An Improved Scout Wireless Localization Algorithm Based On Probabilistic Model

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Abstract. The Scout localization algorithm based on probabilistic model employs on-site reference tags to calibrate real-time transmission parameters to provide high localization accuracy. However, this method requires high hardware consumption, due to the deployment of reference tags. Aim to tackle this issue, we propose an improved Scout wireless localization algorithm based on probabilistic model. This algorithm diminishes hardware consumption by half without compromising localization accuracy.

Keywords: probabilistic model, Scout algorithm, wireless localization, reference tags.

1 Introduction

Nowadays, research of wireless localization algorithm has become an important area and a hot topic. Typical localization algorithms are divided into two categories: range-based localization algorithms and range-free localization algorithms. The range-based determines locations of unknown nodes by collecting distances and angles and using trilateration, triangulation or maximum likelihood estimation, while the range-free localization achieves it based on information such as network connectivity. DV-Hop algorithm, APIT algorithm, centroid algorithm are range-free algorithms, their advantage is low hardware requirement, but their accuracies are too low to meet the requirement of indoor scenarios. RSSI, TOA, TDOA and AOA are typical distance measuring methods[1][2][3]. Among them, the RSSI is the most prevalent method, because it has low hardware requirement and many wireless communication modules have built-in RSSI readers.

Due to propagation loss caused by reflection, multipath propagation, non-vision, antenna gain, RSSI is considered as a rough distance measuring technique[4], it is essential to improve its measurement accuracy. Currently, there are some existing

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wireless Indoor localization algorithms, for example, Weighted centroid localization algorithm based on differential correction, Differential correction distance measuring localization algorithm based on RSSI, Triangle centroid localization algorithm based on RSSI, Distance fixed wireless sensor network localization algorithm based on RSSI, etc. [5][6] propose a Scout localization algorithm based on probabilistic model[7]. With the help of reference tags, this algorithm modifies parameters of corresponding card readers. Then, it estimates the relation between the tag to card reader distance and received signal strength by using a probabilistic model[8][9]. Finally, it determines location of the object by Bayesian Inference. This algorithm is characterized of high accuracy and high hardware consumption with the deployment of a set number of reference tags. In order to lower the hardware consumption, this paper presents an improved Scout localization algorithm based on probabilistic model.

2 Algorithm Model

2.1 Scout localization algorithm

The Scout localization algorithm determines location of the tracking object based on RSSI values by following three steps[10]: 1) Collects readers from on-site reference tags to calibrate propagation parameters; 2) Calculates the distance between the object and the reader on the basis of a probabilistic model; 3) Determines the location by using Bayesian Reasoning. To perform the above procedures, the Scout localization algorithm requires $n(n >= 4)$ card readers, $n(n >= 4)$ corresponding reference tags with known positions, at least one server, and several tags for tracking objects. The card reader is responsible for measuring RSSI values of each tag and sending them to the server, and the reference tags are used to calibrate the parameters.

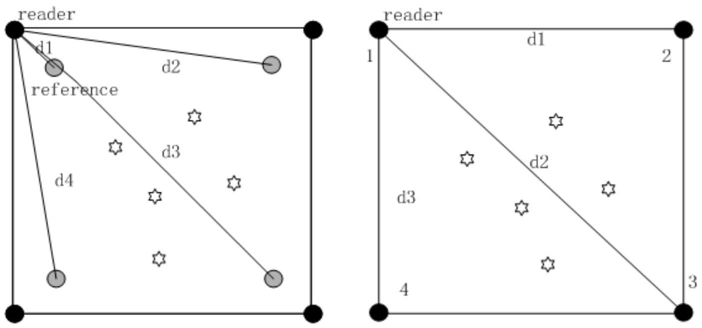
This algorithm calibrates RSSI values by updating parameters such as transmission loss and path loss, according to the relation between the RSSI value and the parameters as (2.1).

$$RSSI = P(d) = a - 10nlog(d) - N(0, \sigma^2) \qquad (2.1)$$

Where, a is the propagation loss, b is the path loss, they are varies with each scenarios to avoid errors. Furthermore, a a and b are key parameters to calibrate RSSI values.

2.2 Improved scout localization algorithm

In this paper, we introduce an improved Scout localization algorithm. We need $n(n >= 4)$ card readers only instead of card readers and reference tags together, because the card readers can be used as reference tags. Compared with 8 nodes are equipped to meet the minimum requirement of the traditional scout algorithm, the improved algorithm needs four card readers only, which has significantly lowered the cost. Nodes distributions of both scout algorithm and improved scout algorithm are illustrated in Figure 2.1.a and Figure 2.1.b separately.



(a) scout algorithm (b) improved scout algorithm

Fig. 2.1 Nodes distribution

To calculate the corresponding propagation loss a and path loss n of the card reader 1 showed in Figure1.b, we only need to combine RSSI values at different distance, as depicted in formula (1.2). Therefore, a_1 and n_1 are obtained by (d_1, d_2) ; a_2 and n_2 are obtained by (d_1, d_3); a_3, n_3 are obtained by (d_2, d_3); a is determined by the mean value of a_1, a_2, a_3; n is determined by the mean value of . RSSI values can be substitute into probabilistic formula (1.2) –(1.4) to estimate probability. In a limited area, we choose the distance d corresponds with the maximum probability.

$$RSSI_1 = a - 10nlog(d_1) - N(0, \sigma^2) \tag{2.2}$$

$$RSSI_2 = a - 10nlog(d_2) - N(0, \sigma^2) \tag{2.3}$$

.

$$p_j(RSSI_j^t) = \frac{1}{\sqrt{2\pi}\sigma} exp\left[\frac{-(RSSI_j^t - a_j + 10n_j\ log\ (d_{PHY}))^2}{2\sigma^2}\right] \tag{2.4}$$

Then, we normalize probabilities of all points and choose $p > 0.9999$, the results are as shown in figure 2.2.

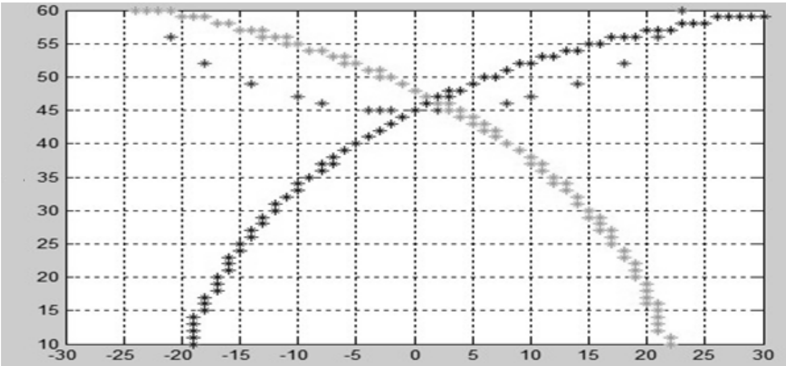


Fig.2.2 Distribution of maximum probabilities

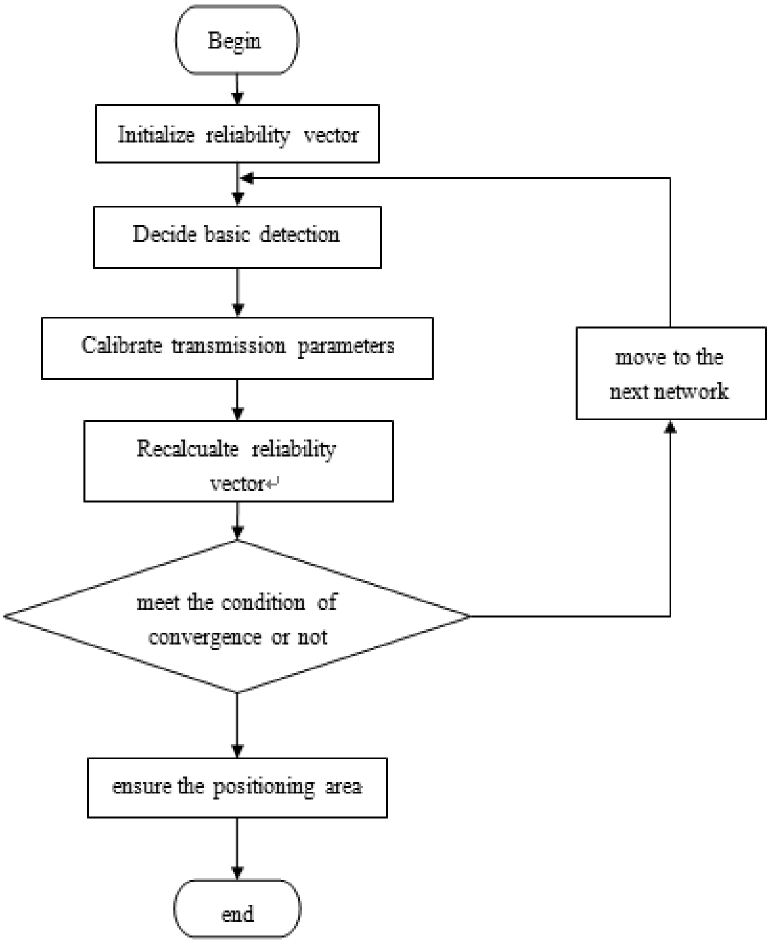


Fig.3.1 Flow chart of the algorithm

In the end, we multiply all probabilities of locations of the target within the coverage of each card readers to get the final probability of the location, and then pick the maximum one as the determined location of the point.

3 Scheme of algorithm

The algorithm steps are shown in Figure 3.1 as following:

1. Initialize reliability vector $\mathrm{Bel}(\mathrm{x}_0)$:

$$Bel(x_0) = \{\frac{1}{N}, \frac{1}{N}, \dots \frac{1}{N}\} \tag{3.1}$$

In the formula, x_0 stands for the initial status of the tracking object, which means its original location in the area; the algorithm divides the whole area into N grid cells, $Bel(x_0)$ stands for the probability that the object exists in eachgird cell at the beginning.

2. Decide basic detection zone

$$[RSSI'^{\ t-w+1} \quad RSSI'^{\ t-w+2} \quad \dots \quad RSSI'^{\ t-w+3}] =$$

$$\begin{bmatrix} RSSI'^{\ t-w+1}_{1} & RSSI'^{\ t-w+2}_{1} & \dots & RSSI'^{\ t-w+3}_{1} \\ RSSI'^{\ t-w+1}_{2} & RSSI'^{\ t-w+2}_{2} & \dots & RSSI'^{\ t-w+3}_{2} \\ RSSI'^{\ t-w+1}_{3} & RSSI'^{\ t-w+2}_{3} & \dots & RSSI'^{\ t-w+3}_{3} \\ RSSI'^{\ t-w+1}_{4} & RSSI'^{\ t-w+2}_{4} & \dots & RSSI'^{\ t-w+3}_{4} \end{bmatrix} \tag{3.2}$$

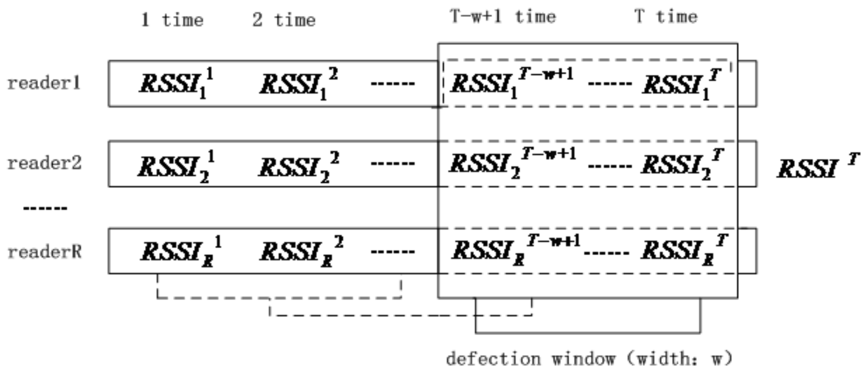


Fig.3.2 Detection of one target

The basic detection zone is the area overlapped by the range of four neighboring card readers; it is presented by the formula (3.1) which contains RSSI values measured by the four card readers in a continuous time. Where,

$RSSI_1{'}^{t}, RSSI_2{'}^{t}, RSSI_3{'}^{t}, RSSI_4{'}^{t}$ stand for the RSSI values measured by card reader 1,2,3,4 respectively. As shown in figure 3.2, w is the size of the observing window; it denotes the number of card readers used to determine the location of the target.

3. Transmission parameters are calibrated as the following formulas:

$$\begin{cases} n_j(i_1{'}) = \dfrac{\overline{RSSI(i')} - \overline{RSSI_j(m)}}{10log(\dfrac{dist(j,m)}{dist(j,i')})}; (i' \neq j \neq m) \\ n_j(i_2{'}) = \dfrac{\overline{RSSI(i')} - \overline{RSSI_j(n)}}{10log(\dfrac{dist(j,n)}{dist(j,i')})}; (i' \neq j \neq n) \\ n_j(i') = \dfrac{n_j(i'_1) + n_j(i'_2)}{2} \\ n_j = \sum\limits_{\substack{i'=1,2,3,4 \\ i' \neq j}} \dfrac{n_j(i')}{3} \end{cases} \tag{3.3}$$

$$\begin{cases} a_j(i'_1) = \overline{RSSI_j(m)} + 10n_j(m)log(dist(m,j)); \\ (i' \neq j \neq m) \\ a_j(i'_2) = \overline{RSSI_j(n)} + 10n_j(n)log(dist(n,j)); \\ (i' \neq j \neq n) \\ a_j(i') = \dfrac{a_j(i'_1) + a_j(i'_2)}{2} \\ a_j = \sum\limits_{\substack{i'=1,2,3,4 \\ i' \neq j}} \dfrac{a_j(i')}{3} \end{cases} \tag{3.4}$$

$$\begin{aligned} RSSI_j^t(i') = [&RSSI_j^{t-w+1}(i'), RSSI_j^{t-w+2}(i'), \\ &\ldots, RSSI_j^t(i')] \end{aligned} \tag{3.5}$$

$$\overline{RSSI_j(i')} = \frac{1}{\omega} \sum_{k=t-w+1}^{t} RSSI_j^k(i') \tag{3.6}$$

The transmission parameter includes path loss n, transmission loss a, and transmission standard deviation σ, calibrated by (3.3) (3.4) (3.5) (3.6). Where, n_j and a_j stand for the path loss and transmission loss of the number j card reader. i' denotes the reference tag associated with the card reader j, m and n stand for the rest two card readers. $dist(m,j)$ is the Euclid distance from the card reader m to the card reader n; is that from j to n; $dist(j, i')$ is theEuclid distance from the card reader j to its corresponding reference tag i'. $\overline{RSSI_j(i')}$ is the average RSSI value of the reference tag i' measured by the card reader j, it can be calculated by (3.6) , where $RSSI_j^k(i')$ isthe RSSI value of tag i' measured by card reader j at time k; N_r and N_o stand for the number of the card readers and the corresponding tags; $std(RSSI_j(i'))$ is the standard deviation of vector $[RSSI_j^{t-w+1}(i'), RSSI_j^{t-w+2}(i'), \ldots, RSSI_j^t(i')]$, in which the $RSSI_j^t(i')$ means the RSSI value of the tag measured by card reader j at the time t.

4. The reliability vector $Bel(x^t)$ is recalculated as shown:

$$
\begin{aligned}
&Bel(x^t) = \beta^t p(RSSI'^{\,t}|x^t)Bel(x^{t-1}) \\
&p(RSSI'^{\,t}|x^t) = \prod_{j=1}^{m} p_j\,(RSSI_j^t|x^t) \\
&p_j\,(RSSI_j^t) = \frac{1}{\sqrt{2\pi}\sigma} \\
&exp\left[\frac{-(RSSI_j^t - a_j + 10n_j\,log\,(d_{PHY}))^2}{2\sigma^2}\right]
\end{aligned}
\tag{3.7}
$$

x^tstands for the status of the target at time t, namely the location in the detection zone at t time; $Bel(x^t)$ is the probability that the target exist in any gird cell at time t; β^t is a constant at time t which is used to normalize $Bel(x^t)$, making the sum of vector $Bel(x^t)$ equals to 1; $RSSI_j^t$ is the RSSI value measured by card reader j at time t; d_{PHY} is the Euclid distance between the target and the card reader j, namely the probably location of the target within the coverage of the card reader j.

5. If the iteration times is smaller than scheduled times, we calculate the following grid cell, and return to step 2. Otherwise, we terminate the procedure of step 4 and determine the location.

$$
Bel'\,(x^t) = \frac{Bel(x_t}{|\max\limits_{k=1,2,\ldots,N}(\,Bel(x^t = C(gx_k, gy_k)))|}
\tag{3.8}
$$

Where, $Bel'(x^t)$ is the relative reliability vector, $C(gx_k, gy_k)$ is the grid cell k while gx_k, gy_k is the grid point; $Bel(x^t = C(gx_k, gy_k))$ represents the probability that the target is located in the grid cell k at time t.

6. Determining the location Calculate the mean of probability of each iteration to determine the final location.

4 Simulation Result

We use MATLAB to simulate both traditional and improved scout algorithms in a 10m*10m detection area, and select the classic free space model and the logarithm-normalcy model as the propagation loss model. We put 4 card readers with customized coordinates with/without corresponding reference tags, depending on the type of algorithm to simulate. MATLAB randomly sets 10 tracking targets distributed within this area. We set path loss exponent n =4, and consider generated Gaussian noise as RSSI variable to simulate the practical environment. The iteration is 10 times and the results are demonstrated in the following figure.

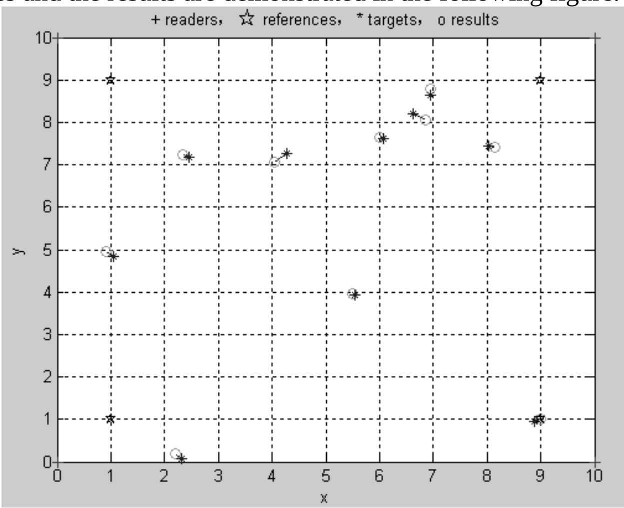


Fig.4.1 Localization result of the Scout algorithm

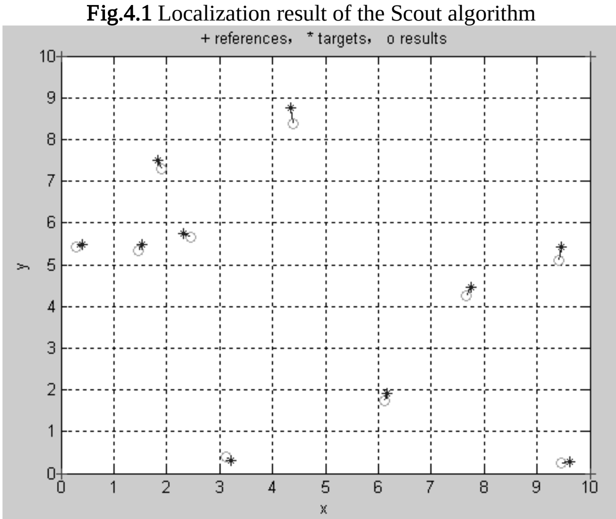


Fig.4.2 Localization result of the improved Scout algorithm

5. Conclusion

In this paper, we propose a improved Scout wireless localization algorithm. In comparison with the traditional Scout algorithm, it lowers the hardware consumption by half, because card readers can be used as reference tags. Besides, on account of employing the same Scout algorithm, its accuracy remains the same level as the traditional Scout algorithm.

Acknowledgement

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