Demonstration of a Realtime Active-Tag RFID, Java Based Indoor Localization System using Particle Filtering

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Abstract. To develop and demonstrate accurate indoor pedestrian navigation, we implemented a flexible location framework which is able to use various sensors as positioning sources. In the current setup, the main positioning data is derived from an active long range RFID system which collects RSS values from various RFID tags in the environment. The position is calculated using particle filtering algorithms. The demonstration shows the real time tracking of a person on a remote visualization screen.

Key words: Real time location demonstration, long range RFID system, particle filtering, received signal strength (RSS)

1 Introduction and Background

Today's mobile devices are capable of using multiple network access methods and they are able of executing custom applications. This pushes many new applications in the area of mobile entertainment, games, communication and also personal navigation. There are numerous devices available, which use GPS for outdoor route finding with cars and even for cyclists and pedestrians. But this last group of users poses the most challenging problem to devices and software, because a pedestrian can walk in nearly every area - especially in the urban canyons of cities and in indoor scenarios. There, the satellite signal is either affected by strong multipath propagation or it is blocked completely. Possible applications for person localization range from security relevant indoor scenarios (watchmen, fire fighter) to office navigation and also leisure activities. For these difficult scenarios, additional sensors at the mobile device can help to increase the accuracy considerably.

In our real time demo we show the use of active RFID technologies for indoor positioning. We use a client-server structure with a notebook as client and a separate server that processes and visualizes the measurements that arrive from the client. The measurements are collected via external hardware at the notebook and transferred to the server via any available wireless network (UMTS or

Wireless-LAN).

There are similar approaches to address indoor positioning with multiple combined positioning sources or passive RFIDs [1]. But the latter has the disadvantage of using tags, which have very short range and require high transmit power. This could be compensated with directional antennas, but they are too large for applications for pedestrians. The RFID reader in our setup uses a standard PCMCI slot card, which could also be used with a Pocket PC.

In this demo, we will show a framework which collects RSS (received signal strength) values from an active RFID reader and combines them to a joint position estimation by using particle filtering. Other sensors like an electronic compass and a GPS receiver are also attached, but the latter can not be used in indoor scenarios. We present a simple positioning-only application with a visualization of the estimated position on a bird's eye view of the building.

2 Demo setup

2.1 RFID Components

We use a long range RFID reader of type *i-Card III* from Identec Solutions [2] in the format of a PCMCIA card and the corresponding driver for our measurement notebook. The tags are the corresponding active tags of type *i-D2* from the same manufacturer. Each tag is approx. 13cm by 3cm by 2cm in dimension and needs no external power. The battery life is indicated to be five years, although we have no data as to the supported duty cycle in this case. The tags have a range of up to 12 meters in free field environments, and the average received power (RSS) or detection rate as a function of distance is a key parameter in our positioning system. The tags use their internal battery for powering the circuit that sends out the identification of the tag. This signal is sent out with constant RF power what gives the opportunity to use the received signal strength at the mobile reader for localization. The tags can be located behind nameplates near doors, or in similar places within a building. For our demonstration we assume that tags are not intentionally mis-placed.

2.2 Calibration

In our calibration we install a few tags (typically 4-5) in representative locations and then measure the RSS distribution and non-detection rate for certain distances around each tag. The total data set is aggregated to yield the distribution of the RSS value (and also that of the non-detection event) over average distance from our RFIDs. We do not currently calibrate on a per-tag basis. For the demo our tags are installed at known locations in a 2D reference frame. The actual number of tags used is strongly dependent on the layout of the site.

After the calibration step, our measurement notebook will trigger the card reader at 1 second intervals and report the list of all discovered RFID tags and their RSS values to the central fusion server. It will also send compass and GPS raw results (where available) at a rate of one per second.

The computation of the likelihoods in the particle filter's update step (based on the calibration process) will be described in more detail in the next section.

Fig. 1. Real time display for positions and other objects at the server side

Figure 1 shows a server side view of the visualization part of the software. The visualization display uses the weight and position of the particles for a real time display over the map and a calibrated building plan. It also shows the currently visible RFID tags (red "X") and their RSS values as well as all tags' locations. We can also show the particles (colored dots), an estimate of the posterior density computed from the particle weights, as well as the MMSE position estimate (blue dot).

3 Implementation and Initial Quantitative Results

The particle filtering algorithm described in [3] and applied to pedestrian navigation in [4] is used to perform data fusion of the RFID measurements, the compass and GPS. With a suitable movement model that also incorporates known walls (i.e. the map layout), and using between 1000 to 10.000 particles we can achieve real time sensor fusion. Initial evaluations show that we can achieve a mean distance error of 2.2m, but it is dependent on the local conditions and the distribution of the tags.

The calculation of the likelihood function for the RFID measurement is shown in the flowchart of figure 2. We generate two lists from the ID of the RFIDs: The ones we actually measure and the tags that should be measured because they are in a certain area around the position in question. According to the decision box, each particle is then weighted with either the calibrated likelihood (section 2) or other very low values for some special "unlikely" cases.

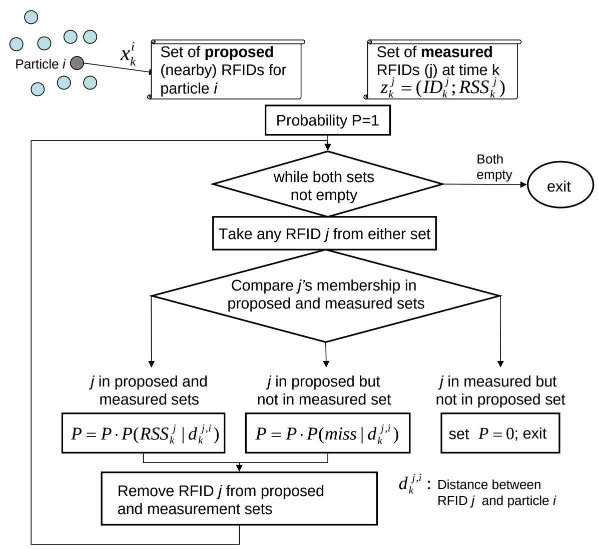

Fig. 2. Flowchart for the "Proposed and Measured" principle in computing the likelihood of measurement, $p(z_k|x_k)$

4 Outlook

We could see from the previous measurements, that a higher number of RFID tags in a critical area improves the positioning accuracy. We will try to find these problem areas in the environment with high positioning error at a system level and optimize the number of necessary tags for optimal performance.

Finally, a seamless integration of the system in outdoor-to-indoor scenarios (with satellite navigation and compass in the outdoor part and RFID/compass in the indoor part) was already tested with promising results and will be developed further.

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