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ORIGINAL ARTICLE

Autonomous mobile robot localization based on RSSI measurements using an RFID sensor and neural network BPANN

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Abstract *Radio Frequency Identification* (RFID) technology is broadly deployed for improving trade and transactions. An RFID tag can identify the region (position) where it resides; thus, a popular trend among researchers is to deploy RFID technology for mobile robot localization. Because the intensities of signals at adjacent regions are similar to each other, it is a challenge to employ an RFID system as a sensor. In this proposed system, tags are scattered throughout a mobile robot's environment in a constrained random pattern and are treated as landmarks. An RFID receiver is mounted on a mobile robot that can navigate such an environment. The robot senses all landmarks in the vicinity to acquire the IDs and *received signal strength indicator* (RSSI) measurements of the scattered tags. The robot can locate itself depending on the classification result provided by a *feed-forward back-propagation artificial neural network* (BPANN) supplied with a set of all RSSI measurements read by this robot at a specific location. To be acceptable, this set should only have one high RSSI measurement. The robot senses the location information from a high-valued RSSI tag and adds it to a list of tag IDs along with the corresponding location information. The robot can use this information to travel between any two identified locations. The experimental results demonstrate the efficiency of this proposed system.

1. Introduction

1.1. Overview

Learning is based on no prior knowledge, but on the perceived states of an environment. The representation of objects within an environment that a mobile robot uses is based on the interaction between the mobile robot and its environment (Brooks, 1991). To be autonomous, the robot must learn, and an

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autonomous robot can locate itself and navigate its environment, specifically, it can determine a path to a specific target using localization and orientation information. The mobile robot may use one of several methods for data classification to divide its environment into regions that may be called, by different researchers, locations or partitions. To locate itself, the mobile robot must be informed regarding the region in which it lies.

To avoid errors, redundant sensors are used, especially to avoid the errors that emerge from computing the robot's position. Information is gathered by fusing the sensor observations with prior knowledge about the environment (Pauly et al., 1998).

Most work using RFID systems for localization purposes in mobile robotic applications uses *rewritable* tags to store the prior knowledge of location information in them (Pauly et al., 1998). In this work, to enhance the autonomous mobile robot navigation and to distribute tags randomly, we consider storing distance information and the initial heading angle of the mobile robot in the robot brain. This information has been gathered as the robot explores the environment using its sensors.

In this work, a supervised form of a feed-forward *back-propagation artificial neural network* (BPANN) is used to classify the signals received from all the sensors for the purpose of localizing the mobile robot.

This paper is organized as follows: the Problem Statement is provided in Section 2. In Section 3, the related works are discussed. Section 4 is dedicated to the implementation details and investigations. Section 5 presents concluding remarks.

1.2. Problem statement

The problem of mobile robot localization has been widely addressed in the literature in recent years. An accurate localization technique will produce coordinates of the mobile robot's position so it can travel from one location to another. Tags, which play the role of landmarks, emit signals to identify environmental regions. To localize itself, the mobile robot should learn how to classify these signals, which requires the use of an RFID system to provide the *received signal strength indicator* (RSSI) measurement throughout the navigation arena.

To perform autonomous navigation, the mobile robot initially gets its heading angle, then explores its environment to find low-cost write-once tags, which provide their IDs. The robot measures their RSSI values by RFID sensor. As a result, the mobile robot stores the location information of these tags on the permanent storage of a server PC. Because the tags have a constrained random distribution, the mobile robot motion should be a systematic motion to ensure that the mobile robot reaches all regions in its environment.

The regular classification process using a supervised form of a feed-forward back-propagation artificial neural network, which classifies the RSSI measurements into groups, results in dilation because the RSSI measurement of each tag should be read several times to be provided to the classifier algorithm for error reduction. Therefore, an alternative classification method for this purpose is applied, also using a supervised BPANN. All environmental features contribute to the decision making; namely, all the RSSI measurements are treated as one input set and processed to produce one output result whose value is either approximately 1 or approximately 0 depending on the input set. Regardless of the number of tags in the mobile robot's environment, whenever the RSSI measurement received from any one of the tags reaches the *detection-RSSI-threshold* value, the tag ID is added to the input set of the BPANN. The *detection-threshold-value* is constantly updated and depends on the difference between the maximum and minimum RSSI measurement received from tags in the mobile robot's sensible environmental space. As the mobile robot moves to explore its environment, just before leaving the immediate vicinity of a tag, the tag's RSSI measurement starts to drop. If the RSSI measurements of two or more tags end up being the maximum RSSI measurement and at the same time equal to each other, the robot will continue the exploration and stop considering any RSSI measurements until one of the maximum values starts to reduce. Using this approach for signal classification guarantees the unique association of the robot with a single tag at any given time.

The constrained random distribution used to scatter the tags ensures that the tags are "randomly" distributed with an acceptable minimum distance between them. The mobile robot is established to be localized at a specific location (or node, in grid-based localization literature) marked by the positive output of the BPANN given an acceptable *input-RSSI-set*. The acceptable *input-RSSI-set* is defined as a set containing all RSSI measurement values greater than the *detection-RSSI-threshold*.

The location information of any tag is determined by its absolute x and y coordinates. The square 2D space on the floor is considered to be the experiment arena. The south-west corner of the square space is the start point. The robot also has a sonar-based localization capability, i.e., the two sonars return the distance of the robot from the 0.5 m high walls along the perimeter of the square space arena. The robot also has a compass sensor to determine its direction (theta). With the coordinates of two locations, the mobile robot can navigate from one location to another by adjusting its heading using an angle computed by a trigonometric function to face the first destination and computing the required traveling distance between these locations.

2. Related works

Several approaches have been proposed for mobile robot localization using environmental features called landmarks (Jang et al., 2002; Saotti and Wasik, 2000; Loevsky and Shimshoni, 2010). Given the logical foundations of RSSI signal strength behavior and the classical machine learning algorithm-based classification, a combination of approaches can solve a typical localization problem. In Tanaka et al. (2007), Tanaka et al. considers short-range RFID sensors and uses a *support vector machine* (SVM) binary classifier, which is trained using the features of signals received at a selected location and of signals received at each nearby location, to distinguish the selected location from the rest. This problem is solved using Fuzzy Logic in Gueaieb and Miah (2009). Gueaieb and Miah propose applying Fuzzy Logic to the phase difference of the two phase angles of the signals received by two receiving RFID-reader antennas. The mobile robot is supposed to turn to the left or to the right if the target tag is on the left or on the right of the receiving antennas, namely if the phase difference is negative or positive, respectively (Gueaieb and Miah, 2009).