GPS Localization Improvement of Smartphones Using Built-in Sensors

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Abstract

Location awareness and navigation are becoming one of the most important features in mobile phones and smartphones. Personal navigation and location based services are enlarging the scope of mobile applications. GPS is the most efficient positioning technology. Thanks to the reduction in the size of the GPS receivers and the integration of GPS with mobile phones, GPS is one of the most important service providers in LBS. By the way, since mobile phones and smartphones usually have relatively low cost GPS chips, the performance of locating accuracy is highly dependent on environmental factors. In addition, the accuracy of GPS varies depending on the number of GPS satellites and is reduced in GPS interfering spots such as in a forest or around buildings. This paper proposes a localization improvement algorithm in GPS interfering spots by integrating information of multiple sensors in smartphones. The proposed algorithm is implemented in a smartphone and the performance is evaluated on a campus. The proposed algorithm has better performance than only the GPS location information in GPS interfering spots and maintains reasonable performance in open spaces where the GPS receiver is accurate.

Keywords: *localization, GPS, smartphone, sensors*

1. Introduction

Location awareness and navigation are becoming one of the most important features in mobile phones and smartphones. Personal navigation and location based services are enlarging the scope of mobile applications. GPS (Global Positioning System) is the most efficient positioning technology. Thanks to the reduction in the size of the GPS receivers and integration of GPS with mobile phones, GPS is one of the most important service providers for LBS.

By the way, since mobile phones and smartphones usually have relatively low cost GPS chips, the performance of locating accuracy is highly dependent on environmental factors. In addition, the accuracy of GPS varies depending on the number of GPS satellites and is reduced in GPS interfering spots such as in a forest or around buildings.

This paper proposes a localization improvement algorithm in GPS interfering spots by integrating information of multiple sensors such as gyroscope and compass in smartphones. The proposed algorithm is implemented in a smartphone and the performance is evaluated on a campus. The rest of this paper is organized as follows. In Section 2, motivation and related work are discussed. Section 3 proposes the design of the localization algorithm to improve localization accuracy in smartphones using multiple sensors. Next, performance of the proposed algorithm is evaluated in Section 4. Finally, we conclude this paper in Section 5.

2. Motivation and Related Work

2.1. Motivation

The reduction in the size of GPS receivers and the integration of GPS with mobile phones have made location based service application more and more popular. There have been many case studies of location based services using mobile phones and smartphones with GPS.

An application study on a taxi calling and dispatching system is proposed in [1]. This is a prototype of a LBS application based on GPS mobile phones. It gives the basic design, modules division, GIS display algorithm design, test results and feature analysis of the proposed system. Another mobile application based on providing LBS using GPS as a location provider is to locate family members and alert when friends are nearby [2]. The applications work in open space areas only since it relies on GPS.

A distributed trajectory similarity search framework is presented in [3]. It focuses on GPS trace search in smartphone networks by decentralized and in-situ data. [4] gives a new method for precise Wi-Fi AP localization using GPS information of smartphones and the received signal strength (RSS) information from Wi-Fi APs.

Since GPS is the most efficient positioning technology, most mobile LBS applications utilize GPS as a location provider. But, as mentioned before mobile phones and smartphones have relatively low cost GPS chips, therefore the performance of locating accuracy is highly dependent on environmental factors such as weather or GPS interfering areas.

To increase the utilization of such various mobile LBS applications, it is important to improve GPS accuracy. Figure 1 shows GPS positioning error in a smartphone when the user is near high rise buildings. So we considered a study to overcome this GPS error.

Figure 1. Positioning Error in GPS Interfering Spot

2.2. Related Work

As GPS is widely used for outdoor localization, there have been efforts to analyze GPS performance in cases and to overcome GPS errors.

Systematic statistical analysis of GPS moving measurements in open sky and under tree shading environments was reported in [5]. The objective of the research was to develop a robust localization system. So it is considered that the first step to achieve such an objective is testing sensor performance through tree foliage environments that present conditions that are not optimal.

Recently, the wireless industry is moving towards convergence of radio technology to cater for multi standards on a single platform such as mobile phone, PDA (Personal Digital Assistant) and smartphone. These platforms provide a wide variety of wireless services, such as voice, data, video and position fixing. Many wireless standards such as 2G/3G, Wi-Fi, b1uetooth and GPS, have been implemented on these platforms. For mobile purposes, the equipment must be small in volume, light weight and low power consumption. These lead to complicated problems with digital and RF operations. The sensitivities in GPS and 2G/3G are tested and the improvements of GPS receiver sensitivities in PDA platforms are presented in [6].

Applications using location based services have been explored due to safety and emergency requirements in wireless communications services. The interworking among heterogeneous systems induces the hybrid positioning concept with multiple positioning technologies. [7] focuses on the improvement of GPS orbit accuracy to enhance hybrid position computation. The results suggest that the proposed approach has a potential in real time applications.

LifeMap, a smartphone-based context provider is proposed in [8]. It is implemented on commercial smartphones and can provide advanced location based services for mobile users. LifeMap uses inertial sensors in the smartphone to overcome the limitations of GPS and provide indoor location information. The information is combined with GPS and Wi-Fi positioning systems to generate user context in daily life.

In an urban environment, the signals from a built-in GPS on a smart phone are always so weak that it causes considerably low position and heading accuracy. [9] presents an approach using the built-in sensor to smooth the navigation process. Our work also focuses on GPS localization improvement in smartphones by integrating the information from built-in sensors with the GPS in the smartphone.

3. Design of Localization Algorithm

3.1. Structure of Algorithm

The proposed algorithm consists of three steps: finding the correct direction of movement, obtaining the distance moved, and integrating the prior results and GPS location information.

To obtain the direction of movement, we get the heading from the built-in compass in the smartphone. However, the compass is highly dependent on the ambient magnetic field so it has lower accuracy. To obtain more accurate values of the user's heading, we stabilize the heading value of the compass by recurrence processing of the data.

After obtaining the direction of the movement of the user, the distance moved is calculated by the summation of the distances of each coordinate from the GPS location information. The GPS location information shows the difference compared to the actual path moved as presented in Figure 2. So the calculated moving distance is greater than the actual distance moved if it is calculated by the summation of the distances between each coordinate from the GPS location information.

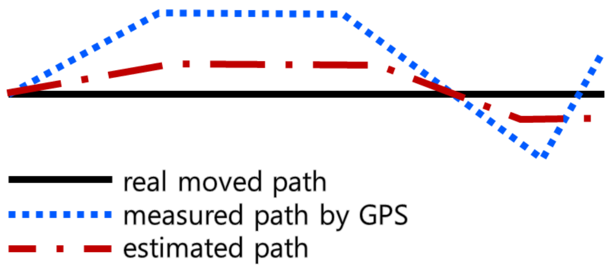

Figure 2. Path and Distance Moved

To fix this problem, we estimate the movement distance by using a trigonometric function as shown in Figure 3.

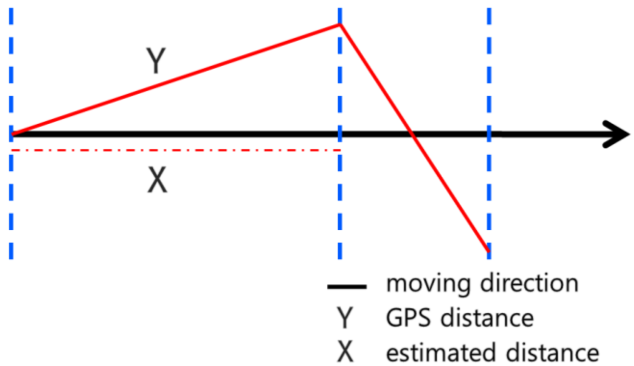

Figure 3. Calculation of Moving Distance

The proposed method estimates the path moved by integrating the GPS location information and sensor data and it prevents the accumulation of location error.

3.2. Recurrence Processing Function of Compass Heading

The measurements of the compass in smartphone are highly dependent on the ambient magnetic field so its accuracy is low. For this reason, we stabilize the measurements of the compass by averaging as shown in equation (1).

$$
\begin{aligned}
&x_0 = a_0 \\
&x_1 = (x_0 + a_1)/2 \\
&x_n = (x_{n-1} + a_n)/(n+1) \qquad (1) \\
&x_i : accumulated\ heading\ value \\
&a_i : a\ new\ compass\ value
\end{aligned}
$$

$$x_0 = a_0$$
$$x_1 = (x_0 + d_1 + a_1)/2$$
$$x_n = (x_{n-1} + d_n + a_n)/(n+1) \qquad (2)$$
$$x_i : accumulated\ heading\ value$$
$$a_i : a\ new\ compass\ value$$
$$d_i : difference\ of\ heading$$

The heading value of the compass can be stabilized with equation (1). But the real heading of a user varies continuously as the user moves. To adjust this value, we apply the difference between the previous heading and current heading and process it recursively as shown in equation (2). The difference in the heading di is obtained from the built-in gyroscope in the smartphone. Although the gyroscope cannot measure the absolute heading like a compass, it has high accuracy in measuring variation of the heading. Eventually, through the prior processing, efficient stabilization of the data is possible.

4. Performance Evaluation

In this section we discuss the performance evaluation of the proposed localization improvement algorithm. We implemented the proposed method on commercial smartphone and performed an experiment by walking through a campus.

Figure 4. Experiment Environment

We traced the path of movement in the smartphone and the path is displayed on the map. There are two kinds of trace: tracing by the proposed method and only tracing by the GPS location information. Figure 4 shows the experimental environment as a GPS interfering spot. The accuracy of GPS is reduced in GPS interfering spots such as in a forest or around buildings.

The experimental results in the GPS interfering spot is presented in Figure 5. As shown in the results, the GPS location information deviates from the real path moved. On the other hand, the adjusted location information through the proposed algorithm can trace the movement path more accurately.

Figure 5. Experimental Result in GPS Interfering Area

Figure 6. Experimental Result in Open Space

Figure 6 shows the experimental results on a soccer field as an open space. In this case, the GPS location information has high accuracy. The proposed algorithm also has reasonable results since it has feedback from the GPS location information.

5. Conclusions

Location awareness and navigation are becoming one of the most important features in mobile phones and smartphones. Personal navigation and location based services are enlarging the scope of mobile applications. GPS is the most efficient positioning technology. Thanks to the reduction in the size of the GPS receivers and the integration of GPS with mobile phones, GPS is one of the most important service providers for LBS. Since mobile phones and smartphones usually have relatively low cost GPS chips, the performance of locating accuracy is highly dependent on environmental factors.

This paper proposes a localization improvement algorithm in GPS interfering spots by integrating information of multiple sensors such as gyroscope and compass in the smartphone. The proposed algorithm is implemented in a smartphone and the performance is evaluated on a campus.

The proposed algorithm has better performance than only the GPS location information in GPS interfering spots and maintains reasonable performance in open spaces where the GPS receiver is accurate. As a future work, we consider localization improvement method for smartphones using other built-in sensors such as accelerometer and camera.

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