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A Review of Virtual Anchor Node Technology: Construction and Application

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Abstract

The localization accuracy of the wireless sensor network node is improved by introducing the virtual anchor node, so the virtual anchor node is constructed and applied by many researchers to optimize the localization algorithm further. This paper presents the broad definition of the virtual anchor node and indicates its significance in the wireless sensor network node localization; the wireless sensor network node localization algorithm based on the virtual anchor node is introduced mainly in two aspects of constructing the virtual anchor node and its application in localization. The scheme for constructing the virtual anchor node includes the random construction method, the geometric constraint method, the node upgrade method, the network training method, etc. And the scheme for its application in localization includes the model reconstruction method, the rank sequence method, etc. By making a concrete analysis of the localization scheme based on the virtual anchor node, its future research prospect and its application development trend are put forward.

Keywords: *Wireless sensor network localization technology, Localization accuracy, Virtual anchor node*

1. Introduction

At present, with the development of network technology, the wireless sensor network that connects the computer world with the physical world is used increasingly widely, and its application value and its research value cannot be neglected. The wireless sensor network is composed of dozens or even thousands of sensor nodes and the sensor nodes are mostly deployed in areas of complex environment, even some areas out of personnel's reach in the method of random seeding [1]. A small amount of known nodes, namely anchor nodes are usually deployed when constructing sensor networks. These nodes carry out self-localization by GPS with a high cost, so not all the nodes in the sensor network have the function of self-localization. So, 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 research on the wireless sensor network mainly includes the supporting technology, the communication protocol, the data management technology, the network data processing technology, etc., in which, the localization technology has become the key issues in the design and implementation of the wireless sensor network and provides the network with the important location information service. As a result, the node localization technology has proved to be one of the basic supporting technologies of the wireless sensor network.

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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 sensor network nodes [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], Amorphous algorithm [5, 6], APIT algorithm [7], etc. The range-free localization algorithm obtains the location coordinate of the unknown node by the location estimation finally. In recent years, the localization technology research on the wireless sensor network mainly focuses on improving the localization accuracy of the range-free localization algorithm.

The remainder of the paper is organized as follows. The definition of the virtual anchor node and its related interpretation are presented carefully in Section 2. The construction scheme for the virtual anchor node and their advantages and disadvantages are illustrated in Section 3. The application scheme for the virtual anchor node is introduced in Section 4. In Section 5, conclusions are given with the importance of the virtual anchor node.

2. Definition of Virtual Anchor Node

In localization area of the wireless sensor network node, without any increase in cost and without the use of auxiliary equipment, several nodes that are equivalents to the anchor node are added artificially, and the node is applied to the localization process of the unknown node, in which the node is defined as the virtual anchor node.

Two main properties of the virtual anchor node are listed below. First, it has the known location. Moreover, it has no functions of broadcasting, receiving and storing information (except the virtual anchor node obtained by the node upgrade method).

The localization accuracy is improved by using the virtual anchor node. It performs an important function in improving the localization accuracy of the wireless sensor network node. The details are as follows. In the localization area, the anchor node is randomly deployed and its number is limited, while the virtual anchor node is purposefully deployed and its number is arbitrary. And it is indisputable fact that the increase in the anchor node proportion improves the localization accuracy and reduces the localization error. The virtual anchor node has the known location, and then the virtual anchor node with the known location increases the amount of the anchor node information in localization area, and increases the proportion of the anchor node in the localization area, so the amount of information is larger for the unknown node to determine its location, and the localization of the unknown node turns out to be more accurate, which achieves the aims of both low network cost and high location accuracy [8-15]. Two key issues in applying the virtual anchor node to the auxiliary localization lie in how to construct the virtual anchor node and how to apply the virtual anchor node without the node executive function to the node localization.

3. Construction Scheme for Virtual Anchor Node

By the systematical collection and research of a large number of literatures, it is found that there are many methods of constructing the virtual anchor node. In this paper, the methods are summarized as four construction methods of the virtual anchor node, including the random construction method, the geometric constraint method, the node upgrade method and the network training method. And the specific content and application scope of the four methods are elaborated on, and their advantages and disadvantages are presented in detail.

3.1. Random Construction Method

The random construction method refers to setting the location and number of the virtual anchor node in localization area at random.

This method may not make much sense if it is adopted in the state of complete random. Generally, this method is applied to set the virtual anchor node when there is the certain orientation or goal. For example, in order to solve the problem that there exists the bigger localization error for the edge node, the virtual anchor node is constructed near the edge of localization area. For another example, because range R of anchor node Ai is limited and Ai is the closest to the unknown node Bi, Bi cannot be localized. Therefore, the virtual anchor node is constructed randomly between Ai and Bi, and its number is determined by R. In addition, this method is frequently adopted to construct the virtual anchor node, combined with other methods.

The random construction method has some notable advantages that it has the simple algorithm and that it is easy to be realized. Meanwhile, it has sort of disadvantages that improvement of the node localization accuracy is not pretty obvious and that the user's anticipation capability is highly demanded.

3.2. Geometric Constraint Method

The geometric constraint method refers to connecting the anchor node in localization area into the line segment or the figure and then setting the virtual anchor node according to the geometric relationship of the line segment or the figure. For instance, the virtual anchor node is set in the center of the circle, the center, the centroid, the point of intersection, the point of tangency, the pedal, the bisector, and so on.

This method is used more commonly and broadly. And there exists the geometric constraint relationship among anchor nodes, which reduces the estimation scope of the unknown node and improves the accuracy of the estimation localization [16]. At the same time, because the virtual anchor node constructed by this method has no physical executive function, its location coordinate information is stored in the anchor node having the geometric constraint relationship with it.

The advantages of the geometric constraint method are that the virtual node is easy to be constructed and that the unknown node localization accuracy in the geometric figure is improved. Its disadvantages are that the edge node localization error is higher and that the application method of the virtual anchor node is complicated.

3.3. Node Upgrade Method

The node upgrade method refers to upgrading the unknown node that has obtained the localization coordinate into the virtual anchor node.

In the process of the wireless sensor network node localization, part of the unknown nodes is localized ahead of other unknown nodes. And then select the nodes with smaller localization error among the unknown nodes that have completed localization and obtained their location coordinates, upgrade them into the virtual anchor nodes with the known location, and then complete localization work of the rest of unknown nodes. This method is not applied widely, because there is the phenomenon of error accumulation. Thus, this method is suitable for circumstances, in which the localization error is quantifiable and part of the unknown nodes has the minimal localization error. For instance, concerning the algorithm that combines range with free range, in the case of insufficiency of the anchor node, the range localization algorithm is adopted to determine the coordinate of part of the unknown nodes, and the coordinate error is small, the node with small coordinate error is

upgraded into the virtual anchor node, and then the free-range localization algorithm based on the virtual anchor node is adopted to locate the remaining unknown node.

The advantages of the node upgrade method are that the virtual anchor node upgraded has the physical characteristics and that it is easy to be applied in the localization. Its disadvantage is that there is the phenomenon of error accumulation.

3.4. Network Training Method

The network training method refers to using the neural network model to train the random node, and selecting the node with the small localization error as the virtual anchor node.

The specific process is listed below. First, the neural network is constructed, and all the anchor nodes in wireless sensor network are selected to train the network. Then, some nodes are selected randomly and input to the network, the nodes with small localization error are reserved as the virtual anchor node. Finally, the unknown node is adopted and input into the network in order to estimate its location.

The advantages of the network training method are that it is used widely and that it connects all the nodes in localization area as an organic whole. Its disadvantages are that the localization accuracy is affected directly by the network model and that it the localization accuracy of most of the nodes is increased while the localization accuracy of a few nodes is decreased to a certain degree.

4. Application Scheme for Virtual Anchor Node

According to the properties of the virtual anchor node, most of the virtual anchor nodes have no physical characteristics, that is to say, these anchor nodes cannot send, receive and store information, and then how to apply them to the real localization process has become one of the urgent problems in application. Thus, in the paper, the model reconstruction method and the rank sequence method are refined in order to solve the problem.

Based on the analysis of the anchor node construction scheme in Section 3, the virtual anchor node constructed by the upgrade method is pretty special, and it has the physical characteristics, so it can be directly applied to the localization like the anchor node. The virtual anchor node can be applied to the localization by the model reconstruction method, in which the virtual anchor node is obtained by either the network training method or the combination of the random construction method and the network training method. And the virtual anchor node can be applied to the localization by the rank sequence method, in which the virtual anchor node is obtained by either the random construction method or the geometric constraint method.

4.1. Model Reconstruction Method

The model reconstruction method refers to adopting the virtual anchor node to reconstruct the localization model that has been constructed by the anchor node, which practically puts the virtual anchor node into localization.

Take the node localization algorithm based on BP neural network as an example, in which the virtual anchor node is obtained by combining the random construction method with the network training method.

In the localization area, assume there are M any placement nodes totally, where first N of M is set as the anchor node and the rest is set as the unknown node. The BP neutral network is established. And the unit number of BP neutral 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). The anchor node is used to train the network. In localization area, assume that S virtual anchor nodes are selected randomly and input into the network, and then Q virtual anchor nodes with small error are obtained. BP neutral network Model is shown in Figure 1.

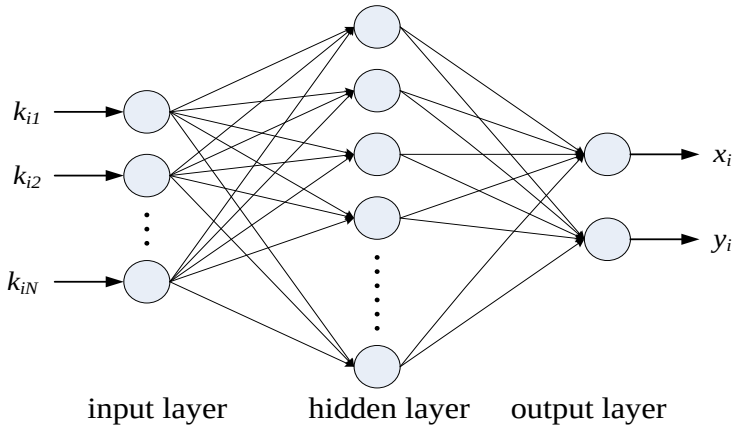

Figure 1. BP Neutral Network Model

After obtaining the trained virtual anchor node, BP neural network needs to be reconstructed. At the moment, the trained virtual anchor node in the 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. The training completion means that all the unknown nodes are relocated.

4.2. Rank Sequence Method

The rank sequence method refers to establishing the rank sequence for each unknown node after the virtual anchor node is constructed so as to practically put the virtual anchor node into localization [17].

Take DRL localization algorithm [18] as an example, in which the virtual anchor node is constructed by the geometric constraint method. In the localization area, the set that is composed of the anchor node coordinate is taken as the point set to construct the Delaunay graph. The midpoint of each edge of Delaunay triangle is taken as the virtual anchor node, and the midpoint coordinates are stored by the two endpoints (the anchor nodes) of the edge. The rank sequence from the unknown node to the anchor node is established in the order of receiving information of the unknown sensor node. The rank sequence is shown in fig 2.

In which, *A*, *B* and *C* represent the known anchor nodes, and *U1*, *U2* and *U3* represent the unknown nodes. The localization sequence of node *U1* is *d11d32d22*. The subscript of *d* has two numbers, for which its first number represents the order of the corresponding sender of received information and its second number represents the hop of the sender of received information at the moment [19]. *d11* represents that the *U1* has received the information from anchor node *A*, in which the first number *1* shows that *U1* has received the information of the anchor node firstly, and the second number *1* refers that the anchor node *A* is within the scope of 1-hop of *U1*, and then *11* is got. Subsequently, the anchor nodes *B* and *C* are expressed as *2* and *3*. Because of crossing node *U3*, the hop from the anchor node *C* to the unknown node *U1* is counted as *2*, and then the anchor node *C* is expressed as *d22*. Because of crossing node *U2*, the hop from the anchor node *B* to the unknown node *U1* is counted as *2*, and then the anchor node *B* is expressed as *d32*. Depending

on the rank, the unknown node with the minimum distance to some anchor node is got.

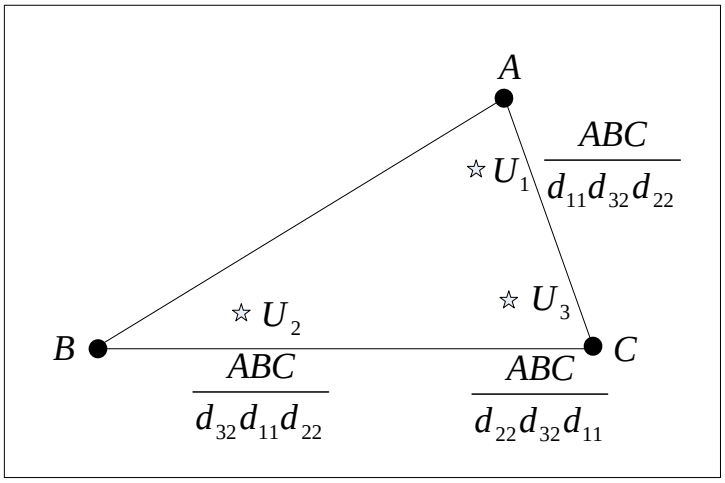

Figure 2. Node Rank Sequence Diagram

Every unknown sensor node in the localization area selects the nearest coordinates of the known anchor node in accordance with the rank sequence, and at the same time chooses all the coordinates of virtual anchor nodes that are recorded by two any anchor nodes of three anchor nodes in the unknown node rank sequence. And Centroid algorithm is used to estimate the location coordinates of the unknown node. The specific estimation is shown in formulas (1) and (2).

$$X = \frac{1}{n}\left(\sum_{i} X_i + \sum_{v} X_v\right) \tag{1}$$

$$Y = \frac{1}{n}\left(\sum_{i} Y_i + \sum_{v} Y_v\right) \tag{2}$$

In which, *Xi* represents the abscissa of the anchor node, *i* represents the number of the anchor node, *Xv* represents the abscissa of the virtual anchor node, *v* represents the number of the virtual anchor node, *Yi* represents the ordinate of the anchor node, *Yv* represents the ordinate of the virtual anchor node, *X* represents the abscissa of the unknown sensor, *Y* represents the ordinate of the unknown sensor, n represents the total number of the anchor node that join in localization, and $n=i+v$.

5. Conclusions

By the analysis of a large number of literatures as well as the research of the wireless sensor network node localization algorithms, the paper makes a summary of the construction and application of the virtual anchor node. Applying the virtual anchor node to the localization process improves the localization accuracy, which is an effective scheme for the research of the wireless sensor network node localization algorithm. And more details still need the further specific analysis. In the future research, this method should be extended to the three-dimensional space node localization, by which the theory and practice of this method will be more perfect.

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