A Practical Indoor Position Estimation by Using a Laptop Computer Equipped With Sensors

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Abstract

The importance of location based service has been recently addressed in many literatures and thus various positioning schemes for outdoors as well as indoors have been introduced. However, there has been a practical issue of implementation over various positioning schemes, although accurate positioning performance can be achieved. In this paper, a practical indoor positioning scheme that effectively locates a pedestrian holding a laptop computer equipped with two commonly used sensors is proposed[1], and the performance of proposed scheme is evaluated with experiments for a simple path as well as a real route in indoor of general building at university. According to the experiment results, the positioning error was less than 1m in simple path, while the average error was 1.61m for a real route.

Keywords: *Indoor positioning, acceleration sensor, geomagnetic sensor, LBS*

1. Introduction

Recently, the importance of location based service (LBS) that provides various contents and services online or offline by using positioning technology is on the rise. Although studies on 'Global Positioning System (GPS)' are active as a representative example, its limitations also has been presented such as its high price, power consumption, and furthermore difficulties in indoor location positioning [1, 2]. Therefore, the GPS technology is unlikely to be recommended for such areas of industry where there are needs for low prices, long-lasting battery or indoor location positioning. Meanwhile, it is known that wireless positioning technologies such as WLAN, UWB, Zigbee, IR, and ultrasonic waves also have their merits like their wider adaptability including indoor positioning and the advantage of using the existing wireless networks [3-7]. However, these technologies are largely affected by surrounding environments and their accuracy is decreased as the distance between users and the access point (AP) is increased [8, 9]. Since the existing indoor positioning methods have errors ranging from 2~3m to several Km, it can be said that they have lack of reliability in indoor positioning [10, 11]. Although some schemes provided accurate positioning performance, there were practical issues because of complexity of implementation.

In this paper, therefore, a practical indoor positioning scheme that effectively locates a pedestrian holding a laptop computer equipped with two commonly used sensors is

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proposed and experimentally evaluated for a simple path as well as a real route. In the proposed scheme, the traveled distance of the user is estimated with the acceleration sensor, while the direction is estimated with the geomagnetic sensor. The traveled distance is calculated by firstly applying the threshold that distinguishes halting and walking to the data measured by acceleration sensor and then by multiplying the estimated number of steps by the average length of a stride. The direction is obtained by applying the trigonometric function to the data measured by the two-axis geomagnetic sensor. For performance evaluation, the proposed scheme has been tested in indoor environments of general building at university. A three-axis acceleration sensor that are named myARS-USB model is used for experiments and the data measured by the sensor is saved into a computer in universal asynchronous receiver transmitter (UART) by the ComPortMaster program. Also, a two-axis geomagnetic sensor, HMC6352, is used for the direction estimation and the collected data is processed by micro-processor Atmega128. In every experiment, the experimenter moved at the speed of 1.35m/s along the designated route.

The rest of the paper is organized as follows. In Section 2, the characteristics of data gained by acceleration sensor and the applied algorithm are discussed. Also, the methods of realization of direction algorithm by use of geomagnetic sensor and the proposed scheme are provided. In Section 3, the performances of the proposed system is evaluated and reviewed. Finally, our concluded remarks including the extended suggestions and future works are summarized in Section 4.

2. System Description

In order to locate the experimenter, the information on both the distance traveled and the direction taken is required. In this section, the algorithm for estimation of traveled distance along a straight route is introduced, and then the realization of the algorithm that detects the direction taken by the step unit and the proposed scheme are discussed.

2.1. Characteristic of Z-axis Data

For calculating the traveled distance correctly, it is required to distinguish whether the experimenter is halting or walking. This paper suggests that characteristics of the data measured by the acceleration sensor be used for differentiation of halting and walking. When it is measured by the acceleration sensor, the data shows the same pattern in all three axes in every step. However, the data of z-axis shows the greater rate of change than those of other two axes, x-axis and y-axis. The reason why is that the most of impulse works toward gravity during movements [12]. Therefore, the z-axis data has more advantage than the data on the X or Y axis in distinguishing the collected data during walking from other types of data, which is collected when the experimenter is not moving forward (such as walking in a place) or when it is affected by outer factors such as noise. In the proposed scheme, therefore, the data for walking status is extracted by using z-axis.

The Figure 1 shows the characteristics of the collected data on z-axis when the experimenter stops, walks in a place, and walks slowly. As shown in the figure, when the experimenter is standing still, the changes of collected data are relatively minor.

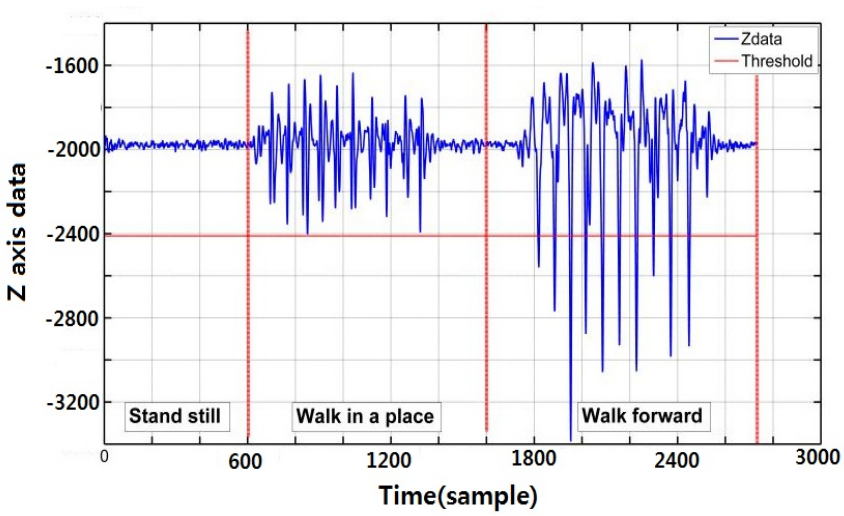

Figure 1. Characteristics of Z-Axis Data

There are arise changes in data values when he walks in a place, depending on the number of steps taken, but the changes are less conspicuous compared to the collected data while walking forward. Since the experimenter is not moving forward in both cases, the data, which is collected while he is walking, can be distinguished with a proper threshold value [13]. As shown in the figure, however, if the threshold is set on the low-bound point of the data that is collected while the experimenter is walking in a place, there is a possibility to recognize it as a halt when the changes in the data is momentarily minimized by environmental factors even if the experimenter is walking. In order to ensure the reliability of the data, therefore, the threshold is needed to be set carefully. Based on the data, which is collected while walking forward slowly and walking in a place, we have decided statistically on the point -2411 as the threshold, which distinguishes data for walking from walking in a place with the accuracy of 90.9%.

2.2. Algorithm for Counting Steps

The algorithm is required in order to count the number of steps recognized as walking by the threshold. As each step has a valley, the number of the valleys can be assumed to be equal to the number of steps. The Figure 2 shows an enlarged picture of the valley of the data for a step that is recognized as walking by the threshold. As shown in the figure, the number of valleys can be counted when 3 samples are compared to check if they make a concave form, and the comparison is made for all the data that the threshold is applied.

The Figure 3 shows the flow chart that calculates the number of steps in walking. In the chart, ACC_Z indicates the data on Z axis and N_S is the number of steps. As described in the chart, the data on Z axis is firstly arranged in an array and the threshold that is set in the paragraph 2.1 is applied to the data in order to extract the data for walking. Then, the number of steps is calculated by making comparisons with 3 samples to check if they make a concave form, and the comparison is made for every data that is recognized

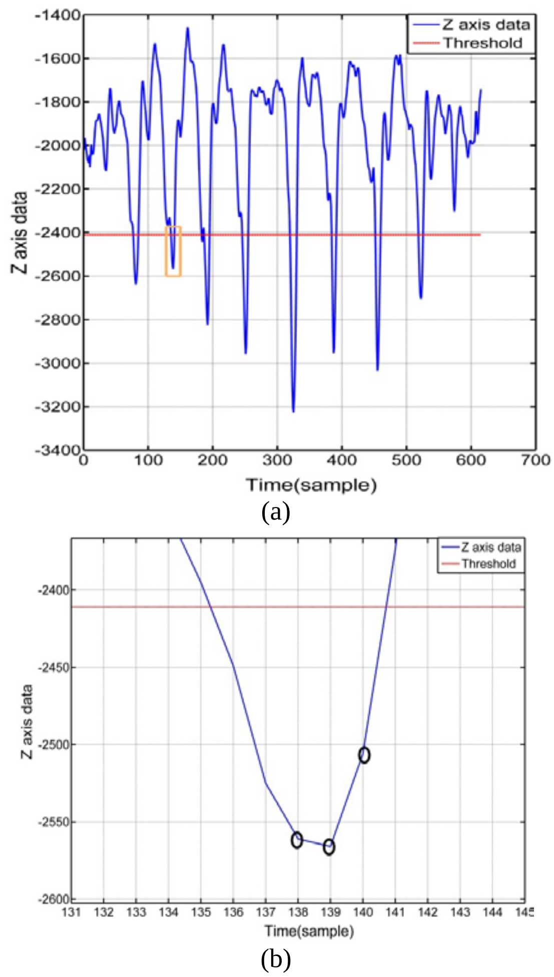

Figure 2. Counting the Walking Steps

as for walking. The distance of a straight route traveled by the walk can be estimated by multiplying the number of steps by the average length of a stride.

However, there are cases that the valleys appear more than twice in a row because of rapid change in acceleration resulted in unexpected movements or noise from outer environments. As these cases add to the number of valleys, the traveled distance of the route is estimated to be longer than the actual distance. Therefore, the repeated valleys need to be excluded to calculate the number of steps more accurately in counting process. As every step has an interval with the previous one when the pedestrian maintains a constant speed, we can eliminate the valleys that appear during these intervals in order to avoid duplicate counting the steps. The average interval between two steps, which is 60 samples, is obtained through experiment that takes 100 steps at a

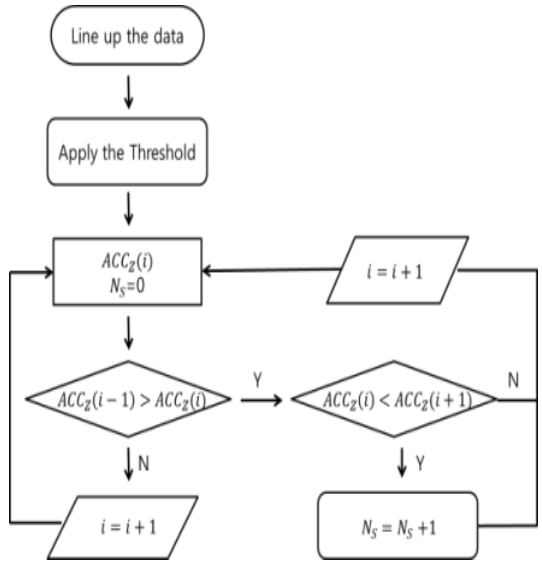

Figure 3. Flow Chart for Counting Number of Steps

constant speed and calculates the average interval between the valleys. Therefore, the repeated valleys appearing within the period of 60 samples are recognized as duplicate and excluded in the counting process.

2.3. Direction Estimation

In order to locate a pedestrian, we also need to detect the direction to where he is moving forward. In general, the direction of a step is decided when the pedestrian's foot reaches the ground. Therefore, the direction of movement can be anticipated if the information is obtained about the angle of his foot at the moment of touching the ground with the reference of the other foot. In this paper, a geomagnetic sensor, which detects the direction based on the Earth's magnetic field, is used in order to obtain the direction that the pedestrian is taking. Although the sensor also enables its users to obtain resolution of 0.1 degree via 0~3600 samples, we have converted it to 1 degree resolution for the experiment to minimize the computational complexity and the influence of the noise both within the sensor and from the environments.

The algorithm of using the geomagnetic sensor to obtain the direction of movement is as follows. First, to get rid of the noise generated by geomagnetic sensor, the initial direction, θ^{init}, is calculated from N samples of data which can be obtained when the measurement starts as shown in equation (1). When the k-th walking step is detected by acceleration sensor, its corresponding angle data is obtained through the geomagnetic sensor. The initial direction and the angle, θ_k, obtained by geomagnetic sensor for k-th walking step are used to get the variation of angle, which is obtained by subtracting each other as shown in equation (2). Finally, through both the equations (3) and (4), we can gain the direction and distance from the previous place. As a result, the above process can estimate the position of user at the k-th walking step. The equations are as follows:

$$\theta^{init} = \frac{\theta_1 + \theta_2 + \cdots + \theta_{N-1} + \theta_N}{N}, \quad (1)$$

$$\theta_k^{var} = |\theta^{init} - \theta_k|, \tag{2}$$

$$X_{k+1} = X_k + D_S \times \cos(90^\circ - \theta_k^{var}), \tag{3}$$

$$Y_{k+1} = Y_k + D_S \times \sin(\theta_k^{var}), \tag{4}$$

where X_K, Y_K is the latest position. X_{K+1}, Y_{K+1} is the new position. D_S is the length of a step. The Figure 4 shows the simplified flow chart of positioning process.

3. Experimental Results

In this section, the performance of the proposed scheme is evaluated for a simple path as well as a real route in an indoor place. In the experiments, the hallway in front of laboratories with various electronic equipments at university building is considered as an indoor place and the pedestrian walks along the track as usual. Before the experiment, we applied 'User Calibration', which is used to reduce the noise from magnetic field generated by each testing site [14], to the proposed scheme. The proposed scheme is composed of two sensor parts and a microprocessor, which is named Atmega128, for processing the data from sensors. In the experiment, an experimenter picks the equipment up and walking along the installed track keeping a level of the laptop off. The experimental equipment is shown in the Figure 5.

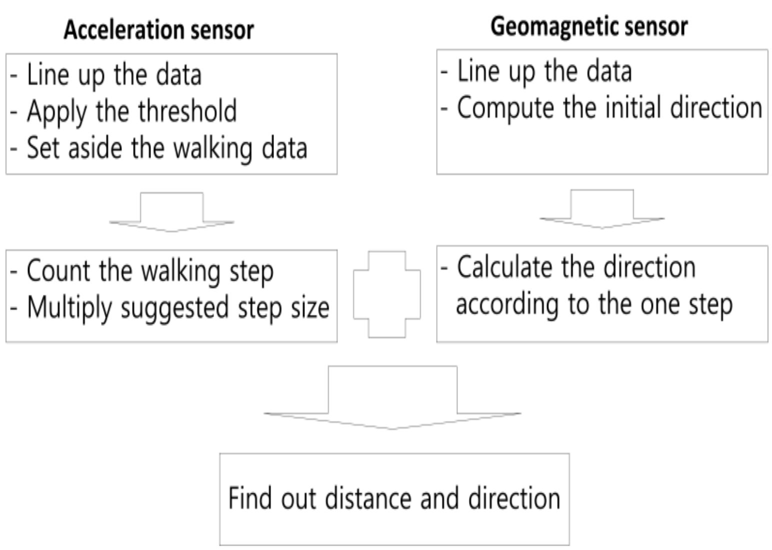

Figure 4. Flow Chart of Positioning Process

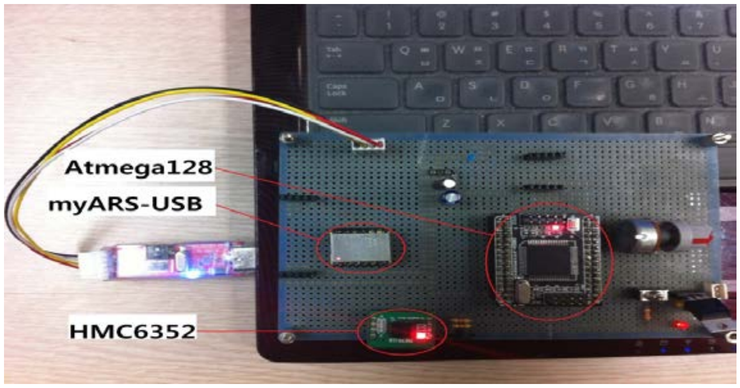

Figure 5. Experimental Equipment

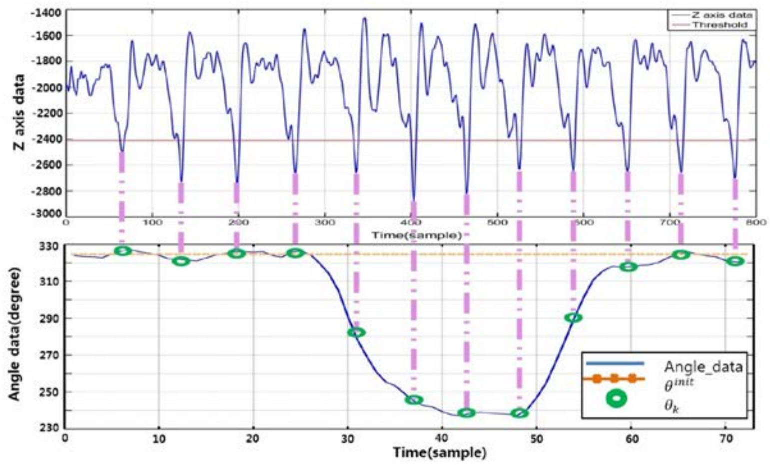

Figure 6. Example of Position Estimation

Figure 6 shows an example of position estimation, which are based on the actual measured acceleration data and geomagnetic data. As shown in the figure, the total of 12 walking steps is occurred in this example and the angles, which are corresponding to the steps, are synchronized at the same time. Through the equation (1), we can calculate that the initial direction is 325 degree with the 10 angle data, which are measured in the first time. Then we can obtain the estimated path through the previously described processes. The results are shown in the Figure 7 and Table 1. As shown in the figure and the table, the average error was 0.425m and the estimated path generally followed the real path. According to the experimental results, however, the error can be occurred more at the corner than in the straight route. In other words, the angle estimation errors can influence more on the position estimation errors.

On the basis of above experimental result, an arbitrary route is selected and the proposed scheme is being carried to check the positioning performance for the real route. The environments for the experiment are the same and the performance is evaluated at the selected 8 points. The Figure 8 shows the real route, the calculated route, and the positioning error at the 8 points. As shown in the figure, we can confirm that the estimated path generally follows the real route well. The average error at the selected 8 points was about 1.61m.

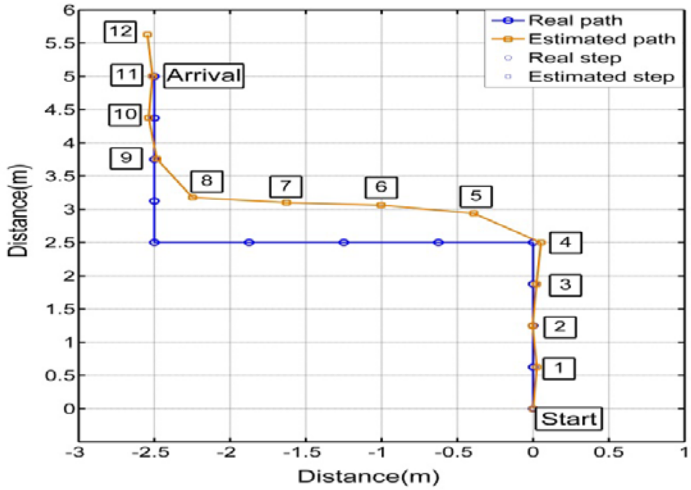

Figure 7. Experimental Results of proposed Scheme for a Simple Path Estimation

Table 1. Positioning Error of each Point

Step Point	1	2	3	4	5	6
Error(m)	0.024	0.003	0.022	0.052	0.496	0.613
Step Point	7	8	9	10	11	12
Error(m)	0.649	0.722	0.631	0.630	0.628	0.629
Mean error(m)		0.425		Standard deviation(m)		0.299

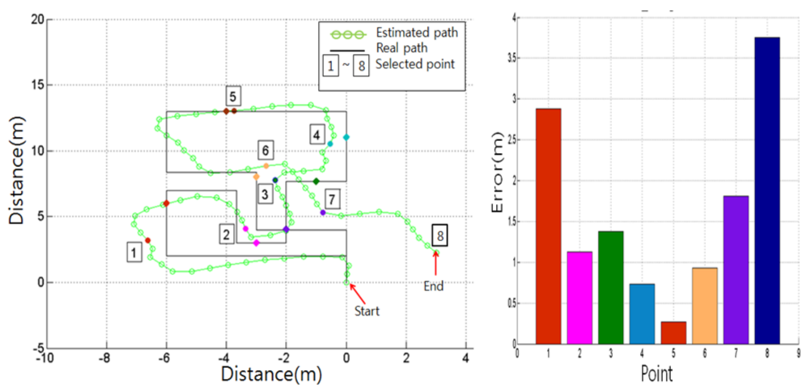

Figure 8. Experimental Results for a Complicated Path

4. Conclusions

In this paper, a practical indoor positioning scheme that effectively locates a pedestrian holding a laptop computer equipped with two commonly used sensors is proposed, and the performance of proposed scheme is evaluated with experiments for a simple path as well as a real route in indoor of general building at university. According to the experiment results, the positioning error was less than 1m in simple path, while the average error was 1.61m for a real route. The proposed simple positioning scheme has a lot of advantages, such as no additional charge for installation of infra, application of a smart-phone.

Even though the proposed scheme provided adequate positioning performance at the simple and short path, there would be some problems, such as cumulative errors and errors caused from changing the direction. As a future work, we have a plan to set the long path that can happen in actual life in order to verify the performance of the proposed scheme. Moreover, the performance of the proposed scheme will be evaluated in both an indoor place and an outdoor place to investigate the performance difference between indoor and outdoor places

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