SPIRIT Navigation: Multi-Technology Indoor Localization

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ABSTRACT

SPIRIT Navigation has developed a software navigation engine that serves for indoor positioning on commercial smartphones. The navigation engine uses only data from smartphone sensors and telecommunication modules and does not require any navigation infrastructure to be installed in the building. Inertial data from smartphone gyroscope and accelerometer, magnetic field measurements from smartphone magnetometer, WiFi RSSI measurement from corresponding telecommunication modules, and a floor plan of the building are used for hybrid indoor positioning in the navigation engine. Our approach to indoor positioning is based on concurrent use of multiple technologies, which include pedestrian dead reckoning (PDR), Wi-Fi fingerprinting, geomagnetic fingerprinting, and map matching. Data fusion is realized on the basis of a Particle Filter, which is an implementation of the Bayesian filter using the Monte Carlo method. Navigation software developed by SPIRIT Navigation can be easily integrated in LBS mobile applications that rely on user position indoors. We present an Android mobile application that demonstrates positioning indoors. The demo application gives an example of our software navigation engine integration. User's position can be shown either on Google Map in global geodetic coordinates or on the floor plan in local coordinates of the plan. The mobile application determines user's starting position automatically and shows accurate and reliable real-time indoor positioning in multi-floor buildings with accuracy of about 1-2 m.

Categories and Subject Descriptors

C.3 [**Special-Purpose and Application-Based Systems**]: Real-time and embedded systems

Keywords

Indoor Positioning, Particle Filter, Navigation Engine.

1. INTRODUCTION

Nowadays smartphones became one of the most popular devices in people's daily life, which very largely go by indoors. As stated in [1], "80 percent of smartphone usage occurs inside buildings". In addition to GPS/GNSS receiver, smartphones are equipped with a large variety of sensors such as accelerometer, gyroscope, magnetometer, barometer, camera, microphone, touch screen, etc. It is also necessary to mention such radio communication modules as NFC and Bluetooth including the newest Bluetooth Low Energy (BLE) in addition to Wi-Fi and 3G/LTE.

Such rich sensing and radio communication possibilities allow to realize on modern smartphones different indoor positioning techniques. Our approach to smartphone-based indoor positioning is based on data fusion of four different sources – inertial data from smartphone sensors, magnetic field measurements from smartphone magnetometer, WiFi/BLE RSSI measurement from corresponding telecommunication modules, and a floor plan of the building. Our approach allows successfully solving principle tasks. First, the navigation engine can automatically start in any place of a building whenever user switches on his or her smartphone without entering initial position manually or starting outdoors where initial position could be determined by GPS/GNSS receiver. Then, operating in a tracking mode, the navigation engine provides a real-time indoor navigation with accuracy within a few meters. At last, the navigation engine recovers tracking from failures that are the known problem of the particle filter occurring when all particles are accidentally discarded. The automatic recovery of tracking allows continuing tracking and increasing the reliability and availability of indoor navigation.

The rest of the paper is organized as follows. In Section 2 we describe different positioning techniques used in our hybrid solution. Section 3 describes the demonstration application that integrates the navigation engine and briefly discusses test results. Finally we give conclusion in Section 4.

2. POSITIONING TECHNIQUES

Fig. 1 shows a block diagram of the navigation engine. The navigation engine is built around the particle filter (PF) that realizes heterogeneous data fusion. Implementation of the PF contains three stages: propagation, update or correction, and re-sampling, which are continuously repeated. There is one more stage not shown on the Fig. 1. It is the initialization of the cloud of particles that is executed once. On the propagation stage, the coordinates and the heading of each particle are propagated using the pedestrian motion model. Data from PDR are used as input of the propagation stage. Weights of particles are corrected on the update stage. The current measurements of RSSI from WiFi access points, magnetic field measurements and map constraints are used for this purpose. Such algorithms like WiFi fingerprinting, geomagnetic fingerprinting, and map matching transform the measurements into new particle weights. At last, re-sampling prevents particle exhaustion. As a result, a user position is estimated at the PF output, e.g. by averaging coordinates over all particles.

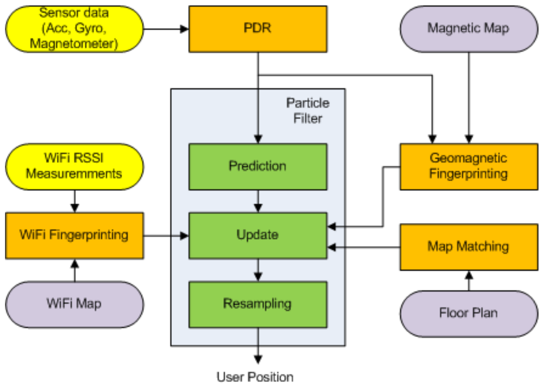

Figure 1. Block diagram of the navigation engine.

The aim of PDR in our navigation engine is prediction of a user relative movement and estimation of current smartphone orientation. The algorithm input data are measurements from 3D accelerometer, gyroscope and magnetic sensor. For each detected step, PDR output data include a stride length and change of heading.

Wi-Fi fingerprinting module uses RSSI measurements to estimate position of a user. The method essence is to compare a vector of RSSI measurements for an unknown position with data in a fingerprint map that contains RSSI in known locations of the building.

Geomagnetic fingerprinting uses measurements of a magnetic field vector. The 3D magnetometer of smartphone measures magnetic field in the device coordinate system. As smartphone may be oriented arbitrarily in the user's hand, the measurements are transformed to horizontal coordinate system of indoor floor plan. Device orientation angles required for the transformation are estimated by PDR module.

The purpose of the map matching algorithm is to refine a route of a user by matching the route with a building floor plan. Improvement of the trajectory estimation is achieved by checking permissibility of a transition from one position to another one. If transition of the particle is not allowed, its weight is set to zero.

Analysis given in [2] shows that geomagnetic fingerprinting provides the most accurate positioning among used techniques. Though WiFi fingerprinting is less accurate, its necessity consists in providing an unambiguous positioning that helps to determine a starting position during initialization and to recover from failures. Besides preventing from crossing walls, map matching is able improving positioning accuracy to some extent. These considerations explain our choice of positioning techniques.

3. DEMONSTRATION APPLICATION

With the object to examine indoor positioning performance, an Android mobile application was created. Before positioning, WiFi map and geomagnetic map should be measured in a building during a training phase. A special mapping mobile application is used for this purpose. Besides WiFi map and geomagnetic map, the floor plan should be preloaded into smartphone for using during positioning.

User's position can be shown either on Google Map in global geodetic coordinates or on the floor plan in local coordinates of the plan. Of the two cases, the former is illustrated with Fig. 2 that shows a screenshot of the application with Google Indoor Map and the current user's position on the map. The latter is illustrated with Fig. 3 that shows a screenshot with the trajectory collected during walk in Hall 6 of Mobile World Congress, Barcelona, 2014. The trajectory shows user's step-by-step positions. Starting position was automatically determined at the right place near SPIRIT's booth 6J55. Ending point of user's route was in the same place.

Figure 2. The screenshot shows user's position on Google Map of a shopping mall.

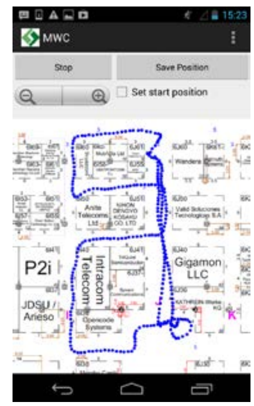

Figure 3. The screenshot shows the trajectory on the official plan of the MWC.

The mobile application features automatic start position determination. User only needs to start the application by touching the button "Start" and wait for about 2.5 s until the fist position mark appears on the screen. Then the user can walk in a building continuously collecting its trajectory.

Tests were provided with the aim to examine indoor positioning performance in public areas of buildings in realistic environments. Detailed discussion of test results is given in [2]. Test results have shown that the accuracy of indoor positioning is about 1-2 m (CEP). The navigation engine automatically determines starting position and shows the mean TTFF of 2.5 s.

4. CONCLUSION

Our approach to indoor positioning is based on concurrent use of multiple technologies, which include PDR, Wi-Fi fingerprinting, geomagnetic fingerprinting, and map matching. The navigation engine uses only data from smartphone sensors and telecommunication modules and does not require any navigation infrastructure to be installed in the building. Navigation software developed by SPIRIT Navigation can be easily integrated in LBS mobile applications that rely on user position indoors. The demonstration application that integrates the navigation engine was created. The demo application determines user's starting position automatically, shows fast TTFF indoors, and provides accurate and reliable real-time indoor positioning in multi-floor buildings.

5. REFERENCES

[1] "Wireless E911 Location Accuracy Requirements", FCC 14-13. http://www.fcc.gov/document/proposes-new-indoor-requirements-and-revisions-existing-e911-rules

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