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Research on Indoor Positioning System Based on the Application Weighted Screening Method

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Abstract: The research on the indoor positioning system based on WiFi signal in the past was mainly divided into three methods: Proximity positioning method, trilateration positioning method and scene analysis positioning method. Aiming at the trilateration positioning method, the weighted screening method based on WiFi signal is proposed to improve the displacement error caused by the trilateration positioning method. Compared with the traditional trilateration positioning method and the Error Correction Algorithm (ECA), the experimental data shows that the method has a better efficiency.

Key words: Weighted screening method, error correction algorithm,trilateration positioning method

INTRODUCTION

As there are many variables in the wireless indoor positioning system, such as the building's complex structure, the influence of indoor crowd, the scalability and the stability of using the transmitter, the sensibility of using the positioning instrument, the current indoor system is difficult to have the comprehensive solution technology. Therefore, the concerned system efficiency can be divided into the following 6 directions to analyze:

- **Accuracy:** Accuracy is the gap size between the actual observed point and the estimation point., that is, the system's estimation error. The common counting method is that the estimation error should be averaged. The system positioning efficiency is mainly based on accuracy in the indoor positioning system
- **Precision:** Precision is the gap size among the estimation points. The Cumulative Distribution Function (CDF) can be used to count the advantages and disadvantages of the precision. If the distribution curve is more concentrated, the accuracy is higher. The main effect of precision is the stability of the transmitter and whether the system positioning algorithm has advantages or not
- **Complexity:** Complexity is the counting time in the positioning algorithm, namely, the immediately aggressing speed. If the complexity is lower, the location rate is faster
- **Robustness:** The good system robustness still can make the positioning efficiency normal operate in the certain precision during the positioning process, even if one of the transmitter is abnormal or can not be received
- **Scalability:** Scalability supported by the positioning system includes the range of the signal cover, the serving range in the geography and the positioning in the 2D/3D space
- **construction cost:** System construction cost includes the consumed time, the consumed money, the consumed power, the hardware's occupied volume and weight

The above aspects ate the design core of the indoor positioning system. At present, the common indoor positioning method is to adopt many kinds of different wireless transmitting technology, such as WiFi (Chen and Luo, 2007; Zaniani and Azid, 2010; Lashkari *et al*., 2010; Slain *et al*., 2010; Bahl and Padmanabhan, 2000), Bluetooth (Kotanen *et al*., 2003), Infrared ray (Want *et al*., 1992), RFID (Radio Frequency IDentification) (Ni *et al*., 2004), Cell-ID base signal (Swedberg, 1999), ultrasound detector (Priyantha *et al*., 2000), image recognition (Krumm *et al*., 2000) and laser (Barber *et al*., 2002). In these technologies, RFID (Ni *et al*., 2004) and laser (Barber *et al*., 2002)'s extra equipment is very expensive and the scalability of the Bluetooth is so small that a large number of the Bluetooth transmitter should be established to cover the indoor environment. Image recognition depends on higher real-time operation speed and establishes the comparison data base in the image node. Although Cell-ID possesses the broad signal coverage and the instrument population, the signal strength in the complex indoor environment is not the relation of the inverse square with the distance. Therefore, it is difficult to achieve in the indoor positioning.

WiFi signal has become the main wireless technology in the indoor positioning system under the consideration of the acceptable precision and the instrument population.

There are two advantages by applying the WiFi in the indoor positioning system. Firstly, the hardware in the wireless network have reached to the ready-to-use population without being changed and installed again; Secondly, the mobile appliances with the WiFi online function which supports IEEE 802.11 is becoming popularized, such as laptop and Smartphone.

The positioning method based on WiFi at present is divided into three principles: Proximity Positioning Method, Trilateration Positioning Method and Scene Analysis Positioning Method. Proximity Positioning Method adopts the strongest AP (Access point)'s Received Signal strength Indication as the system's estimation point position. The method is relatively pure. Although the positioning speed tate is fast, the precision is low compared with other methods. Generally speaking, the positioning error is related to the established density of AP.

Trilateration Positioning Method adopts more than three AP and then uses the received signal time difference or the received signal strength to count the distance. Finally, the users' position can be estimated. The common factors include TOA (Time of Arrival), TDOA (Time Difference of Arrival), AOA (Angle of Arrival) and RSSI (Received Signal Strength Indicator). TOA (Time of Arrival) and TDOA (Time Difference of Arrival) adopt the speed and the total time transmitted by the radio wave in the space or the product of the time difference to count the distance between the transmitter and the observation point. The disadvantage is that all AP are needed to be as time synchronization and the time error can cause the enormous distance error. The collision caused in a large number of users' online also leads to the time error (Llombart *et al*., 2008). Therefore, the method is applied in the CDMA-based system.

Angle of Arrival (AOA) adopts many signal angles with different potations to measure user's position. The special antenna device should be installed in the general mobile appliances. At present, there is only RSSI method can be used in the WiFi system for the attenuation model access to the wireless can be adopted to count the distance from the observation point to AP. The influence of multi-path routing caused by the wireless signal can add many difficulties for the highly precision positioning with the Trilateration Positioning Method and can not abstain the acceptable accuracy and precision.

The environmental analysis is divided into two stages. The system can sample the signal data during the off-line. The system compares the on-line received signal by the observation point with the off-line sampling data point. The advantage of the method is to reduce the multi-path routing problem and the sampling density of the method directly affects the positioning precision. Therefore, the system should consume much time to conduct the high density sampling to the indoor environment.

The paper proposes Weighted Screening Method based on Trilateration Positioning Method of the WiFi signal to improve the error between the position caused in the Trilateration Positioning Method and the actual position. The Two chapter introduces the detail algorithm contents of the Trilateration Positioning Method. The Three chapter explains the experimental results. The last chapter presents thee conclusion.

TRILATERATION POSITIONING METHOD

Trilateration positioning method is to count the observation point position which is counted by distance between the three known reference point positions and the observation points. The basic concept is as shown in the Fig. 1 and applied in the globle positioning system at the earliest. In the positioning theory, the distance between the transmitter and the observation point is used the transmitter as the center and then the sphere can be painted. The sphere is the Pseudo-range equivalent to a certain transmitter's signal strength and the observation point is a certain point on the sphere. When two spheres are intersected in the three condensation space, the intersect point is over one point, the intersect is a circle. If the intersect between the third sphere and a circle is not less than two points, the forth sphere can make sure that one of the points is the observation point, such as GPA's Trilateration Positioning Method application. In the same way, if the pseudo-range in the two dimensional space, the intersect points between two circles are not less than two points, the third can make sure that one of the points is the observation point.

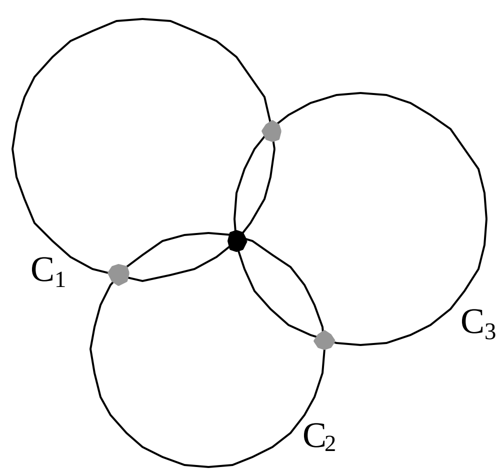

Fig. 1: Trilateration

The distance between the observation point and the reference point can be derived from using the signal's attenuation model in trilateration positioning method. The backstopping distance error and the positional relations among the reference points can affect the positioning precision. Dilution of precision (DOP) can count the number of the precision influenced by the reference point position, as shown in the Fig. 2. Han *et al*. (2007) proposes reference node selection algorithm based on trilateration which can select the three reference points connecting a triangle and then reduces TDOP values.

Chen and Luo (2007) and Lashkari *et al*. (2010) adopts the correction number of OAF in the radio wave transmission model and then converts RSSI into the error value caused by reducing the interference of the undoor building walls, floors or other shelters, as shown in the following formula. The researching result shows that the positioning error values is remarkably declined.

$$P(d) = P(d_a) - 10\log(\frac{a}{d_0})^n - OAF \quad (1)$$

where, P(d) is the signal strength through transmitting to the d position. $P(d_0)$ is the signal strength through transmitting to the a position. The distance is defined as the reference distance, the signal strength can be measured and recorded in advance.

$$10\log(\frac{a}{d_0})^n$$

is the attenuation facto. OAF is the obstacle influence factor, which includes all multi-path routing influences calused by the obstacles. These obstacles include walls, compartments and other things. The important problem is that how to count the OAF in the module. The method needs to add the position accuracy aiming at the OAF values to each positioning space and the slightly different environmental alteration. For example, the positioning precision in the corner has large variations.

Moradi and other people (Slain *et al*., 2010) propose error correction algorithm, ECA. The maximum of offset error is derived from Trilateration matrix and then put the error into the radius variations of the three circles so that the observation point can be approximated and the distance can be counted. The situation of the circle in ECA can be divided into 4 kinds, as shown in the Fig. 3; (1) Three circles are intersected but there is no intersect point, (2) One of the circle is intersected with other two circles but the two circles are disjoint, (3) Any two circles are intersected; the third circle's radius is too small or too large to make it disjoint with other two circles and (4) The three circles are inside disjoint or outside disjoint. In the first situation, ECA gets the most approximating three intersect points and then counts the coordinate's average. In the second situation, ECA gets the most approximating two intersect points and then regards one f the intersect points as the estimation point position. In the third situation, ECA make the relative smaller third circle's radius add ∂/ 2 or make the relative larger third circle's radius reduce ∂/ 2 and then draw the circle again for checking whether the situation is accorded with the situation 1. If not, amplify or reduce the remaining two circles with the inverse directions. When the procedures are finished, the situation 1 is not be reached, the situation has beyond ECA positing system which can offer the precision. Therefore, counting the estimation point position has no reference value. In the situation 4, ∂/3 will be added or reduced and then draw the circle again for counting the correspond coordinate and extract the three intersect points as the average.

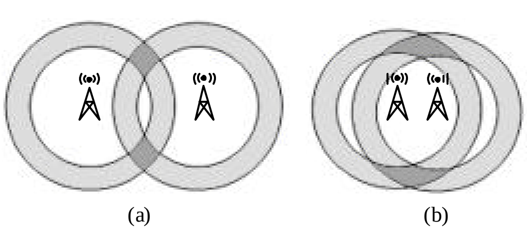

Fig. 2(a-b): DOP diagram (a) is superior to (b) and DOP is relatively low

WSN

The distance between the observation point and the transmitter is mentioned in the GPS and CDMA

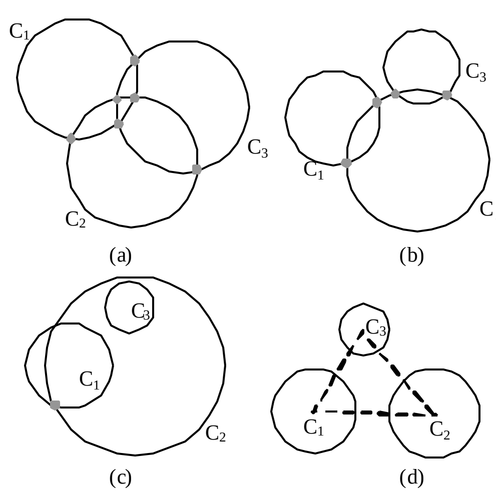

Fig. 3: The four kinds of the three circles situation proposed in ECA

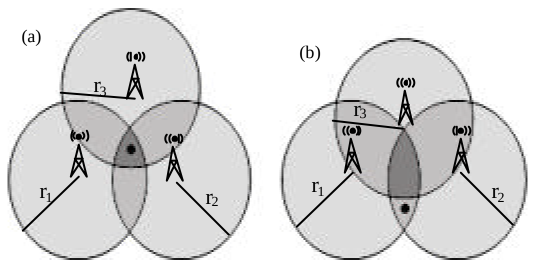

Fig. 4(a-b): Three circles diagram, (a) The overlapping of three circle, the distance is overestimated and (b) Selecting area is the overlapping of two circle, r3 is high estimated underestimated

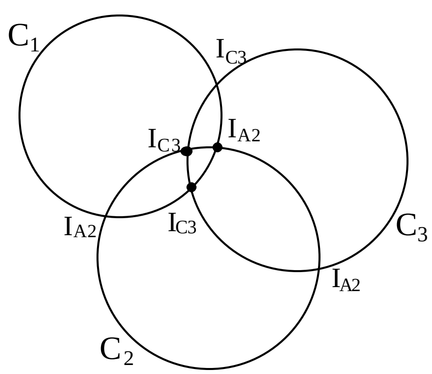

Fig. 5: Intersect point Screening method

(Kotanen *et al*., 2003) positioning. The main factor is the multi-path routing influence during the signal transmitting in the NLOS situation, except for the difference of instrument precision. Therefore, the time multiplying the distance after being converting by the light speed has the overestimate phenomenon and the observation object must be in the overlapping of the three circles. In the Trilateration position based on WiFi signal strength, the signal strength influenced by the environment is not the multi-path routing but the transmitting distance model difference. The distance converted from the signal strength is not accorded with the actual situation. The counting results may have the overestimate and upper estimate phenomenon in the meantime. The Fig. 4 shows the two kinds of differences. The pre-set object point may in the overlapping of the three circles, as shown in Fig. 4a. The pre-set object point may in the other different intersect points, as shown in Fig. 4b.

The weighted screening method, WSM is proposed to find out the intersect points close to the object point and screen other intersect points far away from the object points. Furthermore, the intersect points near to the object

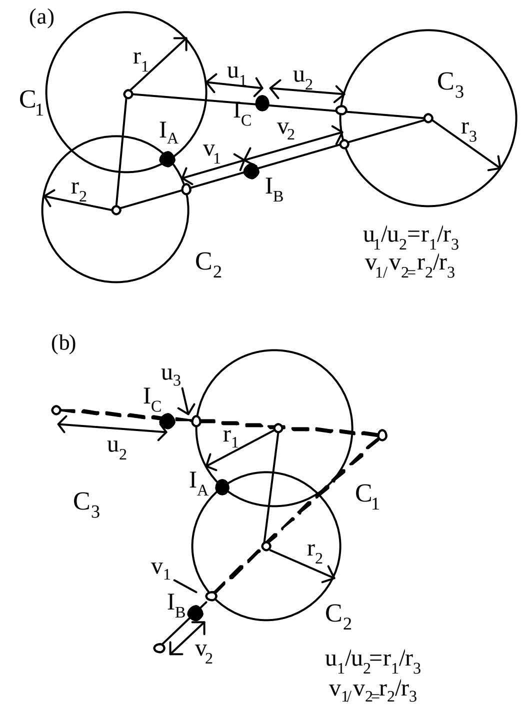

Fig. 6(a-b): WSN (a) Outside situation and (b) Inside situation

points will be averaged and the object point position is obtained. The weighted average point in the circle radius should be find out when the circles are disjoint. In addition, the object and the transmitter are assumed in the plane in the indoor and other non-satellite positioning system. Therefore, adopting the three AP's plane positioning system is applied in the system.

The three circles are C_1, C_2 and C_3 If any two circles of the three circles have no infinite group of solutions, the number of the intersect points among the three circles is between 0 and 6. I_{A1} and I_{A2} (Intersect point) represents the two intersect points when C_1 and C_2 is intersected. I_{B1} and I_{B2} represents the two intersect points when C_2 and C_3 is intersected. I_{C1} and I_{C2} represents the two intersect points when C_1 and C_3 is intersected, as shown in the Fig. 5. After using these intersect points to select three suitable I_A, I_B and I_C, the average will be the estimated to the observation point position. If there is only one intersect point (the circles are tangency), the point just need to be remained without being screened. If the circles are disjoint, the WSN begins to be adopted.

In the disjoint situation, the algorithm extracts a point near to the two circles as the focus. The distance ratio between the point to the circle edge is set as the distance ratio of the two circle radius, as shown in the Fig. 6. The situations of the two circles are divided into outside disjoint, as shown in the Fig. 6a and inside disjoint, as shown in the Fig. 6b. In the outside disjoint situation, if the radius of C_1, C_2 and C_3 is r_1, r_2 and r_3. The edge distance ratio between I_B and C_1, C_3 is r_1: r_3. In the same way, the edge distance ratio between I_c and C_2, C_3 is r_2: r_3. In the inside disjoint situation, the same counting is adopted. The measuring point is to count the distance in theory. Therefore, it is not closer next to the circle center, it is closer to near to the circle edge. The four kinds of the situation in the Fig. 3 is adopted to explain the screening algorithm. In the situation 1, the intersect point close to the circle edge is the focus and then the further points should be screened out. In the example, the I_{A1} can be screened out and the formula $I_A = I_{A2}$ can be obtained. In the same way, the formula $I_B = I_{B2}$ and $I_C = I_{C2}$ can also be obtained. After the three points are obtained, the average can be obtained and then the estimation point position can also be got. In the situation 2 to the situation 4 (there are two circles are not intersected), the I_A, I_B and I_C can be obtained through WSN. No matter whether the two circles are intersected, tangent or disjoint, a certain point can be obtained. Therefore, WSN must obtain the I_A, I_B and I_C position and finally average the three positions to obtain the object point in the Trilateration.

SIMULATION RESULT AND DISCUSSION

Repeat the experiment in the ECA (Slain *et al*., 2010) algorithm and then take advantage of the measured values to count and compare the tow methods' efficiency. The experiment obtains 7 measuring points' information, the positioning information and AP's estimation distance in total, as shown in Table 1. The three AP's positions are set as $S_1(0,0)$, $S_2(10,0)$ and $S_3(0, 10)$, respectively. Table 2 is the efficient effort in the EAC and WSN. The column of|Ìis the average distance error counted through the experiments. σ^2 represents the variance of the error values. The 25, 50 and 75% cumulative distance error are represented by 25th, 50th and 75th. Table 3 is the seven times displacement error counted in the experiments. The values are obtained by subtracting the estomation coordinate position and the original observation point.

Table 1: The estimation distance between the observation point's actual position and AP in the following 7 experiments

Experiment	Coordinates x	y	And to estimate the distance between the AP (m) S1(0,0)	S2(0,0)	S3(0,0)
1	10	10	12.52	9.36	9.51
2	-1	-3	2.438	8.872	14.29
3	4.45	-2.28	3.76	5.15	14.683
4	12	10	18.5	7.00	7.00
5	2	0	1.72	4.54	11.99
6	3.5	2.8	4.36	3.68	5.83
7	-0.5	6.21	6.98	9.43	8.04

Table 2: The relative comparison table between WSN and ECA

Method	μ(m)	σ^2	25th (m)	50th (m)	75th (m)
ECA	2.491	4.363	1.053	1.370	3.572
WSN	1.988	2.296	1.076	1.366	2.193

Table 3: The displacement error between the actual position and the position in WSN and ECA in the following 7 experiments

Experiment	WSN x	y	ECA x	y
1	-0.88	-1.04	-0.88	-1.05
2	2.17	0.047	2.75	-0.08
3	-1.01	-0.16	0.18	-0.97
4	-4.53	-2.53	-4.60	4.60
5	0.18	-2.19	-1.11	-3.68
6	0.06	-1.23	0.06	-1.24
7	-0.73	0.05	-0.73	0.05

CONCLUSION

There are several illustrations to the indoor positioning system based on WiFi signal and then the WSN is proposed to improve the positioning estimation error. The proposed method is compared with the ECA. The experimental results show that the efficiency of the WSN after being calibrated is the best and the average error is 1.988 and 2.491 m, respectively in the ECA, the error variation is reduced 2.067. The experimental results show that the WSN can reduce more error so that the indoor position system based on WiFi is more precision compared with the ECA.

REFERENCES

Lashkari, A.H., B. Parhizkar and M.N.A. Ngan, 2010. WIFI-Based indoor positioning system. Proceedings of the 2nd International Conference on Computer and Network Technology, April 23-25, 2010, Bangkok, Thailand, pp: 76-78.

Kotanen, A., M. Hannikainen, H. Leppakoski and T.D. Hamalainen, 2003. Experiments on local positioning with Bluetooth. Proceedings of the International Conference on Information Technology Computers and Communications, April 28-30, 2003, Las Vegas, USA., pp: 297-303.

Slain, B.J., K.W. Lee, S.H. Choi, J.Y. Kim, W.J. Lee and H.S. Kim, 2010. Indoor WiFi positioning system for Android-based smartphone. Proceedings of the International conference on Information and Communication Technology Convergence, November 17-19, 2010, Jeju, South Korea, pp: 319-320.

Swedberg, G., 1999. Ericsson's mobile location solution. Ericsson Review No. 4, p: 214-221. http://www.ericsson.com/pk/res/thecompany/docs/publications/ericsson_review/1999/19990406.pdf.

Han, G., D. Choi and W. Lim, 2007. Reference node selection algorithm based on trilateration and performance analysis in indoor sensor networks. Proceedings of the IEEE International Conference on Intelligent Computer Communication and Processing, September 6-8, 2007, Cluj-Napoca, Romania, pp: 177-184.

Krumm, J., S. Harris, B. Meyers, B. Brumitt, M. Hale and S. Shafer, 2000. Multi-camera multi-person tracking for easyliving. Proceedings of the 3rd IEEE International Workshop on Visual Surveillance, July 1, 2000, Dublin, Ireland, pp: 1-3.

Ni, L.M., Y. Liu, Y.C. Lau and A.P. Patil, 2004. LANDMARC: Indoor location sensing using active RFID. Wireless Networks, 10: 701-710.

Llombart, M., M. Ciurana and F. Barcel-Arroyo, 2008. On the scalability of a novel WLAN positioning system based on time of arrival measurements. Proceedings of the 5th Workshop on Positioning, Navigation and Communication, March 27, 2008, Hannover, pp: 15-21.

Zaniani, M.M. and I.A. Azid, 2010. Trilateration target estimation improvement using new error correction algorithm. Proceedings of the 18th Iranian Conference on Electrical Engineering, May 11-13, 2010, Isfahan, Iran, pp: 489-494.

Priyantha, N.B., A. Chakraborty and H. Padmanabhan, 2000. The cricket location support system. Proceedings of the 6th Annual International Conference on Mobile Computing and Networking, August 6-11, 2000, Boston, MA., USA., pp: 32-43.

Bahl, P. and V.N. Padmanabhan, 2000. RADAR: An in-building RF-based user location and tracking system. Proceedings of the 19th Annual Joint Conference of the IEEE Computer and Communications Societies, March 26-30, 2000, Tel Aviv, Israel, pp: 775-784.

Barber, R., M. Mata, M.J.L. Boada, J.M. Armingol and M.A. Salichs, 2002. A perception system based on laser information for mobile robot topologic navigation. Proceedings of the 28th Annual Conference of the Industrial Electronics Society, November 5-8, 2002, Taipei, Taiwan, pp: 2779-2784.

Want, R., A. Hopper, V. Falcao and J. Gibbons, 1992. The active badge location system. ACM Trans. Inform. Syst., 10: 91-102.

Chen, Y. and R. Luo, 2007. Design and implementation of a WiFi-based local locating system. Proceedings of the IEEE International Conference on Portable Information Devices, May 25-29, 2007, Orlando, FL., USA., pp: 1-5.