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Application of Improved Dynamic RSSI Algorithm in WIFI Indoor Positioning

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Abstract: The disadvantages for meaning filter and Kalman filter are that real-time culling and modified singular value can not be removed and achieved in WIFI indoor position. This paper proposes an improved dynamic RSSI signal processing method. In order to improve the accuracy of dynamic RSSI signal processing, this algorithm is based on average hop distance and improved method of generalized least squares measuring distance error correction that are used by the algorithm, and the revised RSSI value will be processed by weighted filtering method again. Simulation results show that the algorithm has high accuracy and the precision has been greatly enhanced after filtering ranging error. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Dynamic RSSI Signal Process; Modified Singular value; Weighted filtering; WIFI; Positioning.

1. Introduction

Wireless location is now a hot research at home and abroad, the subject involved in pervasive computing, wireless sensor networks, self-organizing networks, intelligent robots and cross in many areas of the internet and other new research, and have inextricable relationship with the Internet of things. WIFI is a wireless technology that can be connected to each other by personal computer, handheld device (such as mobile phone and PDA) and other terminal and that IEEE 802.11b is a technology implementation. With the development of technology and the emergence of IEEE 802.11a and IEEE 802.11g standards, the IEEE 802.11 standard has now been referred to as WIFI. WIFI wireless network is composed of AP (Access Point) and wireless network interface card (NIC). In an open area, communication distance up to 300 m, and in a closed area, the communication distance is about 75 m to 120 m. It is easy integration with the existing wired Ethernet and more lower cost networking. Regional monitoring in applications such as wireless networks and personnel tracking, location information visually important, along with the development of communication and network technology, indoor environments location-based services are greatly focus on people's attention, indoor positioning is to become a very active research fields. This paper mainly relate to indoor node localization studies of electromagnetic signals emitted by a transmitter, and placed in the region of some fixed point signal receiver to determine the location of a transmitter by the received signal strength and electromagnetic

properties. WIFI its own advantages respected by the people, the application of WIFI technology positioning is also a way of higher cost [1-4].

According to the current state of the mobile terminal positioning, based on the RSSI (received signal strength indication) of the positioning method WIFI signal processing can be divided into static and dynamic RSSI signal processing. Static advantages of the RSSI signal processing method by increasing the number of signal acquisition, processing to improve the accuracy of the RSSI, but the drawback is a longer acquisition time, not real-time positioning. How long without collecting and processing can improve the accuracy of the RSSI signal processing methods become static key issues, existing static RSSI signal processing methods mean model law and Gaussian model method [5, 6]. Estimates of the mean model approach by taking the mean signal collected as signal strength. The method introduces a small error probability signal values, resulting in inaccurate estimates of the signal. The paper [5] by comparing the mean model and Gaussian model, derived Gaussian model is better. However, in the indoor environment using a Gaussian distribution model to describe the signal is not accurate. RSSI is the dynamic signal processing method for real-time signal processing / movement positioning a long time, moving speed can not keep up, causing the position deviation, resulting in a large positioning error, so a RSSI signal processing method is presented. The advantage of this approach is that real-time, but the accuracy is not good enough, how to improve the accuracy is the main problem of dynamic RSSI signal processing method, the existing treatment methods are mean filtering, Kalman filtering method [7, 8]. During the measurement equipment or the environment due to factors such as the singular value will always be the number of mutations, which are the singular values will often bring a large positioning error. But these singular values can not be removed or fixed by the methods of the meaning filter and Kalman filter, so it can not eliminate the singular values caused errors. Based on this, the singular values of the above problems, an improved dynamic RSSI signal processing methods is proposed, in order to obtain a high positioning accuracy. And many simulation experimental studies have been done.

2. Dynamic RSSI Algorithm

2.1. Problem Description

When real-time and moving are needed in the location system, large location error may caused if the time of processing RSSI signal takes so many time that could be wrong location. The advantage of Dynamic RSSI Algorithm is greatly real-time. Suppose the whole space is a simulation environment that the physical location of all is within a two-dimensional plane, that is the position coordinates. There is a signal emission source (WIFI access unknown nodes)in a known simulated environment need to determine its location. The receiving end of a normal wireless card, by measuring the number of anchors in the scene, find the location of emission sources in order to complete the location of unknown nodes. n is the number of fixed observation points, and they get the signal strength from the transmission source, the position vector for each observation point is $\vec{\mathrm{P}}_i = (x_i, y_i)$, and corresponding to the signal strength S_i, for solving the physical position of the transmission source $\vec{\mathrm{P}} = (x, y)$.

2.2. Principle of the Algorithm

Lognormal model for wireless signal propagation attenuation is:

$$s = a\log(d) + b + X_\sigma ,$$

where s represents the signal strength of the signal source d and a, b are the constants. We can get an average value $\bar{s}$ through many measures that could filter the impact of noise X_σ, that is:

$$\bar{s} = a\log(d) + b , \tag{1}$$

According to the existing measurement data, we can construct a matrix R of order $(n-2)\times n$, as followed:

$$R = \begin{bmatrix} \bar{s}_2 - \bar{s}_3 & \bar{s}_2 - \bar{s}_1 & \bar{s}_1 - \bar{s}_2 & \cdots & \cdots \\ & & \cdots & & \\ & \bar{s}_{i+1} - \bar{s}_{i+2} & \bar{s}_{i+2} - \bar{s}_i & \bar{s}_i - \bar{s}_{i+1} & \\ & & \cdots & & \\ & & \bar{s}_{m-1} - \bar{s}_m & \bar{s}_m - \bar{s}_{m-2} & \bar{s}_{m-2} - \bar{s}_{m-1} \end{bmatrix} \tag{2}$$

The elements of the matrix R can be expressed as:

$$R_{ij} = \begin{cases} \bar{s}_{i+1} - \bar{s}_{i+2}, & i = j \\ \bar{s}_{i+2} - \bar{s}_i, & j = i+1 \\ \bar{s}_i - \bar{s}_{i+1}, & j = i+2 \\ 0, & otherwise \end{cases} \tag{3}$$

Suppose that the distance d_i is from observation point $\vec{\mathrm{P}}_i = (x_i, y_i)$ to emission source $\vec{P} = (x, y)$, for that $(x, y) \in \Omega$ is unknown, so d_i is the shorthand of function $d_i(x, y)$.

$$d_i(x, y) = \left\| \vec{P}_i - \vec{P} \right\|_2 , \tag{4}$$

Make $L_i(x,y)=\log(d_i)$, we construct vector function $\vec{L}$ about the place of emission $\vec{P}$ which is the order of $m\times 1$, that is:

$$\vec{L}(x,y)=\begin{bmatrix} L_1 \\ L_2 \\ \vdots \\ L_m \end{bmatrix}_{m\times 1} = \begin{bmatrix} \vdots \\ \frac{1}{2}\log[(x-x_i)^2+(y-y_i)^2] \\ \vdots \end{bmatrix}_{m\times 1} \quad (5)$$

Three known position coordinates for any point $\vec{P}_i$, $\vec{P}_j$ and $\vec{P}_k$, we can get a formula from (1):

$$(\bar{s}_j-\bar{s}_k)L_i+(\bar{s}_k-\bar{s}_i)L_j+(\bar{s}_i-\bar{s}_j)L_k=0 \quad (6)$$

So, the location problem of emission can be transformed the problem of getting the coordinator of point $\vec{P}\in\Omega$, make the evaluation function is minimized and the evaluation function E is defined as followed:

$$\mathrm{E}=\left\|R\times\vec{L}\right\|, \quad (7)$$

from the paper [9]. We can get the point that satisfies the equation (8) is $\vec{P}$, which is the optimal estimation of the signal transmitter of unknown node position, that is

$$\vec{P}=\arg\min_{(x,y)\in\Omega} E \quad (8)$$

3. Improved Dynamic RSSI Algorithm

As the introduction said, dynamic RSSI algorithm in the measurement process due to equipment or environmental factors often encounter the singular values of some mutations, and these singular values tend to give a great deal of positioning error. However these singular values can not be removed by the meaning filter and the real-time Kalman filter in time, so the error can not be fixed through these two methods. Accordingly, an improved algorithm for dynamic RSSI ranging model has been proposed as shown in Fig. 1. We divided it into three parts: the first part is the dynamic acquisition RSSI signal; the second part is the RSSI signal processing, and this section is divided into two processes, they are singular value correction and weighting filter; the third part is treated RSSI and results out.

3.1. Singular Value Correction

In order to improve the precision and accuracy of dynamic RSSI signal processing. This paper presents an approach based on the average hop distance and the measured distance deviation improved method of least squares to correct singular value. And the algorithm is as follows:

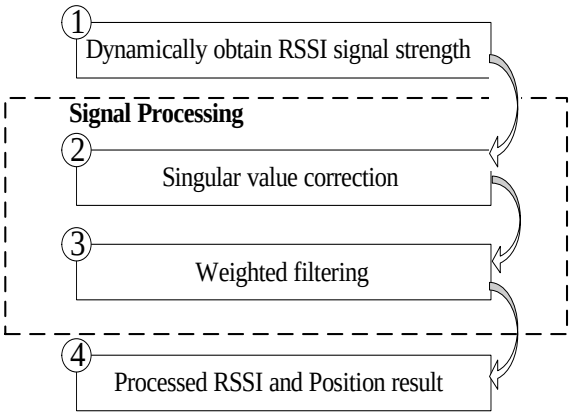

Fig. 1. Improved dynamic RSSI location algorithm.

1) The minimum number of hops between the measurement and the anchor node.

Each anchor node will broadcast their location information to the network, the packet contains its own location information and hop count is initialized to 0. The node received the packet will keep it, and reserve the packet held by the same one node with the smallest number of hops, and then forwarded to other neighboring nodes and the hop count plus one. Using the classical vector routing protocol, we can calculate the minimum number of hops from the unknown node to all anchor nodes. Through this mechanism, all nodes in the network will get the number of minimum hops and location information of each anchor.

2) Calculation of the correction value and broadcast.

When the anchor i gets the number of hops to other anchor nodes, the average hop distance (C_i)to other anchor nodes (j)is calculated. As the following equation (9).And this value is broadcast in the network.

$$C_i=\frac{\sum_{i\neq j}\sqrt{(x_i-x_j)^2+(y_i-y_j)^2}}{\sum_{i\neq j} hops_{ij}}, \quad (9)$$

where the (x_i,y_i) and (x_j,y_j) are the real coordinates of anchor node *i* and anchor node j respectively, and $hops_{ij}$ is the number of hops of two anchor nodes i and j. Correction value will

broadcast across the network using flooding law. Only one average distance per hop will be kept when each unknown node receives more than one corrective values, and then discard the packets behind received. This ensures that most of the nodes receive information of average hop distance from the nearest anchor node.

3) Get the average value.

Calculating the average hop distance of the whole network and broadcasting it in the network when the node gets the correction value. The datasheet will be updated automotively after the unknown nodes gets the correction value.

4) Correction method of least squares.

Usually, error compensation wound act on the value of d, used the method of least squares. The principle is the deviation of the calculated position error of the positioning system according to the measured distance between the anchor nodes.

As followed Fig. 2, assuming the coordinate of unknown nodes N_u is (x, y), the coordinates of anchor nodes $N_1, N_2 \cdots N_k$ are (x_1, y_1), $(x_2, y_2) \cdots (x_k, y_k)$ respectively, and the distances from node N_u to other anchor nodes are $d_1, d_2 \cdots d_k$ respectively, and the distance from node N_A to the other anchor nodes $N_i (i = 1, 2 \cdots k, i \neq A)$ is D_{Ai}', its actual distance is D_{Ai}, then the relationship between the actual distance D_{Ai} and the measured distance D_{Ai}' is followed:

$$D_{Ai} = D_{Ai}' + \Delta \mathrm{E}\ (D_{Ai}'), \tag{10}$$

where $\Delta \mathrm{E}\ (D_{Ai}')$ denotes error and is the function of measuring the distance between nodes.

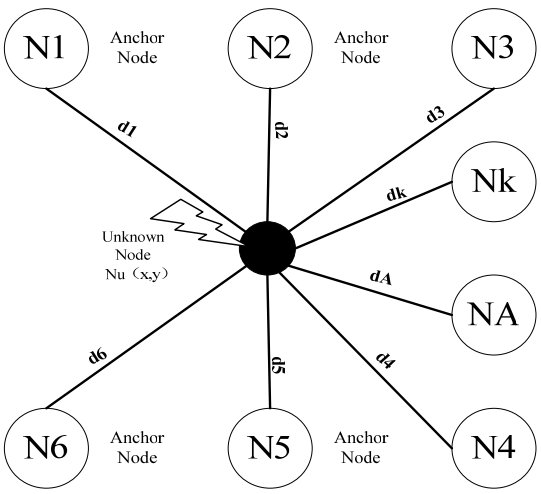

Fig. 2. The sketch map of least squares correction.

Assuming the error $\Delta \mathrm{E}(D_{Ai}')$ is a function of distance measurements. That is:

$$\Delta \mathrm{E}(D_{Ai}') = \mathrm{A} D_{Ai}' + \mathrm{B} \quad (\mathrm{i} = 1, 2 \cdots k, i \neq A), \tag{11}$$

To get the smallest value of the measurement error $\Delta \mathrm{E}\ (D_{Ai}')$, just make the sum of square minimum.

Make:

$$f(A, B) = \sum_{i=1}^{n} \left[\Delta E(D_{Ai}') - (A D_{Ai}' + B) \right]^2 \qquad (i = 1, 2 \cdots k, i \neq A), \tag{12}$$

And get the partial derivatives of $f(A, B)$ about variables A and B respectively, then get the outcomes as followed:

$$A = \sum_{i=1}^{n} D_{Ai}' \Delta E(D_{Ai}') - \frac{1}{n} \sum_{i=1}^{n} D_{Ai}' \sum_{i=1}^{n} \Delta E(D_{Ai}') \Big/ \left[\sum_{i=1}^{n} (D_{Ai}')^2 - \frac{1}{n} (\sum_{i=1}^{n} D_{Ai}')^2 \right], \tag{13}$$

$$B = (\sum_{i=1}^{n} \Delta E(D_{Ai}') - A \sum_{i=1}^{n} D_{Ai}') \Big/ n, \tag{14}$$

So the error, based on equations (11) and (12), which is between the measurement value and actual value of anchor nodes can be get. Then the measurement distance, according to the above error, between unknown node and anchor node can be corrected. The corrected distance is shown as:

$$d_i' = d_i + \Delta E(d_i) \qquad (i = 1, 2 \cdots k, i \neq A), \tag{15}$$

where d_i' is corrected value of measurement distance between unknown node and the i-th anchor node. d_i is the value of distance measurement between unknown node and the i-th anchor node.

The last actual distance of the positioning algorithm is:

d = m* n*(1+k)

m: The average distance per hop

n: Number of jump segments

k: distance deviation

If the deviation is a bit large between the estimation value of the average hop and actual value, then error, we get accordingly, between the unknown node estimation distance and actual distance, would be large.

3.2. Weighted Filtering

In order to get the more accurate value of RSSI, the corrected RSSI value would be processed through

the method of weighted filtering in this paper. Due to the unknown nodes are positioned using mobile, so the filtering window is not too large, otherwise not only requires a lot of work would be included but also the measurement error of farther nodes may be introduced. In the process of moving the positioning signal measurements is real time, so that adjacent points has higher correlation. When the signal strength of the measurement is greater or less than the signal strength value of the adjacent points, it means that the signal strength value is a unreliable singular value, we describe the interrelated grade (ω) which is using measurement point and reciprocal of the adjacent signal strength difference, and the expression as followed:

$$\omega_1 = \frac{1}{|RSSI_i - RSSI_m|} \quad (i = 1, 2, 3, ..., n), \tag{16}$$

where $RSSI_i$ is the signal strength of the i-th node which is adjacent to the measurement. $RSSI_e$ is the signal strength of measurement point and ω_i is the weights value of the $RSSI_m$-th adjacent point.

Since the sampling frequency of the signal is 5 Hz, within one second regardless of the location of the mobile terminal does not greatly change, correlation between adjacent points are not being reduced through environmental impact. Therefore only consider the impact on the correlation which is around the first five adjacent measurement points, without considering other points. Then:

$$\overline{RSSI_m} = \frac{\sum_{i=1}^{5} \omega_i \cdot RSSI_i}{\sum_{i=1}^{5} \omega_i}, \tag{17}$$

where $\overline{RSSI_e}$ is the estimation value of signal strength of measurement points for adjacent point. $RSSI_i$ is the signal strength value of the i-th measurement point. ω_i is the weight value of the i-th adjacent point.

The corrected value of RSSI by the method of singular value is not happen the phenomenon that suddenly drop down. The value is much more accurate after correcting by singular value. So the corrected value and the expression (17) are adopted average filtering, then we can get the expression (18):

$$RSSI_m' = \frac{\overline{RSSI_m} + RSSI_m}{2}, \tag{18}$$

From the expressions of (16), (17), (18), we can get expression (19)

$$RSSI_m' = \frac{\frac{\sum_{i=1}^{5} \omega_i \cdot RSSI_i}{\sum_{i=1}^{5} \omega_i} + RSSI_m}{2}, \tag{19}$$

where $RSSI_e'$ is the signal strength which is corrected by the method of weight filtering.

4. Algorithm Simulation Study

In order to verify the feasibility of the proposed algorithm, this article will compare the simulation methods based on mean filtering, Kalman filtering and improved dynamic RSSI. The average location error comparison and node communication radius error comparison are shown in Fig. 3 and Fig. 4. Experimental parameters set as follows:

1) Network area is set to the two-dimension plane whose area is 80 m * 80 m.

2) 20 unknown nodes randomly deployed in the region.

3) In order to verify the effect of positioning error, the distribution of the density of the anchor nodes. And the number of anchor nodes is about 20-50. To simulate a real scenario, the anchor nodes are randomly distributed.

4) Communication radius is 50 m.

5) Simulation experiments are 50 times, and the mean value is the experimental results.

6) Reference distance is $d_0 = 1$, Gaussian distribution MSE is $X_\sigma = 2$.

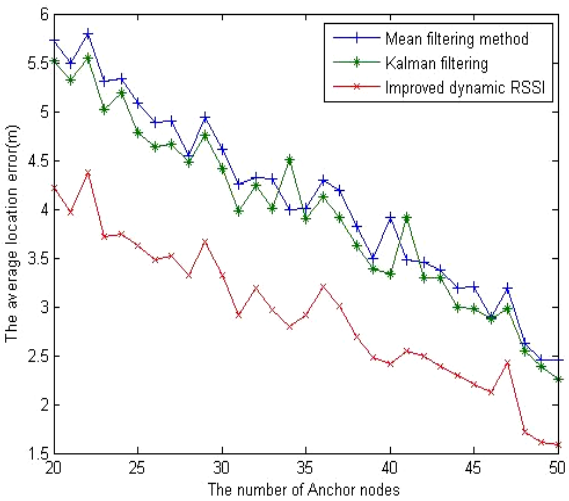

Fig. 3. Average error comparison chart of the algorithms.

As can be seen from Fig. 3 that when the number of anchor node in the network increases. Using the mean filter, Kalman filtering method and the improved dynamic RSSI, the average position error

decreased overall, with the increasing of the number of anchor nodes, the average location error of the three algorithms are also stabilized. In the case of the same number of anchor nodes, the average position error of Kalman filtering is larger than the average position error of mean filter when the anchor nodes are 34, 41, 46. With the increase of the density of the network, the average position error of these two methods tend to be equal. And herein RSSI based on improved dynamic algorithm, the positioning errors significantly less than the two former average algorithms. In this paper, an improved method perfectly proved better able to effectively suppress the influence of the RSSI value of a single measurement of the average error of the algorithm. We can get some conclusion from Fig. 4, with the network node communication radius increase, the average location error of the three positioning algorithm does not change much. When the communication radius increases from 10 to 34, the average position error changes a little, that based on the mean filtering and Kalman filtering, and the maximum fluctuation are: 0.49, 0.46. When the communication radius increases from 36 m to 50 m, the average positioning errors are small increase. Also can be seen from the positioning error figure, when the communication radius is fixed, the average position error for improved dynamic RSSI positioning algorithm is smaller than the former two methods.

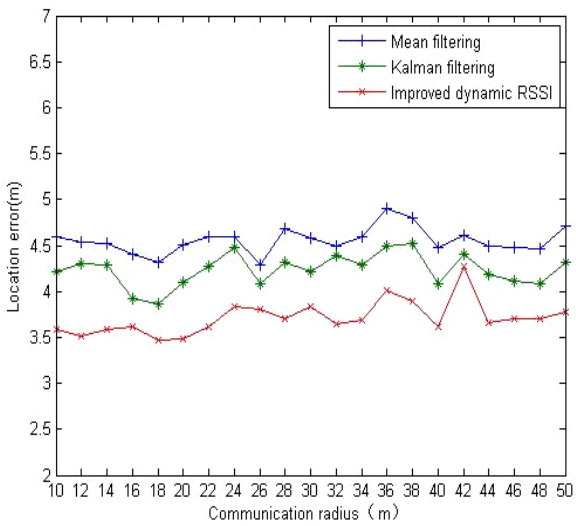

Fig. 4. Impact of node communication radius of errors.

5. Conclusions

In this paper, an improved dynamic RSSI signal processing method is introduced and a method based on the average hop distance and distance measurements to improve the minimum squares to correct singular value is proposed, and then the amended RSSI value is processing again by weighted filtering. For the existing methods of mean filtering and Kalman filtering, Real-time culling and singular value correction can not be done by these two methods. RSSI values for multiple groups of anchor nodes measured value, the best strategy adopted is middle value. Anchor node for the target node issues at different heights, is designed to compensate the model space, reducing the impact of the anchor node and the target node in a different plane of positioning accuracy caused.

Environmental attenuation factors of the various parameters used in the new environment requires re-calibration, and therefore a larger workload. Simulation results show that the algorithm improves the accuracy of the dynamic RSSI signal processing, with high accuracy, filtered through the ranging error has been greatly improved. In future work, the model parameters can be testing in several more indoor environment, and then summed up a set of model parameters can be directly used in the indoor environment.

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