Optimization Method of Node Location Accuracy Based on Artificial Intelligence Technology

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Abstract. Wireless sensor networks (WSN) are one of the hot topics in current information technology research. With the diversification of wireless sensor network applications and the gradual maturity of node positioning technology for static networks, mobile node positioning technology. In order to find a method for optimizing the positioning accuracy of wireless network nodes based on artificial intelligence technology and improve the positioning accuracy, a large-scale simulation experiment is performed in this paper. After constructing a probabilistic model and conducting a large number of simulation experiments, a series of random variable samples are obtained. After statistical processing of these simulation samples, a solution to the problem is found accordingly. By comparing the average positioning error with the ML algorithm, it is found that the SA-L algorithm using artificial intelligence method has less dependence on the density of beacon nodes, improves the accuracy of network node positioning, and is more suitable for node positioning of WSN. Research shows that artificial intelligence technology can improve the accuracy of network node positioning and provide a lot of reference for the development of wireless networks.

Keywords: Artificial Intelligence, Wireless-Sensor Network, Node Localization, SA-L algorithm

1. Introduction

WSN are a hot research area today. In recent years, due to the rapid development of the Internet of Things, the demand for WSN has been promoted. Many miniature wireless devices and embedded devices have appeared one after another. The rapid development of wireless sensors is changing our living environment [1-2]. The wireless sensor network has the characteristics of low cost and good scalability, while bringing more convenience to people's daily life, it also greatly improves the convenience of obtaining information in life [3-4]. The characteristics of WSN are that the cost and power consumption are relatively low, and they have adaptive capabilities, which can automatically change as the external environment changes [5]. It also has the characteristics of intelligent dynamic reconfigurability. It collects and processes the information sent by the nodes, and finally transmits it to the control center. These characteristics make it widely used, such as national defense deployment, site
monitoring, traffic management, personnel rescue, etc. WSN have become one of the indispensable means of collecting and acquiring large amounts of physical data in the future [6-7].

Sensor node positioning is one of the key technologies in sensor network research. The location information of a node is very important for its application. This importance is reflected in two aspects: on the one hand, it is for some monitoring information in the application. If there is no location information in many cases, the observer needs to know "what happened at what location", such as disaster monitoring, animal tracking research, traffic monitoring system, etc.; on the other hand, it is an important support for the normal operation of the sensor network. For example, in the routing based on geographic location information, sensor node positioning has become an indispensable information. In addition, for the security needs of sensor networks, the location information also plays an important role in resisting security attacks [8-9]. With the advent of mobile sensor networks, sensor node positioning faces new challenges. With the continuous in-depth research and development of wireless sensor network technology, node localization technology should be further explored and researched as the main supporting technology for wireless sensor network applications [10]. A wireless sensor network is an independent network composed of micro-sensor nodes. These nodes can collect, process, and transmit data to users in the real-time monitoring area. The positioning of information is a problem that WSN need to solve urgently. As a prerequisite for the widespread application of the network, node localization technology is of great significance.

Based on the theoretical knowledge of WSN, this paper mainly studies the problem of node location in wireless networks based on artificial intelligence technology. This paper uses the trilateration method as the basis for wireless sensor positioning and data acquisition. In the simulation calculation of the collected data samples, the SA-L method is used to anneal to avoid the simulation process from converging. In the area, 100 sensor nodes are randomly arranged to perform simulation experiments. The results show that the accuracy of the model definition defined in this paper is higher than the commonly used method (ML method).

2. Method

2.1 Key Technologies of WSN

(1) Network topology control

Using automatic topology control to create a good network topology can improve the efficiency of routing protocols and protocols, and choosing effective target placement can help save network life. The main research problem of controlling sensor network topology is to provide network coverage to eliminate unnecessary wireless communication lines between nodes, thereby creating a network topology. Two kinds of topology control methods: node power control and hierarchical topology are adopted.

(2) Positioning technology

One of the most important functions of a sensor network is to specify the location of an event or a node that collects data. The sensitive nodes that are randomly placed to provide valid location information should determine their location after placement. Due to the limited number of sensor nodes and random placement, sensitivity to environmental interference, and even node failures, the positioning mechanism must meet the requirements of self-organization, strength, energy efficiency, and distributed computing. Sensor nodes are divided into anchor nodes and unknown nodes according to their positions. The location of the anchor node is known, and the unknown node must determine its location based on several anchor nodes and some placement mechanism.

(3) Data collection

To achieve the functions of aggregation, calculation or transmission, energy is consumed. The energy required to collect depends on the amount of data produced, the sampling frequency, the type of sensor, and the application requirements. The use of energy-efficient network communication protocols and data localization is a feasible solution. According to the US Department of Defense, in military applications, data consolidation involves linking and combining information and information
from multiple sensor sources to obtain accurate location and identity assessments, assessing threats and their importance. Although there is no complete theoretical system and method for data integration technology, the number of people involved in the technology and the number of literature in the field have increased significantly.

(4) Data management

Data management in sensor networks is very different from traditional distributed databases. When the sensor nodes have limited power and are prone to failure, the data management system must provide efficient data services while reducing energy consumption. At the same time, there are a large number of nodes in the sensor network, and the data flow created by the sensor nodes is not limited. Traditional distributed database data management technologies cannot analyze and process them. In addition, sensor network data query is usually a continuous survey or random sampling request, which is not suitable for traditional distributed database data management techniques for sensor networks.

(5) Application-layer technology

The sensor network application-layer consists of various application-oriented software systems. The research at the application layer is mainly multi-task coordination between various sensor network application systems, such as combat monitoring systems, military intelligence systems, information systems, combat control and command systems, environmental control systems and transportation management systems, and civil and engineering facility security monitoring systems, biomedical monitoring, etc.

2.2 Trilateral measurement node positioning algorithm

![Figure 1](image)

In WSN, the coordinate system is mostly two-dimensional space. In the positioning algorithm based on ranging, trilateration is the basic way to calculate coordinates. As shown in Figure 1, the basic principle of the trilateration positioning method is to find the intersection of three circles with known radius and coordinate center. The main principle is that if the distance $d_1$ from the unknown node $D$ to the beacon node $A$, $D$ may appear on a circle with $A$ as the center and $d_1$ as the radius; if you know the distance $d_2$ from $D$ to another beacon node $B$, then $D$ may appear on a circle with the center of $B$ and $d_2$ as the radius, and $D$ may appear on any intersection where the two circles intersect; at this time, if you know the distance $d_3$ from $D$ to the third beacon node $C$, the distance measurement on the premise of accuracy, a circle with $C$ as the center and $d_3$ as the radius must intersect the two circles above to determine the coordinates of $D$.

As shown in Figure 1, assume that the coordinates of the three beacon nodes $A$, $B$, and $C$ are $(X_1, Y_1)$, $(X_2, Y_2)$, $(X_3, Y_3)$, and assume that the coordinates of the unknown node are space distance calculation formula, you can get the system of equations:
In Equation 1, x and y are unknown variables. This is a non-linear system of equations, which can be solved by linearization. The coordinates thus solved are:

\[
\begin{bmatrix}
  x \\
  y
\end{bmatrix}
= \begin{bmatrix}
  2(x_1 - x) & 2(y_1 - y) \\
  2(x_2 - x) & 2(y_2 - y)
\end{bmatrix}^{-1} \begin{bmatrix}
  x_1^2 - x^2 + y_1^2 - y^2 + d_1^2 - d_1^2 \\
  x_2^2 - x^2 + y_2^2 - y^2 + d_2^2 - d_2^2
\end{bmatrix}
\]

(2)

The disadvantage of the trilateration method is that if there is an error in the ranging process, the above three circular areas cannot intersect at one point. When the above errors are solved by the existing errors \(d_1, d_2, d_3\), the correct solution cannot be obtained. Therefore, in the actual calculation of coordinates, the above-mentioned method of solving equations is generally not used, but maximum likelihood estimation or other numerical solutions are used.

2.3 SA-L

During the simulation experiment, the data is easily affected by the irregularity of the acquisition process or the background noise, which causes some sample data to be damaged during the experiment. Therefore, the simulation results in a state of non-convergence. Therefore, in order to obtain the optimal solution, the convergence sample set is “annealed”. In the simulation process, in order to find a local optimal solution, this paper uses the SA-L method to perform the sample optimal solution method. The main steps can be described as follows:

The first step: initialize the parameters, set the initial node vector of the sensor simulation, initialize the solution state parameters, and initialize the upper bound of each vector iteration;

Step 2: Transform the calculated solution to obtain a new solution (for example, use the mutual displacement method to replace the elements);

Step 3: Calculate the incremental value, which can be calculated by the evaluation function;

Step 4: Determine whether the incremental value is greater than 0. If it is less than 0, use \(e^{(-\delta t)/(kt)})\) as the current solution, where \(k\) is the Boltzmann constant;

Step 5: If the condition is met, output the result, otherwise decrease the value of \(t\) and go to step 2.

3. Experiment

This article is carried out by establishing a large-scale simulation experiment. After constructing a probabilistic model and conducting a large number of simulation experiments, a series of random variable samples are obtained. After statistical processing of these simulation samples, the solution of the problem can be obtained. The simulation experiment conditions are: 100 sensor nodes are randomly arranged in a three-dimensional area of 200 * 200 * 200, of which 5 are beacon nodes, the initial temperature value \(T = 0\), the parameter \(a = 1\), and the ranging error is set to 3%. Under this condition, 100 simulation experiments of 3D node positioning were performed, and the fitness value of the iteration in each experiment was recorded. The fitness value was the value of the objective function formula, and then the average value of the fitness value of this simulation experiment was taken to obtain SA-L Evolution curve of algorithm iterations.

In order to ensure the accuracy and rigor of the data, a large number of experiments were performed in this paper. Through the analysis and analysis of the data, the method of optimizing the positioning accuracy of wireless network nodes based on artificial intelligence technology is found, which provides a large amount of data foundation and development direction for the subsequent development of wireless network node positioning.
3.1 Results and Analysis
From the curve in Figure 2, it can be seen that as the ranging error continues to increase, the average positioning error of both algorithms is increasing, and the average positioning error of the algorithms almost rises in a straight line. The amount showed a decreasing trend in each interval. At the same time, the difference between their average positioning errors also increases as the ranging error increases. Under the same ranging error, the average positioning error of the algorithm is always er than that of the algorithm. Therefore, it can be concluded that in the three-dimensional node localization of WSN, the positioning accuracy of the algorithm is higher than the algorithm with the same ranging error, and the algorithm has better positioning performance under this condition. As can be seen from the curve in Table 1, with the increase of the beacon node density, the average positioning error of the two algorithms decreases, and the change rate of the average positioning error shows a decreasing trend in each interval. At the same time, the difference between their average positioning errors gradually increases with the increase of the beacon node density.

Figure 2. Comparison chart of average positioning error under different ranging errors

Table 1. Comparison of average positioning errors under different beacon node densities

| Beacon node density (%) | ML average positioning error | SA-L average positioning error |
|-------------------------|-----------------------------|-------------------------------|
| 5                       | 8                           | 4                             |
| 10                      | 7.5                         | 3.5                           |
| 15                      | 7.2                         | 3                             |
| 20                      | 7                           | 2.5                           |
| 25                      | 6.8                         | 2.3                           |
| 30                      | 6.5                         | 2                             |

3.2 Advantages of Artificial Intelligence Technology in Wireless Network Node Positioning
In this paper, a large number of simulation experiments are used to test the node localization in the sensor network, and compared with the maximum likelihood method. Simulation experiments prove that the use of intelligent optimization algorithms for node position estimation has the following advantages:

(1) Significantly improve positioning accuracy. Under different ranging errors, the intelligent optimization algorithm has good positioning performance. Especially when the ranging error is large, the positioning accuracy is significantly better than that of the maximum likelihood estimation method.
(2) The number of anchor nodes is small and the cost is low. With the same density of anchor nodes, compared with the maximum likelihood estimation method, the positioning error of the intelligent optimal positioning algorithm is significantly reduced, which has obvious advantages. In addition, the intelligent optimal positioning algorithm can show good positioning performance under the condition of low density of anchor nodes, so only a small number of anchor nodes are needed in network deployment, thereby significantly reducing the cost of the network.

(3) Reduced sensitivity to deployment of known nodes. When the physical locations of the nodes are known to be different, the accuracy of the maximum likelihood method is affected to some extent. Utilizing the evolutionary mechanism principle and global optimization characteristics of intelligent optimization algorithms, it can meet WSN with high positioning accuracy requirements.

4. Results

Wireless sensor network has broad application prospects. Positioning technology is one of the main supporting technologies for WSN. Data collection is an integral part of the sensor nodes, and the data has no reference value without providing any location information. Therefore, the research of wireless sensor network location algorithm has great value. In this paper, a large number of data studies are used to study the location of wireless network nodes. However, due to the complexity of the research topics, the research on node localization in WSN is not comprehensive enough and should be improved, but I hope that the work in this article can provide useful reference for further research.

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