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A Localization Algorithm Based On SFLA and PSO for Wireless Sensor Network

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Abstract: With the rapid development of wireless sensor networks, the localization algorithms have drawn more attention by researchers. Due to the network cost and the restricted energy of the sensor nodes, most of the localization algorithms are not well suitable for wireless sensor networks and furthermore the positioning accuracy is relatively low. The paper presents a localization algorithm based on Shuffled Frog Leaping Algorithm (SFLA) and Particle Swarm Optimization (PSO). Firstly, a calculation method of average distance per hop was designed by using the shuffled frog leaping algorithm which makes the average distance per hop closer to the actual value. Secondly, we consider the location problem as an optimization process to obtain the position of the unknown nodes positioning using particle swarm optimization algorithm which further precise unknown nodes positions. The simulation results have shown that the proposed location algorithm has a higher accuracy.

Key words: Wireless sensor network, DV-Hop localization algorithm, shuffled frog leaping algorithm, particle swarm optimization

INTRODUCTION

Wireless Sensor Network (WSN) has received tremendous attention from both academia and industry recent years because of their promise of numerous potential applications in both civil and military areas (Sun *et al*., 2005). Localization is one of the key technologies of WSN. Recently, many localization algorithms for sensor networks have been proposed. They can be divided into two categories: range-based and range-free. Range-based method use absolute point-to-point distance or angle information to calculate the localization between neighboring sensors. Typical range-based localization algorithms include TOA, AOA, TDOA or RSSI. Range-free techniques solution depends only on the contents of received messages which does not estimate the distance or angle between the nodes, such as Amorphous, DV-Hop, MDS-MAP and so on. According to the hardware cost and energy consumption, range-free algorithm is more suitable for low-cost, low-power wireless sensor network. DV-Hop localization algorithm is a typical rang-free measurement the main source of localization error is calculation the distance between unknown nodes and anchor nodes. In this paper, we analyze the DV-Hop algorithm and put forward an improved DV-Hop scheme localization. The main idea of our approach is to reduce the localization error without increasing hardware cost of sensor node. Simulation results show the proposed algorithm has better performance than the classic DV-Hop.

DV-HOP LOCALIZATION ALGORITHM

Researchers have proposed the DV-Hop which is a distributed, hop by hop positioning algorithm. The main idea is: calculating the distance between unknown nodes and anchor nodes which based on the average per hop-length and hops between unknown nodes and anchor nodes. When unknown node receives the distance of three or more anchor nodes.Unknown nodes can make out own position information according to trilateration method or maximum likelihood estimation. It can be divided into three phases which are described as follows:

Anchor nodes broadcast the message that containing self position information and hops to its neighbor nodes. The initial value of hops field is 0.The receiving node first records the minimum hops to each anchor node and ignores the message with larger hops from the same anchor node. Then the receiving node adds 1 to hops field and forwards it to neighbor nodes. All the nodes in the network can record the minimum hops to each anchor node through the method mentioned above.

According to the received messages, the anchor nodes calculate the average hop-length by formula 1 and broadcast its hop-length to the entire network. Unknown nodes only receive the first arrived message and get the

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value of average hop distance, then broadcast the message to its neighbors. This scheme ensures that most of the nodes receive the average hop distance from the nearest anchor node. Unknown nodes then calculate the distance to each anchor node according to the recorded hops.

$$\text{Hopsize}_i = \frac{\sum_{i\neq j}\sqrt{(x_i - x_j)^2 - (y_i - y_j)^2}}{\sum_{i\neq j} h_{ij}} \quad (1)$$

where (x_i, x_j), (y_i, y_j) are the coordinates of anchor nodes i and j.h_{ij} is the hops between anchor node i and anchor node j.

The unknown nodes calculate itself position by adopting maximum likelihood estimation according to the distance to each anchor node which is recorded in phase three.

IMPROVEMENT DV-HOP LOCALIZATION ALGORITHM

In order to improve the accuracy of DV-Hop algorithm, GE use SFLA to calculatethe Hopsize_i (Ge *et al*., 2011). In this study, we optimized the later of the localization algorithm based on PSO and made some improvements on it.

Calculating Hopsize_i based on shuffled flog leaping algorithm: SFLA is proposed by Eusuff and Lansey and is a memetic meta-heuristic that is based on evolution of memes carried by interactive individuals and a global exchange of information among the frog population (Amiri *et al*., 2009).The mathematical model of SFLA is described as follows:

InaD-dimension target searching space, generate randomly F frogs (solution) to compose initial population. The ith frog represent the solution of the problem X_i $(x_{i1}, x_{i2},..., x_{id})$ frogs are arranged from good to bad according to fitness to divide thewhole population into M sub-populations. Among them, the frog ranking 1st isdivided into 1st sub-population, one ranking 2nd into 2nd sub-population one ranking Mth into Mth sub-population, one ranking M+1st into 1st, analogize in sequence until all frogs have been divide.

Every sub-population is used for local area deep-searching which is in any iteration of sub-population, the worst individual X_w, the best one X_b and the global best one X_g of sub-population in this iteration are determined first. Update operation is just done to the current worst individual X_w, of which the update strategy is:

$$X_{new} = X_w+R(X_b-X_w) \quad (2)$$

where, X_{new} is the updated solutions, R represents random number uniformly distributed between 0 and 1. If the fitness value of X_{new} is good enough, $X_w$will be replaced, if it isn't improved, then using $X_g$to replace X_b. If no improvement becomes possible in this case, then X_w is replaced by a randomly generated.

After a predefined number of memetic evolution steps, the frogs in memeplexes are submitted to a shuffling process, where all the memeplexes are combined into a whole population and then the population is again divided into several new memeplexs. The memetic local search and the shuffling process are repeated until a given termination condition is reached.

In this study, we improve the methods which based on SFLA when calculating the averagehop distance. Assume the Hopsize_i is the average hop distance of anchor node I, e_i is the error caused by Hopsize_i and the actual distance of anchor node i and anchor node j is $d_{ij}(\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2})$, therefore, the methods of calculating Hopsize_i should translate into the minimum optimization problemas follows:

$$d_{ij} = \text{Hopsize}_i \times h_{ij}+e_i \quad (3)$$

Then we use formula 4 as the fitness function when calculating the average hop distance of anchors i which combined with SFLA:

$$f(\text{Hopsize}_i) = \frac{1}{N-1}\sum e_i^2 \quad (4)$$

According to the above analysis, when using SFLA to calculate the Hopsize_i the first step is to randomly generate the initial population in the solution space, the first step is to randomly generate the initial population in the solution space [0, max(d_{ij})], then to evaluate the solution according to the formula 4, at last it can calculate the optimal solution of Hopsize_i which based on the update strategy of SFLA. So the coordinates of the unknown nodes can be calculated by the original DV-Hop algorithm.

Localization optimization based on particle swarm optimization (PSO): WSN localization problem is essentially an optimization problem which based on different distance and is a NP hard problem (Aspnes *et al*., 2004). Now many scholars proposed to improve the precision of location which based on heuristic approach. In this paper we use the PSO to check the coordinates of unknown nodes (Xing-zhou *et al*., 2010).

In PSO, each particle represents a candidate to the optimization task and many particles co-exist and cooperate to search the optimum. When the search space is D-dimensional, the position of particle i can be represented by a D-dimensional vector X_i $(x_{i1}, x_{i2},..., x_{id})^T$, then the velocity of this particle can be represented by another D-dimensional vector V_i. Particle swarm optimization updates their speed and position according to Eq. 5 and 6:

$$v_{id}(k+1) = v_{id}(k) + c_1R_1(pb_{id}(k) - x_{id}(k)) + c_2R_2(gb_d(k) - x_{id}(k)) \quad (5)$$

$$X_{id}(k+1) = x_{id}(k)+v_{id}(k+1) \quad (6)$$

$$w = \frac{w_{max} - w_{min}}{T} t \quad (7)$$

where, c_1, c_2 are two acceleration factors, c_1 can adjust the step size of a particle moving toward to its individual best position, while c_2 can adjust the step size moving toward to the global best position. R_1, R_2 are two random values into the range [0,1]. And $v_{id}(k)$ is the velocity of particle number (i) at the kth iteration, $x_{id}(k)$ is the current particle. $pb_{id}(k)$ is the personal best position of particlei, $gb_d(k)$ is the global best position of the whole swarm. w is the weighting factor. In order to avoid particles in the global solution appear around "oscillating" phenomenon, we use Eq. 7 to improve it (Wang and Xu, 2009). T is the current iteration times and t is the general iteration times.

This study proposed localization optimization based on PSO, the fitness function of the algorithm defined as:

$$f_{fit}(x', y') = \sum_{i=1}^{N} a_i^2 f_i^2(x', y') \quad (8)$$

where, a_i is the weight which is in inverse proportion to the hops between the unknown nodes with anchori, N is the number of anchor nodes, (x', y') is the estimated position of unknown nodes.

SIMULATION RESULTS

To evaluate and analyze the performance of the proposed algorithm, we conduct simulation by using MATLAB 7.0. The 200 sensor nodes are randomly and deploy in a square with length L = 100 m. The connectivity of the network is controlled by adjusting the transmission radius of sensor node (R = 10 m). In order to eliminate the accidental error, each experiment is repeated 30 times and we present average value as final result.

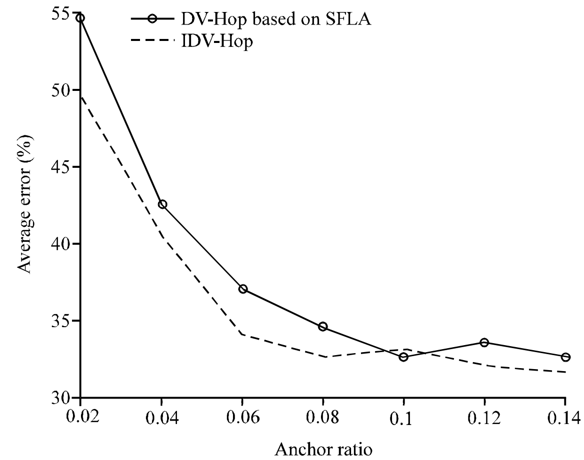

Fig. 1: Relationship between average error and anchor ratio

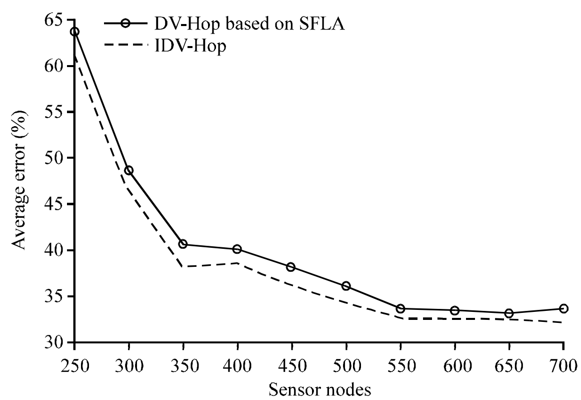

Fig. 2: Relationship between average error and sensor nodes

The positioning error is defined with formula 9:

$$\text{Average error} = \frac{\sum_{i=1}^{m}\sqrt{(x_i - x'_i)^2 + (y_i - y'_i)^2}}{m \times R} \quad (9)$$

where, (x_i, x_j) is the unknown node actual position, (x', y') is the unknown node estimated position, m is the total number of the unknown nodes.

The relationship between location error and anchor ratio and is shown by Fig. 1 and 2 show the relationship between location error and sensor node. Obviously, our algorithm performs better than DV-Hop based on SFLA.

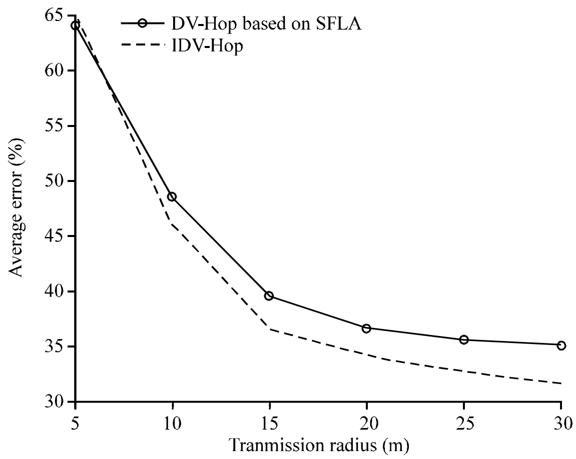

Fig. 3: Relationship between average error and tranmission radius

For the same anchor ratio, the location error in IDV-Hop is smaller than in DV-Hop based on SFLA. Also as the increases of the value of R, the localization accuracy has been greatly improved but under the same condition, the IDV-Hop is better than DV-Hop based on SFLA which are shown by Fig. 3.

CONCLUSION

In this study, we present a localization algorithm based on SFLA and PSO to improve the poor locating performance of DV-Hop algorithm, mainly focusing on two respects: Firstly, we use the SFLA to calculate the average distance per hop which make it more close to the actual value; Secondly, we regard the location problem as a kind of optimization problem and use the PSO to further optimize the positioning. It is shown in the simulation results that our proposed algorithm can improve location accuracy.

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