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Development of a Reliable Positioning Tool for the Navigation of Visually Impaired People

Original working title of the thesis: Filtering Methods in the Field of Integrated Navigation

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***Abstract*—Within the Ph.D. thesis, an accurate and reliable positioning tool being part of a pedestrian navigation system for visually impaired people for indoor and outdoor environments is developed. Current pedestrian navigation systems are usually based on smartphones/mobile devices with position accuracies of 1 m or worse. These systems cannot reliably warn against obstacles like mailboxes, road signs, etc., since for this case a sub-meter accuracy is needed. Therefore, an innovative positioning component based on GPS, inertial, magnetometer and barometer data and incorporating a special user-tailored navigable map and the outcome of a pedestrian activity classification is investigated. The user-tailored navigable map contains specific information for visually impaired persons, which constrains the pathways according to their probability within the filter. Since the creation of such a user-tailored map is very time- and cost-consuming, a SLAM-based approach is planned to be treated within the thesis.**

Keywords— navigation of blind pedestrians, Bayes filters, indoor and outdoor positioning, smartphone sensors

I. BIOGRAPHY

Petra Hafner is a research assistant and Ph.D. candidate at the Institute of Navigation at Graz University of Technology. She obtained her MSc degree in the field of Geomatics in 2009 from the Graz University of Technology. In 2010 she started her post graduate study in the doctoral school of geodesy. The first investigations within her doctorate were focused on the integration of GNSS and INS, while with the start of new projects the focus moved from airborne GNSS and INS positioning to pedestrian navigation. Starting with pedestrian indoor navigation based on smartphones, now the developments are extended to pedestrian outdoor positioning considering the special needs and habits of visually impaired people. The proposed graduation will be the middle of the year 2015. Beside the doctoral thesis, she has worked in the field of positioning and navigation research since 2008. A main focus of her research lies on pedestrian navigation, sensor fusion, and indoor positioning.

The supervisor of the Ph.D. thesis is Dr. Manfred Wieser, the head of the Institute of Navigation at Graz University of Technology.

II. SUBJECT OF THE THESIS

According to the Federal Ministry of Labor, Social Affairs, and Consumer Protection, approximately 3.9% of the Austrian population is suffering from permanent visual impairments. Although their number is respectable, they still experience problems, others do not even think of. One example is the daily navigation through the urban environment, where traffic junctions and busy roads involve many risks and dangers, if one of the sensory organs is impaired. Therefore, especially blind people are lacking accurate and reliable navigation systems to facilitate their daily routes and increase their safety.

Therefore, the goal of the investigations within this thesis is the development of a reliable and accurate positioning tool working in indoor and outdoor environments which is especially tailored for the use by blind persons. The key issue of the investigations or respectively the positioning tool is a particle filter incorporating as much sensor data as is available from a smartphone and occupancy grid maps. Hereby, for the outdoor positioning special occupancy grid maps have been developed and integrated within the filter process. The innovative aspect of this implemented approach is the use of geometric constraints in terms of a special tailored and detailed navigable raster map for visually impaired people. Since the visual impairment leads to a different, more predictable movement compared to the movement of common pedestrians, streets/paths can be divided in different classified categories. For example, blind persons most likely walk on pavements, cross the streets at zebra crossings only and follow tactile ground surface indicators at certain places. Consequently, this knowledge can be used for the creation of a raster map representing the outdoor environment. Regions where the probability of the person's presence is higher will be marked differently in contrast to regions of lower probability. General particle filters just distinguish occupied and free regions (streets, buildings, obstacles etc.), while the presented approach subdivides the streets with regard to the needs and walking behaviour of blind persons.

According to a project consultant who is blind by herself, in indoor environments the movement of blind persons can unfortunately not algorithmically constrained in the same way. The structures are too small in size and the blind's habits are very individual. However, common occupancy grid maps based on building layouts and path verifications are integrated within the position estimation process of the particle filter.

Beside the geometrical constraints based on the different raster maps for indoor and outdoor environments, the outcome of a pedestrian activity classification (PAC), which identifies activities like walking (WA), going upstairs (US), going downstairs (DS) or standing (ST), is used as multiple support within the position filter.

On the one hand, the activity provides additional information about the vertical displacement of the pedestrian which can be used as complementary data for the height estimation. The vertical displacement is gained by combining the information out of the step detection based on inertial data, the activity of the PAC and a standardized step height. If the actual activity is *US* or *DS* and a step is detected, then the step height corresponds to the covered height. The PAC information is considered, since state-of-the-art smartphones do usually not comprise barometers and the WLAN fingerprinting based height information is very critical in regions where floor changes are possible.

On the other hand, the recognized activity is used as support for the 2D position estimation. Depending on the actual activities, the possible state space can be probabilistically restricted. Considering for example a pedestrian going upstairs or downstairs, the probability of being at a stair has to be higher.

As already mentioned, within the investigations, sensors of common smartphones are treated. The positioning indoors is based on absolute positions obtained by a WLAN fingerprinting algorithm, relative position information (heading and velocity) estimated within a PDR (pedestrian dead reckoning) approach using inertial and magnetometer data and a relative height information of a barometer. Outdoors, the WLAN-based positions are replaced by satellite based positioning data using GPS code measurements.

At the moment, the developed framework can only be tested and analyzed within a defined indoor and outdoor test area at the campus of Graz University of Technology. A limited test area had to be defined, since on the one hand the WLAN fingerprinting database and on the other hand the creation of the mentioned user-tailored raster map is a very time- and cost-consuming process. Hence, for the creation of the blinds-tailored map a SLAM-based approach (**S**imultaneous **L**ocalization **A**nd **M**apping) is planned to be treated within the thesis. Generating this map automatically, requires a more precise absolute positioning than the GPS code solution which only provides accuracies in the range of some meters. For that reason, multiple-GNSS precise point positioning (PPP), which enables positioning in the decimeter level, is considered. Within the defined test area, different tests have already been performed and turned out, that PPP could be used for the SLAM-based generation of the map, if enough GNSS satellites (at least four GPS or five GPS and GLONASS satellites) are available within the urban canyons. As at the moment, this is not the case for 24 hours of a day, software packages analyzing the GNSS constellation have been used to plan the optimal measurement time span in advance. However, the automatic generation of the map requires a 24 hours capability to collect as much data as possible to create a reliable probability map. Consequently, the SLAM approach will be treated in a simulation environment as long as the GNSS is not efficiently supported by the European system Galileo, having too less satellites in orbit. The full operational capability of Galileo would fulfil the requirements for the automatic generation of the map.

As a part of the thesis, the application of the SLAM approach for generating blinds-tailored maps for indoor environments will be reviewed. By using SLAM, individual probability maps for different blind persons could be created.

III. STATUS OF THE THESIS

The development of an indoor and outdoor positioning tool for indoor and outdoor environments based on smartphone sensor data, common occupancy grid maps for indoor environments, blinds-tailored navigable maps for outdoor environments and PAC results has been completed. The applicability of multi-GNSS PPP for the SLAM approach has been proofed. The simulation environment for the SLAM is in progress. The developing phase is planned to be finished by the end of 2014 or maybe at the beginning of 2015, while the submission of the Ph.D. thesis is scheduled for April 2015.

The poster at the Ph.D. forum will present the design and the established developments of the described positioning tool specially tailored for the navigation support of visually impaired people. Hereby the focus is put on the performance gained by incorporating blinds-tailored navigable maps and pedestrian activity classification results. Additionally, the design of the proposed SLAM-approach will be illustrated.

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