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Position Visualization in a Combined WSN-PDR Localization System

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I. Introduction and Motivation

Indoor navigation solutions for pedestrians have gained a lot of attention recently. Scenarios where a person localization system could be of enormous help are especially in the field of first responders. Firefighters entering a burning building but also patients and doctors in disaster events need to be localized. These scenarios have in common that position information about team members has to be available to the squad leader to coordinate the mission. Another important requirement is that no assumptions about any infrastructure at the site of operation can be made. This implies that the system needs to be easily installable and set-up within a short time. This can be achieved by means of a dedicated wireless sensor network (WSN) for person localization. Additionally a WSN provides a flexible interface for other sensors to monitor the environment.

II. Related Work

Ever since WSN are under active research, localization has been a major area of interest in this field. Many different localization approaches have been proposed during the last years [1]. One of the simplest methods is using received signal strength (RSS)-values from radio-packets as range information. This information does not require any additional hardware as most radio transceivers provide these values by default. That is why a lot of research has been done in this particular field, e.g. [2].

RSS-values have the drawback that their behavior is very unpredictable due to reflections, diffractions and multipath propagation. This is especially true in indoor environments where walls, furniture and office equipment heavily disturb electromagnetic waves. This often results in inaccurate and fluctuating position estimations. By combining RSS-based position estimation with pedestrian dead-reckoning (PDR) techniques this can be improved to a certain degree [3].

However, most approaches have only been examined in laboratory environments and lack evaluation under real-world conditions, Thus, there is still a necessity for investigations of such systems under application-specific and realistic conditions.

In this demo, a webserver based visualization of positions obtained from a WSN-based localization solution is shown. Figure 1 shows a screenshot of the developed application.

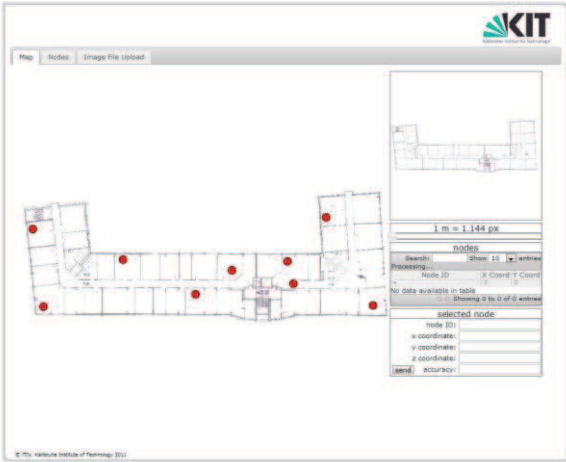

Figure 1. User-Interface for Visualization of Sensor Node Positions.

III. System Concept

A. System Overview

The WSN provides the users with reference positions, i.e., pre-deployed anchor nodes broadcast their positions in regular intervals. A sensor node carried by the person to localize calculates its own position by means of received radio packets. If the node is also equipped with an inertial measurement unit (IMU) the current position is additionally estimated based on information on the person's movement. The mobile sensor nodes regularly send their own position estimates through the network to a central data sink. The central data sink runs a database and a webserver to provide a visualization of the positions of all sensor nodes. The visualization can be accessed with a standard web browser.

B. Position estimation

A linear time-discrete system model is used to describe the movement of the person to be localized. To limit the computational complexity, the state vector $\underline{x}_k$ contains the position of the user only. A Kalman-Filter processes measurement inputs which are position updates either derived from the signal strength of received radio packets or from inertial data if available.

Each anchor node broadcasts its own position in regular intervals. The RSS-value of a radio-packet received by a mobile node from any anchor node within communication range corresponds to the Euclidean distance between the two nodes. The distance d is derived from the path-loss PL

of the log-distance path-loss model by solving the equation

$$PL = P + 10n \cdot \log_{10}\left(\frac{d}{d_0}\right) + N_G\,. \qquad (1)$$

P is a reference measurement of the received power at distance d_0, n is the path-loss coefficient and N_G a noise term. All of these parameters can be determined experimentally for a given environment.

Because this is a nonlinear distance measurement it needs to be linearized by means of an extended Kalman-Filter (EKF).

If the sensor node is extended with an IMU a simple PDR-approach based on step recognition and step length estimation is used to achieve short term stability. PDR can also provide localization in areas where no anchor nodes are within communication range.

C. *Position visualization*

Visualizing the sensor nodes positions is very important as this allows the interaction of the system with the end user. The demonstrated system shows a possible visualization at a central point, e.g., in an emergency car where the operation commander is located.

The system concept of the visualization is depicted in Figure 2. The WSN nodes send position messages to the central data sink (ZigBee Coordinator) which passes them to the Interface-Application over a serial link. All position updates coming from the WSN are stored within a database. A webserver delivers the user interface together with the nodes positions in the database. The end user accesses the visualization via a web browser.

IV. System Implementation

A. *Wireless Sensor Network*

In the demo LocNode sensor nodes are used which are based on a Texas Instruments MSP430 low-power microcontroller and an IEEE 802.15.4 compliant 2.4 GHz transceiver CC2520.

Position estimation as described in Section III.B is implemented into a ZigBee-framework which provides ad-hoc network establishment and multi-hop routing. Each node is configured to broadcast its own position with a rate of *4 Hz* to all neighboring nodes. Additionally, all nodes communicate their position through the network to the data sink (ZigBee Coordinator) on a regular basis.

B. *Visualization*

The coordinator of the ZigBee-Network is integrated with the server hardware. This consists of an Intel Atom D510 processor on a MiniITX-Mainboard. With the avoidance of mechanical parts the system can be easily used in emergency vehicles under rough conditions, for example.

A Linux operating system together with a MySQL-database and an Apache webserver makes the web application available to the user. Based on scalable vector graphics (SVG), position estimations are shown on a map with zoom and pan features. Additionally there is a small overview-map and all sensor nodes can be configured through the web interface. Figure 1 shows the user interface with an exemplary map. The system can be accessed by any web browser and can thus be used on smart phones or laptop computers.

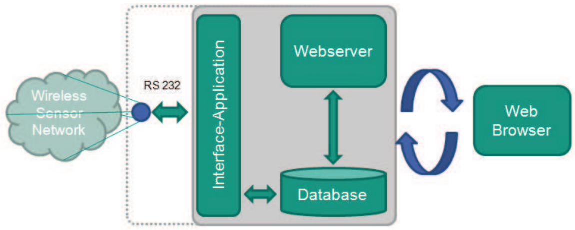

Figure 2. Visualization system.

V. Localization Results

It has been shown experimentally that the system achieves localization accuracies on the order of a few meters, i.e., on room level [4]. This is considered to be sufficient for the targeted applications.

VI. Conclusion and Future Work

Visualization within a hybrid localization system based on RSS and PDR localization is presented in this paper. Mobile sensor nodes estimate their positions based on RSS of radio packets and forward the estimations to a central data sink. A central webserver is directly connected to the central data sink and stores position estimates in a database. The visualization application can be accessed platform independent via a web browser.

We are currently working on a simulation environment for an in depth analysis of the system's scalability. Furthermore simultaneous localization and mapping (SLAM) techniques are planned to be adopted. We are also currently working on our own IMU design.

Acknowledgment

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