Sensor-Based Localization-Assistance for Mobile Nodes

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Abstract – Navigation of mobile robots requires high-quality localization mechanisms. Typical indoor techniques lack of such precise functionality. The focus of this paper is to demonstrate our ongoing research work in the area of localization in sensor networks. We employ these mechanisms for sensor-based localization assistance for mobile nodes, particularly our robot systems. The used methodology is discussed and the according expectations are shown.

1 Introduction

In recent years, many efforts have been made in developing algorithms and methodologies for building efficient localization mechanisms for indoor and outdoor environments. GPS is a de-facto standard for precise outdoor localization. Unfortunately, such an approach fails in indoor environments. Even if the same scheme can be used (pseudolite arrays [5]), it suffers from multipath propagation and other properties of signal dispersion. Mechanisms based on wireless LAN are only useful for detecting a particular room due to the low accuracy of about 5m. Much higher localization qualities are required for navigation issues.

Out goal is to use an installed sensor network for multiple reasons. First, it should be employed for the primary task of gathering environmental information. Secondly, and this is the main focus of this paper, we also use the network for localization of mobile nodes. In an ongoing research project, we connected a sensor network consisting of a couple of Mica2 motes to some mobile robot systems. Using the “quality” of a particular link, the distance to a sensor mote can be estimated. Therefore, given a uniform distribution of sensor nodes with a minimum density, we are able to approximate the current location of the robot system.

First studies to use the capabilities of sensor networks for localization have been done by the group of Estrin and Heidemann [1] and Savvides et al. [6]. Nevertheless, they only concentrated on an inherent localization problem in sensor networks. On the other hand, we are about to include mobility aspects and the application / assistance of fixed sensor motes for mobile systems as proposed by Hu et al. [4].

2 Motivation and Research Objectives

Among others, we are focusing on self-organization, task-allocation, and energy-aware communication in mobile wireless sensor networks. Sensor networks are composed of multiple, independent autonomously working nodes. These individual entities form a self-organizing compound that is able to solve required tasks described at a higher level. Before we concentrate on the application of the sensor networks for localization issues, our ongoing research activities in the research fields of sensor networks and coordination of mobile autonomous systems are briefly described.

2.1 ROSES – Robot Assisted Sensor Networks

The development and the control of self-organizing, self-configuring, self-healing, self-managing, and adaptive communication systems and networks are the primary research aspects of our Autonomic Networking group [3]. We are studying these aspects in the area of autonomous sensor/actuator networks, i.e. a combination of mobile robot systems and stationary sensor networks [2]. The introduction of mobility as well as the limited resources of typical sensor nodes leads to new problems, challenges, and solution spaces in terms of efficient data management and communication. We distinguish between sensor assisted teams of robots and robot assisted mobile sensor networks. The former means that robots might use the sensor network for more accurate localization and navigation or as a communication infrastructure. The latter means the employment of robot systems for maintenance in sensor network or the utilization of robots to provide communication relays.

Research Goals:

Energy efficient operation, communication, and navigation

Sensor network assisted localization and navigation of the robots

Utilization of the robots as a communication relay between a sensor network and a global network, e.g. the Internet

Quality of service aware communication in heterogeneous mobile networks with dynamic topology

Optimized task allocation and communication based on application and energy constraints

Secure communication and data management in mobile sensor networks

In order to address these objectives, we work on novel models for energy and application aware communication, combine different localization techniques for optimized high-precision navigation, integrate mobile robots and stationary sensor nodes to autonomous sensor/actuator networks, and research on bio-inspired communication methods. In our lab, we use the Robertino[1] robot platform as well as the Mica2 sensor motes running TinyOS[2].

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[1] Robertino was developed at the Fraunhofer Institute for Autonomous Intelligent Systems AIS

[2] Mica motes and TinyOS were developed at the University of Berkeley

Current Activities:

We equip our mobile robot systems with a modular control system allowing them to act completely autonomous. In order to achieve this goal, modules for accessing the sensor facilities, for movement, localization and navigation, and task allocation are work in progress. Mostly finished is the connection of a Mica2 mote for intercommunication with the sensor network.

3 Localization using Sensor Information

The objective of this paper is to analyze the quality and performance of the localization based on a pre-installed sensor network. We base our work on preliminary results described in [1, 4, 6].

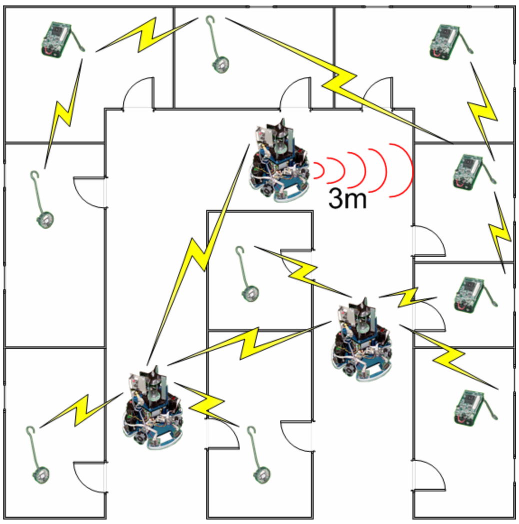

Fig. 1. Lab environment for localization tests consisting of Mica2 and Mica2dot sensor motes and some mobile robot systems (Robertino)

The lab environment used for our tests is shown in Fig. 1. For interconnecting the robot system to the Mica2 motes, the serial interface-board including a single Mica2 mote is employed. The program `xlisten` was ported to the Robertino system in order to query the motes and to receive the sensor information. The methodology of the localization mechanism is described in the following.

3.1 Signal Quality

The signal quality, i.e. the strength of the received signal, can be used to estimate the distance between two corresponding nodes. It was shown that this signal quality allows a good approximation if used in rooms without interfering walls. This assumption is provided in our scenario where multiple sensor motes are deployed in a small area. Based on the received signal quality towards to multiple motes, a triangulation can be initiated. The localization method, therefore, is based on the following data:

addresses (IDs) of neighboring sensor motes
(statically configured) location of each node
distance to each node (signal quality)

3.2 Autonomic Re-Programming

The error introduced by signal fading and other effects on the physical layer is quite high. Therefore, additional measures have to taken in order to increase the accuracy of the localization mechanism. Besides additional hardware solutions such as laser-based distance meters, we want to use the internal possibilities provided by the employed sensor motes. Namely, we want to reprogram the motes according to the requirements of the current measurement.

The signal strength of the sender can be adjusted in software. This feature is used to gradually reduce the signal strength at each sender until it can no longer be received at the mobile robot system. By modeling the transmission range of all sensor motes in the neighborship, the precise location can be estimated using this adaptive re-programming. Obviously, this methodology requires a working ad hoc routing in order to reach the sensor motes being modified even if the direct connection got lost. This localization method is based on the following information:

addresses (IDs) of neighboring sensor motes
(statically configured) location of each node
radio model of all involved motes
signal strength at the sender when the connection is lost

4 Conclusions

The programming and test of the described scenario is current work in progress done in our group. The perceived quality in our lab tests will show the potentials and drawbacks of the localization based on sensor networks. Even in this simple scenario, multipath propagation and other properties of radio transmission will introduce a noticeable error. Further work is to include dynamics due to the inter-node relationship during movement.

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