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High precision positioning for pedestrian navigation in dense urban environments

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Abstract

Due to reflections or blockages of GNSS satellite signals by buildings and infrastructures, urban positioning with GNSS is a great challenge. Traditional receiver autonomous integrity monitoring (RAIM) based methods are insufficient to obtain positioning solutions with high accuracy in urban canyons where the majority of satellite signals may be contaminated by multipath interference and non-line-of-sight (NLOS) reception. This thesis will focus on the positioning performance improvement for pedestrians using lowcost devices in urban canyons. With the help of three-dimension (3D) city models, GNSS positioning performance can be improved by predicting visibility or path delays of satellite signals. Shadow matching is a 3D-mapping-aided (3DMA) approach utilizing SNR of satellite signals, which is available in position (NMEA format data) and measurement (raw GNSS measurement data) domains with a wide range of applications. However, the performance of shadow matching will be degraded when it fails to distinguish the grids of neighboring streets, or when it is affected by dynamic interference or 3D model errors. A new weighting method, grid weight smoothing and clustering (GWSC) method, is proposed to improve the performance of grid identification, and experiments in Hong Kong streets showed that the newly proposed method improved the cross-street accuracy of shadow matching from 19.4m to 2.1m with a large improvement rate (IR) of 89.2%, significantly outperforming the weighted average (WA)-based method of 15.3m accuracy, which had an IR of 21.1%. NLOS correction-based approach is another 3DMA method to improve overall positioning performance by simulating reflected paths of satellite signals in the measurement domain. Diffraction, which is also a type of NLOS, is not considered in the conventional reflection model. In this study, we apply the radio signal diffraction models to develop an improved NLOS correction-based approach using a more comprehensive reflection model considering more types of NLOS, along with the GWSC method in weighting. Through experiments, the estimated delays were consistent with the received errors, where over 95% of signals showed estimated errors below 15m. Moreover, the improved approach achieved accuracy of 7.4-15m in static tests, and 11.9m in kinematic tests, compared with up to 86.4m by the conventional GNSS method in typical Hong Kong streets. The proposed method showed a significant IR between 62.7% and 89.7% of positioning accuracy in all experiments in urban canyons. The computation load with city 3D models is very high as it needs to consider different satellite constellations at different time. Moreover, many cities may not have public 3D models available. In this study, a novel approach, named multi-epoch offset searching (MEOS), which does not need 3D city models, is proposed to mitigate multipath effects. With the implementation of measurement smoothing and the GWSC method, the new approach can provide high-precision positioning solutions for pedestrians in urban canyons. It is showed that the approach achieved accuracy of within 9m and 15m in several static and kinematic tests, respectively, compared to the poor accuracy, up to 57.7m and 27.5m, from raw GNSS outputs from conventional low-cost GNSS devices. The proposed method has significant IRs up to 88.3% in static tests, while its IR reached 47.6% in kinematic tests. To make the positioning system more stable and robust, multiple techniques are integrated with sensors existing in the smartphones. The integration of GNSS-based approaches and pedestrian dead reckoning (PDR) technology improves the positioning availability and further reduces the positioning errors. Further integrating Bluetooth-low-energy (BLE) into the system makes the positioning system more flexible and effective. Owing to the proposal of BLE-based heading estimation and improvement of step detection, this integration system achieved a high accuracy of within 5m in outdoor and seamless areas.

Keywords: GNSS, PDR, Pedestrian Navigation