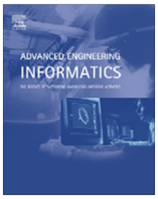
Advanced Engineering Informatics 24 (2010) 490–497

Contents lists available at ScienceDirect

Advanced Engineering Informatics

journal homepage: www.elsevier.com/locate/aei



An intelligent localization algorithm using read time of RFID system

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ARTICLE INFO

Article history:
Received 1 September 2009
Received in revised form 31 March 2010
Accepted 7 May 2010
Available online 8 June 2010

Keywords:
Read time
Localization
Navigation
Radio frequency identification (RFID)
Mobile robot

ABSTRACT

This paper presents a novel method using the read time of an antenna from an RFID system to reduce the localization error of a mobile robot in an RFID navigation system. There are many approaches for reducing the localization error in RFID systems. However, they do not deal with the problems that arise when the antenna can read at most one tag at any given moment. Using this approach, our passive RFID system is capable of estimating the robot's location and orientation more accurately without the use of external sensors, signal strength measurement, or a vision system. Moreover, the proposed method offers a modular and cost-effective alternative to other navigation systems for mobile robot applications related to services in indoor environment. The experimental results show that the proposed method enables the robot to successfully estimate both the location and the orientation during navigation. We discuss results of trajectories of the robot in navigation and compare them with a generally utilized RFID system.

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1. Introduction

As mobile robots are gradually becoming autonomous systems, robust navigation and localization techniques become fundamental robotics problems. It is easy to perform assigned tasks such as guidance, transportation, and human–robot cooperation more safely if a mobile robot is able to move based on accurate estimates of it's location and orientation. In relation to this, existing localization methods for mobile robots in indoor environments can be classified into two categories. One is relative localization such as odometry and inertial navigation. The other is absolute localization using RFID, active beacon, landmark or environmental map. Odometry is the most widely used method for determining the momentary location of a mobile robot. The existing odometry approaches [1,2] enable the robot to estimate the total distance traveled from a starting point. However, odometry is problematic in that the estimation error accumulates over time since no external reference signals are employed for correction. Specifically, the orientation errors will cause large lateral location errors, which increase proportionally with the distance traveled by the robot.

In order to improve the accuracy of localization, many approaches usually combine two different methods. Makela et al. [3] studied the integration of dead reckoning and visual landmark recognition methods for the navigation of outdoor mobile robots. Stella et al. [4] proposed a cooperation strategy between odometry and visual self-location method. Hahnel et al. [5] built 3D models with a laser scanner mounted vertically on mobile robot equipped with a horizontal 2D localization system. Moravec et al. [6] used evidence grids in 3D space based on stereo vision. There are also methods to reduce the accumulated errors by external sensors using landmarks [7,8]. These methods estimate the location and orientation of the robot from the observation of established landmarks in environment. However, the landmarks are not always observable due to the influence of ambient light and shielding obstacles. Additionally, ultrasonic systems, like the Active Bat localization systems [9], use an ultrasound time-of-flight measurement technique to provide location information. In order to determine orientation of a mobile robot, many approaches have used external sensors such as cameras providing 2D and 3D information about the environment [10,11].

In recent years, radio frequency identification (RFID) technology has attracted the attention of researchers into robotics due to ease of use, scalability, and cost-effectiveness. In particular, RFID tags are easily installed in a human living environment. For example, they can even be installed under carpets or other flooring materials, since unlike barcodes they are not identified by laser, LED, or camera-based reader. Furthermore, RFID tags are durable against dirt, jitter, vibration, and wear. RFID can provide location information to a robot, but it is difficult to accurately calculate the location of the robot due to the nature of the antenna, which can only detect if a RFID tag is present or not. Consequently, a mobile robot typically requires other sensors, multiple antennas, or a number of RFID tags within sensing range of an antenna for estimating its precise location and orientation. Here, unlike the above approaches, we have focused on read time of single antenna to obtain more reliable localization. This is because sensor systems for mobile robots are often preferred to be relatively small, lightweight, and inexpensive.

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doi:10.1016/j.aei.2010.05.001

In this paper, we propose a new method for the localization of a mobile robot by utilizing the read time during which the antenna is detecting an RFID tag. RFID tags were laid on the floor in a gird-like pattern and the mobile robot was equipped with an antenna to communicate with the RFID tags. In general, a pair of antennas are necessary when using an RFID system to identify the orientation of the mobile robot. However, we are able to estimate the orientation using the relation between the previously detected and current RFID tags. We also do not utilize simultaneous reading of multiple RFID tags in order to reduce localization error because of the increased number of required tags. To examine the method's validity, we implemented it on an autonomous mobile robot. Using our approach, we can acquire robust and reliable environment information. The remainder of this paper is organized as follows. After discussing related work, we will give an overview of the RFID system in Section 3. A new localization algorithm using read time of RFID system for the location and orientation of a mobile robot is described in Section 4. We conducted a series of experiments with the proposed algorithms, the results of which are presented in Section 5. The conclusion and future work will be presented in Section 6.

2. Related work

In recent years, radio frequency identification (RFID) technology has been utilized in the field of mobile robotics, and a number of approaches have been introduced which employ this for localization and different navigation tasks. Matsumoto et al. [12] reported a traveling system that uses RFID tags as external assistance to determine the robot's position and direction. Kubitz et al. [13] presented a navigation system that uses RFID tags as artificial landmarks. The tags have information of global position(x, y, and z), environment class, environment position, and further optional data. Hahnel [14] utilized RFID to improve localization of mobile robot equipped with a pair of RFID antennas, in the presence of people in their environment. Lionel et al. [15] presented LANDMARC, a location scanning prototype system that uses active RFID for locating objects inside buildings. Seo et al. [16] suggested the sensor model of the RFID tag to reduce the robot's localization error applying the Markov localization and the Kalman filter to localization algorithms. Han et al. [17] present localization scheme for an indoor mobile robot using RFID system. They adopted triangular pattern of arranging the RFID tags on the floor in order to reduce the estimation error of the conventional square pattern. This method also uses an encoder at each wheel for the precise control of the mobile robot, while it estimates localization using a single antenna. Shiraishi [18] proposed a location estimation system using UHF band RFID, with tags deployed on the ceiling. However, such an approach suffers from a variety of obstacles such as lighting fixtures, piping, and ventilation ducts. Most of the above approaches were utilizing multiple RFID tags under the antenna or adopted multiple antennas. Contrary to the above mentioned methods, we have proposed a method that is able to estimate localization and orientation of a robot while navigating [19]. However, though this method acquired an intermediate location based on read RFID tags, this was regardless of the orientation of the robot. Chon et al. [20] used an RFID system along with GPS and a gyroscope to produce highly accurate location information. They installed active RFID tags which stored accurate location information on roads. In RFID technology, there is little research on both localization and pose estimation of a robot. Yamano et al. [21] proposed a method that utilized the received signal strength to determine the reader location by using a machine learning technique (SVM). However, this method does not calculate the orientation of the robot. Kodaka et al. [22] proposed a method that uses Monte Carlo localization to estimate the orientation of robot on the lattice of RFID tags. This research employs a similar tag interval to ours but they use multiple antennas and odometry which uses the traveled distance to estimate location and orientation. In these researches, generally only the location is estimated with the RFID system, while orientation estimation is performed by other sensors. Additionally, some methods which use active RFID tags require maintenance by humans, such as periodical battery change. Contrary to the mentioned methods, we proposed a method that was able to estimate location and orientation of a robot while navigating [19]. However, this approach could not provide location and orientation information about the robot that was more accurate than the RFID tag interval. Recently, Zhou et al. [23] proposed an indoor localization system for mobile robots that uses stereo vision and laser-activated RFID based on the principle of triangulation. RFID tags were equipped with bright LEDs to be recognized. A Bayesian approach is also proposed to predict the location of a moving object [24]. The reader location is calculated by averaging the inferred location from all RFID tags. Therefore, the accuracy of the algorithm depends on the movement probability model. Gueaieb et al. [25] proposed a navigation method based on processing analog features of an RFID signal without a vision system and without building a map of the robot workspace.

3. RFID system

RFID is an automatic identification method, which can retrieve and store information (serial number) remotely from named RFID tags or transponders. In general, RFID systems consist of a reader, an antenna, RFID tags, and middleware. An antenna is sometimes regarded as a separate part of an RFID system. The power required to perform the data transfer in passive RFID tags is provided by non-contact technology from the RFID reader. The communication between the antenna and HF RFID tags uses inductive coupling. RFID systems can be roughly classified into the following four types based on frequency, each frequency having unique features as follows. First, LF is least affected by the presence of liquids and metal. However, it has a very low data read rate when compared to the other operating frequencies. HF has higher transmission rates and longer ranges (less than one meter) when compared to LF. HF also offers better performance near metals and liquids than UHF. UHF has the longest range and its transmission rate is also very high, which allows it to read a single tag in a very short time. Therefore, UHF is most commonly used for item tracking and supply-chain management applications. However, a disadvantage of UHF is that it experiences interference in proximity to liquids or metals. Finally, microwave frequency has a very high transmission rate, but is weak to metal and are typically more expensive than UHF ones. When using RFID systems, we should select the most suitable frequency for our application.

3.1. Reader

We adopted the compact and inexpensive RFID reader (S6350 Midrange Reader Module) made by Texas Instruments. It operates at a frequency of 13.56 MHz and handles all RF and digital functions in order to communicate with Tag-it HF, Tag-it HF-I and ISO15693 compliant RFID tags.

3.2. Antenna

Generally, the size of the antenna in the passive RFID system must be adjusted in accordance with the distribution distance between RFID tags. We constructed an experimental circular antenna that is able to detect RFID tags on the 13.56 MHz frequency band

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