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Research of Positioning Technique Based on Wireless LAN

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Abstract. Along with the development of mobile communications and wireless network technology, positioning services are more and more important and have become the focus of research. The most common technology which supports outdoor positioning services is global positioning system (GPS). But GPS has been subjected to some restrictions in complex environments, while WLAN (Wireless Local Area Networks) has matured gradually in recent years, so positioning technique based on WLAN can assist GPS. In this paper, we describe two positioning techniques based on WLAN: triangulation and fingerprinting. Then the experiment for positioning is presented. Finally, we discuss the differences between those two WLAN positioning method, we find that fingerprinting has higher accuracy than triangulation, but more complex.

Keywords: WLAN, Positioning, Triangulation, Fingerprinting

1. Introduction

Location positioning is more and more important in many application services. The maturity of application services and enormous governmental support has driven the rapid advancement of navigation industry.

In addition, GPS (Global Positioning System) has been widely applied around the world in these years. GPS [1] is a satellite positioning system developed by the U.S. government. It uses 24 satellites orbiting around the earth to broadcast radio frequency satellite signals. When GPS receiver on the ground receives signals from a minimum of 3 visible satellites, it uses the satellite electronic clock as the data to calculate the distance between the satellite and GPS receiver, in order to estimate the coordinates of the mobile terminal by triangulation technique. But the GPS signal may be interfered withed with obstructions and delayed by multi-path easily, and the GPS receiver must receive signals from a minimum of 3 visible satellites. So in the dense city zone, or indoor environment, GPS system is not reliable. Because of these issues, other positioning techniques need to be used to assist positioning.

Wi-Fi based on the IEEE 802.11 standards, is by far the most widespread WLAN class today. The APs (Access Point) of the wireless network have been set up in many places. Compared with GPS, Wi-Fi allows the deployment of WLAN without wires for client devices, typically reducing the cost of network deployment and expansion. Wi-Fi signal is not easily interfered by the climate and NLOS (Non Light of Sight), it can apply in the dense city zone or other complex environments.

There are two main options for WLAN positioning: triangulation and fingerprinting. Triangulation involves mapping signal strength as a function of distance while fingerprinting creates a database of signal strengths at a given area and find the closest match to predict a location by RSS from user.

2. Triangulation

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First, collect the signal strength from three APs at positioning location， and calculate distance between positioning location to each AP by Log-distance path loss model. Then, the positioning location is estimated by triangulation algorithms [2].

2.1. Log-distance path loss model

Because signal strength will lost with increasing of the transmit distance. Log-distance path loss model is described as:

$$P_r(d) = P_t - P_L(d) \quad (1)$$

In this format, P_r (d) [dBm] is signal strength of receiver. P_t [dBm] is the signal strength of transmitter. d is the distance from transmitter to receiver, which is the distance between AP and user. P_L(d) [dB] is the path loss of signal strength between transmitter and receiver. P_L (d)[dB] can be written as:

$$P_L(d)=P_L(d_0)+ 10n\log(d/d_0)+ X_g \quad (2)$$

In this format, X_g is random variable which has Gaussian distribution with standard deviation and zero mean. n is the rate of path loss increases with distance. d_0 is the distance of a "close-in" point, usually 1m. The values of n depend on the building layout and construction material, they are derived empirically. $P_L(d_0)$[dB] indicates the path loss of signal strength between transmitter and reference point.

$$\mathrm{P_L}(\mathrm{d_0}) = -10\log\left[\frac{G_t G_r \lambda^2}{(4\pi)^2 d_0^{\,2}}\right] \quad (3)$$

G_t is the antenna gain of transmitter, it usually equals 1, G_r is the antenna gain of receiver, it usually equals 1, λ is signal wavelength of transmitter, and frequency band of Wi-Fi signal is 2.4 GHz.

2.2. Triangulation positioning algorithms

Distances between positioning location and AP_1,AP_2,AP_3 are written as (d_1,d_2,d_3), then three intersecting circles with radius of (d_1,d_2,d_3) are constructed, the centre of circles are the locations of three APs, the intersection of these circles will be the positioning location(X,Y). The condition illustrates in Fig. 1. (a).

Positioning Equation can be written as:

$$(X-x_i)^2+(Y-y_i)^2=d_i^2, i=1,2,3. \quad (4)$$

In this format, (x_i, y_i) indicates the coordinate of i^{th} AP, (X,Y) indicates coordinate of positioning location .

Because the actual environment is complex, calculated distance always not exactly equal to real distance between AP and positioning location. So these intersecting circle cannot intersect to one single point (Fig.1. (b)).So this approach is not viable. Enhance approach is used usually. Enhance approach is triangulation centroid algorithm.

The idea of the algorithm is calculating the coordinates of intersection of three circles. There are 6 points of intersection, marked A_1, A_2, B_1, B_2, C_1, C_2. $A_1(x_{a1},y_{a1})$, $A_2(x_{a2},y_{a2})$ is the intersection of circle AP_1 and AP_2. $B_1(x_{b1},y_{b1})$,$B_2(x_{b2},y_{b2})$ is the intersection of circle AP_1 and AP_3.$C_1(x_{c1},y_{c1})$,$C_2(x_{c2},y_{c2})$ is the intersection of circle AP_2 and AP_3.Then calculate the distance between A_1,A_2 and AP1,pick the point of smaller distance. Similarly, get B_1 and C_1.Then calculate the centroid of triangle (A_1,B_1,C_1).The coordinates of estimated positioning location is (X,Y).

$$(X,Y)=\left(\frac{x_{a1}+x_{a2}+x_{a3}}{3},\frac{y_{a1},y_{a2},y_{a3}}{3}\right) \quad (5)$$

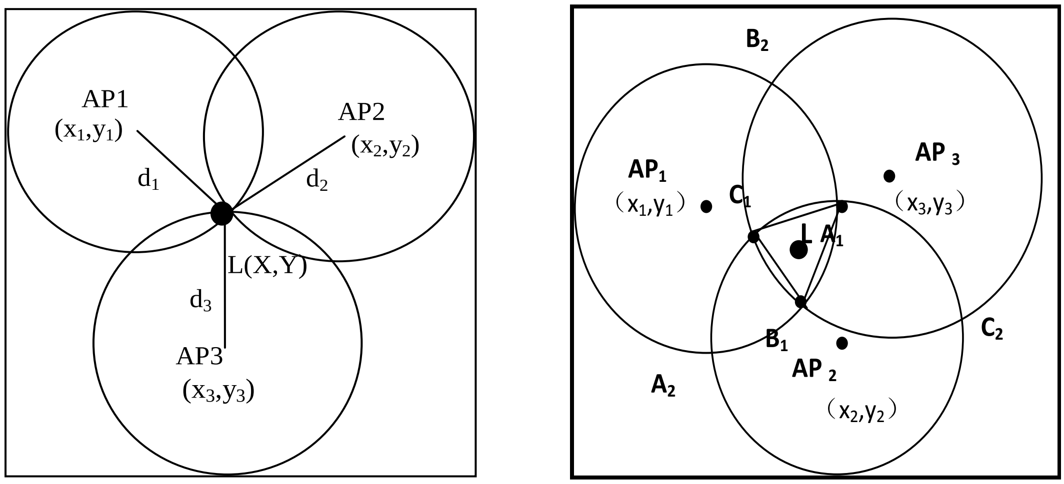

Fig. 1. (a) Triangulation positioning algorithms; (b) Triangulation centroid algorithms

3. Fingerprinting

Fingerprinting positioning has two phases: off-line phase, a location fingerprint database should be constructed in this phase. RSS (Received Signal Strength) form each AP in positioning location should be collected. Each entry in the database is a mapping between a grid and a location fingerprint. The location fingerprint can be N average value of RSS from N APs; Real-time positioning phase, live RSS values are then compared with the location fingerprint recorded in database to find the closest match and generate a predicted location. The whole process is illustrated in Fig. 2.

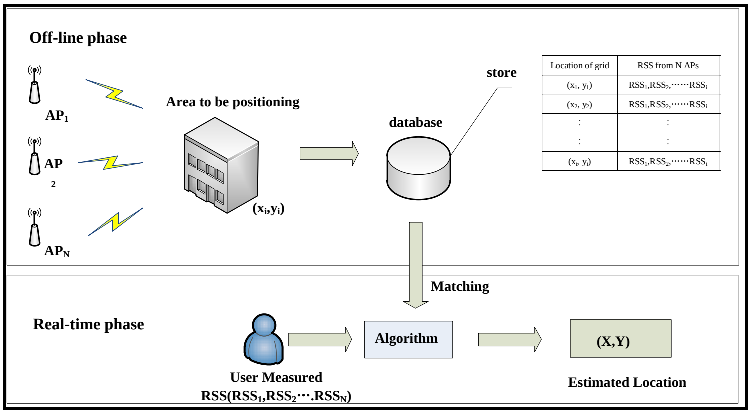

Fig. 2. Principle of fingerprinting positioning

3.1. Off-line phase

Off-line phase is the training phase. A location fingerprint database must be constructed. First, divide the targeted positioning area into grids, usually the grid is 1m*1m. The coordinate of each grid regarded as reference point .Then, at each reference point, signal strength data is collected. Each reference point corresponds to a vector R. A typical $R = (r_1, r_2, \cdots, r_N)$ consists of RSS values from N APs. The database contains RSS vectors for each grid in the positioning area, the coordinate of grid, AP information like SSID and MAC. Different APs can be distinguished by the AP MAC. There are a couple of alternative approaches to construct database.

- The first is the empirical model. We collect average RSS value from different APs. Because the value of RSS is unstable, many RSS samples in each grid should be collected to get the average value. To achieve a good estimation of user location, the more samples obtained at each point the better. It is a significant task in terms of labor and time. So in the large area, this approach is not a viable option.
- The second approach is deterministic model. A model of accounts for RSS loss should be developed. RSS is lost with increasing of distance and influenced by walls and doors in the indoor environment. RADAR model usually be used in the indoor environment. RADAR system is proposed by Bahl, P and Padmanabhan,V.N.[3].It provides flexibility in accommodating wall attenuation factor whiling taking into

account large-scale path loss. The model is described as (6).

$$P(d)[dBm] = P(d_0)[dBm] - 10n\log\left(\frac{d}{d_0}\right) - \begin{cases} nW \times WAF & nW < C \\ C \times WAF & nW \geq C \end{cases} \quad (6)$$

In this format, n is the rate of path loss increases with distance, $P(d_o)$[dBm] indicates the signal power at some reference distance. d is the distance from transmitter to receiver, that is the distance between AP and user location, d_o is the distance from reference point to AP. C is the maximum number of obstructions (walls) up to which the attenuation factor makes a difference, nW is the number of obstructions (walls) between AP and user location, WAF is the wall attenuation factor. The values of n and WAF depend on the building layout and construction material, they are derived empirically. The value of $P(d_o)$ [dBm] can be derived empirically, or obtained from wireless network hardware specifications.

3.2. On-line phase

On-line phase is the location determination phase. In this phase, user observed a sample RSS vector $S(s_1,s_2,\ldots,s_N)$, S consists of user observed RSS values from N APs, then S should be matched in database. The location with best match of RSS in database should be the estimated location.

Many algorithms can be used for finding the best match of RSS. The basic one is Nearest Neighbor in Signal Space (NNSS). The idea is to compute the Euclidean distance between the observed vector $S(s_1,s_2,\ldots,s_N)$ from user and the recorded $R = (r_1,r_2,\cdots,r_N)$ in database, calculate the Euclidean distance between each R in database and S.

$$L = \min dis(S,R), dis(S,R) = \sqrt{\sum_{j=1}^{N}\left(s_j - r_j\right)^2} \quad (7)$$

Where s_j is signal strength observed by user form jth AP, r_j is signal strength recorded in database, j=1… N. L is the minimum Euclidean distance between each R in database and S. The smallest Euclidean distance between R and S mean the smallest distance between user current position and reference point recorded in database.

So the estimated location is the location corresponding to the smallest RSS Euclidean distance which is recorded in database.

4. Experiment

In order to examine the performance of those two approaches, we do experiment in practice. Then measure errors of the calculated locations and compare those two approaches.

4.1. Experiment environment

We launched experiment with the indoor data set. The map is shown in Fig.4. We choose 701,702,703,704 for experiment. The dimension of the four rooms is 24.5 m∗13.4 m and 328.3 m2, it includes one corridor and some walls and doors, and the thickness of the wall is 0.25 meter.

We placed 3 APs to make sure every location in those rooms can be covered by Wi-Fi signals from 3 APs, AP_1, AP_2 and AP_3 at the locations is indicated in Fig.3. The model number of AP is DWL-2000AP+A. All APs are on the table 80 cm above the ground. We adopted a Samsung R467 laptop as the mobile node, with Microsoft Windows XP operating system. We collected 30 samples of realistic RSS data in 30 locations for testing.

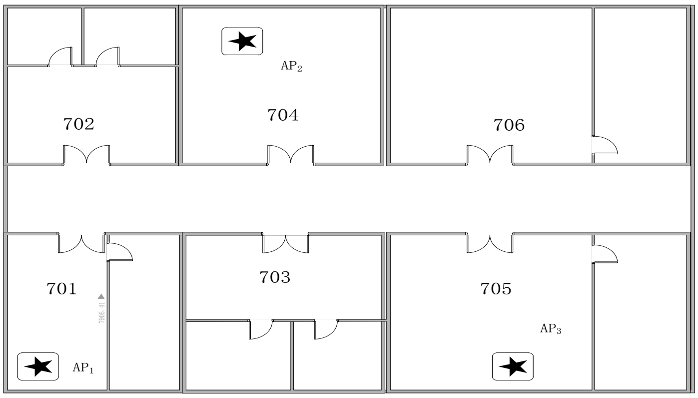

Fig. 1. Map of the lab where the experiments were conducted

4.2. Experiment result

Triangulation algorithm: We evaluated the distances of test points to each AP by RSS measured, and then computed the location of test points by triangulation algorithm. The error of evaluated location listed in Table 1.

Fingerprint positioning: First we divide the area to 329 grids by 1m∗1m as reference points. Then, we determine the values of n and WAF in model (6). We measure the actual RSS at some location in room and 1m away from AP while known number of walls between the receiver and transmitter. Base on measurement, we choose WAF to be 9 dBm and n to be 2.5, and we substituted those parameters in model (6). We used the model (6) to compute the signal strength at each grid. The database of RSS distribution will be constructed by calculated RSS value. The error of evaluated location listed in Table 1.

Table1.Error for each method

Positioning method	Min Error (m)	Mean Error (m)	Max Error (m)
Triangulation	0.9	2.33	6.8
Fingerprinting	0.3	1.97	5.23

Compare with those two positioning approaches. We conclude that:

- The accuracy of triangulation algorithm is lower than fingerprinting. The average error of triangulation is 2.33 meter, compared to 1.97 meter for fingerprinting.
- There must be 3 APs when using triangulation algorithm while there is no quantitative restriction of AP in fingerprinting.
- There are two steps in fingerprinting. RSS database should be constructed before positioning while triangulation doesn't need to construct database. In positioning phase, database should be traversal in fingerprinting. So fingerprinting is more complexity than triangulation algorithm.

5. Conclusion

In this paper, we described two WLAN positioning: triangulation and fingerprinting, and then both algorithms have been evaluated in experiment. From experiment, we can find that the accuracy of positioning application using Wi-Fi signal is higher than using only GPS signal. Wi-Fi can assist GPS in positioning application for higher accuracy, and it can apply in indoor, outdoor and other complex environments. After those two techniques based on WLAN have been compared, the features of triangulation and fingerprinting have been concluded. User can choose suitable approach in different environments. Triangulation can apply to applications required lower accuracy and has three APs in positioning area. Fingerprinting applies to application which requires high accuracy. Accuracy and positioning time should be weighted when alternative.

Therefore, more work still need to do. The effect of user's orientation is significant and the user's orientation should be considered in future study.

6. Acknowledgements

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