Study on Weighted Centroid Localization Algorithm for an Indoor Localization

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Abstract. Localization algorithm is very important in node localization. The received signal strength (RSS) can be used to reduce positioning time. In this paper, an improved weighted centroid localization algorithm based on RSSI (IWCL-RSSI) is proposed for an indoor localization. Theoretical analysis shows know that the proposed algorithm has the advantage of lower complexity, less prior information and lower power consumption. The simulation results show that the proposed algorithm is more accurate than AMWCL-RSSI (anchor_optimized modified weighted centroid localization algorithm based on RSSI), and at least as good as WCL (weighted centroid localization) in terms of the localization accuracy. Real experimental results show that IWCL-RSSI is better than WCL in terms of the localization accuracy.

1. Introduction

Localization is very important in wireless sensor networks (WSNs) [1,4]. A important application for WSNs is the indoor localization of the blind node [2-3]. This application is motivated mainly by the lower cost of the method and the lack of effective positioning and tracking systems working inside buildings.

Most of the localization algorithms are based on received signal strength (RSS) measurements in WSNs. Unfortunately, some studies have shown the large variability of RSS because of negative effects, e.g. reflections and shadowing. As a result, localization algorithms based on RSS cannot obtain a high localization accuracy. However, the attraction of RSS-based method for the localization of WSNs still is tremendous.

Weighted centroid localization has already caused much attention due to their simplicity and robustness to changes in wireless transmission. These advantages make them suitable for the coarse localization of a blind node. Recently many proposed approaches on weighted centroid localization focus more on error control and management. Weighted centroid localization (WCL) is firstly proposed in [5]. In order to reduce high computational complexity of localization algorithms, F. Reichenbach and D. Timmermann [6] have proposed a novel weighted centroid localization algorithm based on RSS for an indoor localization of wireless sensor network. In [6], the RSS value is inversely proportional to the weight. The proposed algorithm is tested in a 3×3 room, four anchors are respectively placed in four corners and an unknown node is placed in 13 different positions. The relative localization error varies between 7.7% and 25.5% when the degree is 1. In [7], Hongyu et al. propose an anchor_optimized modified weighted centroid localization algorithm based on RSSI (AMWCL-RSSI).

The purpose of this paper is to investigate the performance of weighted centroid indoor localization, and an improved weighted centroid localization algorithm based on RSSI (received signal strength indicator) is proposed for localization. The proposed algorithm compares with some existing solutions via simulations.

The rest of this paper is organized as follows. Section 2 presents proposed localization algorithm, followed by performance evaluation in Section 3. The conclusions and the future work are summarized in Section 4.

2. Localization Algorithms

In this part, WCL algorithm [5] and the proposed localization algorithm will be introduced, respectively.

A. WCL

In [5], Blumenthal et al. have proposed the basic idea of WCL, which allocates a greater weight to the anchor closest to the unknown node. Let $a_i = (x_i, y_i)$ indicate the coordinate of anchor node. d_i is the measured distance between the unknown node and anchor node a_i. g is the degree which determines the weight of each anchor node. w_i is the weight which depends on the distance between the anchor node i and the unknown node . w_i can be expressed by

$$w_i = d_i^{-g} \tag{1}$$

So, the WCL algorithm estimates the position of the unknown node as:

$$P = \frac{\sum_{i=1}^{n} (w_i \cdot a_i)}{\sum_{i=1}^{n} w_i} \tag{2}$$

B. Improved Weighted Centroid Localization Based on RSSI (IWCL-RSSI)

In this part, an improved weighted centroid localization algorithm based on RSSI is proposed. In free space transmission, the detected signal strength can be expressed as

$$P_{RX_i} = P_{TX} \cdot G_{TX} \cdot G_{RX} \left(\frac{\lambda}{4\pi d_i} \right)^2 \tag{3}$$

Where P_{RX_i} is the remaining power of wave at the receiver from the i-th anchor node. P_{TX} is the transmission power of the sender. G_{TX} is the gain of the transmitter. G_{RX} is the gain of the receiver. λ is the wave length. d_i is the distance between the i-th anchor node and the unknown node. From Eq. (3), we can obtain the relation between P_{RX_i} and d_i.

In the chip, the received signal strength can be converted to RSSI. Hence, RSSI can be expressed as:

$$RSSI_i = 10 \cdot \log \frac{P_{RX_i}}{P_{Ref}} \tag{4}$$

Where, P_{RX_i} is the received signal strength from the i-th anchor node, P_{Ref} is the reference power.

According to Eq. (3) and (4), the weight w_i can be expressed as

$$w_i = \frac{1}{d_i^{\,g}} = \frac{1}{\left(\lambda \sqrt{\frac{P_{TX} \cdot G_{TX} \cdot G_{RX}}{4\pi P_{Ref} \cdot 10^{\frac{RSSI_i}{10}}}} \right)^g} \tag{5}$$

After w_i normalization, the normalized weight can be expressed as

$$W_i = \frac{w_i}{\sum_{j=1}^{n} w_j} = \frac{\sqrt{\left(10^{\frac{RSSI_i}{10}}\right)^g}}{\sum_{j=1}^{n}\sqrt{\left(10^{\frac{RSSI_j}{10}}\right)^g}} \tag{6}$$

Accoding to [5], $g = 2.5$ is the optimal value in the range of 0~50m. Hence, Eq. (6) can be expressed as

$$W_i = \frac{w_i}{\sum_{j=1}^{n} w_j} = \frac{\sqrt{\left(10^{\frac{RSSI_i}{10}}\right)^{2.5}}}{\sum_{j=1}^{n}\sqrt{\left(10^{\frac{RSSI_j}{10}}\right)^{2.5}}} \tag{7}$$

Therefore, the position of the blind node can be expressed as

$$P = \sum_{i=1}^{n} W_i a_i \tag{8}$$

From Eq. (7) and Eq. (8), the estimated position of the unknown node can be obtained by just knowing $RSSI_i$ and the coordinate of anchor nodes. So, it is not necessary to compute the path loss exponent and obtain other prior informations. Hence, the proposed localization algorithm has the advantage of lower complexity and lower power consumption.

3. Performance Evaluation

A. Wireless Channel Propagation Model

In order to establish the propagation channel, the log-distance shadowing path-loss model is chosen as the propagation model which is expressed by

$$RSS = PL0 - 10\beta \log_{10}(d / d_0) + N_\alpha \tag{9}$$

Where d is the real distance between nodes, $PL0$ is the received signal strength at reference distance d_0 ($d_0 = 1$m), β is the path loss exponent, and N_α is a zero-mean Gaussian noise with standard deviation α.

B. Simulation

In this part, the performance of the studied localization scheme will be analysed through simulations, using Matlab as simulation tool. The improved weighted centroid localization algorithm compares with WCL [5] and AMWCL-RSSI [7]. Eq. (9) is RSS model for simulations.

(1) Localization Error versus the Number of Anchor Nodes

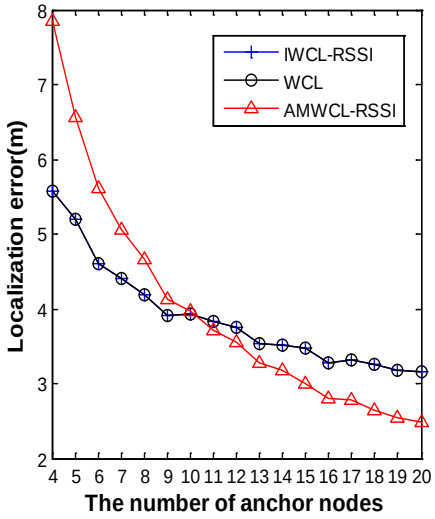

Fig. 1 Localization Error versus the Number of Anchor Nodes

We evaluate the effect that the number of anchors has on the localization accuracy. Figure 1 shows the effect of the number of anchors on localization error. IWCL-RSSI algorithm is tested in a 20m×20m region, anchor nodes and 1000 sensor nodes are randomly placed in this region. We assume that $PL0 = -60dB$ and the zero-mean Gaussian noise N_α in Eq. (8) has a standard deviation of $3dB$. We set $\beta = 3.5$.

In Figure 1, it is shown that as the number of anchors increases, the localization error decreases for all three algorithms. It also can be seen that IWCL-RSSI algorithm and WCL algorithm are almost the same on the localization error. The explanation is that the localization error of IWCL-RSSI algorithm is similar to that of WCL algorithm on the same simulation environment. When the number of anchors increases in the $3 \sim 10$ range, the localization errors of IWCL-RSSI algorithm and WCL algorithm decrease, and IWCL-RSSI algorithm and WCL algorithm outperform AMWCL-RSSI algorithm in the localization accuracy. When the number of anchors increases in the $11 \sim 20$ range, the localization error of IWCL-RSSI algorithm and WCL algorithm also decrease, but the localization errors of IWCL-RSSI algorithm and WCL algorithm are larger than that of AMWCL-RSSI algorithm. Hence, when the number of anchors is in the $3 \sim 10$ range, IWCL-RSSI algorithm and WCL algorithm have a better advantage in the localization accuracy.

(2) Localization Error versus the Path Loss Exponent

Figure 2 shows the effect of the path loss exponent on localization error. IWCL-RSSI algorithm is tested in a 20m×20m region, four anchors are respectively placed in four corners and 1000 sensor nodes are randomly placed in this region. We assume that $PL0 = -60dB$ and the zero-mean Gaussian noise N_α in Eq. (9) has a standard deviation of $3dB$.

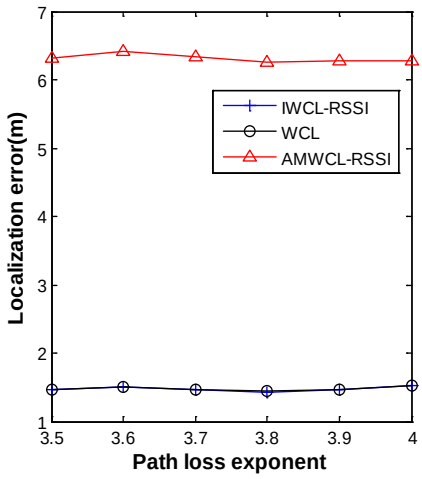

Fig. 2 Localization Error versus the Path Loss Exponent

In Figure 2, it can be observed that the path loss exponent has a little effect on localization error for all three localization algorithms as the path loss exponent increases. Although the localization error of IWCL-RSSI algorithm is as the same as that localization error of WCL algorithm, we do not need to calculate the path loss exponent in IWCL-RSSI algorithm. Hence, IWCL-RSSI algorithm reduces computational complexity, thus energy consumption of nodes is also greatly reduced. In fact, we can quickly know the position of a unknown node due to the reduction of the computation complexity, this is better for our further action such as emergency relief, battlefield surveillance, assisted living and so on.

(3) Localization Error versus Network Size

In this part, we evaluate the effect the size of the network has on the localization error. We simulated three network sizes: 20m×20m, 30m×30m and 40m×40m. Four anchors are respectively placed in four corners, 1000 sensor nodes are randomly placed in this region. We assume that $PL0 = -60dB$ and $\beta = 3.5$.

TABLE 1 shows the localization error in three network sizes. It can be shown that the localization error increases as the network size increases. Because of the large variability of RSS, the explanation is that the error of the RSS measurement increases as the network size increases. Moreover, many volatile factors with the increase of the network size will further affect the localization accuracy, e.g., the wind, reflection and obstacles. Therefore, the increase of the error of the RSS results in the increase of the localization error of IWCL-RSSI algorithm.

TABLE 1 Average localization errors

Average localization errors (meters)	20 m ×20 m	30 m ×30 m	40 m ×40 m
AMWCL-RSSI	6.4	9.8	12.8
WCL	1.4	2.2	2.8
IWCL-RSSI	1.4	2.2	2.8

C. Experiment

In this part, we analyse the performance of the studied localization schemes through a real experiment. A wireless node is based on a MSP430 microprocessor and equipped with an IEEE 802.15.4 compliant Chipcon CC2500 radio module. All nodes are deployed in a 20m×20m area of the gymnasium in our University. Four anchors are respectively placed in four corners, an unknown node is placed in 40 different positions.

TABLE 2 Average localization errors

Localization algorithm	Average localization error (meters)
WCL	1.65
IWCL-RSSI	1.55

TABLE 2 shows that the average localization errors of IWCL-RSSI is lower than the average localization errors of WCL. In our experiment, IWCL-RSSI obtains the location of unknown node faster than WCL. This is because WCL algorithm needs to compute more parameters such as $PL0$, β, the distance between two anchor nodes and the distance between the unknown node and anchor nodes, while IWCL-RSSI algorithm does not need to compute these parameters.

4. Conclusions

Most of localization algorithms have the drawback of high errors in practical localization. For an indoor environment, in this paper, some weighted centroid localization algorithms and RSS-based localization algorithms are researched and analyzed, and a localization scheme called improved weighted centroid localization algorithm based on RSSI is proposed. According to the improved localization algorithm, the estimated position of the unknown node can be obtained by just knowing RSSI and the coordinate of anchor nodes. Moreover, we do not need to calculate the path loss exponent and other prior information. So, the improved algorithm reduces positioning time and energy consumption. The simulations demonstrated that the IWCL-RSSI algorithm has a small localization error. But we can see that some factors more or less influence the positioning error. For example, the increase of the network size would sharply increase the localization error. From real experimental result, IWCL-RSSI is better than WCL in terms of the localization accuracy. It also has been shown that IWCL-RSSI has the advantage of lower complexity and little prior information. For IWCL-RSSI, we will continue to work on improvement of the localization accuracy in the future work

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References

[1] S.H. Li, Hedley. M., Collings. I.B.. New Efficient Indoor Cooperative Localization Algorithm With Empirical Ranging Error Model [J]. IEEE Journal on Selected Areas in Communications, 2014 33(7) 1407 – 1417,

[2] Wyffels. J., De. Brabanter, J., Crombez. P., Verhoeve. P., Nauwelaers. B.. Distributed, Signal Strength-Based Indoor Localization Algorithm for Use in Healthcare Environments [J]. IEEE Journal of Biomedical and Health Informatics, 2014 18 (6) 1887 – 1893.

[3] Y. Ma, L.J. Zhou, K.H. Liu, J.L. Wang: Iterative Phase Reconstruction and Weighted Localization Algorithm for Indoor RFID-Based Localization in NLOS Environment [J]. IEEE Sensors Journal, 2014 14(2) 597 – 611.

[4] Lasla. N., Younis. M.F., Ouadjaout. A., Badache. N. An Effective Area-Based Localization Algorithm for Wireless Networks [J]. IEEE Transactions on Computers, 2015 64(8) 2103 – 2118.

[5] J. Blumenthal, R. Grossmann, F. Golatowski, D. Timmermann. Weighted Centroid Localization in Zigbee-based Sensor Networks [C]. IEEE International Symposium on Intelligent Signal Processing, 2007. 1–6.

[6] F. Reichenbach and D. Timmermann. Indoor localization with low complexityin wireless sensor networks [C]. IEEE Int. Conf. Ind. Informat.. 2006.1018–1023.

[7] Hongyu Shi. A new weighted centroid localization algorithm based on RSSI [C]. 2012 International Conference on Information and Automation (ICIA), 2012. 137 – 141.