A Magnetic Field Based Lightweight Indoor Positioning System for Mobile Devices

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***Abstract*— This paper presents a magnetic field based indoor positioning system, which does not need to deploy any hardware and can be used on the smartphones off-the-shelf. The proposed system can achieve high positioning accuracy with about 1.5 meters and have well navigation user experience.**

Keywords—infrastructure free, indoor positioning, magnetic field, lightweight

I. INTRODUCTION

Indoor positioning is a hot research area in recent years and many technologies are proposed. In general, indoor positioning solutions can be divided into infrastructure based and infrastructure free.

Usually, infrastructure based solutions require some hardware to be pre-deployed to do indoor positioning, e.g., UWB based solution must deploy UWB BS (base station), iBeacon solution must deploy iBeacon station and LED based solution needs to deploy LED lamp. Thus, even infrastructure based solutions may achieve high positioning accuracy (less than 0.5m in UWB solution), the cost of infrastructure based solutions is high. Instead of deploying hardware, infrastructure free solutions do not need any devices are pre-installed and try to utilize the existing data to realize indoor positioning. A typical infrastructure free solution is WiFi fingerprint technology which is widely researched and can usually achieve accuracy with 3~8m.

Considering the cost and universality , infrastructure free solutions may be the better technology for most of application scenarios because 1) the cost to deploy and maintain hardware may be very high; 2) it is difficult to equip special receiver (LED or UWB) in mobile devices which will limit the application scope greatly. As a result, we think the best indoor positioning solution should have the following two features: a) it is infrastructure free, b) it can be applied in the smart phones directly without any additional sensor equipped.

As a result, we propose a lightweight indoor positioning system based on the magnetic field which is infrastructure free. Moreover, most of smartphones off-the-shelf contains magnetometer sensor, which means the proposed solution has the good universality. Besides magnetic field, data from sensors such as accelerometer, gyroscope, barometer are utilized to assistant the position computing to improve the user experience.

II. MAGNETIC FIELD BASED INDOOR POSITIONING

A. Basic Principle

Magnetic field based indoor position technology is a kind of fingerprint essentially. However, different from WiFi fingerprint, magnetic fingerprint is much more difficult for modeling and analyzing.

In theory, the distribution of geomagnetic field on indoor road is different everywhere. But the magnetic field data from smart phone may be the same or have little difference in different locations due to the sensibility of sensor and the affection from other magnetic field source such as electric devices. Thus, it may be impossible to obtain the indoor location with the magnetic field data from a single spot like WiFi fingerprint technology does. As a result, it needs to gather some magnetic field data with smartphone to compute the current position. In practical application, it requires that user holds the smartphone to walk 3~5m to obtain the initial position in our magnetic field indoor position solution.

Besides magnetic positioning & navigation, inertial navigation with data of accelerometer and gyroscope sensors is also utilized to improve the user experience.

B. Implementation

The core positioning algorithm is implemented in the so called Ubirouting Cloud. The main functionalities of Ubirouting Cloud are as follows:

a) Positioning Engine: Computing the current position of the user based on the received data from the client.

b) Map Management: Manage the plan and generate the positioning map.

An application called “Nature Creator” is developed by us supporting both iOS and Android system which is a tool to collect indoor data, generate map and test positioning.

C. Remarks

Before positioning, it is better to calibrate the magnetometer sensor of the smart phone by rotating the phone.

During the initial positioning and navigation, the user should try to put the head of smart phone forward.

Due to the varied quality of magnetometer sensors, the positioning performance may degrade in some low-end smartphones. By our testing, iPhone5 or above, google Nexus and Samsung Galaxy series have good performance with the proposed magnetic field based indoor positioning system.

III. APPROACH OF POSITIONING

The approach to achieve indoor positioning with the proposed solution does not deploy any hardware or device in the test area. The only device needed is a smart phone installed with an APP (Nature Creator). The whole positioning approach can be done by a smartphone such as iPhone6s or Samsung Note5 and the procedure consists of three steps :

A. Planning

Upload the map of the test area and set the scale of the map via the client APP (Nature Creator) or the website of Ubirouting.

B. Data Collecting and Uploading (Mapping)

A smartphone is used to do mapping with Nature Creator. The data is easy to collect by planning the route and walking along the planned route in the test area. The recommended collecting phones are iPhone6/iPhone6S/Samsung Note5.

Fig.1 shows the snapshot of Nature creator in data collecting. The red line in the figure is the planned routes whose data has been collected.

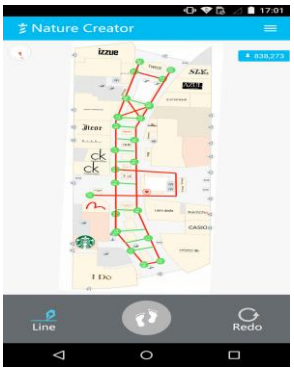

Fig.1 Mapping UI

After mapping, the collected data will be uploaded to the Ubirouting cloud and pre-processed by the positioning engine, which takes a few seconds

C. Positioning

When data uploading finished, the positioning can be tested immediately. As mentioned before, the user should hold the smart phone to walk about 3~5 meters to get the initial position and the position will be fixed and become more accurate if keeping walking. The current position of users will be shown on the map real-time and moves smoothly with walking.

IV. PERFORMANCE EVALUATION

Tens of test areas are selected to evaluate the proposed positioning system and only two typical test results are shown in this part. An underground parking lot and a shopping mall are selected as the typical test areas. The parking lot is a 180m*50m area and the shopping mall is a 150m* 40m area. Two metrics are selected to evaluate the positioning performance. The first metric is the distance for user walking to get the correct location (Initial Distance) and the second metric is positioning accuracy.

Fig.2 The plan of the testing areas

A. Initial Distance

100 tests are done to observe the variety of Initial Distance. The maximum Initial Distance is 11.6m and the minimum value is 2.3m. The distribution of Initial Distance is shown in table I.

TABLE I. DISTRIBUTION OF INITIAL DISTANCE

Test Area	Initial Distance Distribution			
	[2m, 3m)	*[3m, 5m)*	*[5m, 8m)*	*[8m, 12m)*
Parking lot	12%	71%	11%	6%
Shopping mall	9%	69%	13%	9%

B. Positioning Accuracy

100 checkpoints are defined to analyze the positioning accuracy of the proposed system. The maximum positioning accuracy is 3.4m and the minimum value is 0.2m. The distribution of Initial Distance is shown in table II.

TABLE II. DISTRIBUTION OF POSITIONING ACCURACY

Test Area	Initial Distance Distribution			
	[0, 0.5m)	*[0.5m, 1m)*	*[1m, 2m)*	*[2m, 3.5m)*
Parking lot	19%	35%	32%	14%
Shopping mall	13%	28%	39%	20%

V. CONCLUSION

This document presents the magnetic field based indoor position system of Ubirouting. The proposed positioning solution is infrastructure and has high positioning accuracy. The system has been applied in the practical applications such as seeking car in parking lots or navigation in shopping malls.