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Positioning Algorithm for Wireless Sensor Network Based on Adaptive Genetic Algorithm

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Abstract

It is very important for wireless sensor network to position the nodes' location because location information is favorable for providing network service such as geographic routing, people tracking and so on. After researching the range-based atomic multilateration algorithm carefully, this paper presents a novel positioning algorithm based on adaptive genetic algorithm (AGA). The new positioning algorithm uses adaptive genetic algorithm to search the optimal solution of nonlinear multivariate positioning equations set. Furthermore, the proposed algorithm uses a new model to estimate range error in order to improve the localization accuracy. Simulation results show that the proposed scheme has better robust performance. Compare with general genetic algorithm, adaptive genetic algorithm has better localization accuracy and higher speed of convergence.

Index Terms: Wireless Sensor Network; Positioning Algorithm; Adaptive Genetic Algorithm

1. Introduction

A sensor network is composed of a large number of sensor nodes, which are densely deployed either inside the phenomenon or very close to it. Some of the application areas are health, military, and security. Most of the sensing tasks require the knowledge of position. Since sensor nodes are generally deployed randomly and run unattended, they need to corporate with a location finding system [1].

Because it is impossible to equip all sensor nodes with a GPS for sensor networks, paper [2] describes a system called AHLoS (Ad-Hoc Localization System) that enables sensor nodes to discover their locations using a set distributed iterative algorithms. Atomic multilateration is the basic method of AHLoS. If there are more than three beacon nodes in the unknown node's sensing zone, the position of unknown node can be estimated. It is maximum likelihood estimation. There are many ways to get the distance between the unknown node and beacon node, such as TOA (Time of Arrival), TDOA (Time Difference of Arrival) and so on. Because of range error, the positioning error exists.

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In this paper, we propose a new model to positioning the unknown node. The basic thought is to introduce estimated parameter of range error in the positioning equations set. The estimation problem of position and range error can be changed into optimization problem of nonlinear functions. The genetic algorithm is very suitable for that optimization problem. But the general genetic algorithm has the problem of premature convergence and low speed of convergence. So we use adaptive genetic algorithm in order to solve these new problems. Simulation results show that the scheme has better performance than traditional method.

2. Improved Range-based Positioning Scheme

We assume that there are more than three beacon nodes in the unknown node's sensing zone. Then we can use range-based method to calculate the position of unknown node. Fig. 1 shows the basic principle.

In Fig.1, the coordinates of beacon nodes are $(x_1, y_1),(x_2, y_2),(x_3, y_3)...(x_n, y_n)$. The coordinate of unknown node is (x_u, y_u). The measured range between unknown node and beacon nodes is $r_1, r_2, r_3, ...r_n$. The estimated parameters of range error are $e_1, e_2, e_3, ...e_n$. The system of equations can be expressed as follows:

$$\begin{cases} \sqrt{(x_1 - x_u)^2 + (y_1 - y_u)^2} = r_1 + e_1 \\ \sqrt{(x_2 - x_u)^2 + (y_2 - y_u)^2} = r_2 + e_2 \\ \sqrt{(x_3 - x_u)^2 + (y_3 - y_u)^2} = r_3 + e_3 \\ \qquad \cdots \\ \sqrt{(x_n - x_u)^2 + (y_n - y_u)^2} = r_n + e_n \end{cases} \tag{1}$$

The principal factor of range error is time desynchrony between unknown node and beacon nodes in the wireless sensor network. Then the estimated parameters of range error can be defined as:

$$e_n = v \cdot \Delta t_n \tag{2}$$

Where Δt_n is the time difference between the unknown node and the beacon node n, v is the velocity of signal propagation. We assume that TOA (Time of Arrival) is used to get the range between unknown node and beacon node. The sound wave signal is widely used in TOA, so we can calculate the time difference to synchronize time according to the velocity of wave signal if e_n is estimated.

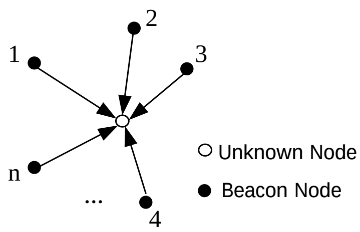

Fig 1. Atomic multilateration

Because these beacon nodes have the same hardware, we assume that the estimated parameters of range error are equal, in other words, $e_1 = e_2 = e_3 ... = e_n = e$.

There are many methods to solve the system of nonlinear multivariate equations, such as least squares technique, maximum likelihood estimation and so on. But these methods can't avoid the linearization error. In this paper, we use adaptive genetic algorithm to search the optimum solution.

3. Adaptive Genetic Algorithm

Genetic algorithm is a kind of collateral probabilistic adaptive searching algorithm refers to biological natural selection and evolution. It is firstly presented by Prof. Holland and his colleagues in Michigan University [3]. Because both crossover probability (p_c) and mutation probability (p_m) in genetic algorithm are invariant, premature convergence may be caused. In addition, it is hard work to choose suitable value of p_c and p_m .

In adaptive genetic algorithm, p_c and p_m can be adjusted dynamically according to the individual fitness and global fitness in order to keep the diversity of individual and the ability of astringency. Using Markov chain, we can prove that adaptive genetic algorithm has global astringency.

The value of p_m should depend not only on $f_{\max} - \overline{f}$, but also on the fitness value f of the solution. Similarly, p_c should depend on the fitness values of both the parent solutions. The expressions for p_c and p_m now take the forms [4]:

$$p_c = \begin{cases} k_1(f_{\max} - f')/(f_{\max} - \overline{f}), & f' > \overline{f} \\ k_3, & f' \le \overline{f} \end{cases} \tag{3}$$

$$p_m = \begin{cases} k_2(f_{\max} - f)/(f_{\max} - \overline{f}), & f > \overline{f} \\ k_4, & f \le \overline{f} \end{cases} \tag{4}$$

In (3) and (4), $f_{\max}$ is the maximum fitness, $\overline{f}$ is the average fitness, f' is the larger of the fitness values of the solutions to be crossed and f is individual's fitness in the current generation. In this paper, we make $k_1 = k_3 = 1$ and $k_2 = k_4 = 0.5$.

The design of object function and fitness function is very important. We use (5) as object function. It is the mean square error of (1).

$$f_{obj} = \sqrt{\frac{\sum_{n=1}^{N} (r_n + e_n - \sqrt{(x_n - x_u)^2 + (y_n - y_u)^2})^2}{N}} \tag{5}$$

Because it is a minimum value problem, we use (6) as fitness function.

$$f_{fit} = \frac{1}{1 + f_{obj}} \tag{6}$$

The positioning scheme can be described as the following steps:

Step 1: Initialize the value of population randomly and encode. The dimension of individual is three (x_u, y_u, e). Then calculate the fitness of each individual according to fitness function.

Step 2: Selection, crossover and mutation constitute Genetic operations. Selection is adopted by roulette wheel. The probability of crossover (p_c) and mutation (p_m) is adaptive as (3) and (4) by the fitness of every individual. Then we can generate the next generation.

Step 3: Calculate the global best fitness in new generation and its individual. If the positioning error is less than a predetermined value or the maximum iteration has been achieved, output the best solution. Otherwise go on with iteration.

4. Simulation and Analysis

4.1. The Design of Simulation

We assume that the sensing zone of unknown node is 100 meters and there are four beacon nodes in the unknown node's sensing zone. The population size of genetic algorithm is 100. x_u and y_u are encoded with 12 bits respectively. We use 10 bits to encode e .

4.2. The Analysis of Simulation Results

The following figures are the results of simulation. The longitudinal coordinate unit of Fig.2 is meter, the abscissa and longitudinal coordinate units of Fig.3 are all meter. In the two figures, Atomic Multilateration means the positioning scheme use simple genetic algorithm but doesn't use error estimation, General GA means the positioning scheme use error estimation and simple genetic algorithm, Adaptive GA means the positioning scheme use error estimation and adaptive genetic algorithm.

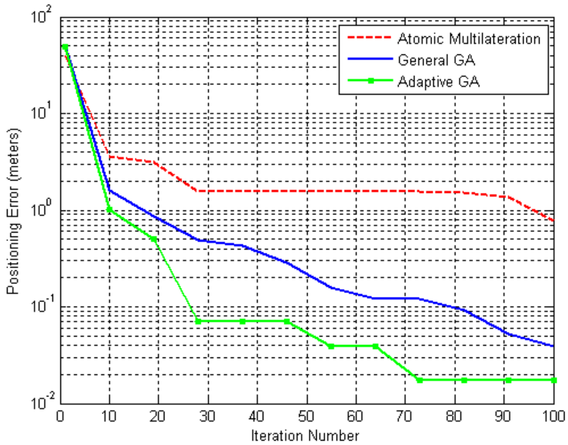

Fig 2. Relation between positioning error and iterations

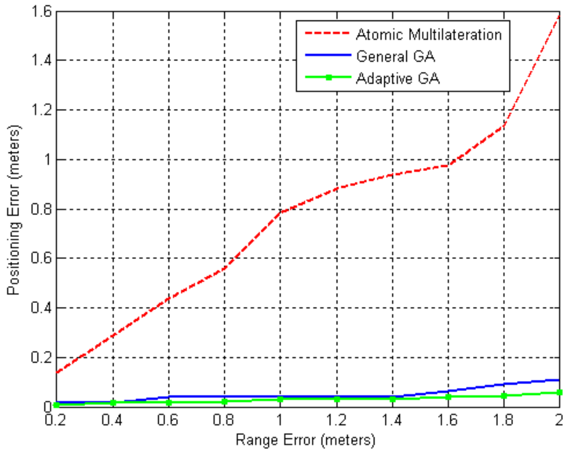

Fig 3. Relation between positioning error and range error

Fig.2 shows the relation between positioning error and iterations. We assume that the range error is 0.5 meters. We can see that the positioning error of Atomic Multilateration is larger than General GA. Compared with General GA, Adaptive GA has higher positioning accuracy and less iterations. Adaptive GA solves the problem of premature convergence effectively.

Fig.3 shows the relation between positioning error and range error. We can see that the curves of General GA and Adaptive GA don't fluctuate along with the increase of range error. But the positioning error of Atomic Multilateration climbs sharply along with the increase of range error. It means that the improved positioning scheme has better robust performance.

5. Conclusion

In this paper, we improve the traditionary atomic multilateration algorithm in order to increase the positioning accuracy. The range error estimation is introduced into the improved positioning scheme. Then we use adaptive genetic algorithm to search the optimal solution of nonlinear multivariate positioning equations set. The results show that adaptive algorithm solves the problem of premature convergence effectively and has better localization accuracy and higher speed of convergence. Furthermore, the proposed scheme has very good robust performance. So it is efficient and feasible in the problem of positioning for wireless sensor network.

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