Enhanced indoor localization using GPS information

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Abstract—**With the development of IT(Information Technology) and as various kinds of smart devices come into wide use, accurate location estimation technology using them is required. In this paper, we enhance fingerprint technology, which is a well-known indoor location estimation technology, by incorporating GPS signal information to reduce localization error especially around the border zone between indoor and outdoor area and improve the efficiency of database search. According to indoor test result where satellite signal is receivable, compared to the existed Fingerprint technology, localization error value is improved by 19.8% and the time required for database search is improved approximately by 24.0%. Therefore, this paper would suggest new direction for efficient indoor and outdoor continuous location estimation through more accurate location estimation at border zone between indoor and outdoor area.**

Keywords-component : GPS, Fingerprint, Indoor localization

I. INTRODUCTION

As various kinds of smart devices come into wide use, technology for user's location estimation is actively studied. Well-known location estimation technology utilizes GPS (Global Positioning System). After GPS has been released to the public diverse signal correction technologies were published. Passing through these correction technologies GPS up to now is the most popularized and the most used technology. However, GPS has a major weakness; in indoor area where satellite radio signal is unstable it is unable to utilize it. Accordingly technology which is able to estimate location indoors is required and currently indoor location estimation technologies are being studied using diversely established wireless communications infrastructure. Among them there is Fingerprint technique, Cell-ID technique, and Weighted Centroid technique for Wi-Fi based indoor location estimation technique.[1] Among these techniques Fingerprint technique is able to provide accurate location compared to other techniques by using location estimation method based on probabilistic modeling, however, due to its complexity of database search to estimate the location of moving object, it can deteriorate the capacity of the system.[2] In addition, propagation loss happens depending on the status or location of Multipath Fading or device and to merely rely on RSSI of Wi-Fi has clear limitations. Therefore, to reduce the localization error value it is imperative to improve the performance by applying Map Matching technique or Kalman Filter technique. This paper aims to suggest the way to improve the complexity of database search and localization error value of border zone between indoor and outdoor area at the stage of Cell determination among preliminary collecting stages of existing Fingerprint technique by grouping sections where GPS satellite signal is receivable. And as distinguishing indoor area and outdoor area it aims to suggest new solution for indoor and outdoor continuous location estimation. Hence this paper examines the indoor location estimation technology which has been studied up to now in chapter 2 and inspects the problems of Fingerprint technique among existing techniques in chapter 3. In chapter 4 it suggest the process of designing, content of experiment and result of it according to suggested methods. Lastly in chapter 5 it concludes.

II. RELATED WORK

A. Fingerprint technique

Fingerprint technique based on probabilistic modeling is one of methods of location estimation. Compared to other location determination techniques, it makes accurate location estimation possible. It can be divided into two stages;[1] preliminary collection stage that collects RSSI frame in the corresponding area by dividing indoor location determination object into cross stripes cells with regular intervals.[2] location determination stage that implement comparison-operation with collected RSSI using RSSI at the located point. Fingerprint technique has an advantage; it does not impose additional establishment costs for location determination because it uses AP signal information which already has been built indoors. However, it requires extra time consumption to build database which has signal collecting information and has the following

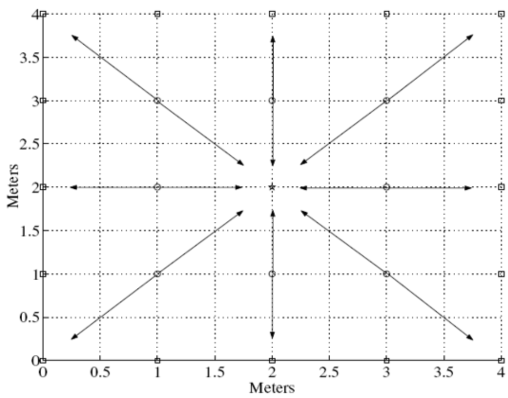

Figure 1. A grid space for an indoor positioning system[3]

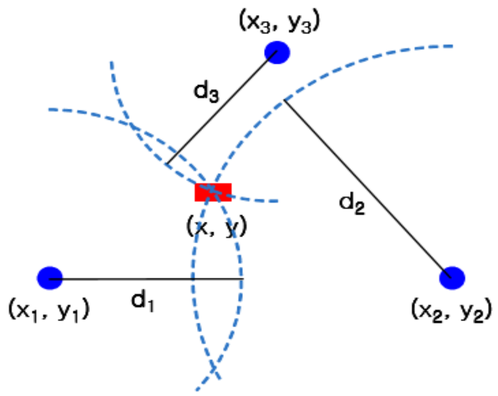

Figure 2. Conceptual diagram of triangulation[5]

weakness. Whenever AP installation status changes, the database should be updated correspondingly.

B. *Weighted Centroid Localization*

Location determination technique based on Weighted Centroid is the method to estimate the location of device by imposing weighted value depending on the size of received signal on the assumption that it recognizes the location of Wi-Fi AP which is already built. By searching Wi-Fi AP built nearby, weighted value is obtained through equation (1).

$$W_i = \frac{1}{(d_i)^g} \tag{1}$$

Coordinate of current location can be obtained using acquired weighting value through equation (2) below. [4]

$$P_i(x,y) = \frac{\sum_{j=1}^{m}(w_{ij} \cdot B_j(x,y))}{\sum_{j=1}^{m} w_{ij}} \tag{2}$$

Weighted Centroid technique is easy to utilize in practice because of its small amount of all computation when estimating location. However, it has weaknesses that location AP should be apprehended and that it is hard to use it in the area where infrastructure has not been established enough.

C. *Triangulation*

Triangulation method is the most commonly used method to estimate real-time location of moving object using simple in a geometric way. To estimate real-time location of moving object, at least three standard points AP1, AP2, AP3 are required.[5] Distance between moving objet and each APs can be calculated using Pythagorean theorem as shown below equation (3).

$$\begin{aligned} d_1{}^2 &= (x-x_1)^2 + (y-y_1)^2 \\ d_2{}^2 &= (x-x_2)^2 + (y-y_2)^2 \\ d_3{}^2 &= (x-x_3)^2 + (y-y_3)^2 \end{aligned} \tag{3}$$

However in the most cases, the number of portable nodes which are required to be recognized is located lower than AP, therefore, if traditional triangulation method is used here, the error between AP and portable node increases.[6] Correspondingly, there are attempts to improve the existing triangulation method.

III. SUGGESETION

A. *Existing Fringerprint Technique*

Fingerprint technique requires preliminary collection stage to build database which has RSSI measured for each cell. Generally database contains coordinate for each cell and corresponding RSSI of standard AP as shown in Table 1 below. At the stage of location estimation, RSSI of currently located cell and collected RSSI within the scope of established database are compared. However, in the process of transmitting RSSI through a medium propagation loss occurs. Therefore, despite they are located in the same cell it is hard to be perfectly matched with collected RSSI. Accordingly, Euclidean Distance method is used as used in equation (4) which is suitable to judge the similarity between two points which are on the multi-dimensional space. [7]

$$\begin{aligned} D(i) &= \sqrt{(\alpha_{i1}-\beta_{i1})^2 + (\alpha_{i2}-\beta_{i2})^2 + \dots + (\alpha_{ij}-\beta_{ij})^2} \\ &= \sqrt{\sum_{i=1}^{M}(\alpha_{ij}-\beta_{ij})^2} \end{aligned} \tag{4}$$

Here i indicates current location index, α indicates measured RSSI and β indicates preliminarily collected information. After calculating D(i) which is closer to 0 is concluded as having similar value and being current location as a final decision. However regarding to the data processing, Euclidean distance requires a heavy calculation. Furthermore, previous data base processing is comparing operation of measured RSSI with all other collected RSSI. If the measurable range is too wide or the amount of data base has been ascending because of narrowed interval between Cell it might cause a problem on performance with extending searching time.

Table 1. General database scheme for fingerprint

Index	X	Y	AP#1	AP#2	AP#3	AP#N
1	x_1	y_1	$rssi_{11}$	$rssi_{12}$	$rssi_{13}$	$rssi_{1n}$
2	x_2	y_2	$rssi_{21}$	$rssi_{22}$	$rssi_{23}$	$rssi_{2n}$
3	x_3	y_3	$rssi_{31}$	$rssi_{32}$	$rssi_{33}$	$rssi_{3n}$
4	x_4	y_4	$rssi_{41}$	$rssi_{42}$	$rssi_{43}$	$rssi_{4n}$
5	x_5	y_5	$rssi_{51}$	$rssi_{52}$	$rssi_{53}$	$rssi_{5n}$
…	…	…	…	…	…	…
m	x_m	y_m	$rssi_{m1}$	$rssi_{m2}$	$rssi_{m3}$	$rssi_{mn}$

Table 2. Proposal database scheme for Fingerprint

Index	Code*	X	Y	AP#1	AP#2	AP#3	AP#N
1	C_1	x_1	y_1	$rssi_{11}$	$rssi_{12}$	$rssi_{13}$	$rssi_{1n}$
2	C_2	x_2	y_2	$rssi_{21}$	$rssi_{22}$	$rssi_{23}$	$rssi_{2n}$
3	C_3	x_3	y_3	$rssi_{31}$	$rssi_{32}$	$rssi_{33}$	$rssi_{3n}$
4	C_4	x_4	y_4	$rssi_{41}$	$rssi_{42}$	$rssi_{43}$	$rssi_{4n}$
5	C_5	x_5	y_5	$rssi_{51}$	$rssi_{52}$	$rssi_{53}$	$rssi_{5n}$
…	…	…	…	…	…	…	…
m	C_m	x_m	y_m	$rssi_{m1}$	$rssi_{m2}$	$rssi_{m3}$	$rssi_{mn}$

B. Fingerprint Technique Using GPS Information

In order to improve the error on researching time and distance in previous fingerprint technique, this paper suggests employing the number of satellites reception on real-time.

At the preliminary collection stage of Fingerprint technique the process to divide each cell is executed in the same way with the existing Fingerprint technique. However, when collecting signal received from each cell, information of the number of satellites used totally to calculate the location information of current devices is collected simultaneously to establish Fingerprint database. Propagation signal of satellite basically is unstable when device locates indoor places, however, it has a feature that in the border zone between indoor area and outdoor area it is possible to receive signal. Thus, database is established by adding the number of satellites received from representative signal of cell at the preliminary collection stage. Table 2 shows suggestive Fingerprint technique database. Code column is distinguished by the number of GPS satellites which is receivable at the current location. Especially, when collecting information of the number of satellites the number of them which is revised on the real-time basis, it should allocate the code by setting the number of satellites which was received mostly at the specific time and location through mode algorithm. Figure 3 presents the algorithm that determines the number of code on corresponding area in a stage for collecting. When the signal from GPS has been scanned on real-time, the number of satellites received is counted in a 'use_count' arrangement. Following this step, the index of ceiling value from 'use_count' array is set as a final number of satellites. Also, the value of 'th2' and 'th1' are 10 and 3, respectively, in this paper. In the stage of location positioning, it determines the final location by researching the database, especially in the rows corresponding to the code number selected using the number of satellites by the procedure in Fig. 3.

```
Procedure Decision of code number()
  start to scan
        if signal receiving == true
              use_count[ sate_num ]++;
        end if
  stop scanning
  for int i from 0 to range of satellites number
        if use_max <= use_count[i]
              use_max = use_count[i]
              mode = i
        end if
  end for
  if mode >= th2
        code(cm) = 2
  end if
  if mode  < th2  and  mode  >= th1
        code(cm) = 1
  end if
  if mode < th1
        code(cm) = 0
  end if
end procedure
```

Figure 3. Pseudo code to determine code number

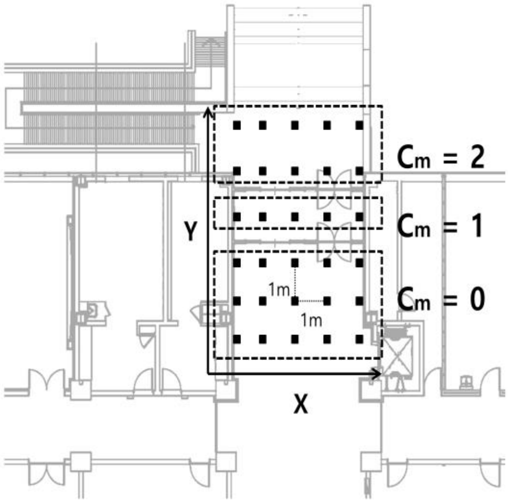

Figure 4. Experiment environment and Cell classification map

IV. EVALUTIONS

A. Environment and Method of Experiment

To investigate the effectiveness of proposed method on the location where GPS information is received with precise boundary district, this experiment was conducted in first floor lobby of IT hall, Yeungnam University. Figure 4 shows the approximate floor plan, cell allocation and the result of Grouping. The code number 2 is an active district with received satellites 10 or more in maximum, code 1 is an unstable district with greater than or equal to 3, but less than 10 satellites, code 0 is non reception area of less than 3 for satellites signal. The gap between cell is given around 1 meter. Additionally, RSSI saves the average of received signal by measuring more than 30 times for each Cell, the number of satellite coded by employing the most frequent one through Mode algorithm. It chooses the strongest and most stable 4 RSSI at the experiment location as a standard AP. The measurement application for experiment is realized by

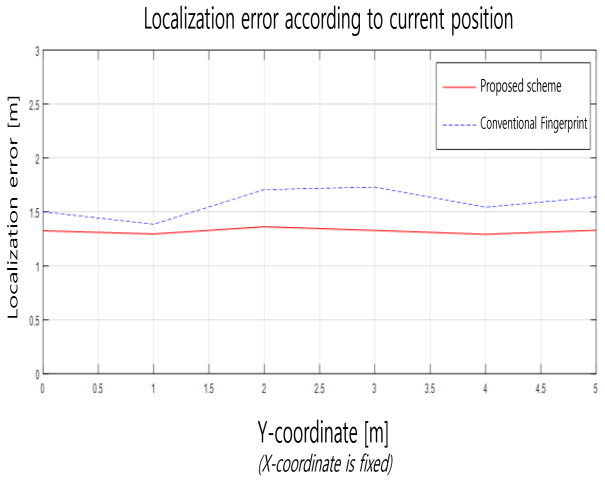

Figure 5. Localization error at each measurement point

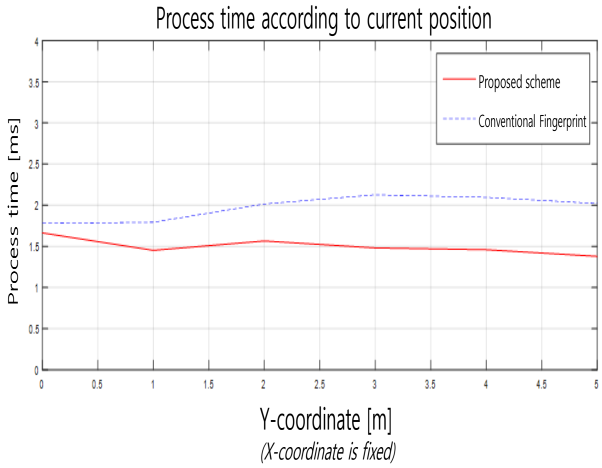

Figure 6. Process time at each measurement point

manually programming with utilizing GPS provided by Android and API relates to Wi-Fi and checks it with Smart Device, identical as the one used for collecting signals in order to guarantee the confidence of the result. Each Cell is measured more than 40 times within the range of measurement, mid-point of X axis to the end point of Y axis. Furthermore, in order to check accurately whether it solves the error for distance or not, it simultaneously measures the current location with received RSSI regards to previous and suggested methodology.

B. Result and Analysis of Experiment

Figure 5 explains the localization error obtained from experiment. The horizontal axis indicates the Y coordinate of the measurement point. As a result, the average error of the conventional fingerprint scheme is about 1.58m and the proposed scheme exhibits an average error of 1.32m, leading to an improvement by 19.82%. Especially, at 2, 3, 4 m point, the boundary area by grouping each code indicates the significant improvement on localization error. Since it only

Table 3. The numerical results of experiment

The ordinate	Localization error [m]		Processing time [ms]	
	Conventional Fingerprint	Proposed Scheme	Conventional Fingerprint	Proposed Scheme
0	1.5012	1.3249	1.7793	1.6628
1	1.3856	1.2954	1.7933	1.4513
2	1.7061	1.3261	2.0151	1.5653
3	1.7303	1.3279	2.1271	1.4808
4	1.5432	1.2921	2.0966	1.4591
5	1.6377	1.3299	2.0207	1.3785
AVG	**1.5840**	**1.3221**	**1.9719**	**1.4996**

searches the rows corresponding to the code number selected based on the number of observed satellites, it eventually reduces the localization error. Figure 6 compares the processing time of the proposed scheme with that of the conventional fingerprint scheme at each measurement point. Because it only needs to search a limited number of rows corresponding to a specific code without investigating the whole database, this methodology can reduce the database searching time compared to the conventional methodology. Consequently, while the average processing of the conventional scheme was measured to be 1.97 ms, our proposed scheme spends about 1.49ms on average, indicating the improvement by 23.6%. Table 3 shows the detailed experiment results. Finally, it assures the effectiveness of this proposed system.

V. CONCLUSION

This paper proposed an enhanced Fingerprint technology to improve the localization accuracy by extending conventional fingerprint schemes with the number of satellites providing GPS information. The experiment results show that the localization error can be improved by 19.8%, and the database searching time can be reduced by 24.0%. Thus, we expect that the proposed scheme can provide a more accurate localization result by extending conventional fingerprint schemes with GPS information, especially around the border area that discriminates the inside and outside of a given building.

VI. REFERENCES

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