A Smart Phone Indoor Positioning system using Hybrid Localization Technology

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Abstract: Localization has gained priority in an increasingly inter-connected world. The majority of industries and sectors require some means of tracking the location of objects and/or people anywhere on the Earth, whether indoors or outdoors. Global Positioning System (GPS) is an already-implemented and viable solution for outdoor localization. However, indoor localization is more challenging to implement and thus has become a broad area of research. Despite the challenges of tracking location in places where satellite GPS signals are unreliable or unreachable (i.e. within a building or structure), there has been considerable progress made in indoor localization research. Although current indoor localization technology can achieve certain accuracy, they usually require extra equipment and thus can be too cumbersome and/or expensive for common purposes. A relatively new field of indoor localization research involves using the sensors built into smart phones to triangulate a user's position within a structure. This eliminates the requirement for extra cumbersome sensors or accessories. In indoor scenarios, GPS signal reception is weak. Therefore, achieving good position estimation accuracy is a challenge. To overcome this challenge, it is necessary to utilize other position- estimation systems for indoor localization. However, other existing indoor localization systems especially based on inertial measurement unit (IMU) sensor data, still face challenges such as accumulated errors from sensors and external magnetic field effects. This paper performs survey on various indoor localization systems and proposes the best technique.

Keywords: Indoor Localization systems, GPS, Tracking Location.

I. INTRODUCTION

Since every smartphone is equipped with GNSS or Assisted GNSS receiver, street navigation with smartphones is ubiquitous. However, there is no single technology that can provide reliable indoor positioning. Among technologies suitable for indoor positioning that potentially can be implemented on smartphones are:

- Use of radio frequency (RF) signals, either those already present such as wireless local area networks (WLAN), or cellular, or those generated by new and dedicated infrastructure (RFID/NFC, Bluetooth).
- Self-contained sensors: tri-axis accelerometer, tri-axis gyroscope, tri-axis magnetometer, barometer
- Indoor map (building floor plan)
- Magnetic field fingerprinting

None of these technologies is a complete solution to all indoor positioning needs on mass-market devices and their advantages and disadvantages depend on the nature of each technology [1]. For example, UWB and RFID-based solutions require deployment of new infrastructure and addition of new hardware components to smartphones. These additional costs currently limit use of tag based solutions to Bluetooth Low Energy (BLE).

Typical tasks for indoor navigation with smartphone include locating people and places in public buildings like universities, malls and airports, at sport events, conventions, etc., keeping track of children and elderly people, and automatically tagging posts and pictures. To meet these requirements, positioning accuracy in a typical office building has to be at the room level and the floor has to be correctly identified. In the case of large open spaces such as airport and shopping malls an accuracy [2] of several meters is enough to establish visual contact and find the required place, for example, an airport gate. For some applications like store navigation or a guided tour of museums better positioning accuracy is required. It can be achieved by BLE based positioning when the beacons are densely placed in the required areas.

Currently most of smartphones use WLAN based indoor positioning that usually satisfies the position accuracy requirements in areas rich with WLAN routers. However, the accuracy significantly depends on the density of WLAN routers [3] and on the quality of the radio map which usually deteriorates over time and has to be updated on a regular basis. Improvement of WLAN/BLE based positioning can be achieved if additional sensors and sources of information are used, for example self-contained sensors that improve accuracy and reliability between WLAN based position updates and during gaps in WLAN/BLE coverage. Other commonly used methods to improve positioning are map-matching and magnetic field fingerprinting [18]. They can be fused with WLAN/BLE and sensors to improve position accuracy [4]. Magnetic field based positioning is conceptually similar to terrain navigation systems in military aircraft and submarines, in which altitude or depth are map-matched to estimate the position [5]; in magnetic indoor positioning the features are the local distortions in magnetic field caused mainly by steel in the building structure.

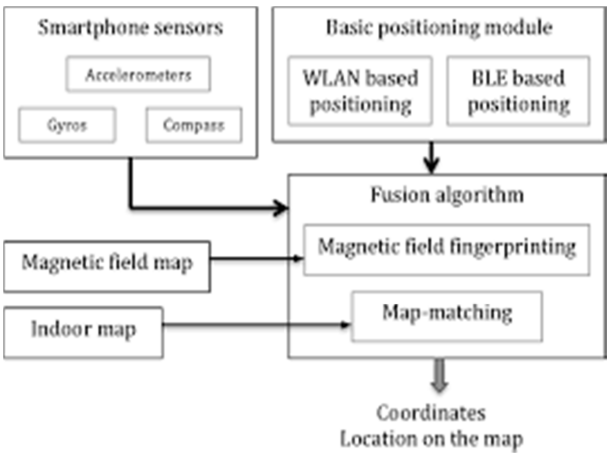

Fig 1. Major components of a smartphone indoor positioning system.

The major components and data flow in a smartphone positioning system are shown in Fig.1. These technologies meet the requirements for mass market deployment on smartphones, however not necessarily all of these components have to be present in the positioning system. Possible combinations of technologies for indoor navigation include:

- WLAN (map is used for display purpose only)
- WLAN and sensors
- WLAN and indoor map for map-matching
- WLAN, map-matching and sensors

Magnetic field fingerprinting and BLE based positioning can be added to any of these combinations. This paper describes the technologies and position-estimation methods of these technology components.

II RELATED WORK

Position estimation has been studied in the past and recently for applications in object detection, robotics, and various tracking purposes. The discussion of this section focuses on related work for position estimation. The position-estimation study is related to two research areas: step detection and heading estimation. The final area of study related to position estimation is sensor-fusion technologies. Various sensor- fusion techniques are used for position estimation for better performance. The performance of position estimation algorithms depends on the accuracy of step detection [19]. It is necessary to estimate the steps and the step length (SL) of the pedestrian for accurate position estimation. Conventional step detector algorithms use accelerometer sensor data to detect steps. Ahmad *et al.* [6] studied the fundamental analysis of step- detection algorithms and discussed their performance based on dynamic step lengths. Ho *et al.* [7] reported an adaptive step length estimator. In their proposed method, a fast Fourier transform (FFT)-based smoother on the acceleration data instead of conventional filtering methods such as high pass and low pass filters was used. Experimental results showed that the proposed method achieves better performance compared to the conventional estimation methods. Another approach for step detection and step length estimation is to use a neural network. Liu *et al.* [8] explained the neural network [20] concept for step detection. In their paper, they describe a compositional algorithm of empirical formula and back-propagation neural network to estimate step length. In this paper, we propose a pitch based step detection algorithm instead of accelerometer-based step detections. The proposed pitch-based approach uses the pitch angle for step detection and estimates the step length based on the pitch amplitude.

The performance of the position estimation also depends on the accurate heading estimation. Magnetometer and gyro-scope sensors are used for estimating heading. Yuan *et al.* [9] introduced a quaternion-based, unscented Kalman filter for accurate indoor heading estimation. In their work, a wearable multisensory system with different sensors was utilized. The experimental results show that the designed system has high heading accuracy with respect to the ground truth-values. Renaudin *et al.* [10] explain about a quaternion-based head- ing estimation method and proposed magnetic angular rate update and acceleration

gradient update. The experimental results show that the proposed method reduces the heading error compared to other methods. The accuracy of the heading depends on the position in which the smartphone is held. Liu *et al.* [11] discusses smartphone-holding postures for heading estimation and have proposed a heading estimation algorithm for different smartphone holding postures. In this study, we use magnetometer and gyroscope sensors. The magnetometer is easily affected by an external disturbance and the gyroscope values are not reliable for long-duration experiments. To overcome these issues, we use the sensor- fusion technique in our algorithm. Quaternion updated gyro- scope values are used for reducing the drift problems.

The position is estimated from combining step length and heading information. In Ali and El-Sheimy [12], a basic position estimation algorithm is explained. Ali and El-Sheimy [13] introduced a sensor-fusion technique for position estimation. The proposed position algorithm has less than 15 m position error in a harsh environment. In this study, we have considered the same experiment scenario and our algorithm achieves less than 2.6 m of position error as compared to results achieved in [14]. In Kang and Han [15], a smartphone-based PDR for an indoor localization was presented. Experimental results show that their proposed system has reasonable location accuracy. Tian *et al.* [16] deals with a multi-mode dead reckoning system for pedestrian tracking using smartphones. Their work introduces mode detection for the PDR system. The mode represents a specific state of carrying a mobile device, and it is automatically detected during pedestrian walk. The mode detection algorithm improves position-detection performance. Their proposed system achieves real-time tracking and localization performance with high positional accuracy. Another way to improve on the performance of a pedestrian navigation system is to create a motion recognition algorithm. Shin *et al.* [17] explain the use of motion recognition-based 3D pedestrian navigation system using a smartphone. This paper proposes an android-based PDR system. The experimental results show that the proposed method has a high positioning accuracy as compared to the conventional PDR systems.

The position-estimation systems discussed here require further improvement related to position accuracy. Therefore, it is necessary to propose a new position-estimation algorithm for different indoor conditions.

III METHODOLOGY

This paper describes the technologies and position-estimation methods of these technology components. This paper also analyses a position-estimation algorithm for different indoor scenarios. The proposed algorithm is validated by three experiment scenarios. The accuracy of the proposed algorithm is assessed and evaluated by computing the displacement error and root mean square error (RMSE). The experiment result shows that the proposed algorithm has higher positional accuracy as compared to conventional method.

SUVEY REPORT

This section surveys several individual methods and/or algorithms for determining the location, direction of motion, and orientation of an object located within a building. Two methods are presented with one or more examples of an indoor localization system that uses the method either in isolation or with an emphasis on it. Figure 2 shows a diagram of the individual methods discussed in the next sections and how they are categorized in relation to one another.

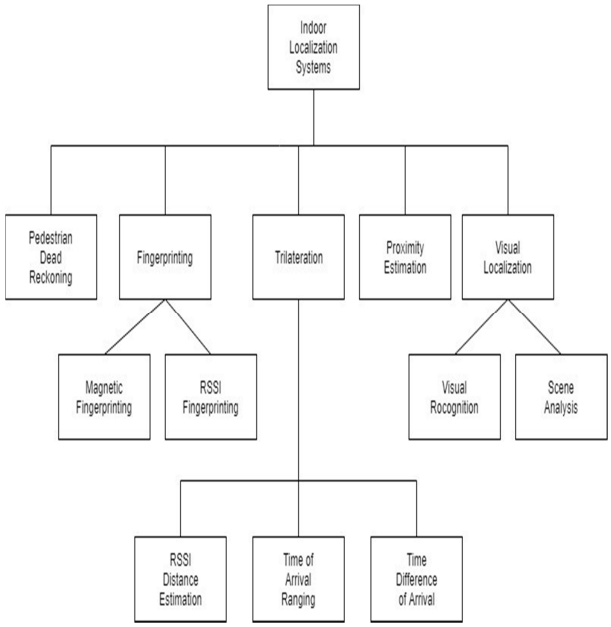

Fig 2. Indoor Localization Techniques

1. Dead Reckoning

Dead Reckoning is a statistical technique in which previously recorded data is used to estimate current data, as demonstrated in figure 3.

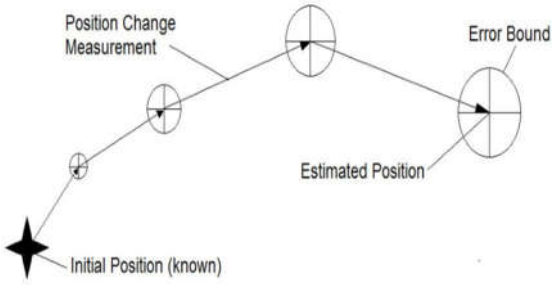

Figure 3: Dead Reckoning

In the case of indoor localization, dead reckoning uses previous location data in order to predict the target's current location. There is several dead reckoning techniques currently used for indoor localization. The most common method is Pedometer-based Dead Reckoning, also called Pedestrian Dead Reckoning (PDR) in which a person's steps are detected and recorded along with stride-length measures in order to estimate where a person is within a given structure. PDR has been shown to demonstrate sufficient accuracy for many indoor localization systems, which is why it is the standard dead reckoning method for indoor localization.

FootPath is a self-contained map-based indoor localization system designed for smartphones that uses step detection and dead reckoning by way of sequence alignment algorithms borrowed from bioinformatics.

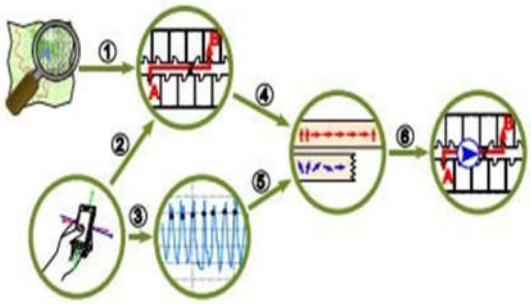

Fig. 4. Overview of FootPath

Indoor localization for FootPath involves five steps, as described in Figure 4 First, FootPath gathers map data using an open-source mapping software. Second, the user uses his/her smartphone to pinpoint a starting location and a final destination, after which the smartphone app traces the best route. Once the path has been traced, FootPath begins step detection using the Smartphone's accelerometer and compass. The FootPath software recognizes a step when the detected acceleration is at least $12 m/s2$ within a window of 165ms (which allows for about five samples) with a timeout of 333ms.

2. Fingerprinting

Fingerprinting is a localization and/or mapping technique involving the gathering of data from several wireless sensors or radios placed at various spatial points. There are two steps involved in the fingerprinting process: an initial setup, and a real-time recording. In the initial setup, selected locations are marked with a unique ID or signature (i.e. a fingerprint, hence the name of the process). During the real time recording, location data is gathered continuously and compared relative to the fingerprinted locations. As the user navigates through a building where fingerprints placed strategically throughout, the indoor localization system will estimate user location based on which fingerprint has the highest received signal strength from the user. To give an example, a floor of an office building has two fingerprints, one in the conference room and one in the manager's office. If an employee logged into the fingerprinting-based indoor localization system is walking toward the manager's office, the office fingerprint will have(increasingly) higher signal strength than the conference room fingerprint. Thus, the system determines that the employee is located in the vicinity of the manager's office. There are two commonly used methods for fingerprinting: magnetic and RSSI.

V CONCLUSION

This paper performs a survey on various indoor localization techniques and proposed two methods Dead Reckoning and Fingerprinting. Human civilization has greatly benefited from every advancement in localization. Indoor localization is a promising area of research that has the potential to benefit human society greatly. With the ability to determine and track the location of people and objects when GPS signals are unavailable within a structure, underground or underwater, under dense forest canopy, etc. the technological advertising and marketing companies can utilize indoor localization technology to greatly improve customer experience. The possible benefits of indoor localization are limitless. When combined with the convenience, ubiquity, and ease-of-use of the smartphone, the power of indoor localization can aid the broadest audience possible.

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