Navigation and Interaction in Physical Spaces using RFID Enabled Spatial Sensing

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Abstract

In this demonstration we show how RFID technology can be used for sensing spatial information in indoor environments. In particular, we demonstrate how this sensed information can be used for navigation and interaction within an environment.

Categories and Subject Descriptors

H.2.8 [**Database Applications**]: Spatial Databases and GIS; I.2.9 [**Robotics**]: Sensors

Keywords

RFID, Self-localization, Automated Navigation, Automated Interaction, Spatial Sensing

1 Introduction

RFID technology is conventionally employed as an identification medium. RFID [1] tags are small transponders that respond to queries from a RFID reader by wirelessly transmitting a unique identifier. RFID is heavily used to track items in production environments and to label items in supermarkets. A new approach for using RFID technology is to deploy RFID tags in large quantities and in a highly redundant fashion over large areas or object surfaces [2]. This approach uses RFID as a means for interaction with the physical space.

We propose a combination of these two approaches by tagging the entire physical space, in such a way that *every location in space* and *every object* present in that space has a representation in terms of RFID tags. Thus we leverage both the identification and the discretization capability of RFID. The ID of a tag can have multiple roles. First, ID of an RFID tag can represent the spatial coordinates of the tag within the physical space. Second, the ID of a tag can also signify the identity of the item to which it is attached. We propose a spatial data management system (SDMS) that provides a seamless translation between spatial information and corresponding tag IDs. Given a tag ID our system will translate it into some spatial information. This information will be either spatial coordinates or a description of an object depending on the input tag. An agent *(agent represents a person or a robot)* roaming in the physical space, equipped with mobile RFID sensing capability can sense the IDs of deployed tags which enables the agent to sense its location and surroundings within the RFID enabled space.

Our proposed SDMS can be implemented in two ways: spatial information can either be encoded in tag IDs which mobile RFID readers can decode autonomously or by a mapping between tag IDs and spatial information provided by a web service. Autonomous decoding requires pre-knowledge of the rules used for encoding the information, however it eliminates the need for any external additional infrastructure. On the other hand, webservice enabled environment makes the system more versatile as the agents do not need any pre-knowledge about tag layout furthermore same tag IDs can have multiple information associated with them. An intermediate approach is to place the rules used in encoding on a remote server and mobile readers download these rules when they enter the physical space for the first time, in order to decode the tag IDs autonomously.

Spatial information sensed from the physical space can be used for a number of tasks. In this demonstration we show how to exploit sensed spatial data for navigation and interaction of agents in an indoor environment.

2 Navigation and Interaction Using Spatial Sensing

Navigation relies on the ability to sense the current location. One approach of self localization is to discretize the space into small partitions. Each agent can then locate itself by sensing the IDs of the partitions close to it. This discrete partitioning of space can be achieved as a direct result of massive RFID tag distributions. Tagging in a redundant fashion will result into physical space where at every point at least one tag can be sensed. All the points with the same values for sensed tags will thus form one partition in space. The spatial information encoded within the tag IDs can be

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used then for precise localization.

In order to interact with the physical space, an agent needs to know its spatial context [3]. Spatial context depends on the location of the agent and objects that are present in its immediate vicinity. Since nearby objects can be identified by decoding their IDs thus using this knowledge along with the location information, an agent can learn its spatial context. Once context has been identified, the agent can then compute its interaction.

3 Demonstration Details

We have developed a prototype implementation that demonstrates the feasibility and the underlying principles of RFID enabled spatial sensing. In the following we explain the hardware and software components that are part of this demonstration:

3.1 Physical Space

A carpet is used as sample RFID enabled space. A 22 × 5 grid deployment of Rafsec G2 ShortDipole RFID tags is used for tagging this carpet [Figure 1]. Spatial information is encoded in the ID of each tag by including a 3 digit prefix in the ID. We used the prefix of tag IDs of a single row to indicate:

110: the left most column

100: the column in the middle of left most and middle column

000: the middle column

001: the column in the middle of right most and middle column

011: the right most column

3.2 Agent

A Lego MindStorms NXT based robot is used as an agent for this demonstration. It carries a NORDICID PL 3000 mobile UHF RFID reader [Figure 2]. The agent senses spatial information by reading underlying tags while it moves on the carpet.

3.3 Spatial Data Management System

For this demonstration we have implemented an SDMS as a web service. This service provides the agent with the rules required for decoding spatial information from tag IDs. An agent queries the service when first tag is sensed, from there on all tag IDs are decoded autonomously by the agent.

4 What will be Demonstrated

There are two parts of our demonstration.

4.1 Navigation

In the navigation part of our demonstration we will show that the robot can be navigated over the carpet using RFID enabled spatial sensing. The goal for this part of the demo is to keep the robot on the center of carpet. We will show that robot first localizes itself by using spatial information. Based on location information the robot then makes either a turn or continues moving in its current direction. Whenever the robot is placed anywhere other than the middle of carpet, it will move to the center, while continuously localizing itself using the sensed spatial information.

4.2 Interaction

In the second part of our demonstration we will show how the robot interacts within the sample physical space. The robot will use its location information and combine this with the identification of its surroundings to perform interactions with other objects. We will demonstrate two behaviors of the robot in terms of this interaction: obstacle avoidance and target placement. For the obstacle avoidance, we will place a tagged object on the carpet. Robot will identify this object as an obstacle and will change its path in order to avoid it. In the target placement behavior we will place an object on the carpet, the robot will identify this object as a target and will grab it and then place it at a new location.

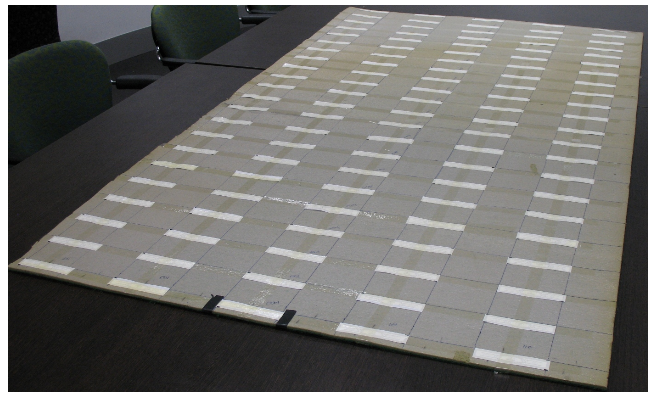

Figure 1. Prototype physical space

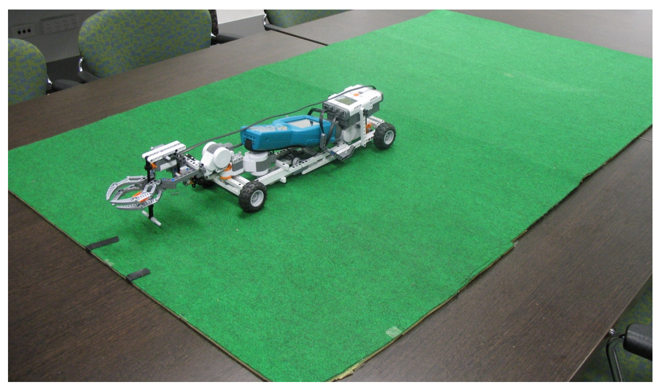

Figure 2. Prototype Agent

5 References

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