder would register wheel revolutions even though these revolutions would not correspond to a linear displacement of the wheel. There are also, several other subtle reasons for inaccuracies in the translation of wheel encoder readings into linear motion.

To correct the errors in positioning resulting from the odometry system and for safe navigation and obstacle avoidance, ultrasonic sensors are frequently used as they can provide good range information based on the time of flight (TOF) principle. They have been widely used in mobile robot applications (Elfes, 1987; Leonard and Durrant-Whyte, 1992; Borthwick and Durrant-Whyte, 1994).