Research into position determination (localization) at the fire department

Preface

Below is a description of a research project that was carried out within the Saxion research group Ambient Intelligence. After the description, there are a few questions about the description as an assignment.

The research

There are many applications where it is important to know where something or someone is. For example, if you get a measurement of a temperature sensor of 180 degrees Celsius, then it is useful to know if the sensor is in your oven or if it is in your living room ... There are many ways in which you can determine the position.

In 2012, the research group Ambient Intelligence received a question from the fire department. The Dutch fire service works in units of 6 people: a commander, a driver, and 4 men. It is the duty of the commander to keep an overview of a deployment. If the deployment is in the open air and the commander can see everyone, then that overview is easy to keep. However, if the troops enter a building, it is much more difficult for the commander to determine where his or her men are. Currently, the troops communicate via the C2000 radio where they are and what they do. "I now walk into the hallway", "I go into the first room", etc.

The question asked by the fire brigade was whether it was technically possible to determine where team members of a fire service team are located, so that this could be shown on an overview map. If the team members walk outside, we can just use GPS, but as soon as they enter a building, that does not work properly. GPS signals are very weak and are blocked and reflected by buildings, for example. The extra requirements were that you can not assume that infrastructure, such as networks, is still working and it has to work mainly within buildings, but also in parking garages.

How to tackle this problem? Suppose this question was asked to *you*, what would be the steps you would take? In what way could you arrive at an answer to the question above?

Some people were already familiar with so-called inertial measurement units (IMUs) within the research group. An IMU is a sensor which measures accelerations, angular accelerations (rotations) and the direction and strength of the magnetic field. These types of sensors are not dependent on radio signals, such as GPS or WiFi access points for the measurement and can therefore be used both indoors and outdoors. Now the question is of course whether you can determine a position based on accelerations. First, we determined that it is theoretically possible. If you know where you are and what your speed is, you can estimate what your new speed is based on measured accelerations and angular

acceleration, and thus also estimate what your new position is. This seemed possible on paper. This was the start of a research project that is still ongoing.

Based on a number of interviews with colleagues who had experience with such sensors, we started investigating what was already known in the field of position determination. We also had to find the terms that are relevant for this. After searching on terms like "positioning" we found articles in which other terms were used: localization, positioning, navigation, localization and tracking systems (LTS). Specifically for systems with IMUs, we found the term "Inertial Navigation System" (INS) and for walking persons Pedestrian Dead Reckoning (PDR). On the basis of these discovered terms, we retrieved more and more research articles and news articles in which such systems were described. We also found a thesis entitled Opportunistic Seamless Localization from someone who had done 4 years of research into these types of systems and obtained his PhD on this topic.

In short, after a few hours we had found a lot of relevant search terms and many more (more than 30) articles about these types of techniques. During the search we also saw that there were many more articles. In the thesis we had found a nice overview (review) of the field. Because it was impossible to read all the articles found in detail, we first went through the summaries (abstracts) to determine which articles were most important. We reviewed these articles and found that you have a lot of problems with measurement errors with IMUs. We already knew that you do not measure what you want to know. You want to know position, but you measure acceleration. Because you estimate the new speed from the acceleration and the new position (dead reckoning) from the speed, the system is very sensitive to measurement errors. A small error in the measured acceleration produces a large deviation in the estimated speed and a huge error in the estimated position. From the research articles we could conclude that it is theoretically possible, but that it is practically difficult to implement.

We then started to experiment with sensors ourselves. Virtually all international articles that we had found used a sensor from the Dutch company Xsens, located in Enschede. The first step was to purchase such a sensor and experiment with it. Our goal was the development of a demonstrator, or proof-of-concept: a system with which you can show others that the principle works. Initially, two students started working on this. They had asked themselves two research questions: 1) Is the sensor as accurate as stated in the specifications? And 2) Can we make software that can process the measurement data into position estimates?

In order to determine whether the sensor was accurate, they made a test set up with which they could do many measurements. Based on the expected measured values and the actual measured values, they could check whether the sensor was accurate enough. This test was very useful, because it showed that one of the sensors we had was not accurate at all. This sensor was sent back to the producer and after it was recalibrated we got it back and it was OK.

In parallel, work was done on the software to be able to make the position estimates. The literature showed that you had to apply a trick to get your algorithms accurate. This trick was called Zero Velocity Update (ZUPT). The starting point of ZUPT is that you make measurement errors and that this has consequences for your speed and position estimates. By recognizing when the foot hits the ground (and thus stands still) you can manually set the

speed estimate to 0. The students processed this in their software and eventually they had a demonstrator where you had to attach an IMU sensor to the shoe. The IMU sent the data to a laptop that stored the data. After a walk you could then draw a map of the route you had walked. The system was quite accurate. After a 10-minute walk, there was a deviation of about 5 meters.

The conclusion of this part of the research was therefore: It is possible to estimate position based on IMU data. We then demonstrated these results to the fire brigade and presented them at a conference. The fire brigade was very enthusiastic and indicated that it like to have such a system. All kinds of new questions arose immediately: Can you do the calculations immediately (while someone is running)? What is needed in a fire service organization to use such a system? Can you send the positions to a central point? Can you embed the sensors in a firefighter boot? ...

Exercises

1. Which research questions do you recognize in the story?
2. Can you think of any additional important questions?

3. Which methods and research strategies do you recognize?
4. Would you use other methods and strategies yourself? Why?