Implementation of Intelligent Algorithms for Localization of Wireless Sensor Network for Secure Wireless Communication Applications

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Research Article

Keywords: Wireless sensor network, intelligent algorithm, firefly algorithm, flower pollination algorithm, sensor node localization.

Posted Date: October 27th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-1009791/v1

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Abstract—

Sensors are important devices to collect the information for many applications. The present era is using internet of things (IoT) which is basically working on sensors. The input/output status of the system is monitored using these sensors. The placement of sensors in the cluster is required to be identified for proper data analysis. When the data is received from the sensors, it is also mapped with it, then only proper action can be taken based on signal and location. In WSN, few sensor locations are known which are called anchors, from these anchors, the location of unknown sensors are estimated. In this paper, intelligent algorithms firefly and flower pollination algorithm (FPA) are used to find the location of the sensors. The algorithms of the process are compared with their accuracy of finding the location and convergence speed.

Keywords— Wireless sensor network, intelligent algorithm, firefly algorithm, flower pollination algorithm, sensor node localization.

I. INTRODUCTION

Smart city, smart home, and many other smart controls are the intelligent operation of the system, which operates independently without human supervision. These intelligent control techniques require monitoring of the environment and change in the state. The monitoring is possible by sensors, and most of the time its wireless. For the smart and better control, many inputs at different locations either with the same time or at particular time slot is essential. This forms the network of wireless sensors [1]. A sensor is a node in WSN, which is tiny and has sensing elements, power backup for its functionality, analog to digital (ADC) converter required to convert the sensed analog quantity into digital format as required by the WSN. It also has a small memory unit, a transmitter, a receiver and a processing unit. The anchor nodes are known and other nodes positions are not known in the WSN. Localization of these unknown nodes depends on terrain, signal strength, hardware functions and irregularities of WSN space [2]. The sensors may be wearable and helpful for the humans in need. Patients in need of medical care and suffering from memory loss may use these sensors. The monitoring of such sensors from the hospital or in central control unit requires to find the locations of the sensors. In predefined search space, artificial neural network (ANN) may train based on the past history to find the present location of the sensors. ANN is an intelligent algorithm and is used to find the locations of the sensors with maximum 0.6% error [3]. In practical applications, hundreds of sensor nodes are deployed to form a WSN and they communicate among them in wireless medium. Accurate location of the sensor nodes is important to make proper control scheme. GPS is the best method but it is expensive and made the sensor nodes bulky and not suitable for many applications. The location may be in 2 dimensional or 3 dimensions based on the applications for which the WSN is designed [4]. Optimization algorithms are widely used for the following applications in WSN, namely sensor localization, energy-efficient clustering, optimal coverage and data aggregation. Bio-inspired optimization techniques are commonly used for this optimization in WSN [5]. Localization is the process of finding the location of the unknown sensor node from the reference of anchor or base station nodes. A cluster consists of a few anchor nodes and many unknown nodes. The process of localization is finding the position of unknown nodes based on the position of anchor nodes [6]. WSN applications are extended to healthcare, military, autonomous vehicle and many more. Most of these applications require efficient localization of the unknown node in the WSN. Its challenging task for the WSN of low cost and low power applications compared to high-power GPS [7]. Many intelligent and bio-inspired algorithms are used for the WSN for localization, energy-efficient clustering and optimum coverage. One among them is the firefly algorithm. It uses the intelligence of the firefly insects for the optimization technique. The firefly is the insect which emits light on its stomach. This light is flashing at some frequency based on the need of the insect [8]. The firefly emits light and observes the light of the brightest firefly then the firefly moves towards the brighter one. This makes the faster convergence of the firefly insect with its groups. The same technique is used in the optimization to get the faster convergence for the localization of the unknown nodes [9]. Firefly is a random search which has attraction between the two light emitting insects; the brighter gives more attraction and fast move towards the results. The less attraction among the firefly makes premature in convergence and hence care to be taken for the implementation of this algorithm [10]. Constraint firefly algorithm finds the solution in the space bounded by the boundary conditions is helpful for the real-time application [11]. Flowering plants survive in the universe for many billions of years and its characteristic is used to develop an algorithm called flower pollination algorithm (FPA) [12]. The steps involving in the FPA is simple and has only two steps, they are local pollination and global pollination. In global pollination, the insect or animals or birds are involved [13]. The insects’ behavior is modeled with levy flight constant and included in the global pollination [14]. The switching constant decides...
the pollination of the flower to be local or global pollination. The global pollination pollinates the flowers with the global flower, and in the local pollination, the global flower is not involved in the pollination process [15].

The section 2 gives the problem formulation, section 3 explains the firefly algorithm, section 4 explains flower pollination algorithm, section 5 explains results and discussion, and section 6 concludes the paper.

II. PROBLEM FORMULATION

The unknown sensor node location is estimated using the known location of anchor node. Minimum of three anchor nodes are required to identify the correct location of the sensor node. The distance between the sensor node and the anchor nodes are calculated and based on this, the location is fixed. The root mean square error is estimated for the sensor node from all the anchor nodes. When the root mean square error is zero, then the correct location is arrived for the sensor node.

\[ D = \sqrt{(x_{est} - x)^2 + (y_{est} - y)^2} \] (1)

The distance between unknown sensor node and the anchor node is calculated using the equation (1).\( X_{est} \) and \( Y_{est} \) are the estimated \( X \), \( Y \) directions distance between anchor and unknown sensor node. The retention distance of the unknown sensor node from the anchor node. The mean square error distance is the objective function of the localization problem and given in the equation (2).

\[ f(d) = \sum_{i=1}^{n} \left[ (x_{est} - x_i)^2 + (y_{est} - y_i)^2 - D_i \right] \] (2)

The equation (2) is the function of distance and it calculates the square root of the distance error. When this error is zero then the actual position of the unknown sensor node is arrived.

III. FIREFLY ALGORITHM

It is an algorithm inspired by optimization algorithm. The intelligence of firefly insect is observed and this algorithm is developed by Xin-She Yang [8]. These insects live in social group. This swarm of insects moves from one place to another in search of food. The position of the insects emits the light at its stomach called flashing lights. The flashing frequency is different in each insect. More insects will emerge where there is more source of food. From this, one can understand that more brightness indicates the availability of more insects and more food available for them. A firefly which is away from the swarm has to observe the brightness of the light and it has to move towards the brighter spot to get food and to get a mating partner. Figure 2 shows the firefly moving towards the brighter firefly in the group.

![Fig.2. Firefly moves towards the brighter firefly](image)

For the development of the intelligent algorithm, few idealizations are added into the algorithm. They are, firefly moves towards the brighter firefly irrespective of the sex of the insect. The attractiveness between the firefly depends on the brightness of the emitted light intensity and inversely proportional to the distance between them. Distance is the destructive factor of attractiveness. When a firefly finds nobrighter firefly, then it moves randomly to explore the better solution for the considered problem. The brightness is calculated using the objective function of the problem. For the maximization problem, brighter indicates the better result. Form minimization problem, the objective function is inversely considered as the fitness function of the firefly.

A. Attractiveness

A firefly moves towards the brighter firefly based on the attractiveness among them. The calculation of this attractiveness is given in the equation (3).

\[ \beta(x) = \beta_0 e^{-\gamma x^m} \] (3)

In the above equation (3), \( \beta \) is the attractiveness, \( \beta_0 \) is the initial attractiveness, \( x \) is the distance between the fireflies, \( \gamma \) is the absorption coefficient and \( m \) is the dimension of the solution space. Most of the problems use 2D dimensional spaces as a search space and considered in this paper.

B. Distance

The distance between the fireflies under consideration for them to move in the equation (4).

\[ x = x_i - x_j \] (4)

The distance is then norm 2 distance between the two fireflies, \( x_i \) and \( x_j \).

C. Movement

The firefly updates its position moving towards the brighter firefly using the equation (5).

\[ F_{p+1} = F_p + \beta(x) \times (x_i - x_p) \times (r - 0.5) \] (5)

In the above equation (5), \( F_p \) is the firefly position to be updated, \( p \) is the iteration count, \( \beta(x) \) is the attractiveness, \( x_i \) is the distance, \( r \) is the randomizing parameter, and \( \text{randomnumber} \).
Algorithm

The firefly algorithm for the localization of the unknown sensor nodes is given below.

Step 1: Initial population of fireflies which contributes to the position in the locationspace are created.

Step 2: Set iteration count = 1.

Step 3: Localization error is considered as the fitness for the firefly.

Step 4: Attractiveness between the considered firefly and brighter firefly is calculated.

Step 5: Distance between fireflies is calculated.

Step 6: The firefly moves toward the brighter firefly.

Step 7: For the flower – global pollination is done using equation (6). After pollination goto step 8.

Step 8: Increment flower count, and if it is less than number of flower population then execute step 5.

Step 9: If the iteration count is less than maximum then jump to step 3 else stop the iteration and print the results.

IV. FLOWER POLLINATION ALGORITHM

It is a nature-inspired algorithm. The flowering plants generation and self-pollination are implemented in this algorithm. This algorithm has two simple steps, one is self-pollination and another one is cross or global pollination. Flowering plants are aimed to produce the seeds of the plant to extend its generation. To produce the seeds, the pollen is transferred to the ovary of the flower. About 10 percent of the flower does not need help from the insects. Honeybees is one of the important insects which help the flowers to produce seeds.

Transfer of pollen from one plant’s flower to another plant’s flower is called global pollination and shown in figure 3. The pollen of plant - B is transferred to plant – A’s flower ovary. This process needs the help of wind or insectorsanimalorbirds. Thetwo-pollination processes are given below.

A. Local pollination

The pollen of the flower in the same plant is transferred to the ovary of the flowers. This process is called local pollination and the mathematical equation for the process is given in the equation (6).

\[ F_{i+1}^p = F_i^p + \varepsilon(F_i^p - F_k^p) \]  (6)

Inteaboveequation (6), \( F_i^p \) is the flower, \( i \) – isthe flower undergoing for the pollination, \( j \) and \( k \) are the flowers of the same plant, \( \varepsilon \) is the scaling factor and \( G \) is the iteration count.

B. Global pollination

The pollen from the flower of plant - B is transferred to the plant- A flower by means of insects or any other biotic nature. This process is given in the equation (7).

\[ F_{i+1}^p = F_i^p + \varepsilon(F_i^p - F_j^p) \]  (7)

Inteaboveequation (7), \( F_i^p \) is the flower, \( i \) – isthe flower undergoing for the pollination, subscript \( G \) is the global flower having the best results, \( i \) and \( j \) is the iteration count.

C. Algorithm

The flower-pollination algorithm for the localization of the unknown sensor node is given below.

Step 1: Initial population of flower which consists of position of the sensor nodes are created.

Step 2: Localization error is considered as the fitness of the flowers.

Step 3: Set iteration count = 1.

Step 5: For every flower, generate a random number, if the random number is less than the switching constant then execute step 7.

Step 6: Forethe flower - global pollination is done using equation (6). After pollination goto step 8.

Step 7: For the flower – global pollination is done using equation (7).

Step 8: Increment flower count, and if it is less than number of flower population then execute step 5.

Step 9: If the iteration count is less than maximum then go to step 4. Else print the results.

V. RESULTS AND DISCUSSION

For the implementation of the firefly and flower-pollination algorithm a test case consisting of 40 nodes are considered. In this 40 sensor nodes, 8 sensor nodes are considered as anchor nodes and those locations are known. Rest of the 32 sensor nodes locations are unknown, the intelligent algorithm has to estimate the correct location of these 32 sensor nodes [1]. The boundary of 0 to 100 units is considered for the search space for the 40 sensor nodes. The 40 nodes locations are randomly generated by the MATLAB software. Among them 8 anchor nodes are identified and fixed to estimate the location of other 32 sensor nodes. These search space is two-dimensional. The location is xy position in the search space of (0,0) to (100,100) units. The unknown sensor nodes locations are estimated one by one. The maximum number of iterations is 100 iterations. The location of the sensor node is not identified then the best near location is considered. Then next sensor node location is searched in the solution space. Same steps are used to identify all the 32 unknown sensor nodes. The result of the intelligent algorithms are given below.
A. Firefly algorithm

Fortysensornodesarecreatedinthesolutionboundedbythe (0, 0) and (100, 100) units of the two-dimensional searchspaces. Eight anchor nodes are considered and rest of the 32 unknownsensornodesaretobelocatedinthesolutionspace.

Fig. 4. Firefly algorithm localization

Inthefigure4.trianglesareanchornodesusedtofindthelocati on of other unknown nodes. The pink colour squareboxesarethecurrentlocationofthe sensornodes.Bluecolourstars are the estimated location of the algorithm. From thefigure it is evident that 15 nodes location are not identified and 17 nodes are identified correctly.

Fig. 5. Firefly algorithm convergence curve

Figure 5 shows the convergence curve for one of the identifiedsensornodes. The location is estimated correctly at around 8th iteration of the algorithm.

B. Flower pollination algorithm

Same localization system is considered for the flower pollination algorithm for the comparison. In this algorithm also 40 nodes are created in the solution space of (0, 0) and (100, 100) two dimensional space. Figure 6 shows 40 nodes in the solution space. In that 8 anchor nodes are given as redtriangle. Based on this position, rest of 32 sensor nodes are estimated. Actual node locations are shown as square box and estimatednodes are shown as bluecolour stars.

Fig. 6. Flower pollination algorithm localization

From the figure 6, all the unknown sensor nodes are identified.

Fig. 7. Flower pollination algorithm convergence curve

Figure 7 shows the convergence curve of the flower pollination algorithm. The nodes are identified and one of its node convergence is shown in the above figure. The node is identified after about 9 iterations.

Both the algorithms, firefly and flower pollination algorithms are used to identify the location of the unknownsensornodes. Firefly algorithm is unable to find all the nodes in the solution space. In flower pollination all the unknown sensor nodes are identified and shown in the figure 6.

Table 1. Comparison of algorithms

| Parameters               | Firefly Algorithm | Flower Pollination Algorithm |
|--------------------------|-------------------|------------------------------|
| Total Nodes              | 40                | 40                           |
| Anchornodes              | 8                 | 8                            |
| Unknownsensor Nodes      | 32                | 32                           |
| Identified Nodes         | 15                | 32                           |
| Values of constants      | $\beta = 1.7 \cdot 0.96$, $\gamma = 0.96$, $\mu = 0.3$, $r = 1$, $\varphi = 0$ | |

Table 1 compares two algorithms considered. From this we come to know that flower pollination algorithm gives better localization.
VI. CONCLUSION

Wireless sensor networks are common and are increasing their use day by day. Due to cost efficiency and miniaturesize, GPS is not included in the sensor nodes. The localization of these sensor nodes is important to take valid and better monitoring and control of the system. Nature-inspired algorithms firefly algorithm and flower pollination algorithm are used to identify the location of the unknown sensor nodes. For this, a case study with 40 sensor nodes are considered. To identify unknown sensor nodes, anchor nodes are used. The intelligent algorithm finds the location of the sensors nodes. In the comparison study, flower pollination algorithm performs better and identifies all the nodes in the solution space.

This investigation finds its application in optimizing mechanical engineering design such as design of springs, pressure vessels, speed reducers, robotics. Wireless sensor networks on the whole finds its application in the mechanical engineering stream mainly in the security aspect in the environment sensing, structural health, and equipment monitoring in the aspect of condition monitoring and in the evaluation and improvement in process automation.

Declarations

1. **Funding**
   Not Applicable

2. **Conflicts of interest/Competing interests**
   There is no conflict of interest from all the authors in the manuscript.

3. **Availability of data and material**
   Not Applicable

4. **Code availability** (software application or custom code)
   Not Applicable

5. **Authors' contributions**
   T Ashok – Overall concepts, literature survey, Working and ideology, Results development
   R Prabhakaran – Supervising, Proof editing

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