Dual-frequency GNSS/Wi-Fi Smartphone Navigation

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Abstract. More and more sensors and receivers are found nowadays in modern smartphones which can enable and improve positioning for Location-based Services and other navigation applications. They include multi-constellation GNSS (Global Navigation Satellite Systems) receivers and other sensors which can be employed for positioning. The state-of-the-art thereby is that dual frequency GNSS capable receivers in smartphones are now recently on the market. With these receivers not only the current 3D positions but also the raw data of the measurements can be utilized leading to higher positioning accuracies. New algorithms need to be developed to make use of the measured GNSS raw data to be able to achieve required positioning accuracies. Therefore, the goal of our research concept is to develop a methodology based on dual frequency GNSS/Wi-Fi smartphone (L1/L5 carrier phases and 2.4/5 GHz frequency bands) for supporting seamless out/indoor navigation. A methodology for processing the measurement results based on fusion of these techniques, its significance and the expected findings are presented in the paper.

Keywords. Dual-frequency smartphone, navigation, GNSS, Wi-Fi

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1. Introduction

Until now, many measurement technologies based on different sensors have been used for indoor navigation. In outdoor navigation, the most important is positioning with GNSS. GNSS performance in out- to indoor transitional environments remains one of the most challenging problems due to inability to use satellites indoors. An indoor cooperative positioning (CP) system was deployed for this purpose. So far CP systems have demonstrated to be useful for positioning of mobile platforms navigating in challenging GNSS, as well as GNSS-denied environments (Wan et al. 2014; Rantakokko et al. 2011). The CP approach relies on information exchange in an inter-connected network of multiple nodes that could be static (called anchor or infrastructure nodes) or dynamic (such as Unmanned Aerial Vehicles (UAVs), pedestrians, vehicles, robots, etc.) in nature (Alam & Dempster 2013, Bargshady et al. 2010). Various CP systems-based on various sensors such as Ultra-Wide Band (UWB) (Chen et al. 2013), Wireless Fidelity (Wi-Fi) (Chen et al. 2009) were developed. Also Bluetooth, or other similar sensors (Savic & Zazo 2013) have been investigated in the literature. These positioning systems can be classified according to their type of sensor observations), type of processing architecture used and the presence or absence of static anchors. However, one of the major limitations of distributed algorithms is the presence of unknown correlation among the states of the nodes (Carrillo-Arce et al. 2013). Various distributed algorithms, such as Belief Propagation (BP) and the Covariance Intersection Filter (Hlinka et al. 2014) have been proposed for CP. Inclusion of static anchor (i.e., infrastructure) nodes has been shown to improve localization accuracy (Goel et al. 2018). On the other hand, anchor-free (or peer-to-peer (P2P) cooperative systems do not rely on the presence of a fixed infrastructure and can use ad hoc networks for positioning. In completely GNSS-denied environments, such as an indoor environment, a CP network can be best utilized by realization of the sufficient number of static anchor nodes, whose precise location is known in advance. Various authors have demonstrated the use of alternative positioning technologies for positioning in GNSS-denied environments (see e.g. Alam & Dempster 2013).

Compared to outdoor positioning, there is still no generally valid solution for indoor positioning. In buildings, a variety of technologies are available that are already installed on site and can be used for indoor positioning, such as infrared, Bluetooth, Wi-Fi, etc. (Bai et al. 2014, Chen et al. 2012). With smartphones, however, the selection of sensors and receivers and their quality differ depending on the device, which means that the position solution can also be influenced differently. In the literature there are different approaches for position determination, which can be divided into cell-based methods (Cell of-Origin CoO), Time of Arrival (ToA) or Round Trip Time (RTT) as well as Angle of Arrival (AoA) measurements, hyperbolic trilateration (Time Difference of Arrival TDoA), scene analysis with measured signal strengths (Received Signal Strength RSS) and digital images as well as fingerprinting (Stojanović & Stojanović 2014). In vision-based positioning, scene analysis involves examination and matching a video/image or electromagnetic characteristics viewed or sensed from a target object (Robertsone & Cipolla 2012, Stojanović & Stojanović 2014). Another technique involves the matching of perspective images of the environment captured by a camera, carried by a person (e.g. camera in the smartphone) or mounted on a mobile robot platform, to prerecorded images or videos which have been collected to build-up 3D models stored in an image/video database. Furthermore, visual odometry with sequentially captured images can be performed while the user is walking along his trajectory (Kazemipur et al. 2013).

In this study, the selected method is trilateration fusing dual frequency Wi-Fi/GNSS smartphone observations.

2. Research Concept

2.1. Principles of Related and Novel Approach

With reference to the developed methods discussed in the introduction, Figure 1 presents our concept of a new approach that can be used in indoor navigation. The novel approach integrates dual frequency Wi-Fi in the 2.4 and 5 GHz frequency band and dual frequency GNSS (in the case of GPS the L1 and L5 signals) measurements.

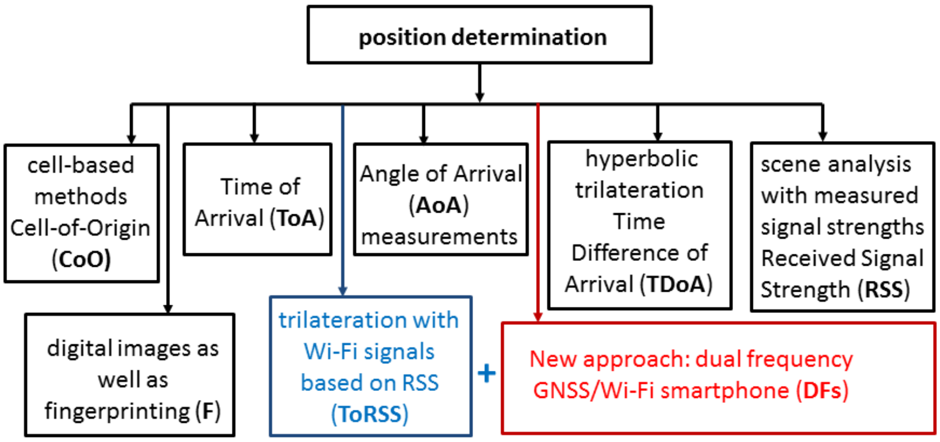

Figure 1. Related and new approach (source: own study)

2.2. Detailed Research Methodology

The main research aim is to investigate and prove the usefulness of emerging wireless sensing data for indoor positioning. Such a solution allows for real-time visualization of the location of people, materials, and equipment. The ability to calculate trajectories holds tremendous potential for indoor localization and visualization, especially if linked to Wi-Fi wireless sensing technologies. Making uses of such technology, we can provide two key pieces of spatial information: (1) the coordinates of objects needed for localization; and (2) the topology and geometry needed to navigate inside the building. Localization sensing technology can provide location and time information. Many various circumstances may appear where poor visibility makes detection of utilities difficult for a worker, causing problems to remain unnoticed and resources to remain inoperative. In such a situation, where this problem is located, additional time is lost while relaying the information to the facility manager for guidance on the necessary corrective measures that must be taken. Moreover, workers unfamiliar with a facility may have difficulties locating themselves, as well as locating a specific room within a facility. It is also very important that the facility can be navigated quickly in the event of an emergency, because a search and rescue crew has no time to waste in getting lost when human lives are the most important. Proposed research solution may provide working personnel, or emergency crews precise location information to navigate around and find their destinations.

Achieving the main goal of our tests requires the following research tasks:

1. Preparation of optimal Wi-Fi network calibration algorithms.
2. Verification of Wi-Fi network based on indoor positioning algorithms.
3. Development of intelligent positioning method using GNSS smartphone module in outdoor environments.
4. Refinement of the RTT method for reducing the number of RSSI data.
5. Implementation and refinement of integrated navigation software for testing positioning accuracy.

3. Significance and Expected Findings

As a result of the conducted research, we expect to obtain the following findings:

1. The most accurate position information being outdoors with various GNSS positioning techniques (mostly Real-time Kinematic RTK) using a dual frequency L1/L5 GNSS smartphone.

2. Indoor navigation software using RSSI data and RTT measurements obtained simultaneously from 2.4 and 5 GHz mobile Wi-Fi routers.

3. The emergence of a new calibration method based on least square fit algorithms for different distances to calculate parameters for obtaining the most accurate range information to all mobile routers serving as anchors.
4. A prototype indoor navigation software implemented on Android-based smartphones.
5. Evaluation of the accuracy of the proposed integrated navigation system.

4. Conclusion

The development of a method and algorithm for seamless and combined out-/indoor navigation integrating dual frequency GNSS and dual band Wi-Fi on smartphones will respond to the user's needs for indoor navigation providing the starting point for innovation and development.

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