A Novel RSS-Ratio Position Estimation Scheme for Wi-Fi Networks

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Abstract—the importance of location based service has been addressed frequently in various fields and the interest about core technique of various positioning scheme for indoor has been increased. The positioning scheme based on Wi-Fi is widely used because the infrastructure is already set up in many indoor spaces. The fingerprinting and the lateration schemes are typical techniques for Wi-Fi based positioning. However, these schemes have some problems for actual execution, such as hard-works for building data base and the time-varying characteristics of wireless signal. In this paper, a novel received signal strength (RSS)-ratio based positioning is proposed to mitigate the problems of conventional schemes. The performance of proposed scheme is evaluated in normal office environment according to various number of selection APs. According to the experiment results, the positioning error of proposed scheme is reduced about 82% than that of conventional RSS lateration scheme.

Keywords—positioning; Wi-Fi positioning; received signal strength (RSS); RSS ratio

I. INTRODUCTION

Recently, the importance of location based service (LBS) is increasing in order to provide service of user-centered in a various application such as online-to-offline, fin-tech, guidance, indoor navigation. Global Navigation Satellite System (GNSS) has been studied and used in various fields. However, GNSS is a useless in indoor spaces because line of sight (LOS) for receiving a satellite signal is not ensured.

To solve this problem, the various method is applied for indoor positioning such as Wi-Fi, Ultra-wideband, Bluetooth, Inertial Measurement Unit, and RFID [1-6]. The Wi-Fi is most preferred method because there are many AP in indoor for communication. Therefore, it is possible to minimize the cost of additional infrastructure installations. There are some method for position estimation method using Wi-Fi such as fingerprinting that use pre-collected training data and lateration that uses a triangular positioning scheme. For this method, Wi-Fi communication module of user, Access Points (AP), and server with database is required.

Fingerprinting scheme estimate the position of user by comparison of real-time received signal strength (RSS) and pre-collected training data in database. Therefore, this scheme requires a lot of preliminary works, and cannot flexibly respond according to change in the environment. On the other hand, lateration scheme estimate the position of user without prior perform using the position of APs. Therefore, it is possible to flexibly cope with environmental change. However, sometimes the intersection of triangulation positioning is not exists because of the characteristic of wireless signal, and the error of estimated position is generated [1].

In this paper, we proposed a novel positioning scheme based on RSS-ratio to mitigate the problem of lateration scheme and to reduce complexity of lateration scheme due to matrix operation. The performance of the proposed scheme was evaluated through experiments in the normal office environment by Wi-Fi transmit module of user, AP for indoor.

The rest of the paper is organized as follows. In section II, the system description about positioning based on Wi-Fi is expressed with typical schemes. In section III, the proposed scheme is described. In section IV, the proposed scheme is evaluated and reviewed. Finally, out conclude remarks are summarized with future works in section V.

II. SYSTEM DESCRIPTION

A. Positioning Based on Wi-Fi

The system architecture of Wi-Fi based position estimation method is shown in Fig. 1. The subject of the positioning can be divided two methods. First, the user device receives the transmitted signal from a peripheral APs and collected RSS is transmitted to database for the position estimation calculation. Another one is the opposite of previous case. In this system, user device transmit the signals and surrounding APs receive the transmitted signal. And this case also transmit RSS to Database. In the first case, even though problem of user devices with different transmission power can be mitigate, operating time of user device is decrease because of limited battery capacity in the service for users. However, the second case can reduce the load of the user device because APs are always supplied power. The user position is estimated by the collected data in the database with position of installed APs and pre-defined parameters.

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B. Fingerprinting Scheme

Fingerprinting scheme is a method most commonly used. This method consists of two phase: offline and online. In the offline phase, the database is built base on training data. Training data is collected at reference position that is located at a constant grid interval. The positioning accuracy is decided by interval of grid. High grid density is required to obtain high precision, which need more collection time. In the online phase, the position of user is estimated through the comparison of the training data in database with the real-time RSS of user. However, the drawback of this scheme is reliability of training data. The reliability of collected training data is decrease according to the change in the environment such as movement of structure, change of building structure, and the density of floating population. Because of this reasons, the training data should be re-collect. In order to solve this problems, various studies have been proceed. In spite of this drawback, installed APs can use without re-install for positioning. Thus, it applied to most of commercial techniques.

C. Lateration Scheme

The lateration scheme is commonly used in the RSS based positioning method. Even though the position of installed APs affect performance of positioning, this scheme can cope with environment change because it does not require collection process for training data. The lateration scheme is a position estimation method via triangulation based on RSS f user. The matrix of lateration is expressed as follows [7]:

$$H = \begin{pmatrix}
  x_2 - x_1 & y_2 - y_1 \\
  x_3 - x_1 & y_2 - y_1 \\
  \vdots & \vdots \\
  x_n - x_1 & y_n - y_1
\end{pmatrix},$$

$$B = \frac{1}{2} \begin{pmatrix}
  (d_1^2 - d_2^2) + (x_2^2 + y_2^2) - (x_1^2 + y_1^2) \\
  (d_1^2 - d_3^2) + (x_3^2 + y_3^2) - (x_1^2 + y_1^2) \\
  \vdots \\
  (d_1^2 - d_n^2) + (x_n^2 + y_n^2) - (x_1^2 + y_1^2)
\end{pmatrix},$$

where, $x_n$ and $y_n$ are the coordinates of $AP_n$ and $d_n$ is the distance between the AP and the user device. Therefore, the least-square solution of (1) is given by

$$X = (H^T H)^{-1} H^T B,$$

and the position of receiver $X$, which is coordinates of $x$ and $y$, can be estimated.

In the above equation, distance is estimated by log normal shadowing model. The log normal shadowing model is used for modeling RSS [8]. This equation is described as follows:

$$RSS[dBm] = P_0 - 10 \cdot N \cdot \log\left(\frac{D}{D_0}\right),$$

where $D_0$ means 1m as a reference distance and $P_0$ is the RSS value at reference distance. Equation (2) is transformed for distance estimation as follows:

$$D = D_0 \cdot 10^{\frac{RSS}{10N}}.$$
Since the strength of a radio signal is inversely proportional to the distance squared, RSS is converted into the distance for linear analysis by (3). \( P_0 \) use the pre-measured power of each AP. The process up to date is same with lateration scheme. Therefore, the problem of the intersection is still present. In order to solve this problem, the weight of each AP is decided based on converted distance as follow:

\[
W_{AP_k} = \left( \sum_{k=1}^{M} \text{dis}_k \right) / \text{dis}_k ,
\]

where, \( W_{AP_k} \) is weight of \( k \)-th AP among selected APs. \( M \) is the number of selected APs for positioning. \( \text{dis}_k \) is converted distance of \( k \)-th AP.

Normalized weight are expressed as follow:

\[
\text{Nor}_k W_{AP_k} = W_{AP_k} / \sum_{k=1}^{M} W_{AP_k} .
\]

Finally, the position of user is estimation by the position of APs and normalized weight of each AP as follow:

\[
\text{Est.Pos} = \sum_{k=1}^{M} \text{AP.Pos} \cdot \text{Nor}_k W_{AP_k} ,
\]

where, \( \text{AP.Pos} \) is installed position of AP.

### IV. Experiment Results

#### A. Environments

The experiment was performed in a normal office environment. The dimension of the office are 12.89m by 12.98m with an area of about 167m² as shown fig. IV. The WiFi transmit module used 802.11 b/g and communication channel auto selection. All APs is installed on the wall of about 2.5m height from the floor. RSS of transmit module is collected at 5 APs from 20 reference position for 30 sec. Each AP collected about 65 average sample from reference points. The transimt module is located on the neck as necklace. The reference signal power of each AP is applied as shown in table I. RSS of each AP is collected in 1m.

#### B. Result of Experiments

The performance of proposed scheme is performed with conventional scheme that is lateration according to the change the number of AP for positioning.

Figure V shown the position error of proposed scheme that is RSS ratio based positioning with conventional scheme at 20 position. As shown figure, the accuracy is greatly improved. The accuracy of the 3, 4, and 5 selection AP case is increase from 19.03m to 3.37m, from 14.42m to 2.71m, and 13.93m to 2.43m. It is performance increase of about 82.3%, 81.2%, and 82.6%. And we can show the increase of performance with increase of the number of selection AP. The result of performance evaluation is given table II.
V. CONCLUSIONS AND FUTURE WORKS

In this paper, the position estimation scheme, which is based on RSS-ratio of Wi-Fi, is proposed, and the performance of proposed scheme is evaluated with various the number of APs in normal office environment. The experiment was implemented with transmit module that is located on the neck as necklace and AP to use indoor. In contrast to the high complexity of conventional scheme through the complex matrix operation, the proposed scheme has a low complexity through simple operation. Also, the estimated position is located in target space always without map information because the position of user is estimated based on distance weight and position of APs.

However, the accuracy of proposed scheme is decided by the position of APs and LOS. We will study about performance analysis according to the position of APs and decision method for optimal AP position.

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