Node Localization Technology of Wireless Sensor Network (WSN) Based on Harmony Search (HS) Algorithm

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Keywords: Harmony Search; wireless sensor network(WSN); node localization

Abstract. Node localization in wireless sensor networks is one of the most important basic questions. By introducing harmony search algorithm to optimize the wireless sensor network node position calculation, reducing the impact of ranging error and improve the positioning accuracy node; reduces the computational complexity, accelerate the speed of operation. Through simulation experiments based on simulated annealing and genetic algorithms for solving methods were compared, the results show that the positioning of this paper computing technology in positioning accuracy, operational performance are better than them.

1．Introduction

WSN is a multi-hop self-organizing network system connected by a number of low-cost tiny sensor nodes through wireless communication. The present node localization algorithm for wireless sensor networks can be generally separated into two types: Non distance-based positioning and distance-based positioning. The non distance-based positioning hops between nodes calculates the node position by using hops between nodes or area centroid, which is hard to obtain the better positioning accuracy in environment where the nodes are randomly distributed or sparse. The distance-based positioning computes the node position through measuring the distance between nodes, which is of smaller positioning error than that of non distance-based positioning and commonly utilized in fields where the positioning accuracy is highly-required.

2. Introduction to harmony search algorithm

HS Algorithm simulates the process where the musicians manage to obtain the beautiful harmony by memory in the process of musical creation depending on repeatedly regulating the tone of instruments in the orchestra. Tonal harmony is compared to solution vector of the optimizationproblem in HS algorithm and the evaluation is to the corresponding objective functions. Compare the instrument i (=1,2, ⋯,m) to the ist parameter in the optimization problem, the tones of each instrument to values of each parameter, the tonal harmony to jstsolution vector in the optimization problem and evaluation on musical effects to the objective function.

In HS algorithm, assume the objective function for solution and optimization as follows：

$$\min f(x)$$

$$s.t. \quad x_i \in X_i, i = 1, 2, \cdots N$$

One harmony is one likely solution for the problem.

Above all, randomly generate HMS harmonies and construct the harmony memory as follows:

$$HM = \begin{bmatrix} x^1 & f(x^1) \\ x^2 & f(x^2) \\ \vdots & \vdots \\ x^{HMS} & f(x^{HMS}) \end{bmatrix} = \begin{bmatrix} x_1^1 & x_2^1 & \cdots & x_N^1 & f(x^1) \\ x_1^2 & x_2^2 & \cdots & x_n^2 & f(x^2) \\ \vdots & \vdots & \cdots & \vdots & \vdots \\ x_1^{HMS} & x_2^{HMS} & \cdots & x_N^{HMS} & f(x^{HMS}) \end{bmatrix}$$

Then through iteration of the algorithm,produce a new and better harmony in place of harmony with the worst fitness in harmony memory until one solution is found to satisfy the conditions and the times of loop iterations are reached.

During iteration of the algorithm, create a new harmony $x_i^{'} = (x_1^{'}, x_2^{'}, \cdots, x_N^{'})$, wherein the tone

$x_i^{'} = (i = 1, 2, \cdots, N)$. Generate through three mechanisms according to probability control in two

steps.

Phase one: HMCR parameter control

If $f(x^{'}) < f(x^{worst}) = \max_{j=1,2,\cdots,HMS} f(x^j)$, then $x^{worst} = x^{'}$ Wherein rand refers to the random number

distributed evenly in [0,1].

Phase two：The parameter PAR is in a position to determine whether to conduct pitch adjustment on harmonic tone of parameters in Phase one

$$x_i^{'} = \begin{cases} x_i^{'} + rand1*bw, & \text{if rand1<PAR}, & \text{(successive type)} \\ x_i(k+m), m \in \{-1,1\}, & \text{if rand<PAR}, & \text{(discrete type)}\not\subset \\ x_i^{'}, & \text{otherwise}; & i = 1, 2, \cdots, N \end{cases}$$

Wherein bw refers to the band width; PAR refers to the pitch adjustingrate; rand1 refers to the random numbers uniformly distributed in [0,1].

3. Harmony search localization algorithm

The node localization in WSN is obtained with HS algorithm and the description on solution problem is shown in Section 2 with the cost function being the objective function for solution and optimization.

Set coordinates of all the unknown nodes as (Xm+1, Ym+1),……(Xn, Yn) which can be denoted by[Xm+1, Ym+1， …， Xn, Yn], i.e. one harmony in HZ algorithm.

The algorithm is represented as follows:

Step1: Define the problem and the parameter value

Assume that n sensor nodes in which m are anchor nodes and of known coordinates are evenly distributed in one rectangular regionwith the length of L and the width of W. The biggest communication distance between nodes is r and the measured distance between blind node and anchor node is dij which can be denoted as （n,m）Rr@L*Y. Then evaluate the coordinates of blind nodes. Apply the intelligent optimization algorithm for the solution and the objective function of optimization is (1).

Besides, the parameters produced of new harmony in the algorithm are HMCR and PAR.

Step2: Initialize the harmony memory

Assume one harmony$(x_1, y_1, x_2, y_2, \cdots, x_{n-m}, y_{n-m})$ and put it into the harmony memory. The forms of harmony memory are as follows:

$$HM = \begin{bmatrix} x_1^1 & y_1^1 & x_2^1 & y_2^1 & \cdots & x_{n-m}^1 & y_{n-m}^1 & cf(x^1) \\ x_1^2 & y_1^2 & x_2^2 & y_2^2 & \cdots & x_{n-m}^2 & y_{n-m}^2 & cf(x^2) \\ \vdots & \vdots & \vdots & \vdots & \cdots & \vdots & \vdots & \vdots \\ x_1^{HMS} & y_1^{HMS} & x_2^{HMS} & y_2^{HMS} & \cdots & x_{n-m}^{HMS} & y_{n-m}^{HMS} & cf(x^{HMS}) \end{bmatrix}$$

Step 3: Produce thenew harmony

Assume the new harmony is: $x_i' = (x_1', x_2', \cdots, x_N')$

Produce one random number r and is r<HMCR, then

Step4: Update the harmony memory

Evaluate the new solution in Step 2 and update it into HM provided that it is superior to the one with the worst function value. The specific operation is as follows:

If $f(x') < f(x^{worst}) = \max_{j=1,2,\cdots,HMS} f(x^j)$, then $x^{worst} = x'$

Step 5: Examine whether the termination condition of algorithm is reached

Repeat Step2 and Step3 until the times of creation (iteration) reach Tmax[20] for localization purpose.

4.Simulation experiment and result analysis

The efficiency of algorithm in resolving the localization problem in WSN is verified with the MATLAB2010B being used to conduct the simulation experiment and is then compared with performance of genetic algorithm and simulated annealing algorithm.

Assume in the experiment there are n sensor nodes in which m nodes are anchor nodes evenly distributed in the X*Yrectangular region. The biggest communication distance between nodes is r which can be denoted as (n,m) Rr@x*y.

To contrast the effectiveness of solutions obtained with algorithms, define the formula for positioning error as Normalized Localization Error (NLE):

$$NLE \triangleq \frac{1}{R} \sqrt{\frac{1}{(n-m)} \sum_{i=m+1}^{n} \left\| P_i - \widehat{P_i} \right\|^2} \times 100$$

For the actual coordinates of node i, evaluate the coordinates of node I for the algorithm.

Assume the problem is (200, 40) R20@100*100, operate separately the genetic algorithm, the simulated annealing algorithm and the HS algorithm for 50 times and compare the results of positioning error with each algorithm as shown in Fig. 1: (contrasts of mean value, abnormal value, discrete value etc.)

Table 1 Contrasts of positioning error of HS, SA and GA

	GA	HS	SA
Minimum	0. 79	0. 6239	0. 7765
Mean value	1. 47	0. 9901	1. 8938
Standard deviation	0. 47	0. 3579	0. 8177
Maximum	3. 07	2. 356	5. 1278

(1) Anchor proportion and positioning error

The relation between various anchor node proportion and positioning error is shown in Fig. 2, which is compared to classical algorithm GA and SA. It is clear that the positioning error reduces

with the increasing of anchor node proportion and the algorithm proposed in this paper is of higher accuracy compared to GA and SA.
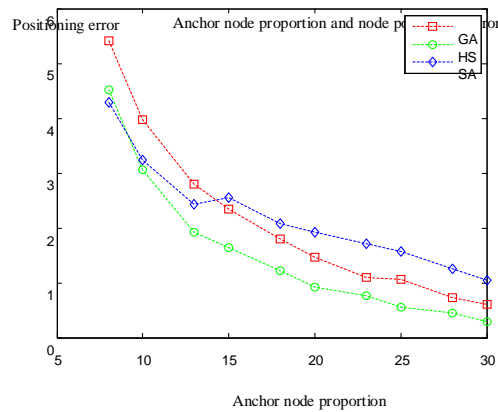

Fig. 1 Node positioning error and anchor node proportion

(2) Communication radius between nodes and positioning error

The influence from variations in values of communication radius of the anchor nodes on positioning error is shown in Fig. 3. It is evident that the positioning error reduces with the increasing of communication radius of the anchor nodes. On account that the anchor nodes are of known positions, the positioning accuracy can get higher if the anchor nodes are endowed with more energy and cover a larger range of communication region.
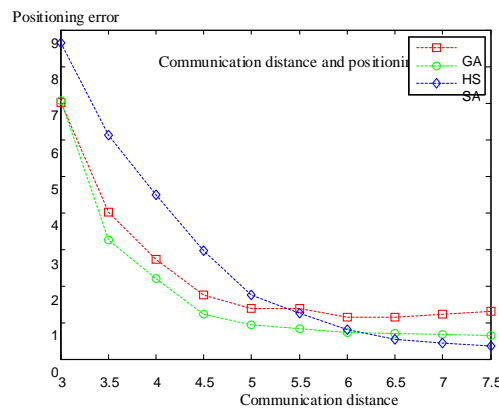

Fig. 2Positioning error and communication radius between nodes

5. Conclusions

The self-localization algorithm in WSN based on HS algorithm is put forward in this paper. It demonstrates that the positioning error is smaller through the contrasts with GA and SA localization algorithms under the same conditions.

References

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