Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 417-423
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

Distributed Collaborative Localization Algorithm Based on UWB

Jinghong Tan*
University of Notre Dame, South Bend, Indiana—IN, USA
*Corresponding author.

Abstract:

For traditional MDS - MAP algorithm, they can realize the distributed computing the default distance matrix. In this paper, we put forward a kind of based on the centroid coordinates of MDS algorithm, according to the distance between UWB wireless sensor node, through the center of mass model list other nodes and the relationship between the reference node matrix equation, and a distributed positioning algorithm flow was proposed. Then, the simulation results showed that compared with the traditional MDS-MAP algorithm, the positioning accuracy of the proposed algorithm was improved by 13%.

***Keywords**: wireless sensor network, Collaborative positioning, UWB range, Iterative estimation, Distributed algorithm.*

I. INTRODUCTION

With the rise of the Internet of things (IOT), the world has entered the era of interconnection of all things, and the scale of sensor nodes has gradually expanded. Wireless communication can be carried out between sensor nodes, forming a wireless sensor network (WSN). The communication between sensors in wireless sensor networks is completed by wireless signals, which has flexible network settings, and can change the geographical location of each sensor node in real time. At the same time, when interacting with the outside world, it can also interact with the Internet through wired connection or wireless communication [1]. Localization (positioning or location) is called the location of each node in wireless sensor networks. In wireless sensor networks, location is usually used as a basic data. Therefore, how to determine the location of each node in the network is a basic research content for the development of wireless sensor network technology. In various application scenarios of WSN, the location of each node is of great significance for the detection task of sensor networks [1-2]

According to whether the location algorithm needs to be based on the measured distance between two nodes in the network, it can be divided into two categories. The first kind of algorithm uses the distance, and the other does not need to use the range free data. The ranging algorithm needs the support of equipment and is equipped with additional modules to obtain some auxiliary measurement. The distance or angle can be obtained through their measurement and a series of processing, and then the error can be properly analyzed and processed to participate in the positioning estimation according to a certain positioning mechanism and algorithm [3]; The non ranging algorithm determines the hop distance according to the number of hops and each hop distance in the process of data transmission, and then estimates the position coordinates in the sensor node by using a certain positioning mechanism and algorithm. Ranging algorithms generally need to be equipped with ranging modules and other equipment, which will increase the communication overhead and computational complexity, but the accuracy will also be improved [4]. The non ranging algorithm does not need additional modules, has simple calculation and low energy consumption. However, due to the estimation of distance, it has poor positioning effect for nodes.

According to the calculation method, it can be divided into distributed positioning algorithm and centralized positioning algorithm. The main basis is whether the solution content of the positioning algorithm is completed in the central sensor node or other central processing nodes [5]. Distributed positioning algorithm means that each sensor node can undertake certain calculation needs during positioning, carry out subsequent calculation and processing for the collected relevant positioning data, and estimate the location coordinates. In the centralized calculation mode, all data is transmitted to a central computing node through wireless communication, which usually has strong computing power, In order to deal with the huge amount of computing, although the accuracy of the obtained position coordinates is high, the calculation is complex, the time is slow, and frequent communication is required, resulting in excessive energy consumption in the network [6]; For a wireless sensor network, if each node undertakes a certain computing task, consumes a certain amount of energy, and the computing can be carried out at the same time, that is, the idea of distributed computing is adopted, which will greatly reduce the computing pressure of the central node and the energy wasted by continuous communication. The disadvantage may be that the positioning accuracy may be reduced [7].

In the case of large-scale sensor networks, the centralized framework algorithm is not suitable. Due to the extremely complex calculation, an adaptive algorithm senses and checks the coordinates based on the distributed idea, which can realize the location estimation of the source. In this process, there is no multi hop transmission, only a single hop, so the communication cost can be greatly reduced and the energy consumption will be reduced. It is found after the simulation test. The convergence, robustness and stability of the location algorithm are also strengthened in different scenarios [8]. In reference [9], for the situation that there are no densely deployed nodes in the environment, the RSSI based non positioning method (RDL) is adopted to realize the high-precision positioning of sensor networks. The cell positioning model composed of different node distances in fine-grained is also constructed in this paper. The simulation shows that the error of RDL is less than 1.5m, and the positioning accuracy is improved by 50% compared with the existing methods. Reference [10] studies a signal strength gradient location algorithm. The implementation of the algorithm is distributed, and only quantitative data is used. Different filtering methods are used to estimate the location [11-12]. Finally, the quantization threshold is designed to quantify RSS data, and a new quantization algorithm based on distributed gradient is proposed. The quantization noise generated by local estimation is gradually eliminated by iteration in the algorithm, and the final performance can reach the index of non quantization data [13-14].

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 417-423
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

In order to solve the problem of positioning accuracy and computational complexity, this paper will hope to study and design a distributed cooperative positioning technology scheme based on ranging, improve the positioning accuracy through ranging, and design a distributed algorithm. Each sensor uses its own unit to carry out different tasks, so as to reduce energy consumption and avoid frequent communication. This will be a focus of the follow-up study of this paper.

II. MATERIALS AND METHODS

Single sided two-way ranging (SS-TWR) means that there are only two messages, and each device sends and receives them once. The ranging process is shown in the Fig 1 [10].

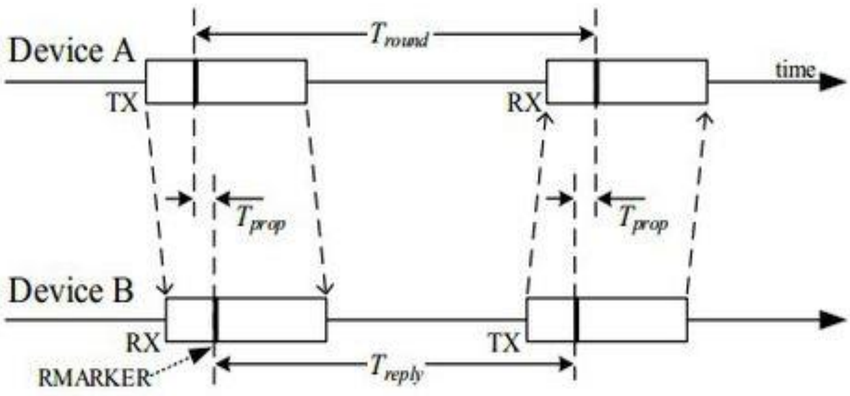

Fig 1: Ranging Process

Ranging process: device a turns on sending, actively sends a (poll) packet, and sends the time stamp $\mathrm{T_{a1}}$ record, timestamp $\mathrm{T_{b1}}$ is recorded when the poll packet reaches device B; Then, after waiting for treply time, at $\mathrm{T_{b2}}$($\mathrm{T_{b2}}$=$\mathrm{T_{b1}}$+$\mathrm{T_{reply}}$), the data packet (RESP) is resent from device B to device a; Until the resp packet is received by device a, the timestamp t is received $\mathrm{T_{a2}}$ is also recorded by A. so far, the unilateral two-way ranging process is completed [11-13].

$$\mathrm{T_{prop}} = \frac{1}{2}(\mathrm{T_{round}} - \mathrm{T_{reply}}) \tag{1}$$

$$\mathrm{T_{round}} = \mathrm{T_{a2}} - \mathrm{T_{a1}} \tag{2}$$

$$\mathrm{T_{reply}} = \mathrm{T_{b2}} - \mathrm{T_{b1}} \tag{3}$$

The difference time t between the two devices calculated by the local $\mathrm{T_{round}}$ and $\mathrm{T_{reply}}$, the clock deviation of each device can be offset, but the small clock offset will exist in different devices. Because device a and device B use different independent clocks, the frequency of the crystal oscillator is also different. Assuming that the e_A and e_B times of the expected frequency are the actual frequency of the clocks of device a and device B, the error formula caused by calculating the crystal oscillator frequency is

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 417-423
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

as follows:

$$\text{error} = \hat{T}_{prop} - T_{prop} = \frac{1}{2}\left(T_{round} - T_{reply}\right) - \frac{1}{2}\left(T_{round} * e_A - T_{reply} * e_B\right) = \frac{1}{2}T_{round}(1 - e_A) - \frac{1}{2}T_{reply}(1 - e_B) \approx \frac{1}{2}(\mathrm{e_B} - \mathrm{e_A}) * T_{reply} \quad (4)$$

III. DISTRIBUTED COLLABORATIVE LOCALIZATION ALGORITHM

For wireless sensor networks, on the premise of generality, it is assumed that any m wireless sensor positions are known (which can be obtained by observation or calculated by phase difference matrix), and the coordinates of reference nodes are p_1,p_2, $\cdots$, p_m. The coordinates of other unknown wireless sensor nodes are p_{m+1},p_{m+2}, $\cdots$, p_n. The entire wireless sensor network has the following pseudo linear representation:

$$\begin{bmatrix} p_a \\ p_s \end{bmatrix} = \begin{bmatrix} I_m & 0 \\ L_{as} & L_{ss} \end{bmatrix} \begin{bmatrix} p_a \\ p_s \end{bmatrix} \quad (5)$$

The matrix $p_a = \begin{bmatrix} p_1 & p_2 & \cdots & p_m \end{bmatrix}^T$ and $p_s = \begin{bmatrix} p_{m+1} & p_{m+2} & \cdots & p_n \end{bmatrix}^T$ represents the relationship between the reference node and the unknown node, and the matrix represents the relationship between the unknown node and the unknown node [14]. Due to the error of UWB ranging in wireless sensor networks, the ranging distance can be fitted by error fitting, so as to improve the positioning accura

$$Bp_s = L_{as} p_a \quad (6)$$

Where $A = B^T B$, $b = B^T L_{as} p_a$,For the above equation, Richardson is introduced for iterative operation

$$p_s(k+1) = (I - \varepsilon A) p_s(k) + \varepsilon b \quad (7)$$

$$\begin{cases} \hat{p}_i(k+1) = \hat{p}_i(k) - \varepsilon \xi_i(k) + \varepsilon \sum_{i \in N_j} a_{ji}\, \xi_j(k) \\ \xi_i(k+1) = \hat{p}_i(k) - \sum_{k \in N_i} a_{ik}\, \hat{p}_j(k) \end{cases} \quad (8)$$

The specific flow of the algorithm design is as follows:

Each wireless sensor node i has a location estimate p_i (due to the convergence of the algorithm, the initial position estimation value can be set arbitrarily), and send it to the neighbor node;

Each sensor node i calculates the residual according to the local estimate and the neighbor node's own estimate $\xi_i(k) = \hat{p}_i(k) - \sum_{k \in N_i} a_{ik}\, \hat{p}_j(k)$;

Each sensor node i sends the residual to the set N_i4:Each sensor node i accepts residuals from neighbor nodes $\xi_i(k)$,And update the estimates:

$$\hat{p}_i(k+1) = \hat{p}_i(k) - \varepsilon \xi_i(k) + \varepsilon \sum_{i \in N_j} a_{ji}\, \xi_j(k) \quad (9)$$

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 417-423
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

Finally, we can obtain stable p_i, and the algorithm can be implemented distributed. The matrix form of the algorithm is shown as follows:

$$\widehat{p_s}(k+1) = (I - \varepsilon B^T B)\widehat{p_s}(k) + \varepsilon B^T L_{as} p_a \tag{10}$$

Where $\varepsilon = 2/(\lambda_{max}(B^T B) + \lambda_{min}(B^T B))$,$\lambda_{max}(B^T B)$ and $\lambda_{min}(B^T B)$ are the maximum eigenvalue and the minimum eigenvalue of the matrix $B^T B$, respectively.

IV. SIMULATION

This paper simulates the distribution of wireless sensors. The initial position of wireless sensor nodes is determined by random sampling in a certain spatial range. It is assumed that there are 8 sensors in total. It is assumed that the blue circle is the sensor with good observation (the position is known), and the red circle indicates the sensor nodes that lose observation due to complex environment or equipment failure. In the simulation, the state of wireless sensor network is assumed as follows: four normal sensor nodes can obtain observations; 4 faulty sensors, no observation. UWB relative distance measurement can be realized between sensor nodes within 100m. It can be seen from Chapter 3 that the standard deviation of relative distance observation between adjacent nodes is 10cm and the positioning standard deviation of GPS observation of anchor node is 1m, shown in Fig 2.

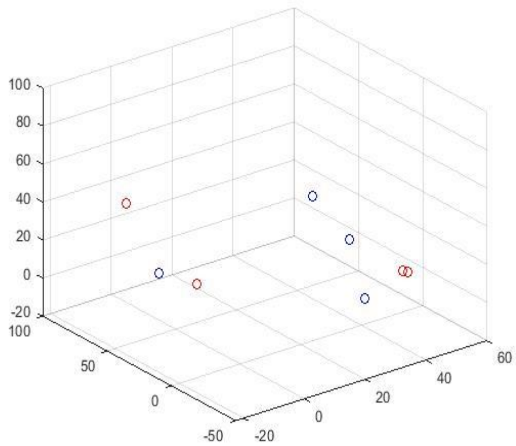

Fig 2: Position distribution of micro group robots

Then, we can represent the unknown node and anchor node through centroid coordinates and convert them into matrix form. The estimated position and real position error using the distributed cooperative positioning algorithm described in this paper are shown in Fig 3.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 417-423
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

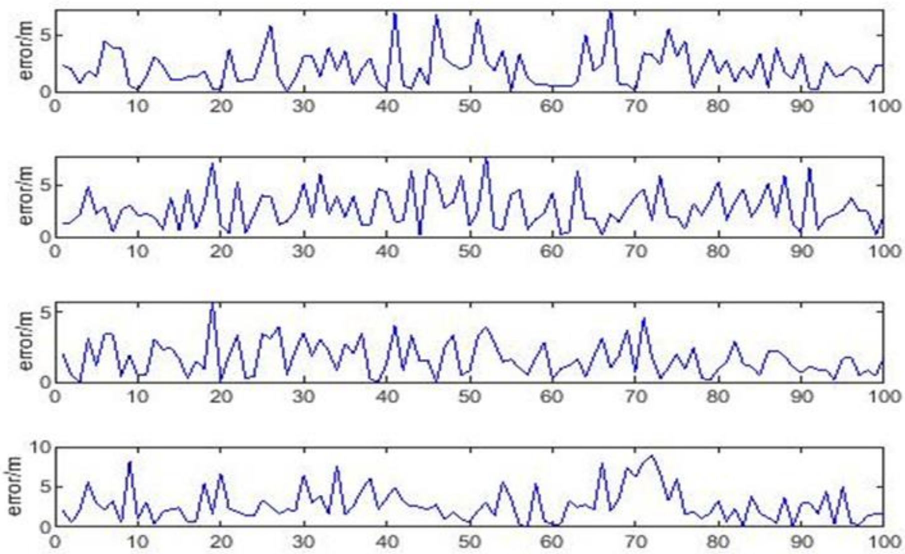

Fig 3: The error between the estimated position and the true position of different position nodes

Under the above parameter configuration, the error between mds-irbe algorithm and MDS algorithm proposed in this paper is shown in Fig 4. It can be seen that because MDS algorithm adopts centralized processing, the positioning accuracy is 2.862m, while the positioning accuracy of this algorithm reaches 2.348m, and the positioning accuracy is improved by 13.31%. In this algorithm, nodes accept the errors from neighbor nodes and update their own estimates. Because the cooperative localization process of the whole swarm robot system only has the interaction between local nodes and neighbor nodes, it can be implemented distributed, so higher localization accuracy is obtained.

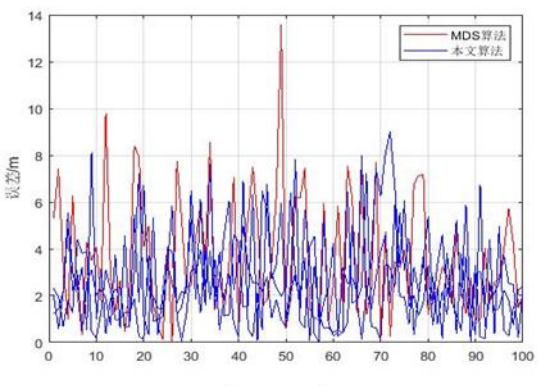

Fig 4: Simulation comparison of positioning error

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 417-423
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

V. CONCLUSION

This paper analyzes the problems of existing distributed cooperative positioning algorithms. For the traditional MDS-MAP algorithm, the improved local MDS algorithm can realize distributed calculation, but when the distance matrix has default, the multi hop distance is used to replace the European distance to realize positioning, which also brings a lot of error to the calculation results, This paper presents an improved MDS algorithm based on centroid coordinates, lists the relationship matrix equations of other nodes and reference nodes through the centroid model, introduces Richardson iteration to iteratively calculate the matrix equation, and puts forward the process of distributed positioning algorithm. Simulation results show that compared with the traditional MDS-MAP algorithm, the positioning accuracy of the proposed algorithm is improved by 13%.

REFERENCES

[1] Yaqoob I, Ahmed E, Hashem I A T, et al. Internet of Things Architecture: Recent Advances, Taxonomy, Requirements, and Open Challenges. IEEE Wireless Communications, 2017, 24 (3): 10-16.
[2] Yetgin H, Cheung K T K, El-Hajjar M, et al. A Survey of Network Lifetime Maximization Techniques in Wireless Sensor Networks. IEEE Communications Surveys & Tutorials, 2017, 19(2): 828-854.
[3] Bellavista P, Cardone G, Corradi A, et al. Convergence of MANET and WSN in Io T urban scenarios. IEEE Sensors Journal, 2013, 13(10): 3558-3567.
[4] Borges L M, Velez F J, Lebres A S. Survey on the Characterization and Classification of Wireless Sensor Network Applications. Communications Surveys & Tutorial IEEE, 2014, 16(4): 1860-1890.
[5] Khan A A, Rehmani M H, Rachedi A. Cognitive-Radio-Based Internet of Things: Applications, Architectures, Spectrum Related Functionalities, and Future Research Directions. IEEE Wireless Communications, 2017, 24(3): 17-25.
[6] Lazarescu M T. Design of a WSN platform for long-term environmental monitoring for IoT applications. IEEE Journal on emerging and selected topics in circuits and systems, 2013, 3(1): 45-54.
[7] Shoari A, Mateos G, Seyedi A. Analysis of Target Localization With Ideal Binary Detectors via Likelihood Function Smoothing. IEEE Signal Processing Letters, 2016, 23(5): 737-741.
[8] Zebbane B, Chenait M, Badache N. A distributed lightweight Redundancy aware Topology Control Protocol for wireless sensor networks. Wireless Networks, 2016, 23(6): 1-14.
[9] Cao M L, Meng Q H, Jing Y Q, et al. Distributed Sequential Location Estimation of a Gas Source via Convex Combination in WSNs. IEEE Transactions on Instrumentation & Measurement, 2016, 65(6): 1484-1494.
[10] Adaptation P. RSSI-Based Distributed Self-Localization for Wireless Sensor Networks Used in Precision Agriculture. IEEE Transactions on Wireless Communications, 2016, 15(10): 6638-6650.
[11] Sayed A.H, Tarighat A, Khajehnouri N Network-based wireless location: challenges faced in developing techniques for accurate wireless location information. Signal Processing Magazine, IEEE, 2005, 22(4): 24-40.
[12] Rao P C S, Jana P K, Banka H. A particle swarm optimization based energy efficient cluster head selection algorithm for wireless sensor networks. Wireless Networks, 2017, 23(7): 2005-2020.
[13] Xia W, Liu W. Distributed adaptive direct position determination of emitters in sensor networks. Signal Processing, 2016, 123: 100-111.
[14] Li Z, Chung P J, Mulgrew B. Distributed target localization using quantized received signal strength. Signal Processing, 2017, 134: 214-223.