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Wireless Sensor Network 3-Dimensional Positioning Method

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Abstract

In wireless sensor network, determine the position of the node position or events is very important to its surveillance activities, however, in the traditional wireless sensor network, are using two-dimensional spatial positioning technology, aiming at this problem, this article will wireless sensor network (WSN) 2 d algorithm is extended to 3 d space, analyzes the main factors affecting the positioning accuracy of wireless sensor network. In order to further improve the stability and precision of the algorithm, by introducing the Newton's method, gives the quasi-newton three-dimensional node localization hybrid localization algorithm. The simulation analysis shows that the proposed hybrid algorithm can under the same conditions with high positioning accuracy and stability, at the same time the CRLB are obtained. The simulation results show that the proposed algorithm can get g Latin American community, simulation analysis of the localization method is effective

Keywords: *Wireless sensor network; Node localization; Positioning accuracy; The three dimensional positioning*

1. Introduction

With the high-speed development of microelectronics technology and manufacturing technology matures, the sensor has been toward integration, miniaturization, intelligent direction. Sensor technology, communication technology and computer technology the rapid development of the three pillar of modern information technology, information transmission and processing technology has achieved gratifying progress. Wireless sensor network (WSN) as a research hot spot on current international, has been applied in military, target tracking, environmental monitoring, health care, space exploration and other fields are widely used. Distribution in the space of each node location information perception is the basis of wireless sensor network applications, but the positioning technology based on node location information in WSN has important research significance. In the face of the serious situation of electronic countermeasures, stealth technology rapid development, the traditional active positioning system will inevitably face with "four threats" (anti-radiation missile, stealth target technology, low level low penetration and comprehensive electronic jamming) advanced challenges, has been difficult to develop power like in the past, and its own survival also became a pressing problem, active and passive positioning technology can overcome the localization of these weaknesses [1-5]. Passive location technology in recent years, research has become more and more deep, also more and more widely used, its application field has been involved in spaceflight, aviation, navigation and electronic warfare, *etc*., with the further research and development of positioning technology, the future technology will permeate all aspects of people's life, so as to

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provide convenience to people's life, to a certain extent changed the way people live. In this paper, both at home and abroad in the field of wireless sensor network localization, on the basis of research and development, based on wireless sensor network node localization problem for the more thorough research, respectively studied the development of wireless sensor network (WSN), research status and applications. Commonly used positioning algorithm based on distance estimation research; On the basis of the existing localization algorithm, proposed the new wireless sensor network node localization method, gives the theoretical derivation and performance simulation diagram analysis.

Wireless sensor network is composed of a random distribution of integrated with sensors, data processing unit and communication module of small nodes by means of self-organizing network, the purpose is to collaborative perception, collection and processing, and distribution network in the geographical area covered by perceived object information and release to the observer. As the communication technology, signal processing technology, embedded computing technology and the rapid development of sensor technology and the increasingly mature, communication ability, computation ability and awareness of the micro sensor network has attracted great attention. Wireless sensor network (WSN) a combination of these technologies to collaboration to real-time monitor, sense and collect network distribution area of various environmental or monitoring object information, and to deal with the information, obtain detailed and accurate information, timely need these information to the user. In sensor networks, the nodes were lying in the monitored area, in addition to monitor specific object, also simple calculation, but also maintains the network connection between each other. Wireless sensor network (WSN) due to objective physical world and the logical information world closer together, making the interaction of human and nature be changed [6-9]. Using wireless sensor network to direct perception of the objective world, the function of existing network is expanding constantly, and constantly improve the ability of humans to know the world. With the constant improvement of traffic and network, people became more sensitive to position concepts, based on the location of the types of services will become more and more widely. Whether indoors or outdoors, people not only want to be able to let oneself or others know your current location, but also look forward to know that some of your near the location information, such as restaurants, supermarkets, bookstores, station, *etc*. So quickly and accurately obtain the location of the object position information and service demand has become increasingly urgent, has become a current research hot spot [10-12]. With the rapid development of wireless sensor network and wide application, based on wireless sensor network positioning technology is also obtained the rapid development and the attention. Based on WSN node localization in the whole sensor network system occupies very important position, sensor nodes monitoring message contained in the main important information of the location of the incident or node location of access to information, and no location information of monitoring data is usually does not make sense. Second, some system functions of the WSN is also a location information, such as the need to determine the scope of the WSN coverage, *etc*.; Finally, the position information is beneficial to the application of sensors in the network service, such as people need to know their surrounding the location of the hospitals, schools, bookstores, *etc*. Along with the advance of WSN technology, application protocol based on location information and naturally will be more.

Positioning information also has the following purposes: target tracking, predict forward trajectory of the target, target real-time monitoring of action, to assist the routing, network management and so on. So the precise localization of sensor nodes in the network have important effects for various applications.

2. Related Research

Locating method based on wireless sensor network (WSN) mainly include the AOA, RSSI, TOA and TDOA location technology. All have their own advantages and disadvantages of each positioning technology, based on AOA location ranging technology is easily influenced by the external environment, the influence of noise on it is more noticeable, and AOA need additional hardware, such as array antenna, *etc*., so the low cost, low power consumption requirements of sensor networks don't apply. TOA ranging positioning need to measure the signal arrival time, because the synchronization error has a great influence to the measurement of the distance, so to achieve high positioning accuracy, must be between monitoring targets and monitoring equipment to ensure the strict clock synchronization, however the request this largely increased the complexity of the equipment on the implementation. Despite the RSSI positioning conforms to the requirement of low power, low cost, RSSI positioning in practice, however, because of multipath spread and non-line of sight makes signal propagation model is complex, such as the change of the external environment has a great instability, often cause the RSSI is positioning result there is a big error [13-15]. To avoid the complexity of TOA synchronous equipment, find better positioning precision positioning technology at the same time, people is proposed based on TDOA positioning mechanism, it only requires monitoring equipment can meet the clock accurate synchronization between conditions, which greatly reduced the complexity of the equipment, at the same time TDOA technology does not need to know to receive transmission time between the signal from transmitter to receiver, but by the time delay estimation algorithm for time delay value.

At present by using least square (LS) criterion, many closed solution based on TDOA location algorithm is proposed, and presents corresponding grams of Latin America's lower bound (CRLB), under unknown variable is in the middle of pseudo linear equation are deduced with the method of weighted least squares, but this method cannot get the best solution, aiming at this problem, Chan and Ho by two-step weighted least-square technique gives the best solution, but the positioning precision is still to be promoted, and the computational complexity is higher. To get a better positioning results, obtained by iterative method for solving nonlinear hyperbolic equation, in which the fundamental Newton's method as a kind of typical iteration algorithm can introduce application, although k. Yang Newton method is proposed based on the basic of constrained least squares algorithm is global, but did not make full use of the algorithm in addition to the other outside the TDOA location information, and the basic Newton method can guarantee each iteration Hessen matrix is positive definite, lead to the results there is no guarantee that converge to the global minimum, and heather matrix calculation is relatively complex, real-time algorithm is restricted.

Can domain information received extensive attention of positioning research, can domain information can be used for positioning because of the perception of the spatial distribution of different node receives the signal energy intensity and signal source is inversely proportional to the square of the distance from the perceptual node to, thus different perceptual node can be used for positioning the difference of the received signal strength. Passive location using the basic technology mainly include TOA location techniques, TDOA location technology and AOA location technology, FDOA positioning technology, the RSSI positioning technology, *etc.* Compared with other location techniques, TDOA location technology as in the case of multiple monitoring node can obtain higher positioning accuracy, at the same time with the receiving system hardware requirements is low, the advantages of easy to network, and applied more widely.

Node position is generally through the node carries GPS equipment such as means to obtain its precise location, through the positioning system to obtain its own node location of these nodes are called anchor nodes or beacon nodes. The distribution of beacon nodes in the actual environment is less, this is because of the use of GPS in wireless sensor network (WSN) for all nodes location is limited by the factors such as cost, volume, power consumption, there are some difficulties. Node blind location problem is based on a few known position of node beacon nodes, namely through some positioning mechanism determines the location of the unknown target source. Real environment due to the limitation of some factors, most of the nodes are not have GPS function, then design a new node positioning mechanism has become an urgent demand. The main research work is to use a few of the beacon nodes monitor the unknown source, and collaboration between multiple sensor nodes to obtain other node location information. Blind localization of nodes is divided into two kinds: the orientation of active and passive. Active positioning refers to the network monitoring nodes in the use of radar, sonar, such as laser active devices to be used to locate the target launch all kinds of signals, and then received by monitoring the target return signal, target is obtained through a series of measurements, such as processing and the process of the source location. Active positioning has the characteristics of all-weather, high precision. But due to the active positioning need to launch power signal, have no concealment, vulnerable to other electronic interference, *etc*. [16-17]. Passive location, can overcome the defects of active positioning, "passive" refers to the monitoring nodes in the network not to be targeted in the process of locating electromagnetic signals or other used to locate a variety of forms, no coordination communication between monitoring node and monitoring equipment, monitoring nodes just by the search for target emission of electromagnetic signal, measuring and processing to get the location of the object and the parameter information, further implement the localization and tracking. Compared with active positioning system, passive location can enhance the anti-reconnaissance of the system in the electronic warfare environment, anti-interference, soft hard skills, such as, at the same time it also has a certain of stealth targets and low altitude, low penetration target detection ability, it can better in target recognition, *etc*.

3. The Model of Network

In wireless location, once get the TDOA measurements can build TDOA location equations. But hyperbolic equations based on TDOA location is a nonlinear equation, to seek the solution is not an easy thing, different method and constitutes the positioning accuracy of localization algorithm, mainly to 2 d Chan algorithm is extended to 3 d space. Chan algorithm is a kind of analytic expression of recursive equations solution, the algorithm is a relatively small amount of calculation, under the environment of noise obeys the Gaussian distribution, high positioning accuracy. If random distribution in 3 d space with a sensor node is responsible for receiving known location target source emission signal, the i th are the coordinates of the sensing nodes (x_i, y_i, z_i), assumptions to determine the position of the unknown target source for (x, y, z).The unknown target signal source and each square of the distance perception nodes can be expressed as

$$r_i^2 = (x_i - x)^2 + (y_i - y)^2 + (z_i - z)^2 \quad (1)$$

Simple as

$$r_i^2 = x_i^2 + y_i^2 + z_i^2 - 2x_i x - 2y_i y - 2z_i z + x^2 + y^2 + z^2, i = 1, 2, \cdots M \quad (2)$$

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$$r_{i,1} = cd_{i,1} = r_i - r_1 \quad (3)$$

Because of the hyperbolic equation (3) is nonlinear in nature. To solve the nonlinear equations must first carries on the linearization. For the traditional algorithm for nonlinear equations linearization, the introduction of auxiliary variables, namely the first hypothesis for the target coordinates has nothing to do with auxiliary variable, using the weighted least square method to get the initial solution.In order to further improve the accuracy of positioning, then get the estimated position coordinates and auxiliary variables such as constraint conditions in a known the WLS estimate, the improved location estimation.

In order to calculate and describe the convenient, first of all make the position vector:

$$z_a = \left[z_p^T, r_1 \right]^T \quad (4)$$

where $z_p = [x, y, z]^T$

To do the type (3) transform and square, namely

$$r_i^2 = (r_{i,1} + r_1)^2 \quad (5)$$

To get the following equation

$$r_{i,1}^2 + 2r_{i,1}r_1 = -2(x_i - x_1)x - 2(y_i - y_1)y - 2(z_i - z_1)z + x_i^2 + y_i^2 + z_i^2 + x^2 + y^2 + z^2 \quad (6)$$

You can get the positioning error, as shown in type (7)

$$w = m - nz_a \quad (7)$$

Where

$$m=\frac{1}{2}\begin{bmatrix} r_{2,1}^2-\left(x_2^2+y_2^2+z_2^2\right)+\left(x_1^2+y_1^2+z_1^2\right) \\ r_{3,1}^2-\left(x_3^2+y_3^2+z_3^2\right)+\left(x_1^2+y_1^2+z_1^2\right) \\ r_{M,1}^2-\left(x_M^2+y_M^2+z_M^2\right)+\left(x_1^2+y_1^2+z_1^2\right) \end{bmatrix} \quad (8)$$

$$n=\begin{bmatrix} x_2-x_1 & y_2-y_1 & z_2-z_1 & r_{2,1} \\ x_3-x_1 & y_3-y_1 & z_3-z_1 & r_{3,1} \\ \vdots & \vdots & \vdots & \vdots \\ x_M-x_1 & y_M-y_1 & z_M-z_1 & r_{M,1} \end{bmatrix} \quad (9)$$

4. A Localization Algorithm based on Time and the Signal Intensity

When a source signal to reach located in different location of the receiver, the space will be affected by different time delay and intensity attenuation, and the intensity of time delay and attenuation are dependent on the distance between the source and receiver. The sensor receives the signal expressed as:

$$x_1(t)=s(t)+n_1(t) \quad (10)$$

$$x_i(t)=\frac{1}{g_{i1}}s(t-d_{i1})+n_i(t), i=2,3,\cdots M \quad (11)$$

Which $s(t)$ is the target source transmitting signals, $s(t)$ and noise $n_i(t)$ are independent of each other $i=2,3,\cdots M$, $s(t)$ and noise $n_i(t)$ are independent of each other, between, and assumed zero mean Gaussian random process. d_{i1} and g_{i1} respectively is to achieve the sensor signals relative to the reference sensor 1 time delay and intensity attenuation. This method is based on the node M , $M \geq 4$ perception of sensor network node location target oriented source localization.

Assume that pending a source of real coordinates $u^r=\left[x^r,y^r,z^r\right]^T$ with said, perceptual node coordinates $s_i=\left[x_i\ y_i\ z_i\right]^T$, said $s_i=\left[x_i\ y_i\ z_i\right]^T$. The real distance between source and sensor i said $r_i^r=\left\|u^r-s_i\right\|_2$, its relationship with the function of the distance is:

$$d_{i1}=\frac{r_i^r-r_1^r}{c} \quad (12)$$

$$g_{i1}=\frac{r_i^r}{r_1^r} \quad (13)$$

Here c represents the signal propagation velocity, d_{i1} and g_{i1} respectively is to achieve the sensor signal relative to the reference node time delay and gain strength. According to the propagation theory of acoustics and microwave, attenuation with the distance between the source and receiving sensor proportional to n times.In this for the convenience to n is set to 1, then is equal to the distance between the source and sensor and the signal source and the ratio of the distance between the sensor 1.Write d_{i1} in vector form $\mathbf{d}=\left[d_{21},d_{31},\cdots,d_{M1}\right]^T$, together to g_{i1} form a vector form.

$\mathbf{g} = [g_{21}, g_{31}, \cdots, g_{M1}]^T$

The first building integrated positioning nonlinear equations. As mentioned earlier, signal source and the real distance $r_i^r = \|u^r - s_i\|_2$ between perceptual node i, select node 1 as the reference node, reference node and source for the real distance

$$r_i^r = r_1^r + r_{i1}^r \qquad (14)$$

r_i^r and r_{i1}^r will work with the expression of substitution, on both sides at the same time square nonlinear equation is obtained

$$r_{i1}^2 + 2r_{i1}r_1^r = (s_i - s_1)^T (s_i - s_1) - 2(s_i - s_1)^T (u^r - s_1), i = 2, 3, \cdots, M \qquad (15)$$

To nonlinear equations linearization, auxiliary variable is introduced here, $r_{i1} = r_{il}^r + \Delta r_{i1}$ will be brought into the type (15), r_{il}^r and $(u^r - s_i)$ ignore the second order error will type (15) can be written as linear equation to get on with:

$$\xi_d (i-1) = 2r_i^r \Delta r_{i1} \qquad (16)$$

Simple, denote

$$\xi = \begin{bmatrix} \xi_d \\ \xi_g \end{bmatrix} = b - H\boldsymbol{\theta}^r \qquad (17)$$

Type (17) is about $\boldsymbol{\theta}^r$ linear equation, using the least squares solution, for weighted least squares solution $M(\boldsymbol{\theta}^r) = (H\boldsymbol{\theta}^r - b)^T W^{-1} (H\boldsymbol{\theta}^r - b)$, minimize it, will be equivalent deformation, can be expressed as

$$M(\boldsymbol{\theta}^r) = f^T W^{-1} f \qquad (18)$$

Using iterative expression, the expression can be expressed as:

$$\theta_{k+1} = \theta_k + \lambda_k d_k \qquad (19)$$

Define $d_k = -M_k g_k$, and M_k can write more

$$M_{k+1} = M_k + \left(1 + \frac{q_k M_k q_k^T}{p_k q_k}\right) \qquad (20)$$

where $p_k = v_{k+1} - v_k$, $q_k = \nabla M(v_{k+1}) - \nabla M(v_k)$.

To get the concrete implementation steps are:

1), the model of the algorithm estimates as the initial estimates;

2), make $H_1 = I_n$;

3), using one dimensional search method λ_k, v, through the calculation of type (18) calculated by type (20);

4), will be the result of step 3) as the initial estimates, and repeat steps 3) until v convergence, convergence, if do not have the initial estimates as the location of the signal source.

5. Simulation Results

This article mainly in this simulation, we the target source is located in [2800, 1800, 2400] m place to locate, and mainly analyzes the positioning accuracy as the signal-to-noise ratio (SNR).In this simulation, participate in the localization of nodes is still the target source is located at far field source [2800, 1800, 2400] m place and near field source [400, 550, 350] m, respectively, to locate the main analysis of the same monitoring node located at different distances of the influence of node location accuracy.

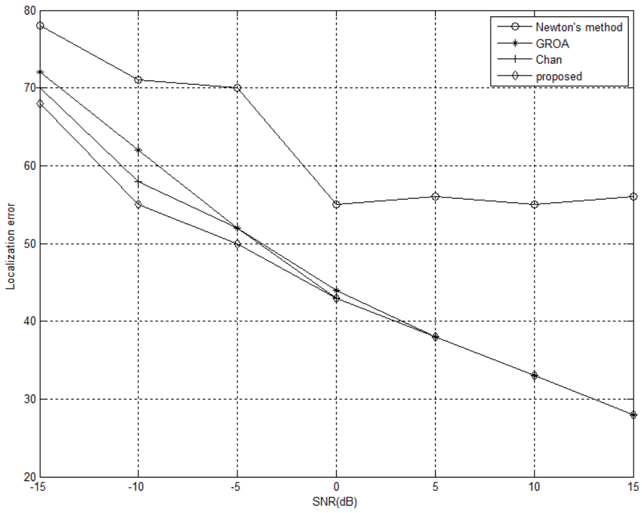

Figure 1. SNR V.S. Localization Error

Figure 1 shows the far field source locating MSE with SNR change. When SNR > 0 dB TDOAs mixed with GROAs positioning based BFGS quasi-newton method and two-step WLS method can reach CRLB, but the basic Newton method is far cannot reach CRLB, this is because the basic Newton method is adopted when each iteration Hessen matrix is not positive definite time, lead to the result can not converge to the global minimum value; When SNR < 0 db, the two-step WLS method MSE has already started to deviate from the CRLB, but the BFGS quasi-newton method didn't begin until the SNR is less than 5 db deviating from the CRLB.BFGS quasi-newton method contrast two step WLS method, the SNR < dB – 6 low SNR circumstance about 3 dB performance improvement, which makes the TDOAs and GROAs in large measure error the BFGS quasi-newton method have more advantages than the two-step WLS method. When high signal noise ratio (SNR), ascension GROA amount can be ignored, this is because at the time of high signal noise ratio (SNR) with TDOA alone can achieve high localization accuracy. But in low signal noise ratio (SNR), RDOA was obtained by TDOA multiplied by the signal travels in space, this is the error of TDOA carries will be amplified, but GROA without the influence, the introduction of the reason in the low SNR GROA can improve the accuracy of positioning.

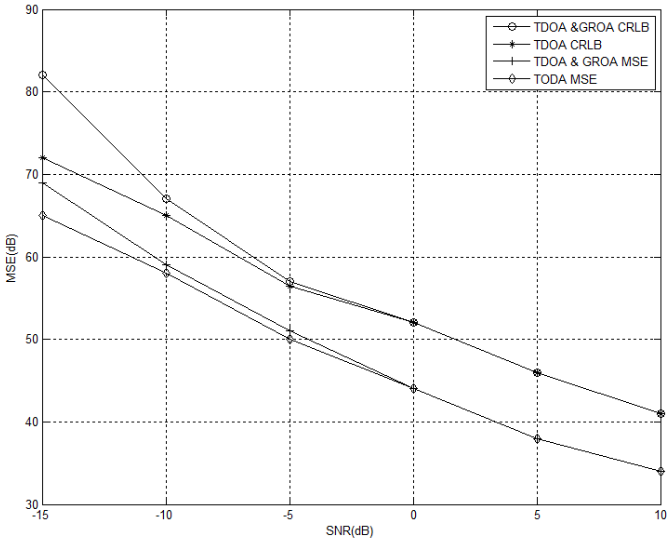

Figure 2. SNR V.S. MSE (dB)

Figure2 shows the respectively in only two steps of TDOA weighted least square method and using TDOA and GROA hybrid localization algorithm with SNR change log 10 M (SE) and the CRLB. From figure shows in the introduction of GROA information positioning CRLB and 10 log (MSE) are smaller than only using TDOA positioning information. These two methods both can reach the corresponding CRLB, but after introducing GROA information better positioning accuracy, especially in the low signal noise ratio (SNR), because the two step WLS in low signal noise ratio (SNR), as a result of positioning used RDOA by TDOA multiplied by the speed of signal propagation in the medium of space, the error of TDOA carries is magnified, but GROA doesn't exist, this problem, in the introduction of the low SNR GROA information when positioning accuracy is more.

6. Conclusions

This article through to the three dimensional positioning system modeling, in order to improve the positioning accuracy, direct use of auxiliary variables and the position of the signal source, the relationship between position based on the Newton iteration method is proposed to estimate. Derived from the theory and process, the simulation results show that the proposed algorithm, its accuracy has a universal enhancement, and the related parameters between the SNR.

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