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Geomagnetism-based indoor location estimation method for future smartphone

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***Abstract*— It has been found that geomagnetic field variations can be utilized for indoor location estimation, because geomagnetic field has sufficient variability in buildings. But similar geomagnetic field values exist at many points in a building. The geomagnetic field ambiguity is the primary reason for localization performance degradation. In this paper, to enhance the robustness in geomagnetic field variation-based localization we propose a geomagnetic field ambiguity elimination method. The proposed search space reduction method improves location estimation error and the first time to fix performance. Simulation results show the effectiveness of the proposed method.**

Keywords-geomagnetism;localization; local anomally;

I. Introduction

There have been considerable research interests for indoor localization technologies. Firstly, location information can be acquired by using global positioning system (GPS) signal in the outdoor environment, but no dominant solutions exist for localization in buildings. Secondly, a diverse set of wireless signal-based location estimation technologies has been proposed : Bluetooth and RFID [1], but these technologies are not as yet vitalized, because they need the deployment of infrastructures. On the other hand, wireless local area network (WLAN)-based location estimation methods have received considerable attention, because sufficient number of access points (APs) are already deployed in buildings. The main drawback of WLAN-based localization is accuracy degradation due to radio signal fluctuations. Considerable amount of received signal strength (RSS) fluctuations may occur due to the movements of people or objects [2]. Thirdly, geomagnetic field is used for heading detection using an electric compass, because geomagnetic field is static and points towards magnetic-north regardless of position.

The magnitude and direction of geomagnetic field, however, differ depending on location in a building. The ferromagnetic substance - e.g. steel reinforcement and H-beam - of a building causes variations of geomagnetic field depending on locations [3]. Variations of geomagnetic field was an undesirable characteristic, which must be overcome for heading estimation. Recently it has been found that geomagnetic field variations can be utilized for indoor location estimation in [4], where the location of mobile robot can be estimated using geomagnetic field variations, because geomagnetic field has sufficient variability in buildings. The geomagnetic field variation, however, is not artificially made for localization, so similar geomagnetic field values exist at many points in a building. The geomagnetic field ambiguity is the primary reason for localization performance degradation. In this paper, to enhance the robustness in local geomagnetic field variation-based localization we propose a geomagnetic field ambiguity elimination method.

II. Localization method

The main benefit of geomagnetic field variation-based indoor location estimation is that the users can get location information without any installation of infrastructures. The geomagnetism-based localization system works in two phases. The first phase is an offline phase, during which it constructs database in respect of geomagnetic field at each location. The database consists of 3-axis component values of geomagnetic field and coordinates in buildings. The second phase is the online estimation, which involves the mobile device scanning the magnetic field and feeding the measured data to the location estimation algorithm. The location is estimated by comparing measured magnetic field values with the magnetic field map. Particle filter algorithm is used to acquire location information.

In this paper, we estimate the location using the magnetic flux density. The magnetic flux density provides a steady scalar value regardless of a sensor direction and inclination at each location, but accuracy degradation and first time-to-fix increase problems can arise due to the ambiguity of the geomagnetic flux density. The larger the considered area is, the higher the probability of an ambiguity problem occurrence is.

To eliminate the ambiguity of geomagnetic flux density, we propose a search space reduction method. Most of the smart phones are equipped with an accelerometer. The accelerometer can provide inclination information of the mobile terminal. The vertical and horizontal component values of geomagnetic field and the dip angle, where the dip angle means angle between vertical and horizontal component values, measured during the online scanning phase can be estimated using inclination information of mobile terminal regardless of direction and inclination of mobile terminal. The exact estimation of inclination status is, however, impossible due to the error of the accelerometer. Boundary values in which the vertical and horizontal components values and the dip angle exist, can be estimated by considering the error performance of the inclination estimation. In this paper, the location is estimated by comparing the measured magnetic flux density with the magnetic field map restricted by vertical and horizontal component values and the dip angle. In other words, the search space on the magnetic field map is reduced to the area where the range of the vertical and horizontal component and the dip angle correspond to the measured data.

III. TEST ENVIRONMENT

Fig. 1 shows Song-dam gymnasium where location experiment is performed. A 3-axis magnetometer is used for building magnetic field map and location estimation. The magnetometer is Micromag3 of PNI sensor corporation. The resolution of Micromang3 magnetometer is 0.015μT. The area of experiment is $105m^2$(7m × 15m). There are not pillars inside the gymnasium, it's average height is about 10m. The primary cause of geomagnetic variations is steel reinforcement in the floor. The geomagnetic field database is constructed by measuring 3-axis magnetic field values at intervals of 0.2m during offline phase. A particle filter-based location estimation [5] is performed to verify the effectiveness of proposed method.

Fig. 2 shows variations of geomagnetic field in the gymnasium. The maximum intensity is 30.5μT and the minimum is 19.95μT. Fig. 3 shows the vertical and horizontal component values of geomagnetic field and the dip angle, respectively. Region A, B, and C are candidate locations, when the user is located in the region A in Fig. 2. This confusability is due to the ambiguity of the magnetic flux density. However, it can be concluded that the user is at the region A, because the vertical and horizontal components and the dip angle in the region B and C are different from the region A, namely measured values during the online scanning phase. Inclination estimation error of ±5° is considered in our location estimation simulation.

IV. RESULTS

Fig. 4 shows probability density of vertical and horizontal component values and dip angle considering inclination estimation error of accelerometer. Our ranges of vertical and horizontal component are 1.07μT and 1.59μT around measured data, respectively. Our ranges of the dip angle is 4.03°. These values correspond to 99% cumulative distribution. Fig. 5 shows location estimation error performance, when the user moves on y = 6.4m path. The solid line shows location estimation error performance of the proposed method. The dotted line shows error performance of localization using only magnetic flux densities. The average search space reduction rate is about 79.8%. The location estimation performance can be improved by reducing the search space 1/5 compare to magnetic map.

Figure 1 Photos from gymnasium of Song-Dam university

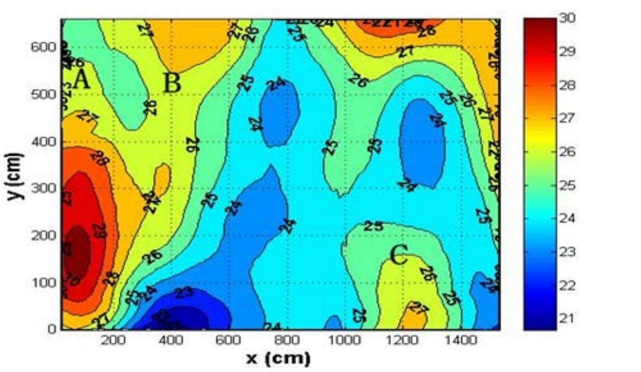
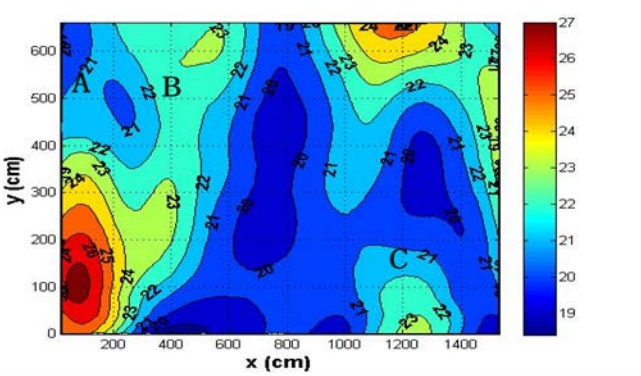
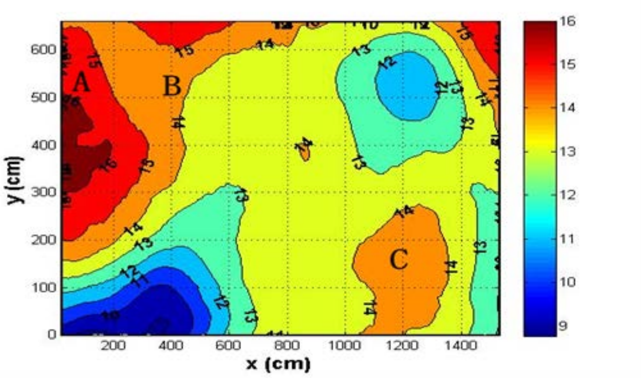


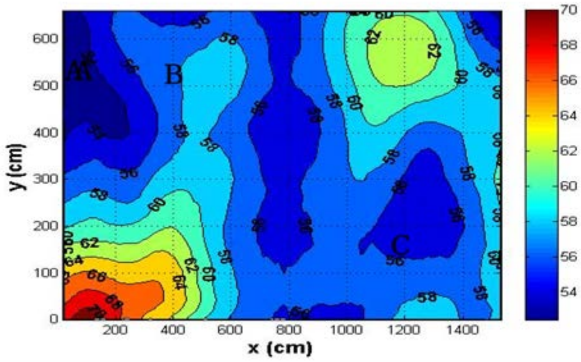
Figure 2 Geomagnetic flux densities of gymnasium



(a)



(b)



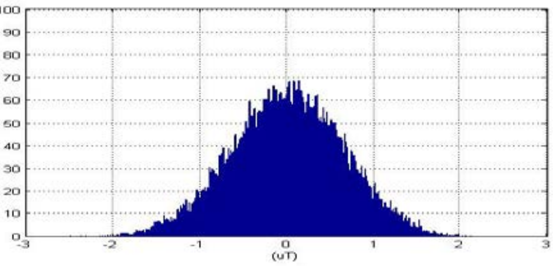
(c)

Figure 3 Geomagnetic components of gymnasium

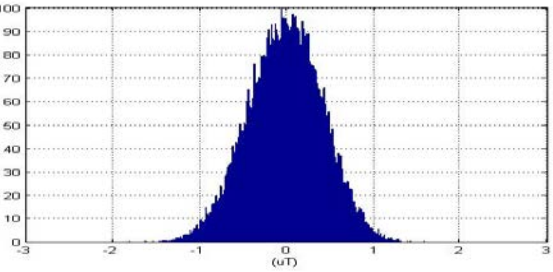
(a) Geomagnetic vertical component of gymnasium

(b) Geomagnetic horizontal component of gymnasium

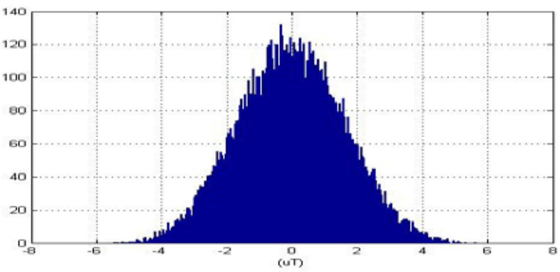
(c) Geomagnetic dip angle of gymnasium



(a)



(b)



(c)

Figure 4 Error distribution of vertical & horizontal components

(a) Error distribution of horizontal component

(b) Error distribution of vertical Component

(c) Error distribution of dip angle

Average location estimation error on six different moving routes is improved from 0.52m to 0.26m by the proposed method. The first time to fix performance, which is defined as the elapsed time for acquiring the first location information under 1.5m error, is also improved from 4.5sec to 1.5sec.

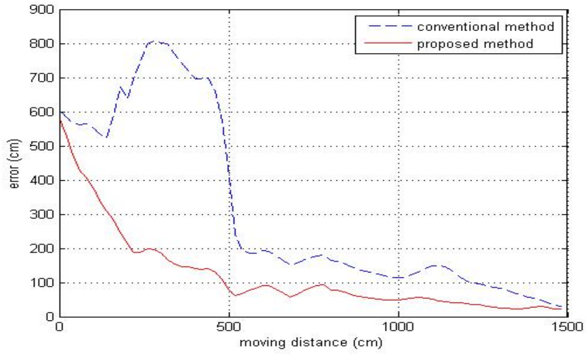


Figure 5 Location estimation error performance

V. CONCLUSION

In this paper, we proposed a novel search space reduction method to enhance the location estimation performance of geomagnetic field-based localization. We enhanced the location estimation error and the first time to fix performances by eliminating the ambiguity of the geomagnetic flux density. We also verified the effectiveness of the proposed method by extensive simulations.

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