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Research on the Positioning of Moving Nodes in Wireless Sensor Network Based on Vector Machine

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Abstract

How to position node in the wireless sensor network has been a popular research topic. Based on the research to the mobile node positioning, this paper proposes position estimation method based on support vector machine (SVM) and game theory. It firstly uses support vector machine to preliminary estimate the position of the mobile node, secondly, it conducts smooth treatment to nude estimation position though game theory. At last, through fisherman algorithm, it conducts treatment to estimation position and noise. From the mobile node localization effect, ranging error, anchor node distribution density and non-line-of-sight coefficient, simulation results illustrate that the algorithm of this paper can effectively improve the effective of node positioning.

Keywords*: Wireless sensor, mobile nodes, support vector machine (SVM), game theory*

1. Introduction

Node positioning has been an important research part of the wireless sensor network, at present, most of the research is focused on the unknown nodes which are fixed in one place, and then to position through anchor nodes. In view of actual condition, considering the influence of the node's environment and other factors, the positioning estimation research on the moving nodes has become the focus of research in recent years [1-2]. Scholars both at home and abroad have relevant research. Based on DV - hop algorithm, Literature [3] puts forward and fixes the every jump distance in network nodes, and effectively reduces the amount of calculation of the algorithm under the premise of position precision. Simulation results show that the new algorithm which combines the centroid algorithm and DV - Hop algorithm has improved in terms of positioning accuracy comparing to the former one and the existed improved one; Literature [4] puts forward a new wireless sensor network positioning algorithm, which realizes the sensor node positioning through the use of collinear and non collinear moving anchor points. This method takes the advantage of the distance between the adjacent nodes and the relevant information about the message transmission direction provided by nodes to estimate the position of nodes. Each node position is from two independent directions. Then use the kalman filter to improve the positioning precision of each node; Literature [5] proposes to use AEKF in the dynamic node positioning in wireless sensor network (WSN) and track the moving node positioning. This method cannot only modify the real-time error of the model, but also can adjust to fix the dynamic range of filter. Simulation results show that compared to EKF, AEKF improves the dynamic performance of the filter and better controls the process of filtering divergence. AEKF has better tracking performance and it improves the positioning accuracy; Literature [6] proposes to sample locally in the signal overlapping area of the beacon nodes which can directly communicate with moving nodes by using the collected signals, which introduces the distance scale factor, weights the average jump

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distance and optimizes the calculation formula of the jump distance in CDL; Use RGB difference sequence to point filter of the sample and take the absolute value of difference sequence as weighted standard to calculate the coordinates of moving nodes; Literature [7] puts forward an algorithm which is adaptive to Monte Carlo moving nodes positioning. The algorithm positions the unknown nodes by using the different affect to the positioning accuracy of the sample particles in different parts to the unknown nodes and the adaptive adjustment of the affect weight of sampling in different areas; at the same, it also uses the sampling particles of last time to increase the qualifications to improve the positioning accuracy; Literature [8] puts forward MCL positioning algorithm based on RSSI, which improves the prediction and filtering process of positioning by using lognormal model of received signal strength and improves the positioning performance. It uses Hermite interpolation method to make good forecast to the current trajectory. Simulation results show that, compared with the traditional algorithm, this algorithm reduces the sampling range, improves the sampling accuracy, so as to improve the positioning accuracy and reduce the power consumption.

On the basis of above research, this paper firstly uses fisherman fishing algorithm to the study of moving node positioning. By vector machine (SVM), get the initial position of moving node positioning, and then by the method of game theory, conduct smooth treatment to the position estimation and then use the algorithm of the fisherman fishing aiming at the position and noise. Simulation results show that the algorithm can effectively improve the positioning estimation accuracy.

2. The Node Positioning Estimation Research

Traditional positioning mechanism usually uses GPS positioning system, but in the actual process, affected by the environment of many obstructions and no line of sight, both the cost and consumption will be high which limits the wide use of the sensor. The algorithm in this paper builds a mapping relationship between TOA and RSSI with the characteristics of the radio frequency and the node coordinates and estimates the frequency characteristic and the positioning relation between the nodes by the way of machine learning, and uses support vector regression model to estimate the relationship between the signal characteristics and coordinates position,

According to the principle of machine learning, the feature vectors will be mapped to high-dimensional feature space by kernel function and the linear regression of high-dimensional feature space is expressed as:

$$p = f(m) = \phi(m)^T w + b \qquad (1)$$

Weight vector w is got by analyzing and estimating the minimizing structure of vector regression operator such as Formula (2)

$$R(w) = \sum_{i=1}^{n} g(f(m_i) - p_i) + \frac{\|w\|}{C} \qquad (2)$$

In order to avoid the difference between the observation values and the predicted values of node position, non-sensitive coefficient ε is introduced. It is believed that if the difference of a certain point is less than ε, $f(m)$ of the point almost approximate to the actual value. Set $g(x)$ as cost function and C as penalty parameter, therefore it is said to be as the following:

$$g(f(m) - p) = \begin{cases} |f(m) - p| - \varepsilon \\ 0 \end{cases} \qquad (3)$$

By Lagrange method, the optimal problem is expressed as its dual problem, therefore, the optimization problem is defined as a support vector regression function, as follows:

$$\max_{\alpha,\alpha^*}\sum_{i=1}^{n}[\alpha_i^*(p_i-\varepsilon)-\alpha_i^*(p_i+\varepsilon)]-\frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}(\alpha_i^*-\alpha_i)(\alpha_j^*-\alpha_j)\phi(m_i,m_j)$$

$$s.t\ \sum_{i=1}^{n}(\alpha_i-\alpha_i^*)=0, \quad (4)$$

$$w=\sum_{i=1}^{n}(\alpha_i-\alpha_i^*)\phi(m_i)$$

In the formula, α_i and α_i^* are respectively lagrane factors. Set $Ker(m_i,m_j)=\phi(m_i)^T\phi(m_j)$, therefore, the formula to support vector machine (SVM) regression function is as follows

$$p=f(m)=\sum_{i=1}^{n}(\alpha_i-\alpha_i^*)Ker(m_i,m_j)+b \quad (5)$$

3. Research of the Moving Nodes Based on Game Theory and Fisherman Fishing Algorithm

3.1. In the Actual Environment, Noise Cannot Be Ignored

The noise has a certain impact on the measurement to the data of sensor nodes. In order to maximize reduce this effect, the filtering algorithm is mainly used which can more accurately estimate the state of the nodes. The vector regression is used to preliminary estimate the positioning of the nodes. Due to the lack of positioning precision, further filtering smoothing algorithm is used. In the position estimation of vector regression machine, set time as t whose position is estimated as $y^{'}(t)=[y_1^{'}(t),y_2^{'}(t)]^T$ and the state vector is $x^{'}(t)=[s_1^{'}(t),s_2^{'}(t),v_1^{'}(t),v_1^{'}(t)]$, in which the first two are the state coordinates of the nodes and the following two are the speed goal of the nodes. As a result, at ΔT, the state component expression is:

$$\begin{cases} x_{k+1}^{'}=A^{'}x_k^{'}+Bu_k+Cw_k+Dd_k \\ y_k^{'}=H^{'}x_k^{'}+n_k \end{cases} \quad (6)$$

In which, k is time index, x is state vector, u is velocity component, w and n are the noise sequences, d is the noise sequence produced by noise countermeasures opponent, among them:

$$A^{'}=\begin{bmatrix}1 & 0 & \Delta T & 0\\ \Delta T & 0 & 1 & 0\\ 0 & \Delta T & 0 & 1\\ 0 & 0 & \Delta T & 1\end{bmatrix}, B=\begin{bmatrix}0 & 0\\ 0 & \Delta T\\ \Delta T & 0\\ 0 & 0\end{bmatrix}, H^{'}=\begin{bmatrix}1 & 0\\ 0 & 1\\ 0 & 0\\ 0 & 1\end{bmatrix}^T$$

Set $x_k=[x_k^{'},u_k]$ and $y_k=y_k^{'}$, Formula (6) is shown as

$$\begin{cases} x_{k+1}=Ax_k+Cw_k+Dd_k \\ y_k=Hx_k+n_k \end{cases} \quad (7)$$

The problem is to find out the state of x_{k+1} and estimate $\hat{x}_{k+1}$ to get the value of y_k. Because d is the noise sequence produced by noise countermeasures opponent, set the input of the noise sequence produced by noise countermeasures opponent in the game theory as follows, in which G_k is a matrix, n_k is noise sequence and L_k is required value.

$$d_k = L_k(G_k(x_k - \hat{x}_k) + n_k) \quad (8)$$

With the time passing by, the dynamic estimation error is as follows

$$e_{k+1} = (A - K_k H + L_k G_k)e_k + Bw_k + (L_k - K_k)n_k \quad (9)$$

In which, e_k is the difference of $x_k - \hat{x}_k$. But in order to avoid the maximum or minimum values in the game theory, e_k shall be divided into two parts and be processed, then Formula (9) is as follows:

$$\begin{cases} e_{k+1} = (A - K_k H + L_k G_k)e_{k1} + Bw_k - K_k n_k \\ e_{k+1} = (A - K_k H + L_k G_k)e_{k2} + L_k n_k \end{cases} \quad (10)$$

Therefore, through the game theory, it builds the position estimation and noise, thus the objective function is as follows:

$$F(K_k, L_k) = \sum_{k=0}^{N} w_k E(e_{1,k}e_{1,k}^T - e_{2,k}e_{2,k}^T) \quad (11)$$

In Formula (11), the core of the game theory is position estimation which hopes to reduce F by K_k and the noise hopes to increase F by K_k. So how to find the corresponding between the position estimation and noise becomes the key to solve the problem. This paper simulate the position estimation and noise into fisherman and fish. Through fisherman algorithm, get the final position of the fisherman and the maximum density of fish which are the two solutions of the equation.

3.2. Fisherman Algorithm

Fisherman fishing algorithm is an optimum algorithm which is a simulation that the fisherman is trying to get as much fish as possible when fishing. Assume that the area of the fish with the unit size is $Area$. There are n areas with the same size. So the area of fish is $Area = \{Area_i \mid i = 1, 2, \cdots n\}$. Set $X = (x_1, x_2, \cdots x_n)$, which means the group of each fish. Set $F(x)$ is the objective function of $Area$. So the goal of fisherman algorithm is to get $\max F(x)$. There are two behavior of fisherman algorithm, one is moving search which is to get the position in $Area$ where the fisherman can get the largest fish density. The other is shrink search behavior which is the group of fishing net after continue falling nets of the fisherman. In $Area$, the number of fishermen is k. Set the initial position of i fisherman is $P_0^{(i)} = (x_{01}^{(i)}, x_{02}^{(i)}, \cdots x_{0n}^{(i)})$. As a results, the net group which takes the position of the fisherman as the center is

$$\Omega_0^{(i)} = \{X^{(i)} = (t_1^{(i)}, t_2^{(i)}, \cdots t_n^{(i)}) \mid t_j^{(i)} \in \{x_{0j}^{(i)} - t_j^{(-)}, x_{0j}^{(i)}, x_{0j}^{(i)} + t_j^{(+)}\}, j = 1, 2, \cdots n\} \quad (12)$$

（1）Moving search. In fishing, if the density at $X_0^{(i)}$ is large than it at the position $P_0^{(i)}$ which the fisherman is, the fisherman shall move to a new position $P_1^{(i)} = X_0^{(i)}$ and takes $P_1^{(i)}$ as the new center. The fisherman shall continue to search for the position where the density of the fish is the largest. The moving trajectory of the fisherman is $P_0^{(i)}, P_1^{(i)}, p_2^{(i)}, \cdots p_{best}^{(i)}$. After several steps, the fisherman find a position in the search area where the density of the fish is the largest.

(2) Shrink search behavior. After a certain number of times of moving position, the

current position of Fisherman i is $P_m^{(i)}$. If the density at Point $X_0^{(i)}$ is less than it at $P_0^{(i)}$ where the fisherman is, the fisherman shall be at the current position. Then, continue to fall nets to four directions at the current position until getting next collection of fishing net.

$$\begin{aligned} & P_0^{(i)} = (x_{01}^{(i)}, x_{02}^{(i)}, \cdots x_{0n}^{(i)}) \\ & \Omega_m^{(i)} = \{X_{m+1}^{(i)} = (t_1^{(i)}, t_2^{(i)}, \cdots t_n^{(i)}) \mid t_j^{(i)} \in \{x_{mj}^{(i)} - t_j^{(-)}, x_{mj}^{(i)}, x_{mj}^{(i)} + t_j^{(+)}\}, j = 1, 2, \cdots n\} \end{aligned} \tag{13}$$

In which, $t_j^{(-)} = \alpha t_{j-1}^{(-)}$ $t_j^{(+)} = \alpha t_{j-1}^{(+)}$ $\alpha \in (0,1)$

3.3. Algorithm Steps

Step 1: Initialize the correlation function parameters and give each node the training set.

Step 2: Choose suitable parameter loss ε and penalty factor C, set the relevant kernel function.

Step 3: Build the observation model between anchor node and mobile node and decision-making functions of vector machine (SVM) to get the preliminary estimation position of the moving nodes.

Step 4: Through game theory, conduct smooth treatment to the preliminary estimate position and build function.

Step 5: Take the two values in the game theory respectively as the parameter in fisherman algorithm and get the results.

Step 6: After a certain number of iterations, if the number of iteration is less than the maximum number of iteration, then go to Step 7 and get the best fisherman location and the maximum density of the fish, in order to get the suitable value of the game value. Otherwise, go to Step 5.

Step 7: Get the accurate estimation of the moving node, then the algorithm is over.

4. The Algorithm Simulation

Under Windows XP operating system, this paper conducts experiment through Matlab simulation tools. 100 sensor nodes randomly distribute in the 2D area with area of 10m x 10m. The number of the unknown sensor nodes is 150, in which there are 100 nodes which are moving with the range of [1m, 3m]. The number of the known anchor nodes is 50 and the penalty factors are 200. This paper evaluate the algorithm in this paper and others from the four aspects, which are the ranging error, anchor node distribution density and no line of sight coefficient.

4.1. The Influence of Noise on Positioning Error

Under different noise error, the positioning results of the algorithms of Literature [7], Literature [8] algorithm and this paper are shown in Figure 2. It can be seen from Figure 1 that with the increase of noise, the positioning errors of the three kinds of algorithms show a trend of increase and the positioning accuracy gradually decreases. But the tendency of increase of the algorithm in this paper is lower than the other two algorithms, which shows that noise value and position estimation are optimized and balanced to a certain degree by the fisherman fishing algorithm, which has strong anti-interference ability and obtains the better location performance.

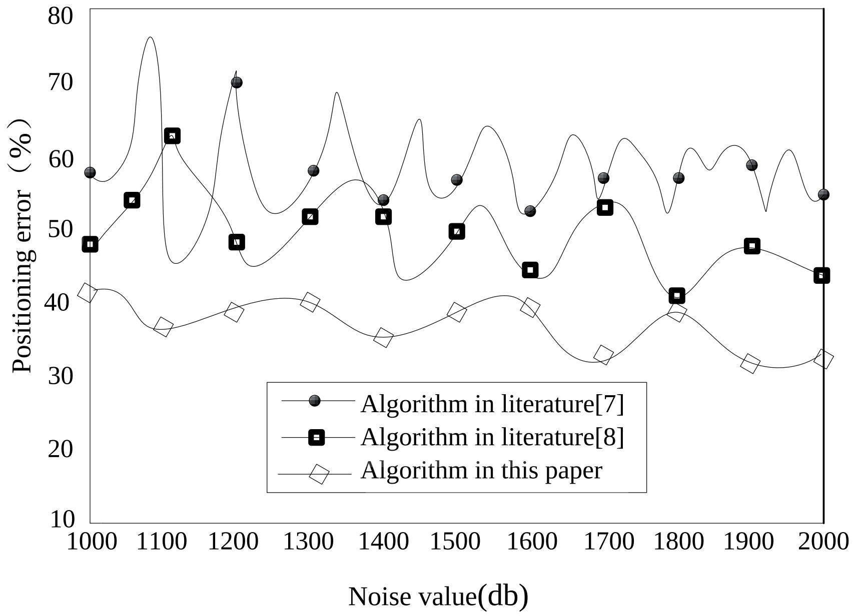

Figure 2. Influence of Noise on the Positioning Accuracy of Three Algorithms

4.2. The Positioning Error Comparison of Anchor Node Density

The distribution density of anchor node is related to the effect of mobile node localization and is more related to the cost problem of wireless sensor network. Under the anchor node density, the changes of the position error of algorithms of Literature [7], Literature [8] and this paper are shown in Figure 2. It can be seen from Figure 3 that with the increase of the anchor node density, mobile node positioning error gradually decreases and the algorithm of this paper can adapt to the environment which does not have much requirements to anchor node density in complex environment and has the very good adaptability.

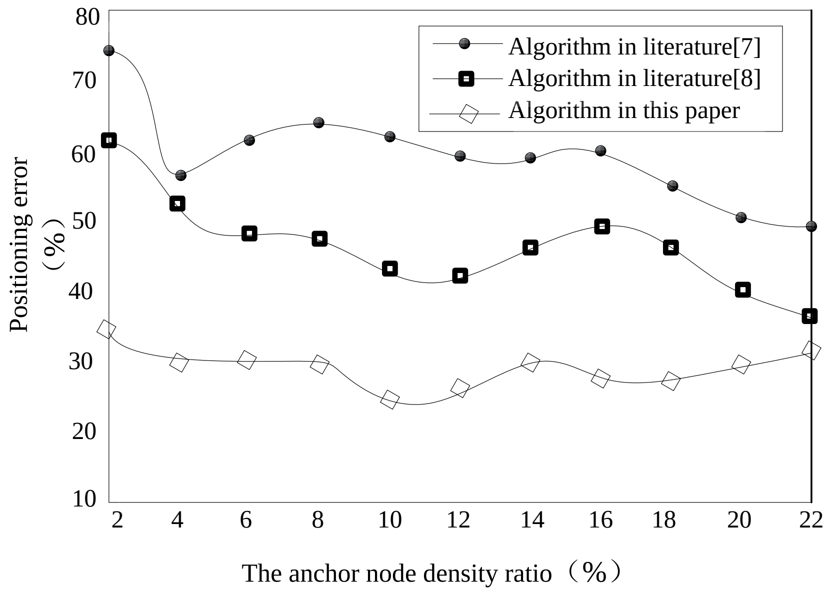

Figure 2 Influence of Anchor Density on Three Algorithms' Positioning Accuracy

4.3. The Impact of Non-Stadia Coefficient

In no line of sight environments, mobile node location estimation is affected by the visibility factor. Under the situation that the observation value of line of sight factor is from 1.0 to 3.0, compare the algorithm of this paper, the least squares algorithm and support vector regression algorithm. It can be seen from Figure 3 and Table 1 that along with line of sight factor value increases gradually, the error of the algorithm in this paper is lower than the least squares algorithm and support vector regression algorithm, which shows that the algorithm in the paper which combines with the support vector regression and game theory can decrease the impact on the location estimation precision in non-stadia environment. As a result, the algorithm has a better position estimation effect.

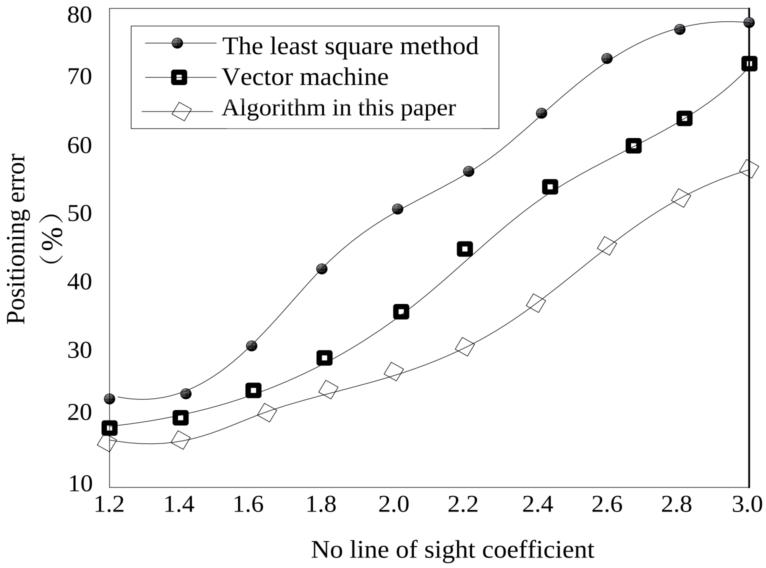

Figure 4. Relationship between Non-Light-of-Sight Coefficient and Three Algorithms' Positioning Errors

Table 1. Comparison Results of Non-Light-of-Sight Coefficient in Three Algorithms

No line of sight coefficient	The least square method	Vector machine (SVM)	Algorithm in this paper
1.0	42m	40m	30m
1.4	46m	42m	32m
1.8	51m	43m	37m
2.2	56m	49m	40m
2.6	69m	57m	42m
3.0	78m	63m	45m

5. Conclusion

Aiming at the impact on positioning accuracy of the mobile node in WSN, this paper proposes position estimation method based on support vector machine (SVM) and game theory. It firstly uses support vector machine to preliminary estimate the position of the mobile node, secondly, it conducts smooth treatment to nude estimation position though game theory. At last, through fisherman algorithm, it conducts treatment to estimation position and noise. Simulation results show that this algorithm can effectively improve the effect of node localization, especially the position precision of no line of sight effect.

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