Map Aided Indoor Positioning Using Particle Filters

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This work addresses the issue of tracking persons wearing small sensor nodes within a radio network. Focus lies on fusing sensor data with map information in an efficient way with consideration to the computationally constrained sensor nodes. Different sensors are stochastically modelled, evaluated, and fused to form an estimate of the person’s position.

Keywords: Inertial navigation, sensor fusion, particle filter, embedded systems, map.

1. INTRODUCTION

Acclerometers and gyroscopes are often used in dead reckoning algorithms. These algorithms can give good short term results, but the position tends to drift in the long term. This is caused for example by double integrating linear acceleration. The global positioning system (GPS) provides an excellent method for positioning of wireless devices, but for the purpose of indoor navigation GPS is not a viable option due to poor coverage.

To overcome these problems, a map of a building or a road can greatly reduce or even completely remove the drift caused by dead reckoning. By using a map, a dead reckoning algorithm can start from an unknown initial position and quickly find the absolute position after some unique movement patterns (Kihlb erg and Tegelid, 2012; Hall, 2001; Forsell et al., 2002; Svenzen, 2002).

Low power radio networks are becoming increasingly popular for cheap low rate communication. Such a network consists of a number of network base stations, and a number of endpoints which are the application level devices. Besides enabling communication, a radio network also provide a great amount of information regarding the location of the endpoints (Maheshwari and Kemp, 2011).

This work aims to develop and evaluate algorithms for sensor positioning with map support in a radio network. The target precision is to locate the user within a few meters and more precisely which room the user is currently in. More details can be found in Kihlb erg and Tegelid (2012). The algorithms are thought to be run in real-time. It is taken into consideration that the energy consumption of the sensor nodes needs to be kept low.

2. EXPERIMENTAL SETUP

The sensor network includes sensor nodes, radio base stations and a centralized computer that controls the network. The sensor node (depicted in Figure 1) consists of an accelerometer, a gyroscope, a magnetometer, and a radio. The accelerometer, gyroscope, and magnetometer are equipped mainly to help finding the absolute attitude of the device but also to detect translational movements of the sensor node carrier.

![Sensor node Illustrations](image)

(a) A sensor node worn by a man.
(b) A sensor node PCB.

Figure 1. Sensor node illustrations.

Radio base stations are spread out in the building much like the topology of a traditional cellular network mainly with having full radio coverage in mind.

3. WORLD MODEL — 2.5D MAP

A map of a building or an area can give substantial information of the possibility to be at a certain position or of taking certain paths.

The map is represented in 2.5D, which means that the environment is divided into two-dimensional planes and...
that all motion is always restricted to lie within these planes (Woodman, 2010). The assumption that all motion lies within a plane can be made without hesitation, since human movement is typically constrained to the floor of a building. The advantage is that the complexity of the state estimation algorithms can be reduced with this assumption, reducing the dimension of the state vector by one. The vertical dimension for the user will instead be represented by the vertical translation of the current plane relative to the world frame.

Figure 2. A map represented as a relative probability distribution, where red indicates higher probability.

4. POSITIONING ALGORITHM

The accelerometer, gyroscope, and magnetometer data is fused in an attitude and heading reference system (AHRS). This information is used to determine the heading of the sensor node carrier. Information from a radio base station upon connection is used to get a rough initial estimate of the position of the user.

To be able to determine when the user is moving, a step detection system is used. Note that we do not double-integrate the acceleration because of the low stability of the accelerometer. An empirical step length combined with the heading can be described as a two-dimensional movement,

\[ d_{\text{step}} = (d_{\text{step,x}}, d_{\text{step,y}}) \]  

(1)

The relative movement given by a step is used for particle updates and information from the map is used to estimate the probability of the state hypothesis in each particle \( \{\hat{x}_k\}_{i=1}^N \). where \( N \) is the number of particles, \( i \) is the particle index, and \( k \) is the time index. We end up with

\[ \hat{x}_{k+1} = \hat{x}_k + d_{\text{step}}, \]
\[ w_{k+1} = w_k p_{\text{map}}(\hat{x}_{k+1}), \]

where \( p_{\text{map}} \) is the probability of being at a given position.

A point estimate is calculated using

\[ \hat{x}_k = \sum_{i=1}^N \frac{w_k^i}{\sum_{j=1}^N w_k^j} \hat{x}_k^i. \]

(3)

5. EXPERIMENTS AND RESULTS

Figure 3 shows how the initial estimate converges as the user is moving in an indoor environment. In blue you can see the particles and how they propagate over time. The green trajectory shows a moving horizon ground truth and the black trajectory in the last image shows a moving horizon of point estimates when convergence is reached. It can be seen how the map effectively rejects false trajectories, leaving a true trajectory after a short while.

Figure 3. Convergence of the position using a particle filter

6. CONCLUSIONS

It is possible to track people by fusing data from simple sensors with a map. The map system built around the idea of a probability density is a great aid to the tracking system. It is computationally efficient and is easy to traverse to follow the user through the map. Step detection using a simple 3-axis accelerometer with the proposed step detection algorithm is possible for a range of surfaces and different wearers.

REFERENCES


