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User Position Detection In An Indoor Environment

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Abstract

Various techniques that employ Global Positioning System(GPS) signals such as A-GPS and GPS transmitters, have been introduced with the hope to provide a solution for indoor positioning detection. Indoor positioning system (IPS) is a term that is used for network devices used to wirelessly locate objects or people inside building. The study is based on the issue in order to determine the position of an object in indoor environment or inside a building. The problems arise when the position of an object inside a building cannot be determined using GPS. We proposed the implementation of trilateration technique to determine the position of users in indoor areas based on Wi-Fi signal strengths from access points (AP) within the indoor vicinity. In this paper, percentage of signal strengths obtained from Wi-Fi analyzer in a smartphone were converted into distance between users and each AP. A user's indoor position could then be determined using a formula proposed based on trilateration technique.

Keywords: *Global Positioning System, Indoor Positioning System, Wi-Fi, Trilateration Technique*

1. Introduction

Global Positioning System (GPS) is a technology developed by United States of Defense (DoD) that has been used for military purposes. It is also the main technology that plays an important role in satellite navigation. The main purpose of GPS is to determine the position or coordinate of an object based on location, time and speed [2, 6] which provide Location Based Services (LBS) [5, 6]. Nowadays, the technology has been used widely in outdoor environment such as in navigation and coordinate measurements. GPS depends on satellites to communicate using radio signals. Common example of GPS receivers such as GARMIN, NAVMAN and TOM TOM are capable to determine the accuracy of a position in the range of 10 meter. Optimum signal performance can be achieved outdoor but not in indoor environment. Multipath interference is a problem that exists in indoor environment which happens when transmitted signal from satellite is reflected due to barriers such as buildings or trees. Weak signal also affects the accuracy of the position [2, 3]. Wi-Fi Positioning concepts [4] are among the most famous solution. Weyn, Maarten, Schrooyen and Frederik used the combination of assisted global positioning system (A-GPS) and Wi-Fi positioning technique using Wireless Local Area Network (WLAN) to achieve the accurate coordinates in indoor environment [4], However A-GPS also have limitations in indoor environment [6] because of A-GPS is unable to decode data from satellites [3]. This paper proposes indoor position detection using Wi-Fi signal strength with trilateration technique.

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2. Related Works

Indoor GPS positioning system is a modular system used to track and locate persons or objects inside buildings. Nowadays, Indoor GPS plays an important role in various domain including consumer's applications, emergency services, machines or gadgets and for military purposes [1]. Referring to the Federal Communication Committee (FCC) and due to the requirements of Enhanced 911 (E911) system, GPS is now embedded into mobile phones which provide Location Based Services (LBS) [3, 4]. It is known as assisted GPS or A-GPS which is built to overcome the limitation of GPS. GPS is only good for outdoor environment activities and work poorly in indoor environment [2]. One of the limitations of indoor GPS is weak signal acquisition because GPS signal is weak inside buildings and cannot penetrate wall structures of buildings [2, 3] which affects performance in coordinate measurement or position detection.

On the other hand, finger printing is another alternative in position determination. It requires comparison of signals from current measurements with a pre-measured data in particular locations [5]. There are two phases in fingerprinting which is offline training phase and online estimation phase. Wi-Fi signal strength is an example of offline training phase in finger printing method. Another solution for position determination involves detection of proximity such as Radio-Frequency Identification (RFID) and Bluetooth technology. Most of the researchers try to apply mobile devices in their study. Research in Radio Frequency (RF) has attracted many researchers to do study on the position and location in indoor environment [12] and compares the capabilities and limitations of research work in different RFID based on four basic categories. For RF wireless Networks, [13] LEASE (Location Estimation Assisted by Stationary Emitters) consists of components and architecture system for location estimation techniques using stationary emitters (SEs) and Sniffers. Based on RFID concept, Daniel [8] have proposed new method using a Radial Basis Function Neural Network (RBFNN) and Localized Generalization Error (L-GEM). In Mobile Adhoc Network (MANET), devices can randomly move in any directions. Stationary nodes broadcast the hello massages signals and the node received the signal automatically determines the location position itself based on three signals received from 3 anchor nodes and run the Kernel AODV platform [9]. Woo *et al.*, [11] have done experiments at a shield tunnel construction site using the fingerprint method of Received Signal Strength Indication (RSSI) from each Access Point (AP). Most an implementation of indoor positioning system which does not concerned about the deployment of access points [AP] [16] has implemented APs deployment method optimally to increase Receive Signal Strength (RSS). The aim is to improve WLAN positioning accuracy in indoor environment. In developing the location-based services for WLAN users in indoor environment; [15] it took a number of issues related to accuracy of user position and factors affecting the characteristics of location fingerprint. Therefore, the findings of indoor geo-location system based on fingerprinting approaches are 5m accuracy and 95% of measurement. Using WLAN signal, [14] deployed position-determination model to get the location information in building. The result from the experiment at IBM China Research Laboratory indicate 2m accuracy in static devices while 5m accuracy in moving devices. Both cases show 90% probability. In a variety of method, [10] Pseudolite system is used as an alternative to find the solution of position location in indoor.

2.1 Trilateration Technique

The technique that is used in this research is trilateration technique. Trilateration technique is a mathematical process that is used by GPS receiver to calculate the position of an object in two dimensional or three dimensional spaces. The definition of trilateration in a geometry part

is the process of determining the absolute location or relative locations of point by measurements of distances, using geometry of circles, spheres or triangles. In this study, the measurement of distance is used in the geometry part to propose a method in indoor position. Then, the measurement of this distance is used to form three equations of a circle that will be solved using linear system of equation.

2.2 System Linear of Equation

In mathematics, the system linear of equation or also known as linear system is a collection of linear equations involving the same set of variables. A linear system in three variables determines a collection of planes. The intersection point is the solution that has been used to determine the intersection between 3 circles in the study. By solving the equations of three three-circle using a linear system, the coordinates of an object can be measured where the calculation of this linear system using the solution of simultaneous equations. Method of simultaneous equations can be solved by three ways, namely the deduction method, the method of addition and substitution methods.

3. Proposed Method

This paper proposes an indoor position detection using Wi-Fi signal strength and a formula to determine position of a user. Based on the concept of GPS, minimum of three access points (AP) are needed to determine the position of a user in an indoor location. The Wi-Fi signals are in the form of radio wave where the movements of the signals are highly dependent on the frequency. Signals with different diameters are transmitted by APs in all direction according to the respective signal strength. Since wireless routers provide coverage of about 100 feet (30.5 meters), signal strength is used to find the collision point in order to specify the accurate position of an object.

The standard protocol of Wi-Fi is 802.11 which was introduced by Institute of Electrical and Electronic Engineering (IEEE) and it is used in wireless LAN [7]. The standards come in several flavors which are 802.11a that transmits at 5 GHz and can move up to 54 megabits of data per second. On the other hand, 802.11b is the slowest and slightly less expensive and transmits in the 2.4 GHz frequency and can carry 11 megabits of data per second. Networking standard 802.11g also transmits at 2.4 GHz like 802.11b but it is much faster and theoretically can handle up to 54 megabits of data per second. 802.11n is the newest standard to improve speed and range. These kinds of protocol standards allow communication via internet through channels of communication medium that is available in Wi-Fi. There are 14 channels available in Wi-Fi where the use of each channel can be selected to avoid interferences in the wireless transmissions.

This study deploys Wi-Fi technique in conjunction with IEEE 802.11g networking standard. Here, we assume the three APs are known as AP_1, AP_2, and AP_3.

Assume that the coordinates of the three APs as Figure 1:

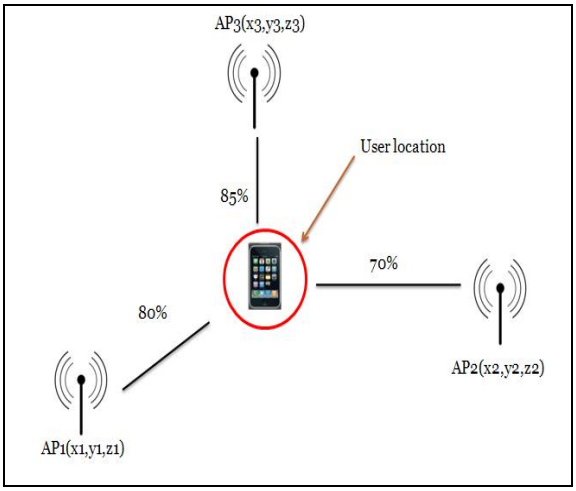

Figure 1. Illustration WiFi signal strenght from three access points

Based on three coordinates of the APs, the coordinate of the user's position that is represented as *Z* can be determined.

Let's assume that a user is using a smart phones that serves as a receiver of the signals transmitted from the access points. Application of Wi-Fi analyzer in the smart phone presents the signal strength in terms of percentage. The highest percentage of signal strength indicates that *Z* is closest to the AP whereas the lowest percentage implies that Z is maximum range of AP.

The percentage of signal strength obtained from the Wi-Fi analyzer can be converted to distance between a user's to each AP using this equation (Equation 1):

$$Distance,\ d_i = p\ (\ 1 - m_i\ ) \qquad (1)$$

Where;

m = is the percentage of signal strength

p = is the maximum coverage of signal strength

i = 1,2,3

From Figure 1, let each AP be placed at the center. Assume a scenario where a student who uses a smart phone, is looking for a book in a library. Then, we assuming that signal strength for each AP will spread the signal in wave forms. The signal strength will form 3 circles and intersect each other. The intersection of 3 circles is the position of user and we want to determine the location of user who is labeled by B (x, y). To simplify the calculations, the equations are formulated so intersection of circle is occurred at Cartesian plane (see Figure 2). The equation for any of these circle is as follow (assuming $z = 0$):

$$(x - x_i)^2 \quad (2) \quad y_i)^2 = r_i^2$$

The intersection of 3 circles is obtained by solving systems of linear equations for 2 variables simultaneously. The linear systems are solved in order to determine the coordinates *x* and *y*.

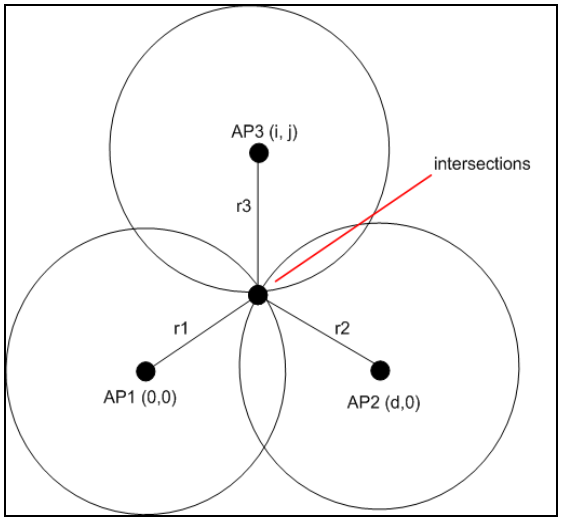

Figure 2. Intersections of 3 circles

Based on Figure 2, we start with the equations for three circles:

$$r_1^2 = x^2 + y^2 + z^2 \quad (3)$$

$$r_2^2 = (x-d)^2 + y^2 + z^2 \quad (4)$$

$$r_3^2 = (z-i)^2 + (y-j)^2 + z^2 \quad (5)$$

To determine the location of B, we have to solve for (*x*, *y*, *z*).

The method to do it is by using systems of linear equations for 2 variables and solve these eaquation of linear system $\tilde{A}\ x = b$. By using this method, the j^{th} constraints is used as a linearizing tool. Adding and subtracting x_j, y_j and z_j in (3), gives:

$$(x - x_j + x_j - x_i)^2 + (y - y_j + y_j - y_i)_+ (z - z_j + z_j - z_i)^2 = r_i^2 \quad (6)$$

With ($i = 1, 2, \ldots, j+1, \ldots, n$).

Linear system is easily written in matrix form $\tilde{A}x = b$,

With

$$A = \begin{bmatrix} x_2 - x_1 & y_2 - y_1 & z_2 - z_1 \\ \vdots & \ddots & \vdots \\ x_n - x_1 & y_n - y_1 & z_n - z_1 \end{bmatrix}$$

$$\vec{x} = \begin{bmatrix} x - x_1 \\ y - y_1 \\ z - z_1 \end{bmatrix}, \vec{b} = \begin{bmatrix} b_{21} \\ \vdots \\ b_{n1} \end{bmatrix} \quad (7)$$

Based on the calculation by using (7), the position of *B* is given by (*x*, *y*, *z*).

From the Figure 1, assuming that all 3 centers are in the fixed Cartesian plane and $z = 0$, the 3 coordinates respectively as follow, AP1 is at (4,4), AP2 is at (26, 10) and AP3 at (16,26) and B is the user unknown position at (*x*,*y*).

With the signal strength that received from the APs, the distance between each APs and the B can be calculate as follow.

Lets consider, the maximun range of these APs is 30 meter. Then, from (1), we get the distance between center of each AP and B as follow:

$$d_1 = 30\ (\ 1 - 0.8) \quad = 6m$$
$$d_2 = 30\ (\ 1 - 0.7) \quad = 9m$$
$$d_3 = 30\ (\ 1 - 0.85) = 4.5m$$

Then, 3 lines are formed from the 3 circles. Then, construct the new equation by using the 3 lines. The equations are as follow:

$$AP_1: (x - 4)^2 + (y - 4)^2 = 6^2$$
$$AP_2: (x - 26)^2 + (y - 10)^2 = 9^2$$
$$AP_3: (x - 16)^2 + (y - 26)^2 = 4.5^2$$

A linear system in 2 variables determines a collection of planes. The intersection point is the solution. By solving this equation using systems of linear equation of 2 variables, we get a solution for the systems as:

$$x = 11.97$$
$$y = 14.31$$

Thus, the position of user labeled as *B* in the Cartesian plane is (11.97, 14.31). To determine the exact location in reality, where is the exact location with coordinates (11.97, 14.31) in the library, we have to perform a simulation showing the exact Cartesian planes on library.

4. Simulation and Evaluation

The prototypes systems are developed and simulations were done to measure the accuracy of user in an indoor environment.

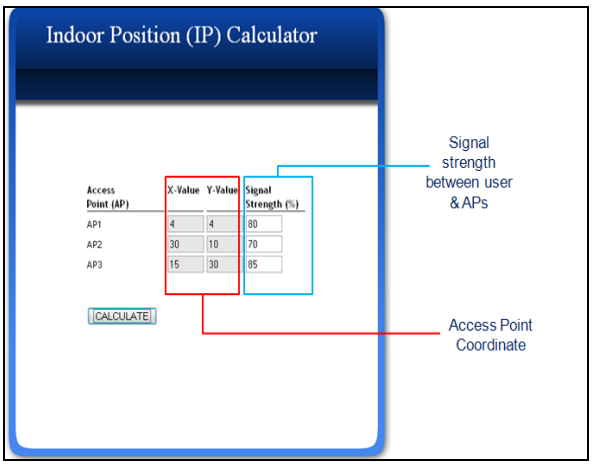

Figure 3. Three access point coordinate

Figure 3 shows three access points used in our simulation. In the study, assuming that the three access point coordinate as follows :

Access Point 1 (AP1) = (4,4),
Access Point 2 (AP2) = (30,10),
Access Point 1 (AP3) = (15,30)

The access points are located at a fix position. There are three input field of signal strength that user received from each access points. The data of the signal strength is required by this system in order to calculate the user location in indoor environment.

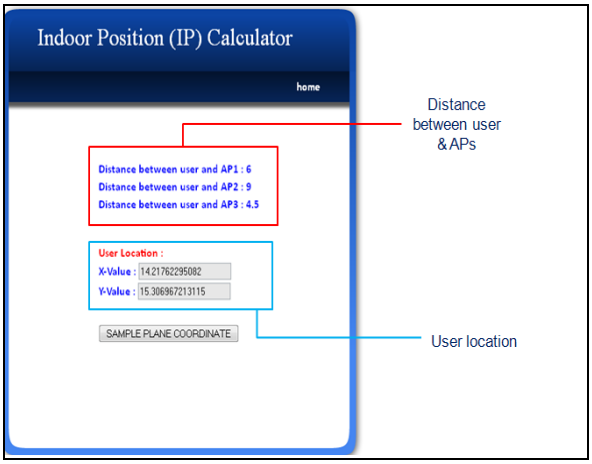

Figure 4. Result of user location

Figure 4 will show the result of user location from the data in Figure 1. Using the proposed method and trilateration technique, the distance between user and each access point can be determined and the user location in indoor environment is calculated. Based on the given examples, the coordinate of the user is as the figure above.

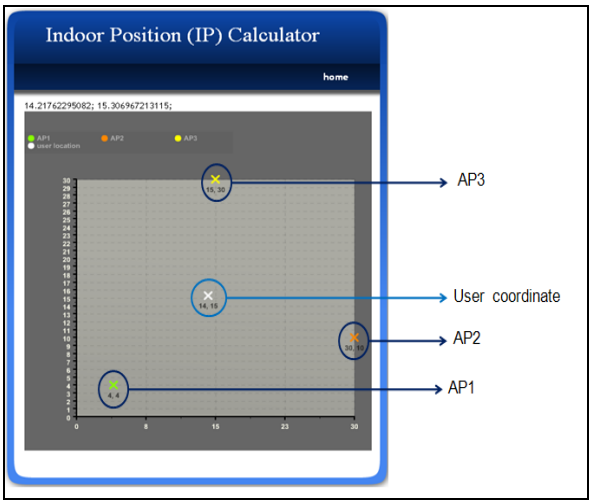

Figure 5. User location in a Cartesian plane

Figure 5 shows the graph plane coordinate of user location in a cartesian plane. The graph displays the coordinate of three access point which is labelled by ' X ' sign. The green sign represents AP1, orange sign represents AP2 and yellow sign represents AP3. The sign of user location is represent by white sign.

5. Conclusion and Future Works

This paper proposed a method to calculate the location of a user in indoor area using Wi-Fi signal strength with IEEE 802.11g networking standard based on trilateration technique. The proposed method serves as a preliminary step that could be integrated in future work where it is envisaged that the method can be applied by taking into account transmission barriers such as walls or blocks of large items.

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