Performance of PSO with Different Ranges for Wireless Sensor Node Localization

Satvir Singh
SBS State Technical Campus
Ferozepur, Punjab [INDIA]
satvir15@gmail.com

Shivangna
SBS State Technical Campus
Ferozepur, Punjab [INDIA]
keershivangna@yahoo.com

Etika Mittal
SBS State Technical Campus
Ferozepur, Punjab [INDIA]
etimital@gmail.com

Abstract

Accurate location of target node is highly desirable in a Wireless Sensor Network (WSN) as it has strong impact on performance of the WSN. Localization includes Range-based and Range-free methods. In this paper Range-based method is used for localization in WSN. An investigation on distributed iterative localization is presented in this paper by using 10 anchors for determining 50 unknown nodes coordinates with PSO for different ranges. A Comparison for different ranges in terms of number of nodes localized, localization accuracy and computation time is presented. Nodes having wider range are localized better as compared to network having sensor nodes with less range.

Index Terms—Particle Swarm Optimization, Localization, Wireless Sensor Networks

I.INTRODUCTION

WSN is a collection of large number of sensor nodes those are connected wirelessly in an ad-hoc manner [1]. Each node is provided with sensors, transceiver, information processor and power supply, etc. The purpose of WSN is to collect and supply sensed information to a designated sink from a wider area. However, due to size, power supply and constraints the transreceiving range is limited and are networked with each other to pass information to the sink. Information received at destination is of use only if the origin of the source, i.e., location of the sensor node is known. Moreover, location of all randomly deployed sensor nodes are also required to determine the route for information passing. Self organizing and fault tolerance characteristics of WSN make them promising for a number of military and civilian applications [2], [3]. To determine the physical coordinates of group of sensor nodes in WSN is one of challenging problem. Some WSN challenges and constraints are Self-Management, Wireless Networking, Design Constraints, Security.

B. Localization

Localization is most active research area in WSN and it usually refers to the process of determining positions of unknown nodes(target nodes) that uses information of positions of some known nodes i.e., anchor nodes based on measurements such as distance, Time of Arrival (TOA), Time Difference of Arrival (TDOA), Angle of Arrival (AOA), etc. [4], [5], [6]. Many of the applications proposed for WSN require knowledge of sensing information which gives rise to problem of localization. The localization estimation is a two-phase process involving:-

1) **Ranging**: Node estimates their distance from anchors (beacons or settled nodes) using signal propagation time or strength of received signal. Precise measurement of these parameters is not possible due to noise; therefore, results of localization algorithms that use these parameter are likely to be inaccurate.

2) **Position Estimation**: It is carried out using the ranging information. This is done either by solving a set of simultaneous equations, or by using an optimization algorithm that minimizes the localization error. This is an iterative process, where settled nodes i.e., anchors and localization process is repeated until either all nodes are settled, or no more can be localized [7], [8].

II. LITERATURE SURVEY

A survey of localization systems of WSNs is available in [9]. An efficient localization system that extends GPS capabilities to non-GPS nodes in an ad-hoc network as anchors transmit their location information to all nodes in the network is proposed in [10]. Then, each target node estimates its location by performing triangularization. Localization accuracy of node is improved by measuring their distances from their neighbors in [11]. The issue of error accumulation is addressed in [12] through Kalman filter based least square estimation in [13], [14] to simultaneously locate the position of all sensor nodes. Node localization problem is addressed using convex optimization based on semi-definite programming. The semi-definite programming approach is further extended to non-convex inequality constraints in [15]. In [16], Gradient search technique demonstrates the use of data analysis technique called multidimensional scaling (MDS) for estimating the target node positions. WSN is treated as multidimensional optimization problem and addressed through population based stochastic approaches. In [17] centralized location of WSN nodes is proposed by PSO to minimize average localization error. In this approach it provides more accurate localization as compared to simulated annealing algorithm proposed earlier [18]. This approach required few known nodes (anchors) to localize all target nodes. Range Based localization using PSO, BBO and its variants are presented in [19]. Comparison of two different ranges using PSO and BBO and its variants are presented in [20]. Non-Dominating sorting for BBO is presented in [21]. Multi-objective gain impedance optimization of Yagi-Uda antenna is presented in [22].

Some Genetic Algorithms (GA) based node localization are proposed in [23], [24], [25], [26]. Centralized algorithm determines location of target node by estimating their distances from all one hop neighbors. Each target node is localized under imprecise measurement of distances from three or more neighboring anchors or settled nodes. The method proposed in this paper has following advantages over some of the earlier methods:

1) Localization is robust against uncertainty of noise associated with distance measurement.

2) Localization accuracy is better and has fast convergence.

3) In each iteration, one node gets settled. Thus, each node gets more references in its transmission range. This leads to minimization in error due to flip ambiguity, the situation that arises as reference (anchor) nodes are in non-collinear locations.

This paper proposes optimization algorithm of PSO for distributed iterative node localization in a WSN. PSO [27] with comparison of different transmitting range have never been proposed for distributed iterative node localization. The rest of the paper is organized as follows: Section III explains PSO for localization in this study, Section IV explains how the localization problem is approached using the above mentioned optimization methods, Section V discusses numerical simulation and results obtained. At the last, Section VI presents conclusions and make a projection on possible future research path.

III. LOCALIZATION METHODS

The stochastic algorithms PSO, BBO, Blended BBO, EBBO, Refusal BBO are discussed in the following subsections.

A. Particle Swarm Optimization

PSO is a robust stochastic optimization technique based on the movement and intelligence of swarms. It was developed in 1995 by James Kennedy (social-psychologist) and Russell Eberhart (electrical engineer). It uses a number of particles that constitute a swarm moving around in the search space looking for the best solution. Each particle keeps track of its coordinates in the solution space which are associated with the best solution (fitness) that has achieved so far by that particle. This value is called personal best, pbest. Another best value that is tracked by the PSO is the best value obtained so far by any particle in the neighborhood of that particle. This value is called gbest. The basic concept of PSO lies in accelerating each particle toward its pbest and the gbest locations, with a random weighted acceleration at each time step as shown in Fig. 1.

Consider that the search space is M-dimensional and i-th particle location in the swarm can be represented by $X_i = [x_{i1}, x_{i2},.... x_{id} ..., x_{iM}]$ and its velocity can be represented by another M-dimensional vector $V_i = [v_{i1}, v_{i2},.... v_{id} ..., v_{iM}]$. Let the best previously visited location position of this particle be denoted by $P_i = [p_{i1}, p_{i2},.... p_{id} ..., p_{iM}]$, whereas, g-th particle, i.e., $P_g = [p_{g1}, p_{g2},.... p_{gd} ..., p_{gM}]$, is globally best particle location.

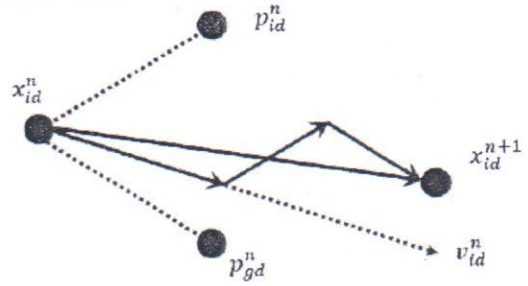

Fig.1. PSO Characteristics

Fig. 1 depicts the vector movement of particle element from location x^n_{id} to x^{n+1}_{id} in (n+1)-th iteration that is being governed by past best location p^n_{id}, global best location p^n_{gd}, and current velocity v^n_{id}. Alternatively, the whole swarm is updated according to the equations (1) and (2) suggested by [28], [29].

$$v^{m+1}_{id} = \chi(wv^m_{id} + \psi_1 r_1(p^m_{id} - x^m_{id}) + \psi_2 r_2(p^m_{gd} - x^m_{id})) \quad (1)$$

$$x^{m+1}_{id} = x^m_{id} + v^{m+1}_{id} \quad (2)$$

Here, w is inertia weight, φ_1 is cognitive learning parameter, φ_2 is social learning parameter and constriction factor χ, are strategy parameters of PSO algorithm, while r_1 and r_2 are random numbers uniformly distributed in the range [0,1].

IV. STEPS FOLLOWED FOR LOCALIZATION

The objective of WSN localization is to determine maximum number of N target nodes by using M anchor nodes which know their locations by the process followed:-

1) N target nodes and M anchor nodes are randomly deployed in a 2-Dimensional sensor field. Each target node and anchor node has a transmission range R. At each iteration one node gets settled and works as anchor node in the next iteration and transmits information as the anchors do.

2) Target node which has atleast 3 anchor nodes in its transmission range is said to be localized.

3) Mean of coordinates of anchor nodes fall within transmission range, i.e., $(x_1, x_2, ... x_5 .., x_n)$ mean $(y_1, y_2, ... y_5 .., y_n)$ is termed as centroid position.

4) Randomly deploy few nodes around estimated position and distance between nodes in deployment and anchor nodes in the transmission range are calculated. The distance measurement are effected with gaussian additive noise. A node estimates its distance from anchor i as $\hat{d} = d_i + \eta_i$. Where d_i is the actual distance and given by following equation

$$d_i = \sqrt{(x - x_i)^2 + (y - y_i)^2} \quad (3)$$

Where (x, y) is the location of target node and (x_i, y_i) is the location of i-th anchor node in neighborhood of target node. The measurement noise η has a random value which is uniformly distributed in the range $d_i \pm d_i \, {P_n}/{100}$ where P_n is percentage noise in distance measurement.

5) Case study for PSO is conducted . Each localization target node runs PSO for different transmitting range to localize itself. The objective function is to minimize the average localization error between measured distance and estimated distance. It is defined as follows

$$f(x,y) = \frac{1}{M}\sum_{i=1}^{M}\left(\sqrt{(x-x_i)^2 + (y-y_i)^2} - \hat{d}_i^{\,2}\right) \quad (4)$$

Where $M \geq 3$ is the number of anchor nodes within transmission range R, of target node.

6) When all the N_l localizable nodes determine their coordinates, total average localization error is calculated as the mean of square of distances of estimated node coordinates (x_i, y_i) and the actual node coordinates (X_i, Y_i), for $i = 1,2,3....N_l$, determines for case of PSO for comparison of different transmitting range in following equation

$$E_l = \frac{1}{N_l}\sum_{i=1}^{N}\left((x_i - X_i)^2 + (y_i - Y_i)^2\right) \quad (5)$$

7) Steps 2 to 6 are repeated until all target nodes get localized. The performance of localization algorithm is based on E_l and N_l, where $N_{Nl} = N - N_l$ is number of nodes that could not be localized. The minimum the values of E_l and N_{Nl}, the better will be the performance.

V. SIMULATION RESULTS

WSN localization simulations and its performance evaluation were conducted using PSO in C/C++ environment. Common strategic settings for each case are: (1) Maximum number iterations = 20 (2) Population size = 10, (3) Number of target nodes = 50, (4) Number of anchor nodes = 10, Different Transmission ranges for each node = 25, 20, 15 respectively. These target and anchor nodes are randomly deployed in 2-dimensional sensor field having dimensions of 100×100 square units. In Fig. 2 - Fig. 4, ∇ defines node localization estimated by PSO, * defines location of node, • defines non-localized nodes and remaining defines the location of anchor nodes.

A. Localization using PSO

In this case study, each target node that can be localized, runs PSO algorithm to localize itself. The parameters of PSO are set as follows.

1) Acceleration constants $c_1 = c_2 = 2$

2) Limits on particle position: $X_{min} = 0$ and $X_{max} = 100$

25 trial experiments of PSO-based localization are conducted for $P_n = 2$ and $P_n = 5$. Average of total localization error E_l defined in (5) is computed and shown in Fig. 2.

B. Discussions on Results

The actual locations of nodes and anchors, and the coordinates of the nodes estimated by PSO in a trail run are shown in Fig.2 - Fig.4. The results are summarized in Table 1 and it can be observed that PSO used here have performed fairly well in WSN localization. Nodes having wider range are localized better as compared to network having sensor nodes with less range.

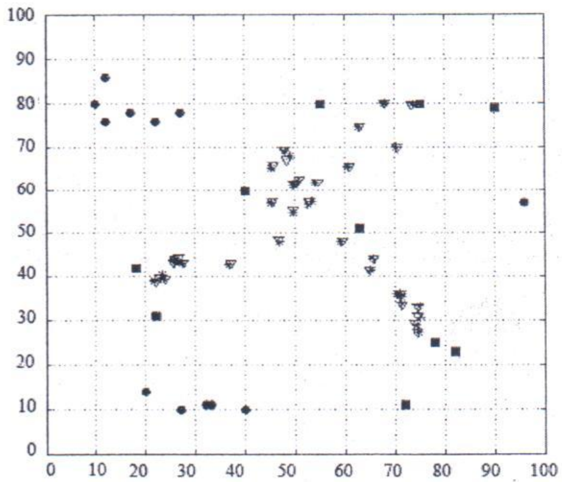

Fig.2. Location Estimated by PSO for Range=25

TABLE I.

SUMMARY OF 25 TRIAL RUNS OF PSO FOR RANGE=25

3) Mean of coordinates of anchor nodes fall within transmission range, i.e., $(x_1, x_2, ... x_5 .., x_n)$ mean $(y_1, y_2, ... y_5 .., y_n)$ is termed as centroid position.

4) Randomly deploy few nodes around estimated position and distance between nodes in deployment and anchor nodes in the transmission range are calculated. The distance measurement are effected with gaussian additive noise. A node estimates its distance from anchor i as $\hat{d} = d_i + \eta_i$. Where d_i is the actual distance and given by following equation

$$d_i = \sqrt{(x - x_i)^2 + (y - y_i)^2} \quad (3)$$

Where (x, y) is the location of target node and (x_i, y_i) is the location of i-th anchor node in neighborhood of target node. The measurement noise η has a random value which is uniformly distributed in the range $d_i \pm d_i \, P_n/100$ where P_n is percentage noise in distance measurement.

5) Case study for PSO is conducted . Each localization target node runs PSO for different transmitting range to localize itself. The objective function is to minimize the average localization error between measured distance and estimated distance. It is defined as follows

$$f(x, y) = \frac{1}{M} \sum_{i=1}^{M} \left(\sqrt{(x - x_i)^2 + (y - y_i)^2} - \hat{d}_i^{\,2} \right) \quad (4)$$

Where $M \geq 3$ is the number of anchor nodes within transmission range R, of target node.

6) When all the N_l localizable nodes determine their coordinates, total average localization error is calculated as the mean of square of distances of estimated node coordinates (x_i, y_i) and the actual node coordinates (X_i, Y_i), for $i = 1,2,3....N_l$, determines for case of PSO for comparison of different transmitting range in following equation

$$E_l = \frac{1}{N_l} \sum_{i=1}^{N} \left((x_i - X_i)^2 + (y_i - Y_i)^2 \right) \quad (5)$$

7) Steps 2 to 6 are repeated until all target nodes get localized. The performance of localization algorithm is based on E_l and N_l, where $N_{Nl} = N - N_l$ is number of nodes that could not be localized. The minimum the values of E_l and N_{Nl}, the better will be the performance.

V. SIMULATION RESULTS

WSN localization simulations and its performance evaluation were conducted using PSO in C/C++ environment. Common strategic settings for each case are: (1) Maximum number iterations = 20 (2) Population size = 10, (3) Number of target nodes = 50, (4) Number of anchor nodes = 10, Different Transmission ranges for each node = 25, 20, 15 respectively. These target and anchor nodes are randomly deployed in 2-dimensional sensor field having dimensions of 100×100 square units. In Fig. 2 - Fig. 4, ∇ defines node localization estimated by PSO, * defines location of node, • defines non-localized nodes and remaining defines the location of anchor nodes.

A. Localization using PSO

In this case study, each target node that can be localized, runs PSO algorithm to localize itself. The parameters of PSO are set as follows.

1) Acceleration constants $c_1 = c_2 = 2$

2) Limits on particle position: $X_{min} = 0$ and $X_{max} = 100$

25 trial experiments of PSO-based localization are conducted for $P_n = 2$ and $P_n = 5$. Average of total localization error E_l defined in (5) is computed and shown in Fig. 2.

B. Discussions on Results

The actual locations of nodes and anchors, and the coordinates of the nodes estimated by PSO in a trail run are shown in Fig.2 - Fig.4. The results are summarized in Table 1 and it can be observed that PSO used here have performed fairly well in WSN localization. Nodes having wider range are localized better as compared to network having sensor nodes with less range.

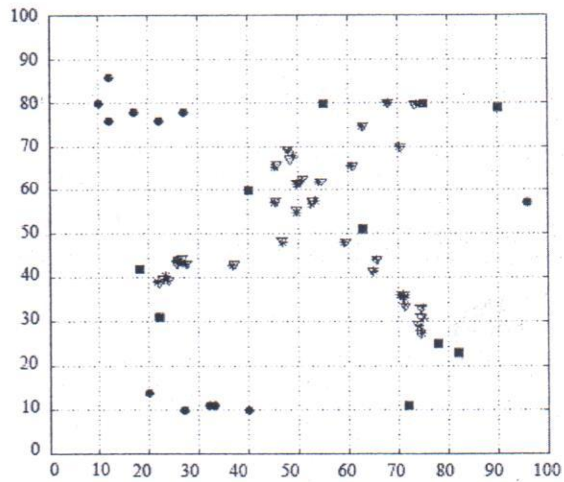

Fig.2. Location Estimated by PSO for Range=25

TABLE I.

SUMMARY OF 25 TRIAL RUNS OF PSO FOR RANGE=25

networks," in Local Computer Networks, 2005. 30th Anniversary. The IEEE Conference on. IEEE, 2005, pp.2-pp.

[19] E. M, Satvir Singh, Shivangna, "Range Based wireless sensor node localization using PSO and BBO and its variants," 2013.

[20] S. Singh, Shivangna, and S. Tayal, "Article: Analysis of different Ranges for Wireless Sensor Node Localization using PSO and BBO and its variants," vol. 63, no. 22, February 2013, pp. 31-37, published by Foundation of Computer Science, New York, USA.

[21] S. Singh, E. Mittal, and G. Sachdeva, "Nsbbo for gain impedance optimization of yagi-uda antenna design," in Information and Communication Technologies (WICT), 2012 World Conference on. IEEE, 2012, pp. 856-860.

[22] --, "Multi-objective gain-impedance optimization of yagi-uda antenna using nsbbo and nspso," vol. 56, 2012.

[23] G. Nan, M. Li, and J. Li, "Estimation of node localization with a real-coded genetic algorithm in wsns," in Machine Learning and Cybernetics, 2007 International Conference on, vol. 2. IEEE, 2007, pp. 873-878.

[24] S. Yun, J. Lee, W. Chung, E. Kim, and S. Kim, "A Soft Computing approach to localization in wireless sensor networks," vol. 36, no. 4. Elsevier, 2009, pp. 7552-7561.

[25] Q. Zhang, J. Wang, C. Jin and Q. Zeng, "Localization algorithm for wireless sensor network based on genetic simulated annealing algorithm," in Wireless Communications, Networking and Mobile Computing, 2008. WiCOM'08. 4th International Conference on. IEEE, 2008, pp. 1-5.

[26] Q. Zhang, J. Huang, J. Wang, C. Jin, J. Ye, and W. Zhang, "A new centralized localization algorithm for wireless sensor network," in Communications and Networking in China, 2008. ChinaCom 2008. Third International Conference on. IEEE, 2008, pp. 625-629.

[27] J. Kennedy and R. Eberhart, "Particle swarm optimization," in Neural Networks, 1995. Proceedings., IEEE International Conference on, vol. 4. IEEE, 1995, pp. 1942-1948.

[28] X. Hu, Y. Shi, and R. Eberhart, "Recent advances in particle swarm," in Evolutionary Computation, 2004. CEC2004. Congress on, vol. 1. IEEE, 2004, pp. 90-97.

[29] Y. del Valle, G. Venayagamoorthy, S. Mohagheghi, J. Hernandez, and R. Harley, "Particle swarm optimization: Basic concepts, variants and applications in power systems," vol. 12, no. 2. IEEE, 2008, pp. 171-195.