A Hybrid Indoor-Position Mechanism Based on Bluetooth and WiFi Communications for Smart Mobile Devices

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***Abstract*—With the development of embedded systems and the advance of communication network technologies, the positioning and creative value-added applications have been used widely. The global positioning system (GPS) cannot satisfy the requirements of indoor position applications. The GPS signals cannot be received in the indoor environment. Although the Wi-Fi position technologies are used for indoor location applications, the position accuracy is not accepted. Thus, this paper proposes a hybrid indoor-position mechanism based on Bluetooth and Wi-Fi communications. In the experiments, the position performance of using Wi-Fi and Bluetooth wireless signals with Neighboring Weighted Positioning method is better than that of using only Wi-Fi wireless signals. The average deviation of less than 5 meters and standard deviation of less than 2 meters.**

Keywords—Smart Mobile Devices; Fingerprint Location; Indoor Positioning Navigation; Web Service; Wi-Fi Position; Bluetooth Position

I. INTRODUCTION

In recent years, with the rapid development of wireless communication technologies, the positioning applications become to one part of our life, such as the GPS navigation applications on most cars and smart phones. The GPS (Global Positioning System) can be used for outdoor positioning services. However, the GPS signals cannot be received in the indoor environment. The indoor position technologies are needed by many indoor touring applications. Although the Wi-Fi position technologies are used for indoor location applications, the position accuracy is not accepted.

In this paper, we use the smart mobile device to achieve the indoor location service. We proposed the Wi-Fi and Bluetooth hybrid Positioning mechanism and designed the navigation APP. Both different signals of Wi-Fi and Bluetooth are used by the hybrid positioning technology. In the experiments, the position performance of using Wi-Fi and Bluetooth wireless signals with Neighboring Weighted Positioning method is better than that of using only Wi-Fi wireless signals. The average deviation of less than 5 meters and standard deviation of less than 2 meters.

II. RELATED WORK

A. Angle of Arrival (AOA)

Angle of Arrival (AOA) [1][2] uses of signal arrival for positioning. The principle is the base station uses directional antennas or antenna arrays to determine the angle when the received signal. When there are two or more base station receives the signal emitted by the device to know the direction, and then based on the direction of the intersection of the signal to position. In this method, the more base station, the higher positioning accuracy.

B. Time of Arrival (ToA)

Time of Arrival (ToA) [3][4] uses the travel time from the transmitter to the receiver to measure the distance between the two. In TOA method, there must be at least three sensors to properly localize. When the distances from three different sensors are known, the location can be found by calculate the distance from the time difference between sending and receiving. The disadvantage of this measuring method is that it takes time high measurement accuracy, so that the space for the indoor environment from the very small, this method is difficult to achieve indoor positioning.

C. Time Difference of Arrival (TDoA)

Time Difference of Arrival (TDoA) [4][5][6] is very similar to ToA. Instead of using the travel time to find the distance between the transmitter and receiver, calculating the difference travel times from each sensor to find the distance between each sensor. The location of the transmitter is intersection of several hyperbolas. The space for the indoor environment from the very small, TDoA method is difficult to achieve indoor positioning.

D. Fingerprinting

Fingerprinting [7][8][9][10] method is also known received signal strength indicator (RSSI). It's a common method of indoor positioning navigation. As shown in Fig. 1, this method has offline training phase and online determination phase. In the offline training phase, we need to make a map of the radio environment by measuring the signal strength. In the online determination phase, device position estimation by comparing the online RSSI value of the device with the offline RSSI database. Compared with ToA method and TDoA method, fingerprinting method does not need to make high measurement accuracy of time, and does not need large number of operation.

III. System Architecture

This paper positioning system is received by the indoor environment in Wi-Fi and Bluetooth RSSI, to establish signal strength database at the time of orientation, the user receives the current environment, Wi-Fi and Bluetooth RSSI, signal and previously established library strength to do comparison, calculated user current location coordinates. The system consists of two parts, training and learning subsystem, the positioning calculation subsystem, these two systems are built in the cloud, the cloud is up to us to set up and maintain their own servers, the relevant data is stored in the repository such as signal strength information of locate, navigation information ... etc., operation data are carried out through the cloud server, reducing the amount of the phone's operation, allowing users to navigate the phone can complete presentation effect, this chapter describes the architecture of the paper system, the following points introduction of several parts.

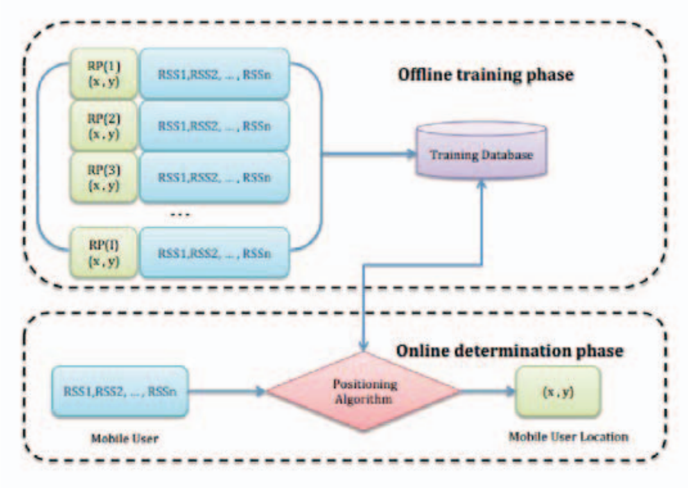


Fig. 1 The fingerprinting method.

A. System Architecture

The proposed the system architecture is shown in Fig. 2. Cloud and positioning environment is divided into two parts. Cloud from the repository and Web Service composition, data inventory stood location data and navigation data, Web Service includes training and learning services, location services and tour operator services, system administrators can make data management even into the server and locate operation correction. Location environment for the navigation service area is divided into two part outdoor and indoor, outdoor mainly by GPS positioning and Wi-Fi to assist positioning, while the interior includes a plurality of wireless AP with a Bluetooth base station, mainly located in the Wi-Fi and Bluetooth to assist positioning.

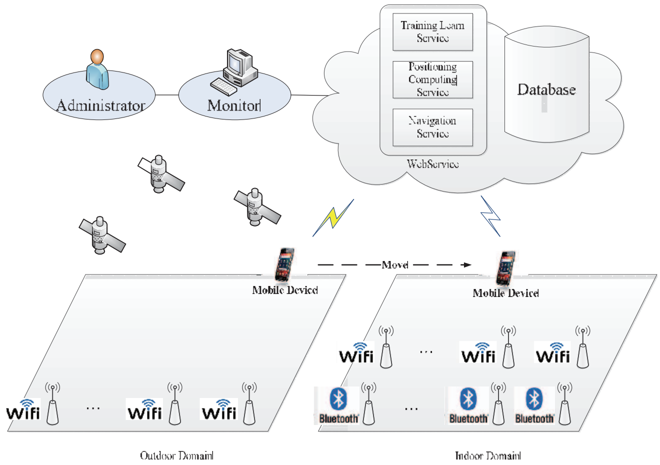


Fig. 2. System Architecture

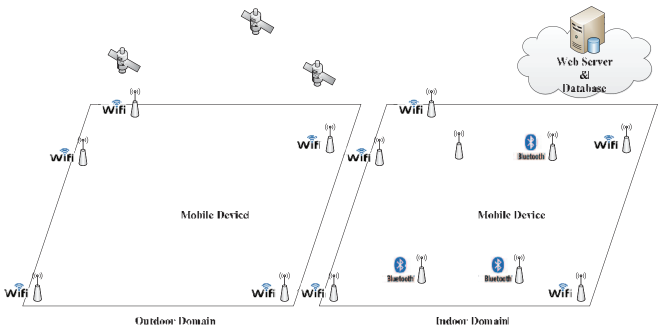
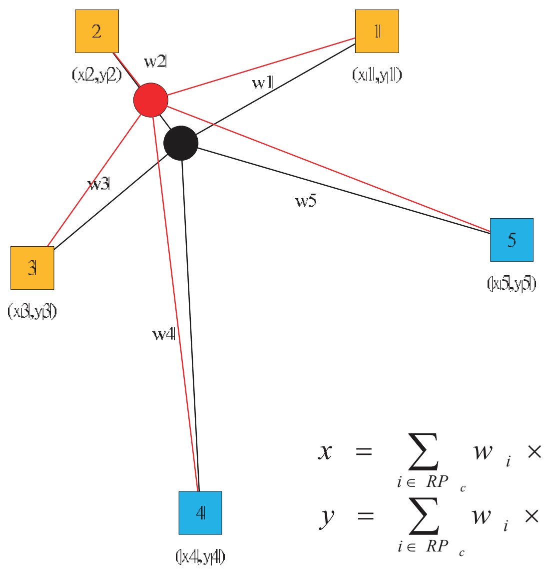


Fig. 3. System Environment



$$x = \sum_{i \in RP_c} w_i \times x_i$$

$$y = \sum_{i \in RP_c} w_i \times y_i$$

Fig. 4. The neighboring weighted positioning method.

The system environment is illustrated in Fig. 3. In the outside environment, we mainly use GPS satellites to locate. We use the signal-assisted positioning with Wi-Fi and Bluetooth in and indoor region. Because GPS is covered by the buildings. the signal cannot be received well in the indoor area.

Thus, we proposed the Wi-Fi and Bluetooth hybrid Positioning mechanism that allows the users from the outside into the indoor area and the positioning navigation function is still working well. In our system, there is a centralized data base and web server to provide the position calculating service to mobiles. Our mechanism enhances the RSSI fingerprint positioning method. Additionally, the two signal fingerprint databases are needed in our system. Moreover, the neighboring weighted positioning method was proposed and implemented in our system. The mobile collects the RSSI strength of the near WiFi APs and Bluetooth base stations periodically and continuously. The collected RSSI information indicates the signal fingerprint of the blind point. The mobile can deliver the signal fingerprint of the blind point to the web server via the existing WiFi, 3G or 4G networks. The server will calculate the blind position with the neighboring weighted positioning method, and response the result of position estimation to the mobile. Finally, the navigation application can works according to the position results. The detail of neighboring weighted positioning method will be explained in the next subsection.

B. Neighboring Weighted Positioning Method

Due to the complex calculation and power consumption, the position estimation algorithm is performed by the centralized web server. After finishing the collecting of RSSI information from mobile, the neighboring weighted positioning method is to estimate the blind mobile position. According to the training database of signal fingerprint, the Euclidean Distance [11][12] is used to select the n most similar training points. Because the signal strength of receiving RSSI is nonlinear with distance, the neighboring weighting is proposed in this paper. For example, there are five RSSI signals are sensing in the blind point, shown in Fig. 4. The black circle is calculated with five neighboring training points, and the red point is calculated with three neighboring training points. In our experience, we can observe that the far training points is unconfident. The weighting of the far training points should be very small or approximate to zero. Finally, the estimated location (x, y) would be calculated with the distance weighting.

IV. System Measurement and Analysis

The positioning navigation APP was design for the smart phone. We use navigation system with hybrid positioning technologies based on Wi-Fi and Bluetooth that can reduce computational of smart mobile devices by cloud computing services. We implemented an indoor navigation system based on RSSI fingerprint positioning, and combined with the neighboring weighted positioning algorithm to estimate user's position.

Our experiment environment is located on the third floor, dept. of electrical engineering, National Formosa University. The map is shown in Fig. 5. The central area of this map is a courtyard on first floor. The yellow points indicate the training points. The distance of both training points is 3 meters.

In our experiment environment, we find six test points. The red point on Fig. 5 is one of the six test points. We randomly choose the points on the walkway on both sides. In our experiment, we analyzed the positioning accuracy of three methods on the red point. The first method is only use the Wi-Fi positioning algorithm; the second method is only use the Wi-Fi and neighboring weighted position system; the third method is use hybrid positioning technologies based on Wi-Fi and Bluetooth and neighboring weighted positioning algorithm. Every method was tested 20 times, and total results have 60 estimated position values.

First we only compare between the Wi-Fi positioning method and the Wi-Wi positioning with neighboring weighted position algorithm. Final, we compare the accuracy between the Wi-Wi positioning with neighboring weighted position algorithm and the hybrid positioning algorithm with Wi-Fi and Bluetooth.

A. The Compare of Positioning Algorithms

Figure 6 shows the average deviation and standard deviation and compares between method 1 and method 2. We can observe that the average deviation of the method 1 is 9.8675 meters. The average deviation of method 2 is 7.191 meters. Therefore, we can observe that the average deviation of the method 2 is lower than the method 1. The neighboring weighted positioning algorithm can improve the Wi-Fi fingerprint positioning method well.

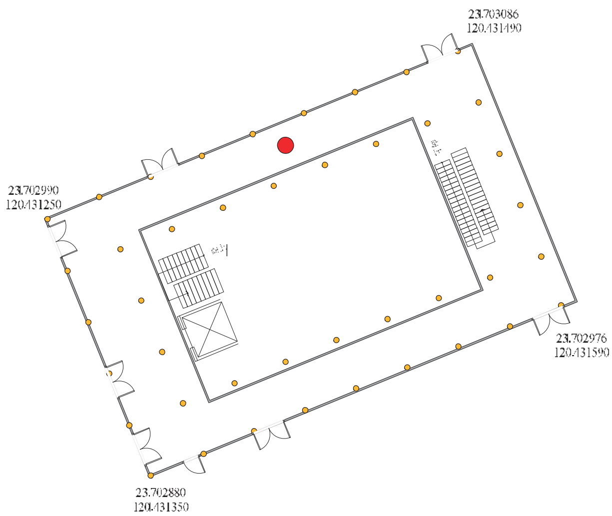


Fig. 5. The experiment environment.

B. The Compare of Hybrid Position algorithm

Actually, the accuracy of 7.191 meter may not be acceptable for some indoor navigation applications. Figure 7 shows the average deviation and standard deviation and compares between method 2 and method 3. We can observe that the average deviation of the method 2 is 7.191 meters. The average deviation of method 3 is 4.87 meters. Therefore, we can observe that our proposed hybrid position algorithm can improve the position accuracy effetely.

V. Conclusion

The paper proposed an indoor navigation system with hybrid positioning technologies based on Wi-Fi and Bluetooth for smart mobile devices that combine two wireless signal strength values that Wi-Fi RSSI as the main, Bluetooth RSSI as the minor.

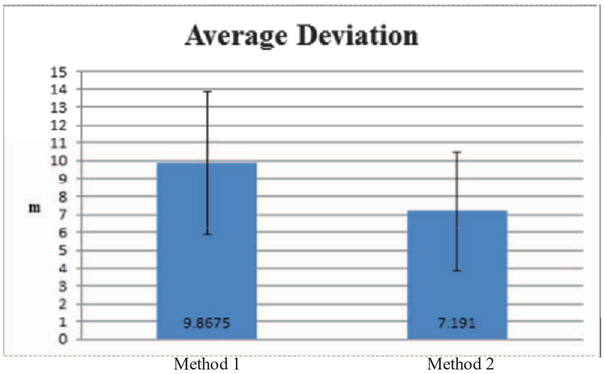


Fig. 6. The comparation between method one and method two.

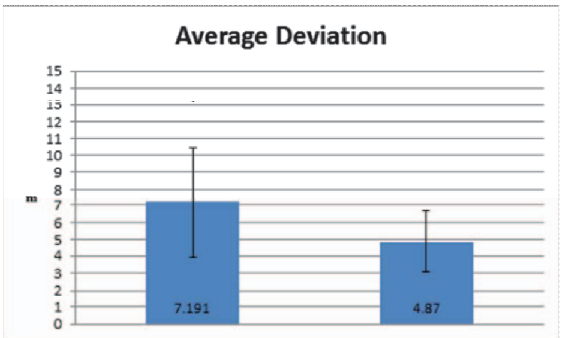


Fig. 7. The comparation between method two and method three.

The system divided into two parts: training learning phase and positioning computing phase. The training learning phase that created Database to store RSSI by using Administrator's smart mobile devices. The positioning computing phase that users use smart mobile devices search RSSI and use cloud computing to compare with RSSI database, and the computing result will transmission to users', the method reduced computation task on the devices. And the Positioning System average deviation are less 5m.

In the future the system will provide extra applications for indoor and outdoor navigation. We can design a system to connect with indoor and outdoor, such as: In the large area including indoor and outdoor, we can locate with GPS outside, when we are inside that locate with Wi-Fi and Bluetooth, and the system will be the smarter.

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