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Study of sensor network position algorithm based on wave spectrum

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ABSTRACT

The submarine wireless sensor network receives more and more nation the attention, but due to the sea water fluidity, the sensor node also can along with the ocean current movement, then cause in the network the node relative position to have the change frequently. Traditional method of non-active network position, kindly update the geography coordinates of sensor node, time and space complexity of this algorithm, not only a waste of system resources, and will also result in reduced network responsive to the same problem even cause positioning errors. Through analyze the characteristics of wave spectrum, the wave spectrum is applied to the node positioning, improved MCMPA algorithm for node position in forecasting steps, proposed MCMPA position prediction method based on wave spectrum (WMCMPA), and using simulation tools to experiment, evaluate the performance of various aspects of the algorithm.

KEYWORDS

Sensor network; Position algorithm; Wave spectrum.

INTRODUCTION

Monte Carlo (Monte Carlo, MC) method, also known as statistical simulation, during the middle of the 20th century was to resolve a variety of issues relating to the calculation and their mathematical basis is the Probability Statistics theory [1]. In 2004, the scholar Lingxuan Hu, David Evans, who first introduced MC positioning in wireless sensor network applications, achieve a distance-independent mobile nodes prediction positioning [7]. Monte Carlo algorithm of basic thought is: For some problem, solutions has may is a event occurred of probability, also may happens to is a arandom variable of expectations, so on this class problem solution, except can using General of mathematics method outside, also can through specific of "experiment" of method, get this event occurred of frequency, or this random variables of expects, to this as problem of solutions.

First gives the superiority, consistently, the real three definitions:

Definition 1: Set a real number P(0.5＜P＜1), Monte Carlo methods for probability of any one instance to be the correct solution is greater than or equal to p, then P-0.5 is the advantage of this algorithm, called the algorithm p correctly.

Definition 2: For the same instance, if Monte Carlo algorithm gives only the unique solution, then the algorithm is the consistent.

Definition 3: A Monte Carlo method for solving decision problems, return TRUE if he was absolutely correct, then called this algorithm is real.

Using the Monte Carlo method requires two steps, the first simulation process of the event with some simple method, generates an event the uniformly distributed random process. And then estimate the digital model using statistical method, and obtain the solution of the problem.

PREDICTION METHOD OF MCMPA NODE POSITIONING BASED ON WAVE SPECTRUM

Part of sensor nodes in wireless sensor networks for monitoring the oceans water fixed anchoring buoys or dive under and is known for its position, which is the anchor node. Remaining node as a normal node, is not subject to the control of nodes with the free movement of marine positioning.

Numerical simulation of ocean wave spectra

Wave spectrum S(ω) in the study of the wave theory occupies an important position [6]. It is a digital description of the sea internal structure, but also reflects some characteristics of waves outside. We use the wind speed as the reference coefficient of Pierson-Moscowitz spectrum [11], its mathematical expression such as function (2.1) shows

$$S_{PM}(\omega)\frac{8.1\times10^{-3}g^2}{\omega^5}\exp\left[-0.74\left(\frac{g}{u\omega}\right)^4\right] \qquad (2.1)$$

Among: g=9.8; u is the wind speed above the application environment of the water; ω is the angular frequency. By function (2.1) shows that P-M spectrum is described in relation with the energy frequency distribution, but the actual energy and direction, here are the directional spectrum function D (θ) [8]. D (θ) needs to meet:

$$\int_{-\pi}^{\pi} D(\theta)d\theta = 0 \qquad (2.2)$$

Direction of spectral function form is:

$$D(\theta) = \frac{2}{\pi}\cos^2\left(\frac{\theta}{2}\right) \qquad (2.3)$$

Because the distribution of energy in frequency and direction is not related, so the wave energy distribution function can be expressed as the product of wave spectrum function and directional spectrum function. The function (2.1) and (2.3) to get:

$$S(\omega,\ \theta) = S_{PM}(\omega)D(\theta) = \frac{8.1\times10^{-3}g^2}{\omega^5}\cdot \exp\left[-0.74\left(\frac{g}{u\omega}\right)^4\right]\frac{2}{\pi}\cos^2\left(\frac{\theta}{2}\right) \qquad (2.4)$$

The actual wave is composed of a large number of phase jumbled waves mixed, their wavelength, direction of propagation, and high frequency waves are all different, the wave is called a random combination of the waves [10].

$$z = \sigma(x, y, t) \qquad (2.5)$$

The wave equations of three-dimensional random wave can be described by Longuest-Higgins model [9]:

$$\sigma(x, y, t)\sum_{i=1}^{m}\sum_{j=1}^{n} a_{ij}\ \cos(k_i x\cos\theta_j + k_i y\cos\theta_j - \omega_i t + \sigma_{ij}) \qquad (2.6)$$

Our amount of formula (2.6) in the following definition: static water is xOz plane, the plane positions itself as the origin, to the positive x axis, z axis to the right as positive, a direction perpendicular to the surface as the y axis, up is positive; a is one of the amplitude of wave, i is the frequency of the wave, j is wave propagation range; k_i is the wave number; σ is between $[0, 2\pi]$ a random phase; n is number of frequency division; m is the direction of the partition number. Sensor nodes with the waves in the ocean and freedom of movement, the movement trend should be consistent with the ocean wave spectrum, that is to say the movement of nodes meet (4.6).

a and ω relation as follows:

$$a_{ij} = \sqrt{2S(\omega_i, \theta_j)\Delta\omega\Delta\theta} \qquad (2.7)$$

$S(\omega)$ take the form of equation (2.4), is the wave energy distribution function. $\Delta\omega$ is the increment of ω, is called angular frequency interval; $\Delta\theta$ is the increment of θ, called direction interval.

Based on the linear theory of waves, the wave spectrum of scattered waves is not on all frequency significantly, but relatively concentrated. As shown in figure 2.1, P-M spectral power distribution under different wind speed [14].

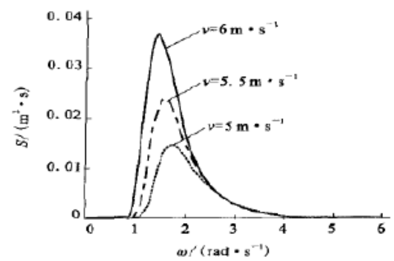

Figure 1: P-M spectral energy distribution under different wind speed

Figure 1 shows, with the increase of wind speed, more and more spectrum distribution in the low frequency waves, wave spectrum narrowing, spectral curve and the horizontal axis surrounded the area becomes large, the wave height also increased significantly. Therefore, in the simulation of random waves, only to meet the requirements of the precision of simulation can choose the most representative spectra in a. In the division of the frequency interval in general can be divided according to the energy or frequency of two characteristics, this algorithm is divided according to frequency. According to the precision of system requirements determine ΔW to divide the spectrum.

For the selection of frequency interval, need to take into account the realistic and real-time of the two factors. The frequency interval must not be too large, otherwise it will cause the number of wave caused by insufficient details about the wave of serious loss; on the other hand: frequency interval can not be too small, or because the number of wave too much and increase the system simulation time, affect the real-time network. According to the current research results can choose to use an eight wave superposition of waves to simulate

Direction of propagation of wave number $\vec{k}$ represents a single wave. $k = 2\pi / \lambda$, k and angular frequency ω satisfies the following function:

$$\omega^2 = gk\tanh(kD) \qquad (2.8)$$

Where D is the depth of water, if the water is deeper than the wavelength of 1/2, then the function (2.9):

$$k = \omega^2 / g \qquad (2.9)$$

ϑ is direction angle, is one of the direction of wave propagation. From the above definition can be concluded:

$$\vec{k} = (2\pi / \lambda) \times (\cos\theta, \sin\theta) \qquad (2.10)$$

But in practice, the ocean energy is concentrated in the range of $\pi / 2$ on both sides of the wind. So $\theta \in (\vec{W} - \pi / 2, \vec{W} + \pi / 2)$, $\vec{W}$ is the direction of wind. Direction range can be divided into m direction:

$$\Delta\theta = \pi / m, \theta_j = \vec{W} - \pi / 2 + \Delta\theta(j - 0.5), j < m \qquad (2.11)$$

Node movement prediction

To the ocean, an ordinary unknown node P as an example, assume that Node P in 3D marine space to move freely. In the localization initial time interval, select P with in its communication range anchor node exchange information, uses the traditional localization algorithm to calculate own in the front k+1 time coordinates, this time in sensor point P saved following information:

In $T_0, T_1, T_2, \ldots, T_K$, the node coordinates respectively are: (x_0, y_0, z_0), (x_1, y_1, z_1),..., (x_k, y_k, z_k), However, if this has been calculated down, due to the point *P* is in constant motion, and the calculation need some time, so we can always be node position in a moment before even the first few moments, real-time position instead of point *P*, it is not meet our ocean monitoring the application requirements. Therefore the present needs initial point *P* the front *k+1* spot position, calculation of interpolation to determine movement along the track to predict the position of nodes in $k+2$ moments(x_{k+1}, y_{k+1}, z_{k+1})and the direction of movement.

Definition 4: Known function $f(x)$ $n+1$ interpolation point is (x_i, y_i), $y_i=f(x_i), i=0,1,\ldots,n$, $\frac{f(x_i)-f(x_j)}{x_i-x_j}$ known as $f(x)$ at the point of (x_i, y_i) first-order difference quotient , denoted by $f[x_i, y_i]$.

Addition of n order difference quotient of the difference quotient is called $N+1$ order difference quotients. Using Newton interpolating method to interpolation nodes store the coordinates, you can find the coordinate x_{k+1} for the nodes in the *k-th* moment.

$$x = f(t) = N_k(t) + R_k(t) \qquad (2.12)$$

Among

$$N_k(t) = f(t_0) + f[t_0, t_1](t - t_0) + f[t_0, t_1, t_2](t - t_0)(t - t_1) + \cdots + f[t_0, t_1, \cdots, t_k](t - t_0)(t - t_1)\cdots(t - t_{k-1}) \qquad (2.13)$$

$$R_k(t) = f[t_0, t_1, \cdots, t_k](t - t_0)(t - t_1)\cdots(t - t_k) \qquad (2.14)$$

Similarly, can obtain:

$$y = g(t) = N^*{}_k(t) + R^*{}_k(t) \qquad (2.15)$$

$$z = s(t) = N^\#{}_k(t) + R^\#{}_k(t) \qquad (2.16)$$

The function (2.12), function (2.15) and function (2.16) respectively on t derivative, get point P in the x, y, z direction of the speed of v_x , v_y , v_z :

$$\begin{aligned} v_x &= f'(t) \mid t = k \\ v_y &= g'(t) \mid t = k \\ v_z &= s'(t) \mid t = k \end{aligned} \qquad (2.17)$$

The origin of coordinate system is established to coordinate the moment of $t=k$ node. The direction of movement of nodes in this coordinate system can be represented by a linear equation below:

$$\begin{cases} xv_y - yv_x = 0 \\ yv_z - zv_y = 0 \\ zv_x - xv_z = 0 \end{cases} \qquad (2.18)$$

The angle between the direction of motion and the *xOy, yOz, zOx* plane respectively is:

$$\begin{cases} \tan\theta_{xOy} = \dfrac{v_z}{\sqrt{v_x{}^2 + v_y{}^2}} \\ \tan\theta_{yOz} = \dfrac{v_x}{\sqrt{v_y{}^2 + v_z{}^2}} \\ \tan\theta_{zOx} = \dfrac{v_y}{\sqrt{v_z{}^2 + v_x{}^2}} \end{cases} \qquad (2.19)$$

The movement speed of nodes is:

$$v = \sqrt{v_x{}^2 + v_y{}^2 + v_z{}^2} \qquad (2.20)$$

After the node completes many times position, need to first f moment of interpolation point for maintenance, $f(t_0)$, $f(t_1)$,$\cdots$, $f(t_k)$ selection cannot completely rely on the unknown nodes and anchor nodes exchange information to determine the.

Flowchart of the selected interpolation point, as shown in Figure 2:

Node position forecast method

In node movement forecast stage, node P the movement speed is $v = \sqrt{v_x{}^2 + v_y{}^2 + v_z{}^2}$, set

m^i_{t-1} is position of node P, that is waiting for locating in some time. $V_{\max}$ is the maximum speed of movement of nodes, $V = \max(V_{\max}, v)$,Node P in the current moment only possible in m^i_{t-1} as the centre, V as the radius of the sphere area [13]. If expressed in $d(m_1, m_2)$ Euclidean distance between points m_1 and m_2, at the same time node speed v in uniform distribution on *[0, V]* interval, the node P now the position of the predicted probability distribution as shown in (2.21).

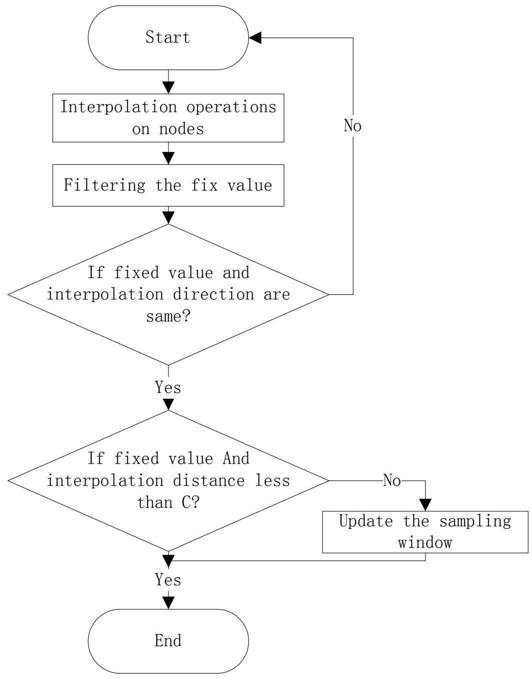

Figure 2: The selected interpolation point flowchart

$$p(m_t \mid m_{t-1}) = \begin{cases} \dfrac{3}{4\pi V^3} & d(m_t, m_{t-1}) < V \\ 0 & d(m_t, m_{t-1}) \geq V \end{cases} \qquad (2.21)$$

The actual sea level in most cases will not be in smooth water, so for the description of the need to take into account the effect of wind, the influence range using the stroke related research at home and abroad on the sea waves to select frequency simulation. Table 1 gives the when the wind speed in different interval, the interval number, interval and frequency division

TABLE 1: Simulation frequencies, the interval, the number of the waves selected table

Wave level	Sea State	Wind speed $v(m/s)$	Wave angular frequency			Number divided
			ω_{PM}	Simulation frequency	$\Delta\omega$	
1	Small wave	(0,5.5)	(1.57,∞)	(1.2,6.0)	0.100	48
2	Light wave	[5.5,8)	(1.07,1.57]	(0.6,4.0)	0.068	50
3	Wave	[8,12)	(0.71,1.07]	(0.4,2.5)	0.041	50
4	Big wave	[12,14)	(0.62,0.71]	(0.4,1.8)	0.023	56
5	Billow	[14,17)	(0.51,0.62]	(0.3,1.4)	0.020	55
6	Rage wave	[17,∞)	(0,0.51]	(0.2,1.2)	0.020	50

According to the sea level, from the table to select the appropriate values of table 1, can get the accurate wave spectrum curve. Through the following steps to determine the position of the predicted node:

Step1: Before each network to interpolation, all anchor nodes to the network in the form of broadcast information on the current sea wind speed at a time, according to the linear wave theory, the wave is smooth movement, before the next to the interpolation can use the corresponding data in table 1 to numerical simulation.

Step2: Using the node position of previous time is the vertex, V is bus. Node movement direction is height, ω is bus and high angle for a cone.

Step3: According to the wind speed information in table 1 to select appropriate numerical simulation to simulate the wave motion spectrum. On the curve of randomly selected one of the few paragraphs and node movement direction and tangent, point of contact for the node coordinates in a moment.

Step4: Simulation curves with random intercept a total of d segment, the d curve to select any N in a conical internal point as the prediction value.

Step5: If after filtering to meet the requirements of point number less than n, may be extended by increasing angular frequency or interpolation interval of degrees of vertex w appropriate larger, increasing the range of selected forecast points, repeat Step2-Step3 until you find the points that meet the requirements.

SIMULATION AND ANALYSIS

Respectively the WMCMPA algorithm and USP algorithm, SLMP algorithm are compared. Simulation experiments on a $500m\times500m\times500m$ within the cube area, node communication radius R is $15m$. The simulation experiments under *NS2* environment.

The relation between position error and time

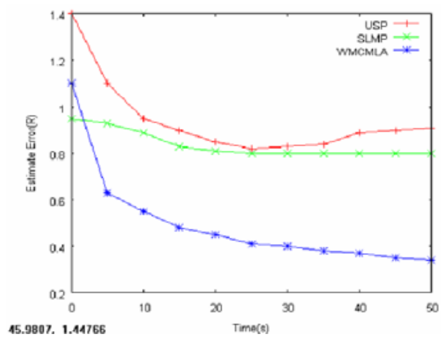

Figure 3:Positioning error change with node time curve

The proposed WMCMPA algorithm application of wave spectrum simulation node in seawater movement trend to predict the position of nodes, nodes in the prediction range of choice, according to the sea wave angular frequency to determine the node predicted vertex angle of the cone, which can further improve the positioning accuracy. It can be seen from the figure compared with two other methods, WMCMPA algorithm has more advantage.

CONCLUSION

The marine monitoring node localization in wireless sensor network based algorithm to do a lot of research, according to the Monte-Carl theory and the theory of wave, the paper introduces MCMPA position algorithm and WMCMPA position algorithm is applicable to marine environment, using the simulation tools to compare localization method is proposed in this paper algorithm, experimental results show that in this particular marine environment algorithm shows good performance.

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