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A Review of Friis Equation Based Indoor Positioning

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Abstract. Wireless Local Area Network (WLAN) based Indoor positioning does not require any special equipments dedicated for positioning only and it is economical. WLAN based indoor positioning techniques can be classified into fingerprinting methods or friis equation based methods. Fingerprinting methods are pretty accurate but collecting fingerprints takes a long time. Friis equation based methods require exact coordinates of access points (AP) and easy to implement. Therefore, this paper reviews friis equation based indoor positioning techniques.

Keywords: Indoor Positioning; Trilateration; WLAN; Access Point; RSSI.

1 Introduction

Location based services (LBS) are information services accessible with mobile devices through the mobile network and utilizing the ability to make use of the location of the mobile device [1]. LBS services include identifying a location of a person or object, parcel tracking, vehicle tracking, mobile commerce, weather service, game, traffic advisories, and so on. Since these LBS services are so helpful to people's daily life, so many scientists and engineers are developing new technologies and applications of LBS every day.

Since LBS cannot be realized unless the location of the mobile device is identified, positioning is one of the essential techniques in LBS development. For outdoor LBS, Global Positioning System (GPS) provides general solution for positioning. However, GPS signal is so weak indoor or underground that we cannot determine user's location with GPS alone. Consequently, techniques for indoor positioning have been studied by many researchers. Active Badge, Active Bat and Cricket are pioneers of indoor positioning. These systems are highly accurate. But they require special equipments dedicated for positioning [2].

Many indoor positioning systems which do not require special equipments have also been developed. Most of them utilize WLAN (Wireless Local Area Network) equipments. Nowadays, WLAN is being serviced everywhere including college campuses, airports, hotels and even homes [2]. There are many alternative techniques we can choose in implementing WLAN based indoor positioning. Among them, the trilateration is one of the most economic and easiest one to be installed.

The trilateration estimates the distance between an access point (AP) and a mobile device with the radio frequency (RF) propagation loss model which is a simple

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mathematical expression representing the relationship between the received signal strength (RSS) and the distance between the sender and the receiver. Then, it estimates the location of the mobile device with the estimated distances and the coordinates of the APs. That is, in order for the trilateration to be applied, the coordinates of the APs must be available. Therefore, one of the main purposes of this paper is to propose a repository of floor maps and coordinates of points of interest (POI) including APs so that any software developer can use them after getting authorization.

RSS is influenced by so many environmental parameters and establishing an appropriate RF propagation loss model is very difficult. As the result, one of the drawbacks of the trilateration is that it is less accurate than other methods and it sometimes returns an inordinately wrong answer. Therefore, we investigate the pros and cons of various modified versions of trilateration and propose our own solution for indoor positioning.

2 Trilateration

If we measure N ranges, $r_1, r_2, ..., r_N$ from N base stations, $n_1 = (X_1 Y_1 Z_1)^T, ..., n_N = (X_N Y_N Z_N)^T$ to a mobile terminal, $m = (x\, y\, z)^T$ as shown in Figure 1, then we can estimate the coordinates of m by using trilateration. By squaring, we can obtain the following expression for r_i^2:

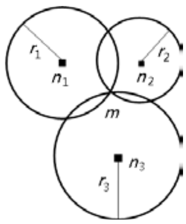

Fig.1. A diagram to illustrate trilateration.

$$(x - X_i)^2 + (y - Y_i)^2 + (z - Z_i)^2 = r_i^2, \, (\, for\ i = 1, 2, ..., N)$$

By subtracting r_1^2 from $r_i^2 (i = 2, ..., N)$, we have $A\vec{x} = \vec{b}$, where,

$$A = 2\begin{bmatrix} (X_2 - X_1) & (Y_2 - Y_1) & (Z_2 - Z_1) \\ \vdots & \vdots & \vdots \\ (X_N - X_1) & (Y_N - Y_1) & (Z_N - Z_1) \end{bmatrix} \qquad \vec{x} = \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

$$\vec{b} = \begin{bmatrix} (X_2^2 - X_1^2) + (Y_2^2 - Y_1^2) + (Z_2^2 - Z_1^2) - (r_2^2 - r_1^2) \\ \vdots \\ (X_N^2 - X_1^2) + (Y_N^2 - Y_1^2) + (Z_N^2 - Z_1^2) - (r_N^2 - r_1^2) \end{bmatrix}$$

When the coordinates are 3 dimensional, we need to have at least 4 base stations. Applying the MMSE (Minimum Mean Square Error) method, we can estimate the location of m, $\hat{\vec{x}}$ with the following position estimates [3]:

$$\hat{\vec{x}} = (A^T A)^{-1} A^T \vec{b}$$

3 Kalman filter

The author of [4] proposed a new algorithm which is very similar to the Kalman filter process. It is described as follows:

$$\Delta = (B^T B)^{-1} B^T F = \begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix}$$, where

$$B = \begin{bmatrix} \frac{(x_1 - x_e)}{\sqrt{(x_1 - x_e)^2 + (y_1 - y_e)^2}} & \frac{(y_1 - y_e)}{\sqrt{(x_1 - x_e)^2 + (y_1 - y_e)^2}} \\ \cdots & \cdots \\ \frac{(x_i - x_e)}{\sqrt{(x_i - x_e)^2 + (y_i - y_e)^2}} & \frac{(y_i - y_e)}{\sqrt{(x_i - x_e)^2 + (y_i - y_e)^2}} \end{bmatrix}$$ and

$$F = -\begin{bmatrix} d_1 - \sqrt{(x_1 - x_e)^2 + (y_1 - y_e)^2} \\ \cdots \\ d_i - \sqrt{(x_i - x_e)^2 + (y_i - y_e)^2} \end{bmatrix}$$

where, (x_i, y_i) is AP_i's coordinates and (x_e, y_e) is the current location of the mobile device. We can initialize (x_e, y_e) with any value. With Δ, we update the mobile user's position (x_e, y_e) as follows:

$$x_e = x_e + \Delta x,\ y_e = y_e + \Delta y$$

4 Weighted Centroid Localization

In [5], Weighted Centroid Localization (WCL) is described. WCL belongs to the category of coarse grained approaches. Considering Figure 1, WCL estimates the coordinates of m as follows:

$$\hat{x} = \frac{\sum_{i=1}^{N} \frac{x_i}{r^i}}{\sum_{i=1}^{N} \frac{1}{r^i}} \qquad \hat{y} = \frac{\sum_{i=1}^{N} \frac{y_i}{r^i}}{\sum_{i=1}^{N} \frac{1}{r^i}}$$

5 Conclusion

The friis equation based indoor positioning in WLAN environment is one of the most economic and easiest to implement indoor positioning methods. Therefore, we reviewed existing friis equation based indoor positioning techniques.

The trilateration suffers from the noise sensitiveness of RF signal and relatively inaccurate. Sometimes, the coordinates returned by the trilateration are inordinately wrong. After discussing the pros and cons of various versions of trilateration, we can propose our own indoor positioning process based on them. With the new indoor positioning method, we are planning to build up a practical indoor location based service in the near future.

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