

# A Novel Wireless Sensor Network Localization Approach: Localization based on Plant Growth Simulation Algorithm

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**Abstract**—This paper proposes a novel wireless sensor network (WSN) localization algorithm. Accurate localization is the key technology of WSN. From various aspects many scholars consider localization problem, which is more effective to regard WSN localization problem as an optimization problem. Plant growth simulation algorithm (PGSA) is a kind of new intelligent optimization algorithm, which is intelligent simulation of plant growth in nature way. In addition to the common characteristics of intelligent algorithms, PGSA could be good robustness and guarantee the global optimal solution, etc. In this paper, further enhances the algorithm by adding the plant root of adaptive backlight function to effectively improve the computing speed and localization precision. Comparing this algorithm with simulated annealing algorithm (SAA), simulation results show that this algorithm has a higher and more consistent localization precision and faster computing speed.

**Index Terms**—wireless sensor network (WSN), localization, PSGA, simulated annealing.

## I. INTRODUCTION

In recent years, because of its unique charm and value WSN attracts the attention of many scholars. WSN refers to a large group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of the environment and organizing the collected data at a central location [1]. In general, the sensor nodes should be low cost and small size that allows them to be deployed in large amounts. Moreover, the power consumption should be small enough to make it the largest network lifetime as possible. Based on these characteristics, WSN has been applied in many fields, such as environmental measurement, medical, industrial and military applications [2].

In WSN applications, the node location information plays an important role for the entire application [3]. Without node location information, many applications will not work properly. In order to get accurate location information of nodes, the simplest way is to equip all nodes in GPS. GPS could accurately locate the position information of each node,

but the equipment of the GPS module is high cost and high power consumption, so in large or medium WSN applications, instead of all nodes, only some nodes locate via GPS. On the other hand, in complex or dangerous place, it's impossible to manually deploy all nodes.

Therefore, many scholars have proposed a series of localization algorithm [1]–[4]. The common feature of all localization algorithms is using such a priori knowledge about the location information of the beacon nodes to estimate the unknown node location. WSN localization is divided into two phases. The first phase is the ranging phase that measures the distance between the unknown node and the beacon nodes. Measurement methods include: Received Signal Strength (RSS), Angle of Arrival (AOA), Time Difference of Arrival (TDOA), or Round Trip Time (RTT). The second phase is to estimate the location of the unknown nodes through the measured information in ranging phase. But either ranging method, with the effect of environmental noise, it will exist certain range error values. In order to improve the location precision, it must minimize the location error. And this problem could be regarded as optimization problems. This paper proposes a WSN localization method based on plant growth simulation algorithm (PGSA). PGSA is a bionic random algorithm that characterizes the growth mechanism of plant phototropism. At present, research on PGSA is still in its infancy, such as integer programming problems [5], transmission network planning problems [6] and some intelligent optimization computing [7], but no previous method of spatial localization PGSA has yet been found. Compared to other similar optimization algorithm, PGSA is simple, fast convergence and robustness, which is more suitable for the large-scale environment.

The rest of the paper is organized as follows: Section II is the description of the related work. Section III introduces enhanced PGSA; Section IV presents the localization algorithm based on enhanced PGSA; Section V simulation results. Section VI is some conclusions of the work.

## II. RELATED WORK

In the field of WSN, [1] gives an overview of the WSN localization. Reference [2] regards localization as a multi-dimensional optimization problem, and applies Particle Swarm Optimization (PSO) to WSN localization. Reference

[3] proposes a Comprehensive Learning Particle Swarm Optimization (CLPSO), and applies it in the localization. Experimental results show that CLPSO will be more accurate than PSO. Reference [4] proposes a localization algorithm based on simulated annealing algorithm (SAA). The SAA is an intelligent algorithm and widely used in the field of optimization. Compared to other convex optimization algorithm, localization algorithm based on SAA can be more accurate localization precision.

In the field of intelligent optimization, [5] proposes PGSA, and further improves the algorithm using the finite element method (FEM). Reference [6] proposes the algorithm for transmission network planning, through some instance, verifies the stability of the algorithm, which could effectively escape from a local optimum.

This paper proposes a WSN localization method based on PGSA. By adding the root point of adaptive backlight function, PGSA could obtain a more accurate location, and better performance compared with SAA.

### III. ENHANCED PLANT GROWTH SIMULATION ALGORITHM

PGSA is a bionic random algorithm that characterizes the growth mechanism of plant phototropism. The dynamic characteristics of PGSA are derived from plant growth phototropism. Based on the inherent power of the plant growth and phototropism force, it establishes the dynamic mechanism of plant growth and reproduction, regards the plant throughout growing space as the solution of the feasible region, and regards the light source as a global optimal solution, so the use of PSGA for solving optimization problems is the simulation process of plant to grow towards the light source (global optimum solution). Here is the probability growth model of plant phototropism simulation, and morphactin concentration equations of growing point in trunk and branches respectively. (The probability of a branch to grow from a node depends on the morphactin concentration of a node. The node with higher morphactin concentration is preferred for growth.)

Assuming that the growing points (Better growth environment than the root  $X_0$ ) in the trunk  $M$  and branches are  $p$  and  $q$ ,  $S_M = (S_{M1}, S_{M2}, \dots, S_{Mp})$ ,  $S_m = (S_{m1}, S_{m2}, \dots, S_{mq})$ , satisfy  $f(S_{Mi}) \leq f(X_0)$ ,  $f(S_{mj}) \leq f(X_0)$ ,  $i = 1, 2, 3 \dots p, j = 1, 2, 3 \dots q$ . Their morphactin concentration  $P_{Mi}$ ,  $P_{mj}$  are computed as follows:

$$\begin{cases} P_{Mi} = \frac{f(X_0) - f(S_{Mi})}{\sum_{i=1}^p (f(X_0) - f(S_{Mi})) + \sum_{j=1}^q (f(X_0) - f(S_{mj}))} \\ P_{mj} = \frac{f(X_0) - f(S_{mj})}{\sum_{i=1}^p (f(X_0) - f(S_{Mi})) + \sum_{j=1}^q (f(X_0) - f(S_{mj}))} \end{cases} \quad (1)$$

where  $X_0$  is the root of plant,  $f(*)$  is the backlight function of growing point, when the light is smaller, the greater the value of  $f$ , and therefore it's inversely proportional to the amount of received light of the growing point.

Obviously, (1) and (2) shows that  $\sum_{i=1}^p \sum_{j=1}^q (P_{Mi} + P_{mj}) = 1$ . Trunk and branches have  $p + q$  growing point totally, and their morphactin concentration are  $(P_1, \dots, P_{q+p})$  as shown in Fig. 1. A number  $r_0$  is randomly generated between  $[0,1]$  and thrown into the morphactin concentration state space to find new basis points  $S_1$  and grow a new branch

and delete the corresponding growth point, as shown in Fig. 1.

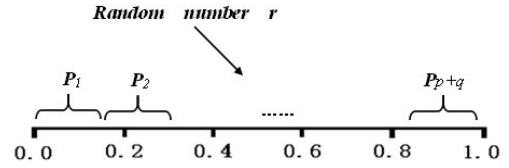


Fig. 1. Morphactin concentration state space.

Taking into account the growth of plants tends to grow in the trunk and the new branches, the fastest growth of plants must be outermost, so the probability of growth of around the root will become smaller. In order to better simulate the growth morphology of plant, this paper proposes adaptive improvement of the root  $f(X_0)$  as follows

$$f(X_0) = \begin{cases} \alpha f(X_0), & f(X_0) \geq \beta, \\ \gamma, & f(X_0) < \beta, \end{cases} \quad (3)$$

where  $\alpha$ ,  $\beta$ ,  $\gamma$  is determined according to the environment situation.

$f(X_0)$  is updated according to (3) and step  $u_1$  is also updated, growing point is sought at the basis point  $S_{1i}$  ( $i = 1, 2, 3 \dots m_1$ ). In accordance with (1) and (2), morphactin concentration of the growing points are recalculated, and new basis  $S_2$  is got to grow a new branch, and the corresponding growth point would be deleted.

Similarly,  $f(X_0)$  is repeat updated according to (3) and step  $u_k, k = 2, 3, \dots, k_{max}$  is also updated, growing point is sought at the basis point  $S_{ki}$  ( $i = 1, 2, 3 \dots m_k$ ). In accordance with (1) and (2), morphactin concentration of the growing points are recalculated, and new basis  $S_{k+1}$  is got to grow a new branch, the corresponding growth point would be deleted.

After these steps, the growth model grows rapidly to the global optimum in the feasible region until no new branches gives birth. At this time gets global optimal solution  $X_{min}$  to obtain the minimum  $f_{min}$  of  $f(x, y)$ .

### IV. LOCALIZATION ALGORITHM BASED ON ENHANCED PGSA

In wireless sensor networks, the location known nodes are called beacon nodes whereas the location unknown nodes are called unknown nodes. The goal of the wireless sensor network localization is to estimate the location of  $N$  unknown nodes distributedly according to the priori information from  $M$  beacon nodes. Considering the WSN localization system, this paper makes the following reasonable assumptions:

- 1)  $N$  unknown nodes and  $M$  beacon nodes randomly deployed in a 2-dimensional or 3-dimensional space. Each unknown nodes and beacon nodes have the same communication range  $R$  simplifiedly;
- 2) When the unknown node has been located, then be automatically into a beacon node;
- 3) When there are less than 3 beacon nodes in the unknown node communication range, the unknown node can't be located;
- 4) In the ranging phase it will be blurred by the noise, so the ranging value is  $\hat{d}_i = d_i + n_i$ , where  $d_i$  is the actual

distance between unknown node and beacon node,  $n_i$  is the Gaussian white noise from unknown node ambient.  $\hat{d}_i$  is the detected distance between unknown nodes and beacon nodes by using RSSI, AOA, TDOA or RTT ranging technology. This paper doesn't consider any particular ranging technology.

Based on the above reasonable assumptions, the localization algorithm process is as follows.

The beacon nodes set up a network, the unknown nodes communicate with the beacon node around to get ranging value  $\hat{d}_i$ ,  $i = 1, 2, \dots$

Through ranging correction method further determine the ranging values  $\hat{d}_i$ ,  $i = 1, 2, \dots$  between the unknown node and beacon nodes around.

Each unknown nodes set its root  $X_0 = (x_0, y_0)$ ,  $X_0$  could be processed by Centroid Algorithm as follows:

$$x_0 = \frac{1}{M} \sum_{i=1}^M x_{Mi}, \quad (4)$$

$$y_0 = \frac{1}{M} \sum_{i=1}^M y_{Mi}, \quad (5)$$

where  $(x_{Mi}, y_{Mi})$  is the actual location of the  $i$ -th beacon nodes.

Through the PGSA, each unknown nodes minimizes the objective function, the backlight function is minimum localization error as follows:

$$f(x, y) = \frac{1}{M} \sum_{i=1}^M (\sqrt{(x - x_{Mi})^2 + (y - y_{Mi})^2} - \hat{d}_i)^2 \quad (6)$$

Until there is no new branches gave birth each unknown nodes could obtain the minimum of  $f(x, y)$  with global optimal solution  $X_{min}$ .

To sum up, the flow chat of PGSA localization algorithm is as Fig. 2.

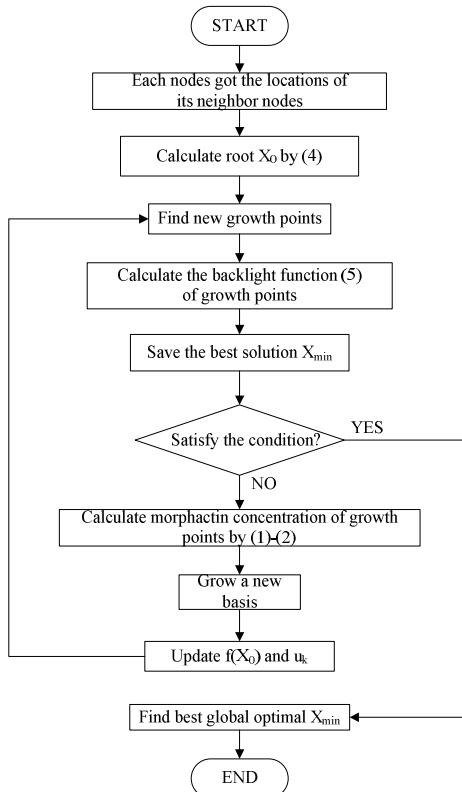


Fig. 2. Flow chat of PGSA localization algorithm.

## V. SIMULATION AND ANALYSIS

WSN localization simulation and performance analysis of the proposed scheme are processed in Matlab with a total of 60 nodes. The unknown nodes and beacon nodes are randomly deployed in a  $100m \times 100m$  sensor filed. Each node has the same communication radius  $R = 30m$ . Do not consider any specific ranging technology. As previously mentioned, it is assumed that the ranging value is only blurred by the additive white Gaussian noise (AWGN), such as  $\hat{d}_i = d_i + n_i$ , where  $n_i$  is assumed to be a zero mean Gaussian noise with variance  $\sigma^2$ . Every experiment results are based on an average of 30 tests.

In order to measure the average localization error, define the mean localization error  $E_L$  as follows.

$$E_L = \frac{1}{L} \sum_{i=1}^L ((x_i - \hat{x}_i)^2 + (y_i - \hat{y}_i)^2), \quad (7)$$

where  $(x_i, y_i)$ , is the actual location of the  $i$ -th unknown nodes,  $(\hat{x}_i, \hat{y}_i)$  is the estimated location of the  $i$ -th unknown nodes,  $L$  is the number of the nodes located.

### A. PGSA versus SAA (Ideal situation)

In the ideal situations, there are no noises during measuring the distances between sensor nodes. In Fig. 3 and Fig. 4 it shows the localization performance between PGSA and SAA when there is no noises. Both algorithms have a good localization performance.

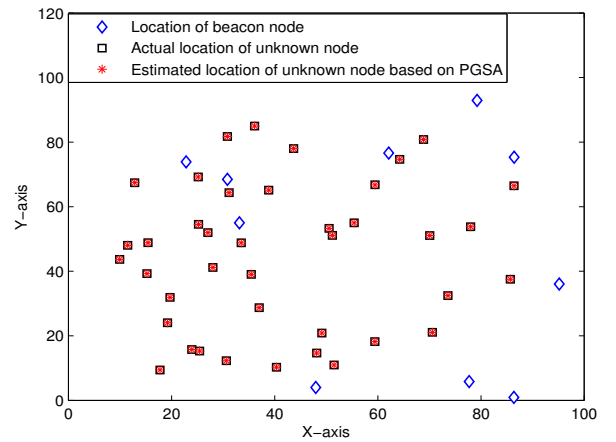


Fig. 3. Location estimated by PGSA.

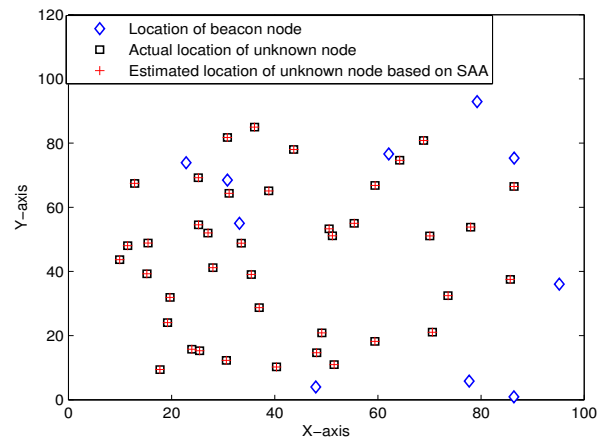


Fig. 4. Location estimated by SAA.

However, the localization error of each node is shown in Fig. 5.

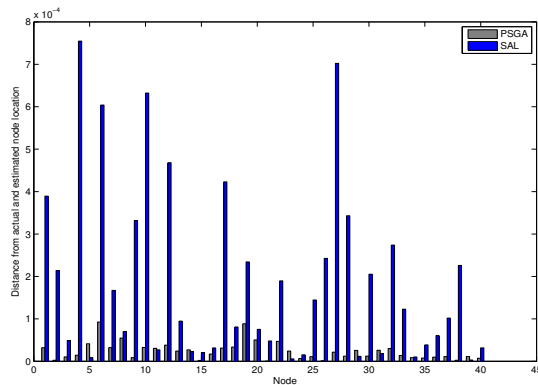


Fig. 5. Comparison of distance estimated by PSGA and SAA.

From Fig. 5, PSGA has higher precision than SAA obviously. In fact, by the (6) their mean localization errors are the following Table I. They have almost computational complexity (Actually, the computational complexity of PSGA is lower than SAA), so the PSGA localization performance is better than the SAA.

TABLE I. COMPARISON OF PSGA AND SAA PERFORMANCE.

	Computing time, (s)	Mean Localization error, (m)
PSGA	2.3394	$2.3904 \times 10^{-5}$
SAA	2.6513	$1.8742 \times 10^{-5}$

#### B. PGSA versus SAA (Non-ideal situation)

In this situation, there are noises in ranging between sensor nodes. In many WSN applications, the actual environmental noise often occurs, which could cause search time and localization error increase. Therefore, based on this situation, this paper shows some localization tests under the influence of the noise with different variance  $\sigma^2$ . The variances of noise increase 0 to 7 by a step of 0.5. From Fig. 6, the mean localization error is proportional to the noise variance. And in the same noise environment, PSGA has a better performance.

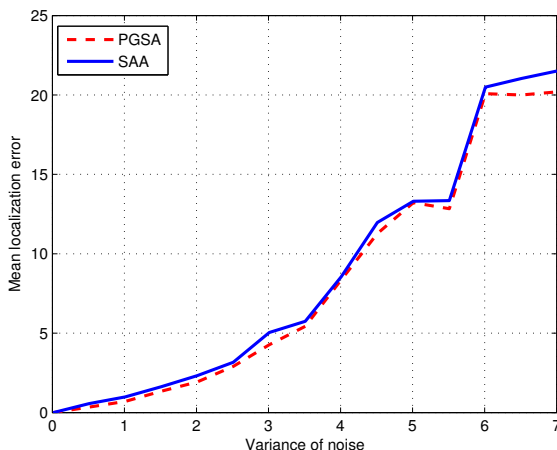


Fig. 6. Comparison of mean localization error by PSGA and SAA.

## VI. CONCLUSIONS

This paper proposes a novel WSN localization algorithm based on PGSA, which could effectively escape from local optimal solution of the problem that often appeared in nonlinear optimization problem.

From the analysis of simulation results, the proposed algorithm has better localization precision and computing speed than the SAA. Although the paper were considered only 2D space, but the algorithm could be easily expanded to 3D space. Recently mobile wireless sensor localization and target tracking require higher localization precision and faster computing speed, so the PGSA may be suitable to this field. Therefore, this is an important direction for future research work.

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