

A Novel Wireless Sensor Network Node Localization Algorithm Based on BP Neural Network

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Abstract

The accurate localization of wireless sensor network node is one of the supporting technologies of network application. A novel localization algorithm of wireless sensor network node based on BP neural network is put forward in the paper. This localization algorithm constructs the BP neural network model in accordance with the number of the anchor node firstly, and then trains the network by the anchor node and estimates the location of the unknown node. Moreover, the virtual anchor node is introduced into this algorithm in order to realize its optimization, which increases the anchor node scale in the network and improves the localization accuracy of the node. The simulation experiment results in two different conditions show that compared with Centroid algorithm and DV-Hop algorithm, the localization algorithm of this paper estimates the location of the unknown node more precisely and improves the location accuracy more effectively. This algorithm demonstrates its merits greatly.

Keywords: wireless sensor network, BP neural network, anchor node, virtual anchor node

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1. Introduction

The wireless sensor network is composed of dozens or even thousands of the sensor nodes and these sensor nodes are mostly deployed in areas of complex environment, even in some areas out of personnel's reach in the method of random seeding [1]. A small amount of the known nodes are usually deployed when the sensor network is constructing. These nodes carry out self-localization by GPS with a high cost, so not all the nodes in sensor network have the function of self-localization. Thus, to realize the high-precision localization of the node has become one of the hot issues in the wireless sensor network research in order to meet requirements of applications.

The localization technology research on wireless sensor network is mainly divided into two categories: one is the range-based localization algorithm; another is the range-free localization algorithm. Considering the factors of volume, energy and cost of the sensor network node [2], the range-free localization algorithm is more practical. The range-free localization algorithm that is commonly used includes Centroid algorithm [3], DV-Hop algorithm [4, 5], Amorphous algorithm [6, 7], APIT algorithm [8], etc. In recent years, the localization technology research on wireless sensor network mainly focuses on improving localization accuracy, for example, nonlinear least squares are used to research the node localization in [9]; fine-grained hop-count is used to research the node localization in [10]; virtual central node is used to research the node localization in [11], and so on. In addition, some excellent localization algorithms have been widely applied to the daily production and life [12]. The paper adopts BP neural network and the virtual anchor node to research the localization algorithm.

The remainder of the paper is organized as follows. The localization algorithm based on BP neural network is presented carefully in Section 2, including constructing BP neural network model, training network and estimating location, setting virtual anchor node and relocating the node. Then, the simulation experiments and analysis are shown in Section 3, which proves the

superiority of this algorithm. In Section 4, conclusions are given with the importance and practical value of this algorithm.

2. Localization Algorithm Based on BP Neural Network

This algorithm uses a key data value that is the minimum hop between the node. And the minimum hop is determined by the following methods: the anchor node broadcasts its location information to the neighbor node, including the hop (Its initial value is 0.) and its ID information; the receiving node stores the hop; if the receiving node gets the hop from the same anchor node and the hop is bigger than the stored one, the newly-received hop is ignored; and then there exists the hop plus 1, which is broadcast to the neighbor node continuously, so the minimum hop to each anchor node is stored by the network node. The algorithm is divided into four steps in detail as followed [13].

2.1. Constructing BP Neural Network Model

In the localization area, assume there are M any placement nodes totally, and make $m=1, 2, \dots, M$, where first N of M is set as the anchor node and the rest is set as the unknown node. $C_i=(x_i, y_i)$ represents the position coordinate of node i . Make $K_i=[k_{i1}, k_{i2}, \dots, k_{in}, \dots, k_{iN}]$ represent the minimum hop between the anchor node, where k_{in} represents the minimum hop between anchor node i and anchor node n , and $i=1, \dots, N$, $n=1, \dots, N$, and when $i=n$, $k_{in}=0$. Then make $K_j=[k_{j1}, k_{j2}, \dots, k_{jn}, \dots, k_{jN}]$ represent the minimum hop between the unknown node and the anchor node, where k_{jn} represents the minimum hop between unknown node j and anchor node n , and $j=(N+1, N+2, \dots, M)$, $n=1, \dots, N$. The unit number of BP neural network input layer is N , which is determined by the number of the anchor node, the unit number of the hidden layer is determined by the experiment, and the unit number of the output layer is 2, which represents the node coordinate (x, y) .

2.2. Training Network and Estimating Location

After constructing BP neural network model successfully, the localization algorithm carries out training network and estimating location.

For the training stage, the anchor node is used to train BP neural network, and the training sample selects all the anchor nodes in wireless sensor network. The training input is the minimum hop between the anchor node, namely $K_i=[k_{i1}, k_{i2}, \dots, k_{in}, \dots, k_{iN}]$, $i=1, \dots, N$, $n=1, \dots, N$. And the training output is the corresponding position of the anchor node, namely $C_i=(x_i, y_i)$, $i=1, \dots, N$.

For the estimating stage, the estimation input is the hop between each unknown node and each anchor node, namely $K_j=[k_{j1}, k_{j2}, \dots, k_{jn}, \dots, k_{jN}]$, $j=(N+1, N+2, \dots, M)$, $n=1, \dots, N$. And the estimation output is the position of the corresponding unknown node, namely $C_j=(x_j, y_j)$, $j=(N+1, N+2, \dots, M)$.

2.3. Setting Virtual Anchor Node

By definition, the virtual node is defined as the node that does not exist in reality and has no communication ability of the real node. However, it is the artificial node to make the localization algorithm result more accurate, and its characteristic is that the coordinate is known or can be calculated accurately [14].

In localization area, assume that there exist S virtual anchor nodes, and its location coordinate is $C_l=(x_l, y_l)$. Makes $K_l=[k_{l1}, k_{l2}, \dots, k_{ln}, \dots, k_{lN}]$ represent the minimum hop between the virtual anchor node and the anchor node, where k_{ln} represents the minimum hop between virtual anchor node l and anchor node n , and $l=1, 2, \dots, S$, $n=1, \dots, N$.

Because the virtual node has no abilities of communication and information transferring, the minimum hop is detected directly between the virtual anchor node and the anchor node, and the distance from virtual node to anchor node is converted to hop. In the simulation experiments, the hop is first calculated, and then the distance is compared with the wireless range of the node.

The trained BP neural network is used to estimate the location of all the virtual anchor nodes. The input of the network is the minimum hop between the virtual anchor and the anchor node, which is described as $K_l=[k_{l1}, k_{l2}, \dots, k_{ln}, \dots, k_{lN}]$, $l=1, 2, \dots, S$, $n=1, \dots, N$. The output of the

network is the estimation location of the corresponding virtual anchor node, that is, $C'_l = (x_l, y_l)$, $l = 1, 2, \dots, S$.

For the virtual anchor node, its estimation location and its actual location can be compared and figured out, which is based on the fact that the assumption of the virtual anchor node location is known as restrictive conditions, namely C'_l and C_l . For the comparative result, select Q virtual anchor nodes with small error, which sets the minimum hop as $K_q = [k_{q1}, k_{q2}, \dots, k_{qn}, \dots, k_{qN}]$, $q = 1, 2, \dots, Q$, $n = 1, \dots, N$.

2.4. Relocating Unknown Node

After obtaining the trained virtual anchor node, BP neural network needs to be reconstructed. At the moment, the trained virtual anchor node in network is added into the anchor node. Therefore, the unit number of BP neural network input layer has been changed because the number of the anchor node has altered. And then the network training is carried out again according to Section 2.2. The training completion means that all the unknown nodes are relocated.

3. Simulation Experiment and Analysis

For simulation experiments in this paper, a series of simulation experiments are carried out on Matlab software by using Centroid localization algorithm, DV-Hop localization algorithm, the BP localization algorithm without the virtual anchor node, the RN-BP localization algorithm with the untrained virtual anchor node, and the VN-BP localization algorithm with the trained virtual anchor node with small error respectively. In the simulation experiments, the wireless sensor network node is distributed in the area of $100m \times 100m$ randomly. Because prediction results of BP neural network are affected by the initial weight to some extent, in order to ensure that the simulation experiment results reflect the merits of the algorithm correctly, the simulation experiments are carried out in the same experimental conditions for many times, such as 50 times, and then the average localization error values are taken and analyzed. The simulation experiments and performance analysis are carried out in two different experimental conditions, namely changing the anchor node scale and the total number of the node.

3.1. Experiment on Changing the Anchor Node Scale

Of the simulation experiments on changing the anchor node scale, set the total number of the node as 150, set the wireless range as 30m, and the specific results are as shown in Figure 1.

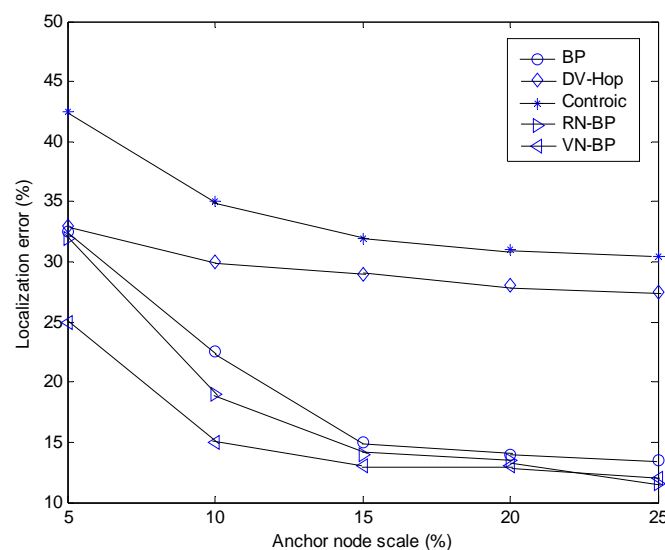


Figure 1. Anchor node scale and localization error

The simulation results show that with the increase of the anchor node scale, the localization errors of five different algorithms decrease. In the same conditions, the localization error of the BP localization algorithm of this paper is on average 14.754% lower than that of Centroid localization algorithm and on average 10.340% lower than that of DV-Hop localization algorithm, and the error curve of the BP localization algorithm drops fastest. The localization error of the RN-BP localization algorithm is on average 3.814% lower than that of the BP localization algorithm. Thus, the anchor node scale affects the localization error. Also, the localization error of the VN-BP localization algorithm is on average 2.452% lower than that of the RN-BP localization algorithm. So for the different scale states of the anchor node, the introduction of the virtual node reduces the localization error effectively.

3.2. Experiment on Changing the Total Number of Node

The simulation experiments are carried out in different conditions of the total number of the node, and set the anchor node scale as 15% and the wireless range as 30m, whose specific results are as shown in Figure 2.

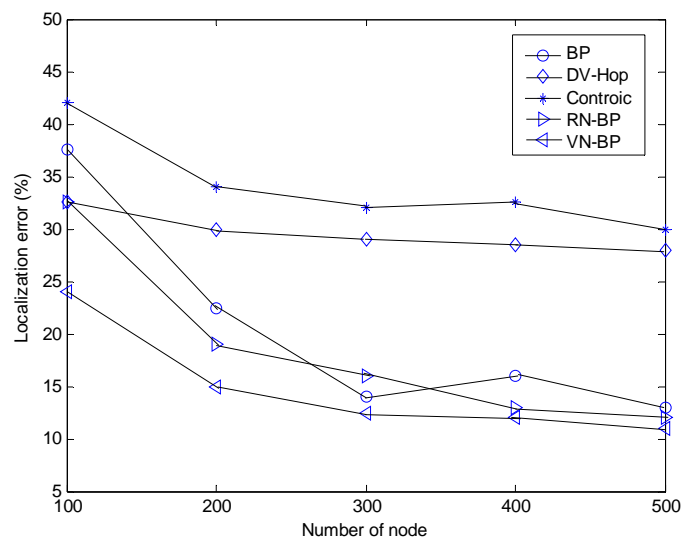


Figure 2. Node Number and Localization Error

In the experiments, for these five different algorithms, the localization errors on the whole take on a gradually decreasing trend. However, in the same conditions, in comparison, the localization error of the BP localization algorithm is on average 12.600% lower than that of Centroid localization algorithm. When the number of the node is 100, the experiment results show that the localization error of DV-Hop localization algorithm is obviously lower than that of the BP neural network algorithm. But when the number of the node is over 200, the localization error of the BP neural network localization algorithm quickly decreases and is obviously lower than that of DV-Hop localization algorithm. When the virtual anchor node is introduced in the localization algorithm, the localization error of the RN-BP localization algorithm is on average 2.221% lower than that of the BP neural network localization algorithm, which shows that introducing the virtual anchor node into the localization algorithm reduces the localization error effectively. At the same time, the localization error of the VN-BP localization algorithm is on average 3.912% lower than that of the RN-BP localization algorithm, which shows that introducing the trained virtual anchor node improves the localization accuracy effectively.

4. Conclusion

This paper introduces the concept of BP neural network into the wireless sensor network node localization, using BP neural network to train the anchor node in order to reduce the localization error. At the same time, aiming at anchor node scale in localization area, it puts

forward the application of the trained virtual anchor node so as to improve the anchor node scale and reduce the localization error. The simulation results in two different experimental conditions show that the localization error of the VN-BP localization algorithm is much lower than of the BP neural network localization algorithm as well as that of the RN-BP localization algorithm. Moreover, the results show that the localization error of the BP neural network localization algorithm in most cases is lower than that of Centroid localization algorithm as well as that of DV-Hop localization algorithm. To sum up, the localization algorithm based on BP neural network of this paper has the superiority and the research value to some extent.

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