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An Accurate Fingerprinting based Indoor Positioning Algorithm

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Abstract
Recently, many studies of indoor positioning system using wireless signals such as WiFi, Bluetooth, have been researched actively. There are three types of indoor positioning system, triangulation method, fingerprinting technique and Cell-ID technique. Triangulation method has advantages in searching locations in wide environment, but its accuracy deteriorates in narrow indoor environment due to physical obstacles and signal interference. Fingerprinting technique results less error because it determines position based on reference in actual environment, but it has disadvantage in determining precise position in selected cell size. This study proposes an accurate fingerprinting based indoor positioning algorithm. To improve accuracy, K-NN algorithm and moving average filter is used. The performance of triangulation method, fingerprinting technique, and our proposed technique is analyzed under same situation. Experimental results show that the accuracy of the proposed method is 86%, which is better than the accuracy of fingerprinting method 72.58%, and triangulation method 45.63%.

Keywords: Indoor positioning system, Wireless signals, Triangulation, Fingerprinting technique, Cell-ID, K-NN algorithm, Moving average filter.

INTRODUCTION

Today, people benefit from location by Location-based service, which is also known as Location Base Service (LBS) [1~4]. LBS covers all wireless contents services that provide appropriate information based on users' location. These services require location determination technologies in indoor environment. Under outdoor settings, Global Positioning System (GPS) is commonly used. However, GPS has limitation in using indoor settings because it relies on signal from satellite [5][6]. In order to cover these challenges, indoor positioning system using wireless signal such as WiFi and Bluetooth - which are commonly used in indoor setting - is growing interest [7~10]. As well as WiFi and Bluetooth, variety of indoor positioning system based on other types of wireless communications like UWB(Ultra-Wideband) and LED are being researched [11~14]. However, most of indoor positioning systems lack accuracy due to complex structure, mobility of people and indoor obstacles. To increase the accuracy of positioning system using wireless communications under instable circumstances, this paper suggests a matching algorithm based on Fingerprinting technique [15] out of indoor positioning system. Matching algorithm combines K-NN algorithm [16] which finds the most similar data by calculating weighted value scores and moving average filter [17] to increase accuracy for predicting changes of data. To compare and analyze performance of triangulation method, fingerprinting technique, and our suggested technique, we perform experiments. Experimental results show that the accuracy of the proposed method is 86%, which is better than the accuracy of fingerprinting method 72.58%, and triangulation method 45.63%.

The rest of this paper is structured as follows. Section 2 explains about our suggested fingerprinting algorithm with higher accuracy. In Section 3, we compare the accuracy of our proposed algorithm with fingerprinting technique and triangulation method. Finally, Section 4 concludes this paper.

PROPOSED ALGORITHM

Prior experiments for this paper concluded low accuracy of indoor positioning system based on triangulation method is caused by physical obstacles - such as doors and walls, as well as instability of RSSI value of Bluetooth - such as wireless interference, distortion, and refraction. Although, results from indoor positioning using fingerprinting technique were more accurate than triangulation method, it still showed limitation. For example, jump phenomenon, which output data skipping cells in moving direction, or continuously outputting false data once error is detected. To cover the disadvantages of indoor positioning system using triangulation method and fingerprinting technique based on this prior experiment, combining K-NN algorithm and moving average filter to fingerprinting technique tempt to raise accuracy.

Firstly, suggested fingerprinting technique divides cells based on fingerprinting technique and determines the cell user is located. At this moment, K-NN algorithm and moving average filter are used to increase accuracy. RSSI data from K-NN algorithm are gathered and the most similar cell is outputted by comparing those clustered RSSI data and user's actual location. Error of RSSI data is reduced using moving average filter. From this, disadvantage of triangulation method with regard to Positioning environment and low accuracy of fingerprinting technique could be modified.

A. Fingerprinting algorithm configuration for higher accuracy

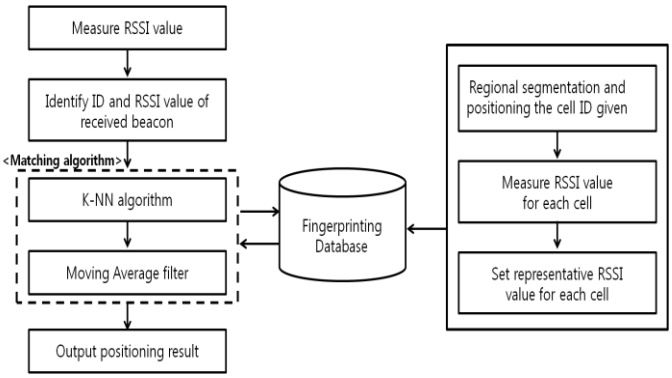

Figure 1. Fingerprinting based Indoor positioning algorithm configuration for higher accuracy

Figure 1 shows whole structure of Suggested fingerprinting based Indoor positioning algorithm for higher accuracy. Firstly, each cell gets an ID when positioning sectors are divided in order to form database during Training process. Among the measured RSSI data of each cell, representative RSSI data is set and saved in database. After establishing fingerprinting database through Training process, Bluetooth RSSI data is measured by Bluetooth signal receiving device. Received beacon's ID and RSSI data get checked up before outputting the positioning result using matching algorithm. Matching algorithm used throughout this paper consist of K-NN algorithm and moving Average filter. K-NN algorithm begins by arranging RSSI data of received beacon's ID in ascending order. The top three RSSI data of beacon's ID gets calculated by weighted value given. Any error of cell with the highest score can be detected using moving average filter. In other words, if the data of selected cell is within error range, the original weighted value is used and in other case, moving average is used to calculate the final value. Lastly, the output of measured positioning is shown.

B. K-NN Algorithm

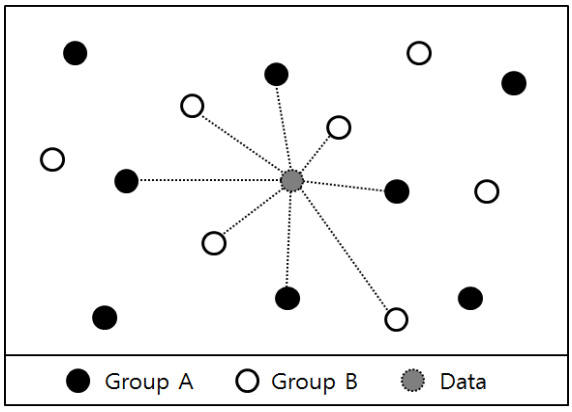

Figure 2. Concept of the K-NN algorithm

In order to raise accuracy of fingerprinting technique, K-Nearest Neighbors (K-NN) algorithm is used to classify cells' value. K-NN algorithm is crowding algorithm that sorts data object set with most similar attribute by fixed rule. K-NN algorithm has advantage of high accuracy and easiness of realization. It is also suitable to fingerprinting technique because it acts as the standard if measured position is included in multiple cells.

K-NN algorithm defines Distance Metric, which provides criteria of deciding which data is classified in which group. It allows proximity and similarity to be judged. After defining Distance Metric, existing dataset is segmented to training and test data. Then, K-NN is executed to Multiple K and the optimum K of calculated value can be found. Throughout this process, possible error of which RSSI value belongs which cell can be minimized during indoor positioning. However, deviation still exists due to variation of signal strength. It causes difference in signal strength of receiving device and data of fingerprinting map. Therefore, the variations of signal strength and map data of every cell are compared. The highest score is given to the set with minimum difference, and the cell with the highest score becomes candidate of the user's location. Also, stronger signal gets more weighted score.

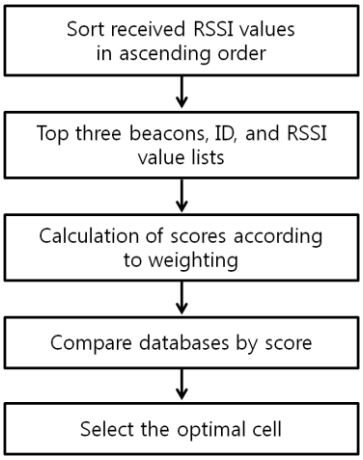

Figure 3. Applied K-NN algorithm flowchart

Figure 3 shows the flowchart of applied K-NN algorithm. Received RSSI data is arranged in ascending order and three RSSI data of beacon ID with the strongest signal is selected. Scores are calculated based on the weighted value given to these extracted data. The optimal cell is selected after comparing the calculated score and Fingerprinting database.

C. Moving average filter

Moving average is averaging method of continuously calculating multiple connected data. It is called moving average because it counts out the oldest variable and adding new variable as time lapse. Moving average filter is improved technique to solve misleading prediction of data change. Also, it is commonly used when input data is not constant.

Formula of moving average filter is shown below. n represents size of a subset and P_d represents the data value.

$$MA = \frac{\sum_{i=0}^{n-1} P_{d-i}}{n}$$

Based on a typical data, the number of subset is repetitively added and divided by the size of subset.
RSSI value sent from Beacon is calculated using moving average formula and shown as Table 1.

Table 1. Result of using Moving average formula

RSSI	Moving average	Theoretical RSSI
-67	-67	-69
-63	-63	-69
-63	-65	-69
-75	-67	-69
-67	-69	-69
-79	-74	-69
-75	-75	-69
-67	-74	-69

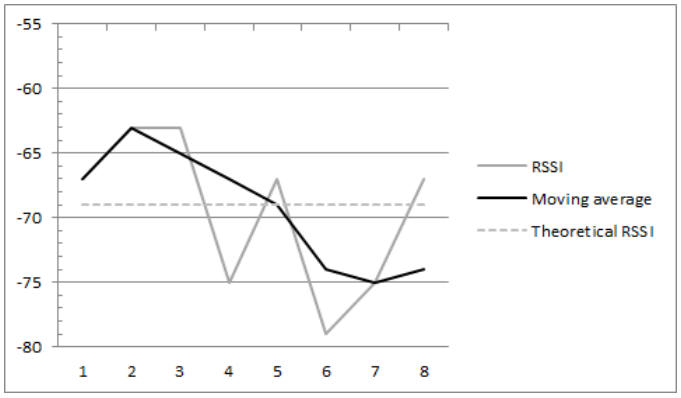

Figure 4. Bluetooth RSSI value with Moving average

Figure 4 is graph of the resulted data listed in Table 1. It shows moving average filter can minimize error boundary when the signal value drastically decreases - which is common attribute of Bluetooth.

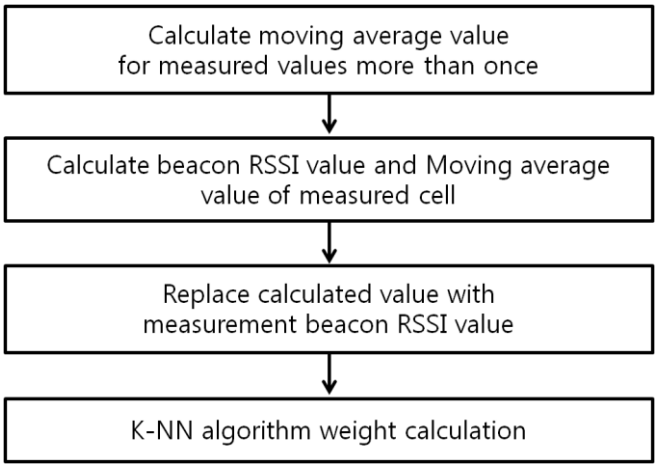

Figure 5. Applied Moving average filter flowchart

Due to the attribution of Bluetooth, signal tends to be unstable. In this case, the result of indoor positioning algorithm can vary from user's actual location. To cover this problem, moving average filter is used and data that exceed possible moving distance within certain time are excluded. Also, if score difference among cell candidates of fingerprinting map is small, the nearest cell from previous cell is outputted to increase accuracy.

Figure 5 shows the flow of moving average filter used throughout this research. Moving average data is calculated when measured more than twice. Representing RSSI value of selected cell and moving average data are compared and the selected cell data is used if within the error range. Otherwise, the Moving average data is used instead of the selected cell data.

EXPERIMENT

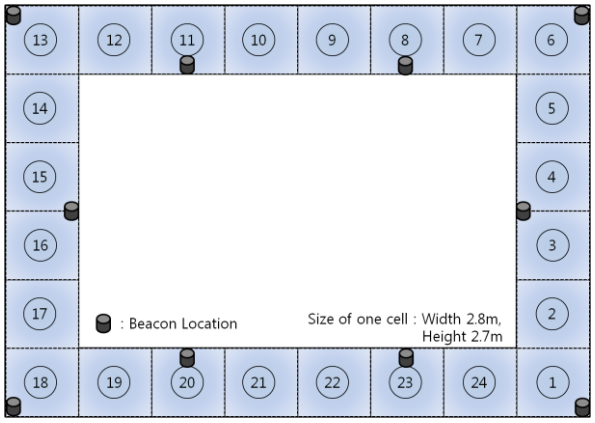

Figure 6. 10 Beacon installation environments

To verify performance of Indoor positioning algorithm based on this study's Suggested fingerprinting technique, accuracy comparison test is executed. As shown in Figure 6, a floor of bugilding was divided into 24 cells (3x3 meters) and installed 10 beacons. Accuracy of triangulation method, fingerprinting technique and the suggested technique are tested in equal setting. For each 24 location, 30 times of signals are tested in 5 minutes and nRF Beacon was used for Bluetooth signal.

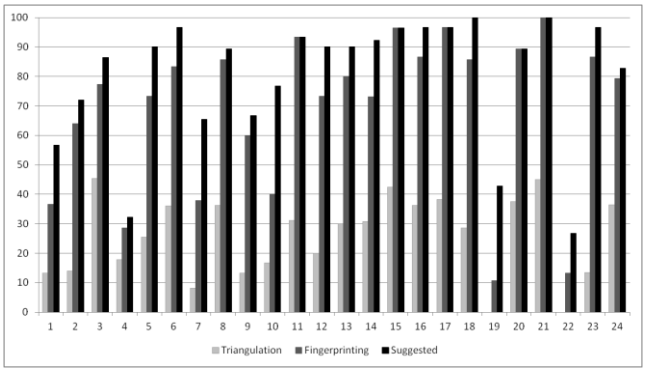

Figure 7. Accuracy Comparison of Three Techniques for 10 Beacons

Figure 7 shows the result of three technique's accuracy test when 10 beacons are installed. The average accuracy of 24 cells for suggested technique was 80%, which is higher than Fingerprinting technique (68.81%) and triangulation method (25.68%).

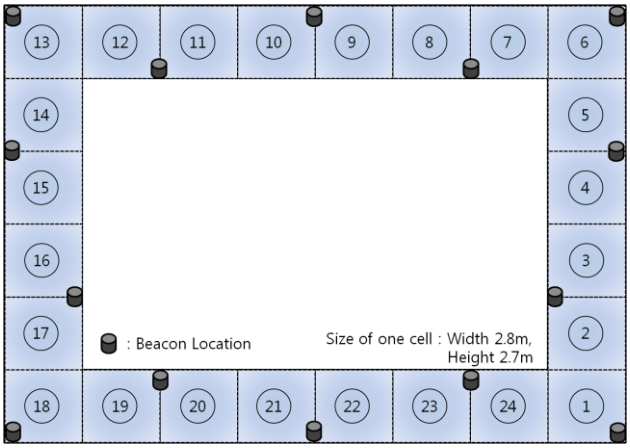

Figure 8. 14 Beacon installation environments

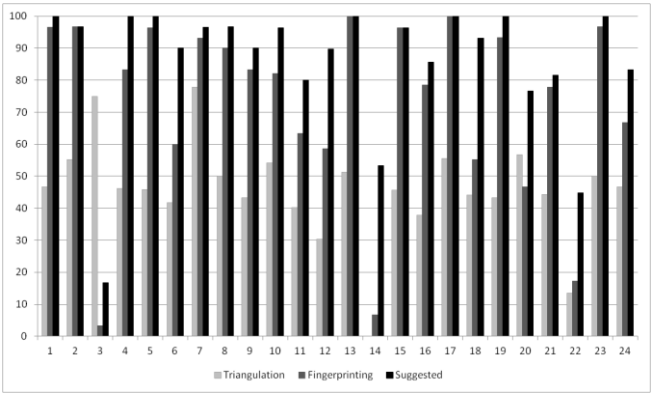

Figure 9. Accuracy Comparison of Three Techniques for 14 Beacons

Also, because the number of node influences accuracy of indoor positioning, same testing process of triangulation method, fingerprinting technique, and the suggested technique were experimented with 14 beacons. The result of this test, as shown in Figure 9, accuracy for each of three techniques increased. As well, average accuracy of the suggested technique was 86%, which is still higher than the fingerprinting technique (72.58%) and triangulation method (45.63%).

CONCLUSION

This study suggests an indoor positioning algorithm based on Fingerprinting technique with higher accuracy. First of all, positioning location is divided during training process. Then, particular ID and representing RSSI data was set for each cell and saved in database. The result of positioning was output, using the matching algorithm during the positioning process. Matching algorithm of this study consists of K-NN algorithm and moving average filter process. The weighted value and score are calculated using K-NN algorithm and cell with the highest score is selected. The selected cell decreases error range using moving average filter. According to the result of performance analysis for justified system, average accuracy of suggested technique was 86% - which is higher than triangulation method (45.63%), and fingerprinting technique (72.58%).

In the future, if machine-running algorithm is grafted on to the training process of suggested indoor positioning algorithm, its accuracy and efficiency are likely to increase.

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