Improved indoor position estimation algorithm based on geo-magnetism intensity

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***Abstract*— This paper proposes the improved indoor position estimation algorithm based on geo-magnetism intensity which compensate the flaw of particle filter. Indoor position estimation based on geo-magnetism can find most suitable algorithm by applying existing indoor position estimation. Among many ways, using particle filter is most used method. Existing particle filter which acquires highly expensive arithmetic operation along with high convergence time make this filter not suitable for low specification terminal. In order to solve this problem, the research to supplement the existing particle filter was done. Proposed indoor position estimation which used modified particle filter generates few particles to most similar intensity location estimation which is measured by magnetism intensity. Pedestrian's location can be estimated by created filtered arithmetic operation which created few particles. This process requires fewer arithmetic operations than the existing method therefore creates more precise location estimation while acquires shorter travel range.**

Keywords— earth magnetic field; particle filter; positioning; indoor;

I. INTRODUCTION

Currently, most location-based services (LBS), which are for locating user positions, make use of the Global Positioning System (GPS) satellite signals for outdoor settings and cellphone network, wireless local area network (WLAN), and Access Point (AP) for indoor settings. The positioning accuracy of GPS is reliable enough to be used by the public, but its indoor accuracy is relatively subpar due to subdued signals. Due to this technical issue, much research is necessary to make indoor LBS more usable. Especially, since cellphones are used more widely than corded phones nowadays, the inaccuracy of indoor LBS need to be solved for critical situations like emergency calling. In the United States, this issue is being tackled by assessing the performances of various positioning systems that offer indoor E911 cellphone services. On October 2012, a workshop was held among mobile network businesses and navigation solution companies for improving positioning accuracy. As such, many companies attempt to improve indoor accuracy through developing indoor positioning technologies using UWB, WLAN, and Cell [1-3]. However, these methods have several disadvantages such as requiring an infrastructure which can be very costly. For such reasons, researchers are looking into positioning systems that do not need an infrastructure and make use of pre-existing systems.

Positioning systems based on the geomagnetic field (which is a resource unique to the earth) can function without requiring an infrastructure. Therefore, researchers are looking into this resource for developing a new positioning system. Changes in the field intensity are not enough for the purposes of indoor LBS [4]. However, the researchers are focusing on the advantage of not needing an infrastructure. Recently, research is on developing a positioning system using the terrestrial magnetism sensor installed in smartphones. This system closes the error gaps by using particle filter in combination with the preinstalled IMU sensor of smartphones [5, 6]. The often used method is object-positioning which makes much use of particle filters. Since particle filters are based on inferences from sampling, the calculation cost can be high for multiple particles. In addition, if the particle collection time is long, it can take longer time to estimate the accurate locations of users.

To solve the problems above, we have decrease the calculation cost of particle filter by using few particles with similar intensities of terrestrial magnetism rather than multiple particles. Furthermore, we decreased the particle collection time so that it takes less time to estimate user locations.

The contents of this paper are as follows. The second chapter introduces the past research on positioning systems that are based on the magnetic field, and the third chapter offers an algorithm. The fourth chapter is about a testing environment in which the suggested system can be validated as well as the testing results, Finally, the fifth chapter consists finishes the paper by offering a conclusion and future works.

II. RELATED WORK

Researchers have recently started looking into positioning systems based on the magnetic field because they offer an advantage of not requiring a separate infrastructure. The

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geomagnetic field can be modified by natural changes as well as artificial objects such as steel, ferroconcrete, and home appliances. Similar to WLAN, the magnetic field locates using the fingerprint method which takes account of environmental factors by establishing Database (DB) through measuring terrestrial magnetic intensities of each location.

In [7], Suksakulachai et al. installed a digital compass to a moving robot for determining orientation. They were the first to detect orientation changes by saving data about terrestrial magnetism. J. Chung, et al. [8] researched into a positioning method that does not rely on odometer or other models. In this study, data came from four terrestrial magnetic sensors that were installed to a human body in a four-way badge formation (radius of 5cm). Based on extensive data from these four-way high-performance sensors, positions were located with the K-Nearest Neighbor (KNN) method. However, since smartphones only have one sensor for collecting data from which locations are calculated and displayed, high performance cannot be expected as in [8].

Consequently, K. Park et al. [5] conducted research in a corridor using only the terrestrial magnetic sensor and accelerometer that are preinstalled in smartphones (without relying on additional sensors or establishing databases). In this method, the positioning system detected corners and locations by gathering data from the two sensors that are used for calculating speed and direction. When detecting a corner, relevant location is corrected by comparing with information from the magnetic sensor and previous magnetic sensor data in each corner. Although, like previous studies, S.E. Kim [6] used sensors that are default to smartphones, it also used particle filter based on pre-established terrestrial magnetic data for determining locations. The particle filter improved the accuracy of location positioning. However, related calculation cost and energy consumption are excessive for smartphones, causing overhead issues. In addition, due to the characteristics of the particle filter, users need to move a certain distance before determining their locations.

In this study, we suggest an algorithm that can decrease processing loads of the particle filter (for usage by low-spec devices) and can detect user locations more quickly.

III. PROPOSED POSIONING ALGORITHM

One characteristic of terrestrial magnetism is that a wider indoor search radius leads to a higher number of locations with similar intensities of components of terrestrial magnetism – decreasing errors in position locating. This disadvantageous characteristic is currently tackled by researchers using chain position locating based on the particle filter from smartphones' IMU sensor [6]. Particle filter is the most widely used algorithm nowadays for object tracking. Unlike the Karman filter which interprets a posteriori distribution, the particle filter is expressed through multiple particles that can represent state variables and also the weight value of each particle. However, the particle filter can be slow in processing speed because its performance is proportional to the number of particles that are used for tracking. Since the operational speed of particle has a proportional relationship to the number of particles, it is suggested that, for improving speed, particle number needs to decrease. However, decreasing the particle number accompanies less accuracy. Therefore, to maintain its accuracy, the particle filter should focus on particles with high weight values.

Indoor positioning systems based on terrestrial magnetism tend to show more errors when magnetic intensity is evenly distributed [9]. To alleviate indoor positioning errors due to limited resource availability, we suggest a modified particle filter which extracts location candidates that have similar intensity to measured terrestrial magnetism and uses the Euclidean distance for replacing locations with the least distance differences with particles regarding the intensity around the candidates. This algorithm repeats four steps of inference process as shown in the picture below (Fig. 1.). The measurement step measures magnetic intensity of the current location using the magnetometer. Then, these data are compared to magnetic intensities saved in DB. Next, particles are generated in locations (with a number *k*) with the most similar intensities. In the prediction step, the generated *k* number of particles are calculated for weight values via prior probability $p(x_t \mid x_{(t-1)})$ of previously generated particles with a number *k*. During the weight update step, Gaussian density function is used for updating weight values. Finally, in the re-sampling step, with a probability proportional to the weight value ω_t , x_t particles that are to be included in the new particle group X_t are selected. Among the particles x_t that are selected, particle x_t with the highest weight value is considered to signify user location.

After studying magnetic intensity signals based on extensive pre-existing data of magnetic intensities the modified particle filter can estimate user locations via magnetic intensity value z_t in any arbitrary location. The probability of current user location makes use of the weight value ω_t that is calculate during the weight update step. ω_t can be calculated using the Gaussian density function as below.

$$\omega_t = p(z_t \mid x_t) = \frac{1}{\sigma_r} \exp\left(1 \frac{(z_t - \|f(x_t)\|)^2}{2\sigma_r^2}\right) \quad (1)$$

In this equation, $f(x_t)$ is a function for finding magnetic intensity of a location x_t in database, while σ r is a pre-established standard deviation for magnetic intensity that is

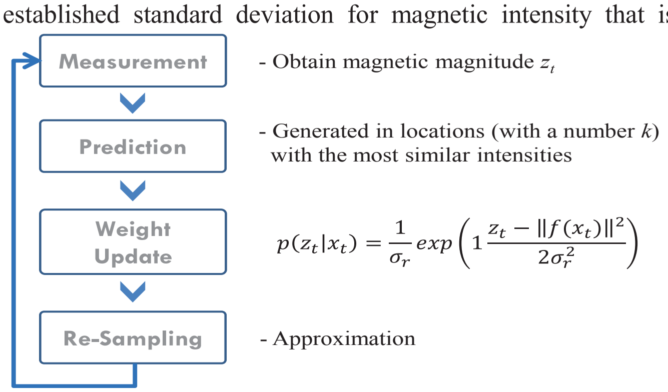

Fig. 1. Proposed algorithm flow chart

based on DB.

The traditional method is to generate lots of particles in arbitrary locations and then collect particles of candidate locations where users may reside. A problem with this method is the large loads of calculation required for labelling the weight value to each particle. To solve this problem, particles are generated only in few candidate locations using Euclidean distance. This way, not as many particles are needed as the previous particle filter. Since few particles are generated for weight value calculation, there are fewer number of particles that consume processing power than the pre-existing method – causing less overhead issues. In addition, locations can be estimated more quickly due to less time required for collecting particle distribution.

In the next chapter, the performance of the new algorithm is assessed in comparison with the pre-existing algorithm.

IV. EXPERIMENTS AND RESULTS

The geomagnetic field is known to distort by construction materials like ferroconcrete and H-beam [10]. However, most positioning systems based on the geomagnetic field locate positions by creating DB. This is because such systems make use of information about the surrounding environment which is already registered to DB. As a result, locations can be provided regarded of environmental modification and noise.

Instead of the resolution of the sensor instrument used in [6] is good, we conducted experiments using a smart phone that is actually used. The experimental system is implemented based on the Galaxy Note smartphones from Samsung Electronics. It was constructed DB in developing an application for measuring the intensity of geomagnetism with built-in magnetometer, an acceleration sensor, gyro sensor or the like is equipped. Using this device, data were collected with 45cm intervals and 10 seconds spent in each location. The data of each location was calculated and saved based on the average intensity of measured data. By applying interpolation for making more accurate map, two-dimensional vector DB was created such as $\{x, y, m_x, m_y, m_z\}$. Formatted as rectangular coordinates, x and y signified corridor locations where magnetic intensity values were measured.

The experiment took place on the third floor of the electronic building of Yeungnam University (Fig. 2). The corridor was squared-shaped, 67m wide, and 12m tall. The surroundings included spaces such as lab, office, and library.

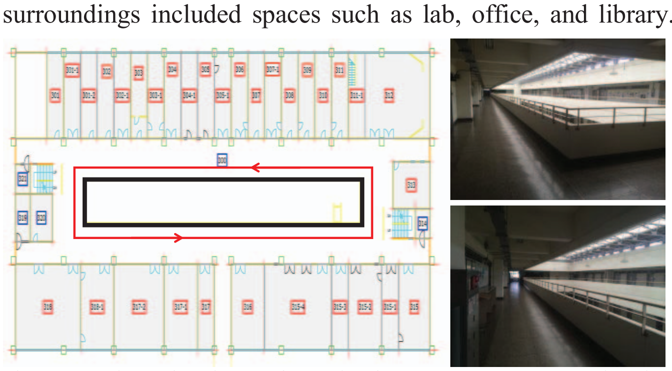

Fig. 2. Experiment location at Electronics department, Yeungnam University (left), front view of the location of measurement (right)

Although having various sorts of space around, the corridor had few passers and little environmental change. We used the Galaxy note to an apparatus for the position estimation of the user. It was estimated position by developing an application that measures the magnetic intensity and step detection, executing each algorithm. The tested algorithms were NN algorithm, particle filter, and modified particle filter. The range of initial location was limited to 5m. Since testing each algorithm requires different moving distances, the estimated final locations was used for determining the initial locations. The default number of particles of the pre-existing particle filter is 100, while that of the modified particle filter is 10. NN algorithm, pre-existing particle filter, and modified particle filter measured locations of people who stood still, walked 10 steps, and walked 15 steps, respectively. We conducted simulations on a total of 14 locations with 1m intervals.

The TABLE 1 below summarizes the simulation results. The error values signify the differences between maximum and average error values. According to this table, the modified particle filter (although taking 5 more steps) showed 35% less average location positioning error. In addition, despite walking 5 less steps than the pre-existing particle filter, the average location positioning error decreased by 15%.

TABLE I. LOCALIZATION PERFORMANCE

Algorithms	Error mean (cm)	Error max (cm)	Deviation (cm)
NN	147.86	290	142.14
Particle filter	113.07	286	172.93
Modified particle filter	95.36	290	194.64

Despite a reduced amount of calculation by reducing the number of particles, the proposed algorithm to the experimental results, it can be seen that the performance showed good performance. This can be seen by generating particles where it appears in the position of the pedestrian, faster than particles existing filter, to estimate the position of the user more accurately.

V. CONCLUSION

In this paper, we propose an algorithm with the calculation amount is lower than the traditional particle filter in the positioning of the geomagnetic-based.

The proposed algorithm creates a particle in a position similar to the strength of the geomagnetism are determined using the Euclidean distance. It is now possible to detect the position of the pedestrian immediately as a result, even to generate a small amount of particles. Using a smart phone users are actually used, and compared with the particle filter NN algorithm is an algorithm of existing and proposed algorithm. As a result, it is possible to reduce the amount of calculation than the traditional particle filter, the performance of the 35% best showed improvement.

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