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Characteristics of Indoor Geomagnetism and Geomagnetic based Indoor Localization

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***Abstract*— One of approaches to estimate the position of targets inside of buildings where the GPS signal is insufficient to be used is to use geomagnetic value that is sensed by magnetometer. To estimate the target's position using geomagnetic value, the algorithm should measure the magnetic field on its own position using a magnetometer embedded in smartphones and compare the sensor measurement with the magnetic map. The estimated position is calculated by a stochastic system based on particle filter algorithm. For this approach, geomagnetic map in the buildings should be generated in advance, but the distribution of the geomagnetic value depends on the elements of the buildings, especially steel elements. This paper proposes how structure of the buildings effect to the disturbance of geomagnetic value that can be used for the estimation approach. How to build the maps is introduced by several papers, but the researchers try to find better and faster way to do it. This paper focuses on maps that are built from various types of buildings. So, we tried to obtain the map data from as many places in different buildings as possible for the research. Also, we figured out that measurement height is one of the critical effects to the sensed geomagnetic field, so the maps are generated from various heights. Then this paper tries to analyze the relationship between the building structures and distribution of the geomagnetic field. At last, the maps are compared with each other by simulation test.**

Keywords-indoor positioning; localization; geomagnetic; magnetic fingerprinting; particle filter;

I. Introduction

There have been considerable research interests for indoor localization technologies. Most of outdoor positioning system using the Global Positioning System (GPS) signal which provides reliable positioning information. However, the GPS is not useful for indoor positioning system because satellite signals are attenuated thorough building structures and degraded due to multipath propagation [1]. Therefore, alternative methods are Bluetooth beacon or wireless access point based approaches have been proposed [2], [3]. Although the approaches achieve high accuracy solution, they need the deployment of expensive infrastructures. So another method is magnetic field-base positioning system. This approach is used unique features of the indoor magnetic field distortion [4].

In this paper, Monte Carlo Localization (MCL) utilizing a particle filter method [5], [6] was used to estimate the position of the user, knowing the observations of the magnetic field and the approximate dynamics of the user in general.

This paper is organized as follows. In section II, we reviews related work. Section III describes the experimental setup. Section IV presents Geomagnetism by building and analysis the relationship between the building structures and distribution of the geomagnetic field in section V. Section VI provides experimental results from simulation. Finally, a conclusion and Further Work is given in Section VII

II. Related Work

WLAN (802.11)-based positioning has been the most popular system. This system includes two main methods for localization: One is using triangulation by measuring signal strength, or times of arrival from known access points (APs), And other one is a fingerprint method to measure relative signal strength from nearby APs when the positions of the APs are unknown [7]. This method relies on a map of fingerprints (received signal strengths (RSSI) distribution) of corresponding locations in order to infer locations. That accuracy depends on WLAN infrastructure complexity (more APs gives more unique RSSI fingerprints) and environment stability (RSSI values are sensitive to the movements of people or objects).

Instead of using the RSSI distribution, the magnetic field distortion can be used to create a reference map for localization in indoor environment. Haverinen [8] proposed a global self-localization method i.e., Robot ran through a corridor and collected magnetic field distortion data to create a map of the hallway. They used Monte Carlo Localization (MCL) (a particle filter) to determine its location from any starting position.

In our work, we tried to obtain the map data from as four places in different buildings as possible for the research and the maps compared with each other by simulation test

III. Experimental Setup

A. *Measurement system*

The earth generates a three dimensional magnetic field. This field can be sensed by orthogonal arrangement of magnetometers. So we used 3 axis (x, y, z) magnetometer named as Micro mag3 invented by PNI sensor corporation. The resolution of Micro mag3 magnetometer is 0.015uT. Magnetometer can be obtain by (1)

$$\cdot \text{Total Magnetic field} \quad M = \sqrt{x^2 + y^2 + z^2} \quad (1)$$

We use Total Magnetic field M as observation because M is a rotation invariant scalar quantity.

B. *Building Structures*

For this research, the buildings are classified as two groups by its structure. One is named H-beams structures, and the other one is reinforced concrete structures. For this paper, the experiments were performed in four different places. Table I. shows the places of experiments.

TABLE I. DATA COLLECTION

Structures (pillar, beam)	H-beam structures	Reinforced concrete structures		
Detail characteristics	Brick wall	Corridor structures	Open space structures	
			Around the pillars	Hall type
External View				
Building name	• LED	• Dorm	• RIC	• Contemplation

IV. GEOMAGNETISM BY BULIDING

In the experiments the magnetic field value had been measured at the points of 0.2meter interval and the size of each experiment space is LED 4×2 m^2, Dorm 7.8×1 m^2, RIC 5×4 m^2, Contemplation 3×3 m^2, respectively. Fig. 1 shows the pattern of the magnetic field in each space. Even if the geomagnetic is measured in the same building, the pattern of data changes as the measuring height varies.

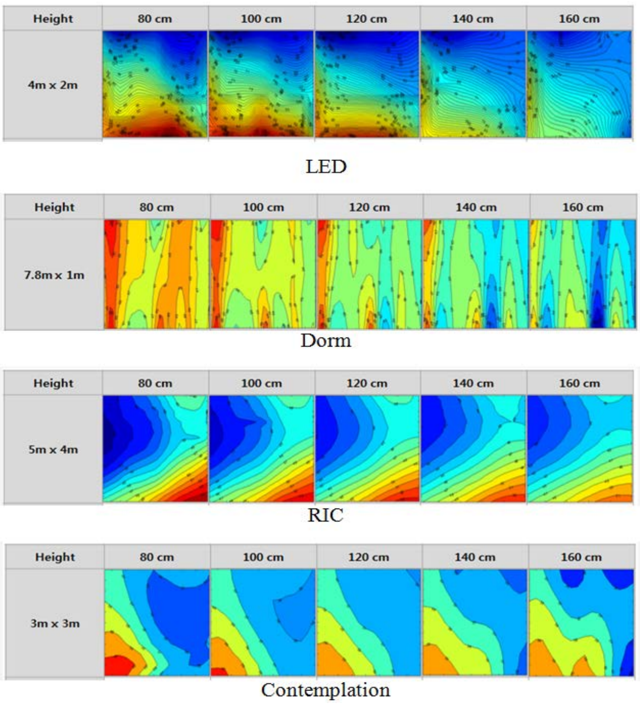

Figure 1. Geomagnetism pattern

V. RELATIONSHIP BETWEEN STRUCTURES AND GEOMAGNETIC

Fig. 2 shows minimum, mean, and maximum of measured magnetic value depending on the measure height and X-axis and Y-axis represent measure height and magnetic value, respectively. In the LED building which is H-beam structure, the widest range of magnetic value exists at the 0.8 meter measure height (min: 44 ~ max: 120uT) and the difference between max value and minimum value is bigger as measure height is higher (76uT→42uT). In case of dorm type structure, mean value of magnetic data varies in about 3uT depending on the measure height. For RIC, mean barely changes, but difference between max and minimum is about 5uT. In case of contemplation area, both mean and the difference are negligible.

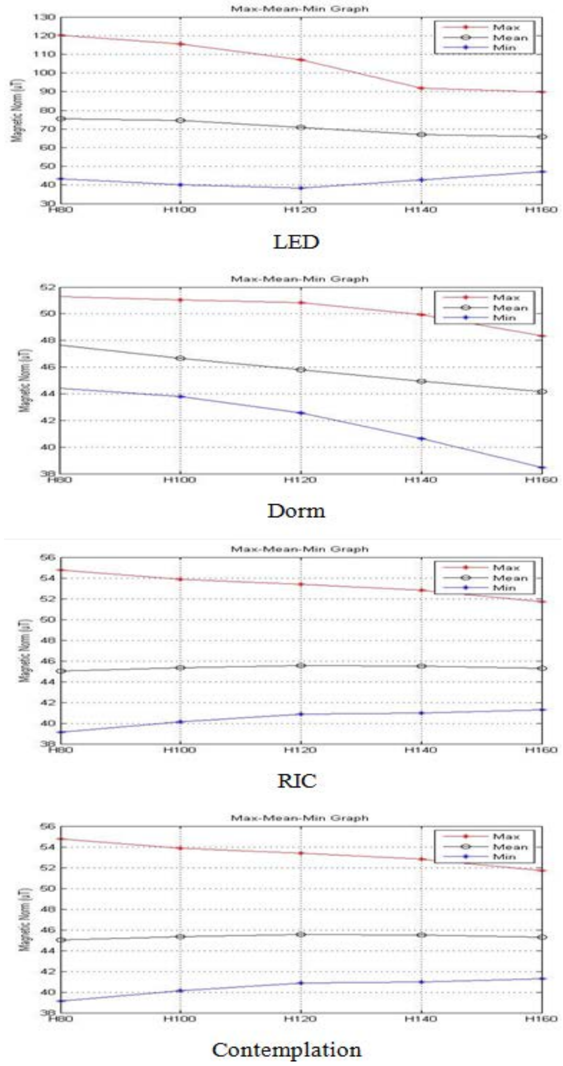

Figure 2. Magnetic field distribution by building structure

Table II shows the magnetic variation. In case of H-beam structure, horizontal and vertical interference of geomagnetic is significantly big. The horizontal and vertical interference at corridor area is the biggest in reinforced concrete structures, since there are walls and doors in this area that can effect to variation of geomagnetic value. This phenomenon is also observed in RIC that has several pillars and contemplation room that is open space. For example, contemplation room has 1.15uT/m and 0.40uT/40cm variation for horizontal and vertical, respectively.

In short, the bigger horizontal and vertical magnetic variation occurs in H-beam structure building than in reinforced structure buildings. In addition, even if the buildings had been constructed using same structure, the bigger variation is observed in the buildings that have more walls, pillars, doors etc.

TABLE II. MAGNETIC VARIATION

Building name	• LED	• Dorm	• RIC	• Contemplation
Detail characteristics	Brick wall	Corridor structures	Open space structures	
			Around the pillars	Hall type
Magnetic variation (hor., vert.)	• 15.00 μT/m • 7.1 μT/40cm	• 2.17 μT/m • 1.77 μT/40cm	• 1.67 μT/m • 0.64μT/40cm	• 1.15 μT/m • 0.40 μT/40cm

VI. POSITIONING SYSTEM AND RESULTS

A. System Model based on the Particle Filter

The particle filter is sequential Monte Carlo (SMC) methods based on probability densities [9]. It follows a framework of the sequential importance sampling (SIS) algorithm, which proceeds by generating a set of N samples from a priori probability density as $x_t^i \sim p(x_t \mid x_{t-1}^i)$ and then assigning a weight $w_t^i \sim p(z_t \mid x_t^i)$ to each sample corresponding to the measurement density. The basic idea of resampling is to remove small weights particles and to concentrate on large weights particles.

B. Simulation Tests using Simulator

The simulator for the experiment has been implemented by C++. The simulation was performed using the geomagnetic map generate in advance. For the magnetic map in use for simulator, the height of the target to be tracked is fixed at 120cm. a path is set shown in Fig. 3. The measured value at the points to be tracked is computed using the measured data in advance for map with 0.3 standard deviation noise. For this simulation, we use particle filter and the number of particles is set to 1000, the moving direction of each particle is set to 45degree variation of designated path direction, and the moving velocity is assumed as 0.5m/s. We carried out 100 experiments to evaluate the prediction error. We suppose that the initial starting point is unknown.

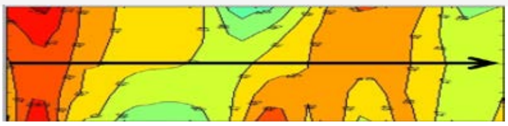

Figure 3. Path setting (Dorm)

C. Result

Fig. 4 shows location estimation error from simulation performed in Dorm. The error of simulations performed at 120cm path is in 1 m, but in the case of 80cm path the error diffuses more than 3 meters, so the tracking is failure.

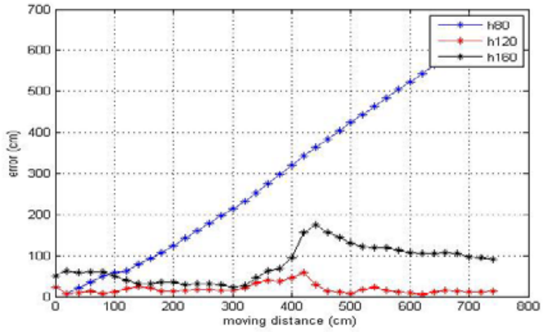

Figure 4. Simulation Performance in Dorm

Table III shows location estimation average error of simulation result. However, the maps for test areas are small size about 8m², so if the error is about more than 1meter it is assumed as tracking failure. In the table, the error of the simulation at 120cm path is less than 1meter, so it can be assumed that the tracking is successful, but the simulation at 80cm path of LED and Dorm resulted in more than 1meter error, so it can be assumed as tracking failure based on the our standard. In case of RIC and contemplation, the tracking is successful, but the performance of tracking is much worse than the test at the same height. This result means that precise tracking is resulted in if and only if the height of measure data during tracking the position is same as the height for the magnetic map.

TABLE III. PERFORMANCE OF LOCALIZATION

Building name		**LED**	**Dorm**	**RIC**	**Contemplation**
Avg. error	**H80**	127 cm	301 cm	33 cm	40 cm
	H120	33 cm	18 cm	19 cm	13 cm
	H160	78 cm	133 cm	35 cm	32 cm

VII. CONCLUSION AND FURTHER WORK

We suggest how different horizontal and vertical variation of magnetic is depending on the building structure. Using the simulation results we also mention that for indoor localization using geomagnetic, if the heights for the map generated in advance and device to be tracked are different, it is possible that the localization could be impossible. Proposed indoor system was designed to work in small scale positioning in several buildings. As further work, we will test the proposed indoor system in large scale area, and studying solution by height problem.

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