

APPLICATION OF FIREFLY AND FLOWER POLLINATION
ALGORITHM FOR WIRELESS SENSOR NETWORK
LOCALIZATION

Bilvaprasad Hima Bindhu[#], Thangaraju Jesudas*

Received on February 23, 2023

Presented by Ch. Roumenin, Member of BAS, on March 28, 2023

Abstract

A wireless sensor network is a cluster of sensors that work communally to carry out a certain important job. The nodes that make up these sensor clusters have their own power and communication capabilities with the other nodes in the cluster. Identification of the sensor locations inside the cluster is necessary for accurate data analysis. Only then, based on the signal and position, can the appropriate action be done. In wireless sensor network (WSN), a select few sensor positions are referred to as anchors, and it is from such anchors that the positions of unknown sensors have been inferred. The location of the sensors is identified using firefly and flower pollination algorithms (FFPA) in this research work. The effectiveness of the proposed technique is assessed by evaluating their accuracy of the position and convergence rate. The firefly and flower pollination algorithms are utilized to detect the position of the unidentified sensor nodes after the ninth iteration. When we compare both algorithms, the firefly algorithm is incapable to discover the nodes which are available in the location area. From the results it is evident that the flower pollination algorithm successfully identifies all the unknown sensor locations.

Key words: localization, sensor node, firefly, flower pollination, wireless sensor networks

Introduction. The innovative intelligent system works independently without human supervision, namely smart city, smart homes and many other smart

[#]Corresponding author.

DOI:10.7546/CRABS.2023.05.13

control systems. Monitoring of the environment and state changes is necessary for these intelligent control systems. Sensors make monitoring possible, and they frequently use wireless techniques. Numerous ideas on several positions, each at a similar time or throughout a specific moment in the time frame, are necessary for smarter and better control. This creates the wireless sensor network. An analogue to digital converter is needed to transform the perceived analogue capacity into numerical layout as expected by the WSN [1]. In the wireless sensor networks, a sensor is a tiny node with detecting components, home automation, and an analogue-to-digital transformer. In addition, it has a tiny memory building block, a processing unit, a receiver, and a transmitter. The locations of the anchor nodes are known while those of the other nodes are unknown in the WSN. It depends on the geography, signal quality, hardware capabilities, and abnormalities in the WSN space to localise or locate these unknown nodes [2]. These sensors might be portable and beneficial for people in need. These sensors can be used by patients with memory loss who require outside assistance. Finding the positions of the sensors is necessary for supervising of these sensors by the clinic or by a main management unit. Artificial neural networks (ANN) can be trained to determine the current location of the sensors in a predefined hunt space using ancient information. An intelligent algorithm called ANN is employed to locate the sensors with a maximum inaccuracy of 6% [3]. A WSN is a network of wirelessly connected sensor devices used for real-world applications. To create an effective control scheme, the sensor nodes must be located precisely. The best approach is Global Positioning System (GPS), but it is affluent, makes sensor nodes big, and is unsuitable for many applications. The geolocation may be two-dimensional or three-dimensional, depending on the purposes for which the WSN is designed [4]. Localization of the sensor, clustering of nodes with respect to energy-efficiency, coverage optimality, and summarization are four WSN implementations that heavily rely on optimization techniques. For this optimization in WSN, bio-inspired optimization approaches are frequently applied [5]. By using this anchor or base station nodes as a reference, localization determines the locality of an unidentified sensor node. The cluster has been formed with a small number of anchor nodes and a great number of unknown nodes. In localization method, unknown nodes are located depending on top of the position of anchor nodes [6]. There are numerous applications in the fields of healthcare, defence, and autonomous vehicles using wireless sensor networks. The majority of these applications call on the WSN's unknown nodes to self-localize. When compared to high power Global Positioning System, it is a very difficult challenge for the wireless sensor networks of lower price and less energy product [7]. The WSN uses a variety of clever and biologically inspired algorithms for locale of sensors, grouping of nodes with respect to energy-efficiency, and ideal exposure. The firefly algorithm is one of them. The optimization technique makes use of the firefly insects' intelligence. The bug that produces light on its stomach is called a firefly. Depending on the insect's

needs, this light flashes periodically [8]. The firefly releases its own light, watches the light of the firefly with the brightest light, and then goes toward the brighter firefly. This causes the firefly bug to converge with its group more quickly. The optimization process uses the same technique to speed up convergence for the localisation of unknown nodes [9]. The brighter light producing insect attracts more attention and moves quickly toward the best results in the random search known as Firefly. The implementation of this method must be carefully considered because the fireflies' lower attraction causes premature convergence [10]. The constraint firefly algorithm locates the solutions for the real-life application in the region confined by the boundary layer [11]. Flower pollination algorithm (FPA) was developed using the fact that flowering plants have existed for several billions of years [12]. Local and global pollination are the only two processes that make up the FPA's basic process. Insects, animals, or birds participate in global pollination [13]. Levy flying constant is used to model the insect's behaviour and include it into the theory of global pollination [14]. The switching constant determines whether a flower will be pollinated locally or globally. The global pollination uses the global flower to pollinate the flowers, but the local pollination does not use the global bloom [15–18].

Concept of the problem. The undetermined sensor node's position is determined using the anchor node's known position. Minimum three anchor nodes are required for the sensors to be positioned correctly. Based on the calculated gap or space among the anchor nodes and then the sensor node in the network, the placement is fixed. The sensor node's root mean square error is discovered by using all of the anchor nodes in the network. The sensor node has been positioned correctly if the value of the square root mean square error is zero. The space between both the unidentified sensor node and the anchor node is intended using equation (1). The approximate space between both unidentified sensor nodes considered here is 'X' and 'Y' and the anchor nodes are denoted by X_{est} and Y_{est} , respectively. X_a and Y_a calculate the actual separation in the middle of the anchor node and the unidentified sensor node.

$$(1) \quad D_i = \sqrt{\langle (x_{est} - x_a)^2 + (y_{est} - y_a)^2 \rangle} \quad .$$

The localization problem's objective function is the mean square error distance, which is represented by equation (2).

$$(2) \quad f(d) = \left[\sqrt{(x_{est} - x_a)^2 + (y_{est} - y_a)^2} - D_i \right]^2 \quad .$$

The square root of the distance error is computed using equation (2), which functions as a function of distance. If the distance error is 0, then the position of the unidentified sensor node is in its real position.

Firefly algorithm. It is an optimization algorithm with natural inspiration. This algorithm was created by Xin-She Yang after studying the intelligence of firefly insects [8]. These bugs coexist in social groups. In search of food, this swarm of insects travels from one location to another. These insects' biochemistry causes their stomachs to emit what are known as flashing lights. Each bug has a different flashing frequency. Where there is more food available, more insects will grow. This demonstrates that greater brightness suggests the presence of more insects and a greater supply of food for the fireflies. When the fireflies are detached from the group, it must assess the illumination of the lightness and migrate toward the brighter area in order to obtain food. A few idealisations are incorporated into the algorithm to help it develop into an intelligent one. Regardless of the sex of the insects, fireflies gravitate towards the brighter firefly. The brightness of the light intensity that is released and the distance between the fireflies are both factors that affect how appealing they are to one another. The detriment to attraction is distance. A firefly moves arbitrarily to look for a better solution to the situation at hand when it cannot find another firefly that is brighter. The problem's objective function is used to determine the intensity. The superior solution for the maximisation problem is shown by a brighter result. In minimization issues, the firefly fitness function is seen in the opposite direction as the objective function.

Attractiveness. By contrasting their appearances, a firefly is drawn to the more appealing firefly. The attractiveness is calculated by using equation (3).

$$(3) \quad \beta(x) = \beta_0 e^{-\gamma x^m}.$$

The attractiveness, the starting attractiveness, the space between the firefly, the concentration coefficient, and the dimension of the solution space are all given in equation (3). The majority of the problem, which is taken into account in this study, utilizes two-dimensional spaces as a hunt space.

Distance. Equation (4) specifies the separation between the fireflies that will be taken into account for movement.

$$(4) \quad x = \|x_i - x_j\|.$$

The space or gap is the norm 2 spaces stuck between the two firefly's x_i and x_j .

Movement. By using equation (5) the firefly adjusts its location as it advances towards the more brilliant firefly.

$$(5) \quad F_i^{p+1} = F_i^p + \beta(x) Xx + aX(r - 0.5).$$

Firefly position is represented by F_i that needs to be updated, the number of iterations is to be indicated by p , $\beta(x)$ is for specifying the prettiness, ' x ' is the gap, ' a ' is the randomising constraint, and ' r ' is the arbitrary integer.

Algorithm of the firefly method for finding unidentified sensor nodes.

Step 1: First, a firefly population is produced that provides to its place in the location area.

Step 2: Initialize the iteration count to 1 in step two.

Step 3: Localization inaccuracy is taken into account when determining the firefly's fitness.

Step 4: A comparison of the attractiveness of the brighter firefly and the under-consideration firefly is made.

Step 5: The gap among fireflies is measured.

Step 6: The firefly improves on the firefly that is more visible.

Step 7: Repeat steps 4–6 for each firefly.

Step 8: Increase the repetition calculation and search for the greatest benefit.

Step 9: Print the results if the number of iteration is smaller than the maximum value; otherwise, skip to third step and print the results.

Flower pollination algorithm. This algorithm was inspired by nature and it incorporates the creation and survival of flowering plants. This method consists of two straightforward steps: self-pollination and cross- or global pollination. The goal of flowering plants is to create seeds that will allow the plant to continue to grow. The pollen is delivered to the flower's ovary in order to develop seeds. Just about 10% of flowers require insect assistance. One significant insect that aids flowers in producing seeds is the honey bee.

Global pollination, depicted in Fig. 3, is the transport of pollen from one flower of the plant blossom to a different flower of a plant. The flower ovary of plant A receives pollen from plant B. Wind, insects, animals, or birds are required for this process. This is a list of the two-pollination procedure.

Local pollination. The ovary of the flower receives pollen from another flower of the same plant. The arithmetical expression for local pollination is given in equation (6).

$$(6) \quad F_i^{p+1} = F_i^p + \epsilon \left(F_j^p - F_k^p \right),$$

where F is the flower, i is the flower being pollinated, j and k are the blossoms of the similar plant, ϵ is the ranging factor, and p is the number of iterations.

Global pollination. By use of flies or any other biological creature, the sperm from the blossoms of plant B is carried to the flower of plant A. Equation (7) outlines this procedure.

$$(7) \quad F_i^{p+1} = F_i^p + L \left(F_G^p - F_i^p \right).$$

Here F is the flower, i is the flower that is being pollinated, subscript G is the global flower that produced the best outcomes, and p is the number of iterations.

Algorithm of the flower pollination approach for locating unidentified sensor nodes.

Step 1: The sensor nodes' positions are constructed as part of the initial population of the flower.

Step 2: The suitability of the flowers is determined by localization mistake.

Step 3: Set iteration count to 1.

Step 4: Set the blossom count to 1.

Step 5: Create a random number for each flower and then carry out step 7 if the result is smaller than the switching constant.

Step 6: Using equation (6) local pollination is carried out for the flower i . Subsequent to pollination, proceed to step number 8.

Step 7: Using equation (7) the flower's universal i 's pollination is carried out.

Step 8: Increase the number of flowers, and if it is smaller than the population of flowers, proceed to step 5.

Step 9: If it is below the maximum value, then increase the iteration count value.

Results and discussion. A test scenario with 40 nodes is taken into consideration for the firefly and flower pollination algorithms' implementation. Eight of these 40 sensor nodes whose locales are well-known are regarded as anchor nodes. The clever system must predict the precise location of the remaining 32 sensor nodes whose locales are unidentified. The 40 sensor nodes' search space is bounded by a range of 0 to 100 units. The MATLAB software generates the placements of the 40 nodes at random. To determine the placement of the remaining 32 sensor nodes, 8 anchor nodes among them were found and fixed. Two dimensions make up the search space. The place is at coordinates x, y in the range of $[0, 0]$ to $[100, 100]$ units used for the search. One by one, the positions of the unidentified sensor nodes are estimated. A hundred iterations are considered to be the maximum number of iterations. The best nearby location is taken into consideration if the sensor node's position cannot be determined. The solution space is then searched for the locality of the subsequent sensor node. The 32 unidentified sensor nodes are all identified using the same techniques. These are the outcomes of the clever algorithms.

A. Firefly algorithm. In the solution defined by the units $(0, 0)$ and $(100, 100)$ of the 2D investigated spaces, 40 sensor nodes are generated. The remaining 32 unidentified sensor nodes are to be placed in the result space, and eight anchor nodes are taken into consideration. The triangles in Fig. 1. serve as anchor nodes that are utilised to pinpoint the places of other unidentified nodes. The real locations of the sensor nodes are indicated by the pink square boxes. The algorithm's estimated position is indicated by blue coloured stars. The graphic makes it clear that fifteen nodes locations are incorrectly acknowledged, whereas seventeen nodes locations are accurately detected. One of the recognised sensor nodes' convergence curves is depicted in Fig. 2. Around the eighth iteration of the algorithm, the position is accurately calculated.

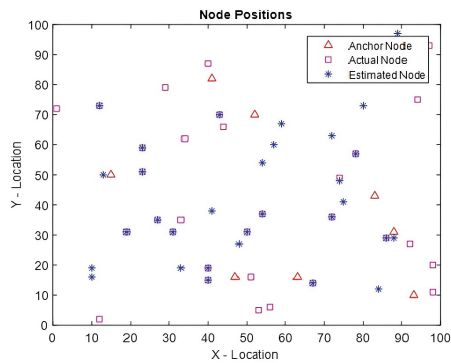


Fig. 1. Localization using Firefly algorithm

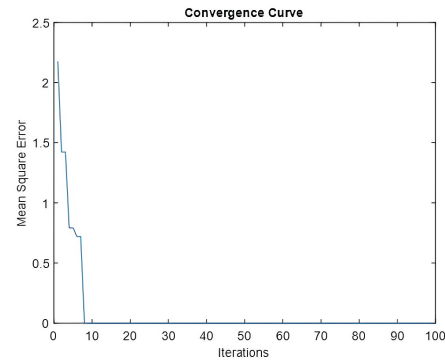


Fig. 2. Convergence curve using Firefly algorithm

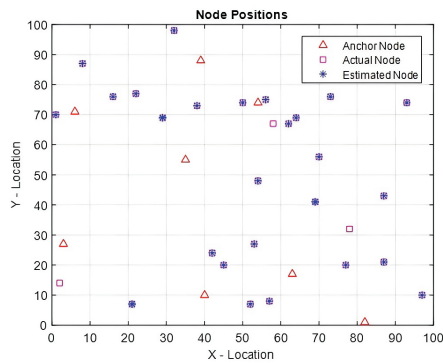


Fig. 3. Localization of Flower pollination algorithm

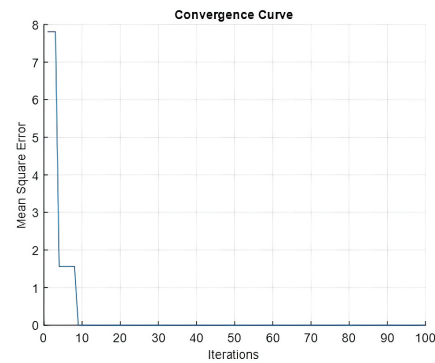


Fig. 4. Convergence curve using Flower pollination algorithm

B. Flower pollination algorithm. The flower pollination algorithm is compared using the same localization mechanism. Moreover, 40 nodes are produced in the two-dimensional solution gap of $[0, 0]$ and $[100, 100]$ in this approach. Forty nodes are depicted in the solution space in Fig. 3. Eight anchor nodes are shown as red triangles in that. The remaining 32 sensor nodes are estimated based on this position. Real node positions are displayed as square boxes, whereas estimated node locations are displayed as blue stars. All the unidentified nodes are identified as indicated in Fig. 3. The flower pollination algorithm's meeting curve is shown in Fig. 4. The graphic depicts one of the node convergences along with the identification of the nodes.

After about 9 iterations the node is identified. The unknown sensor nodes' locations are determined using both the firefly and flower pollination algorithms. The firefly algorithm is powerless to locate all of the solution space's nodes. In the pollination algorithm every unidentified sensor node has been located as depicted in Fig. 3.

In evidence, the total nodes in the firefly and flower pollination algorithms are 40, the total anchor nodes in both algorithms are 8, the total unknown sensor nodes in the algorithm are 32, 15 nodes are identified in the firefly algorithm, and 32 nodes are identified in the flower pollination algorithm; hence, it is clear that the algorithm for flower pollination provides more accurate localization and that the flower pollination algorithm works better than the firefly algorithm. The constants are $\beta_0 = 1$, $\gamma = 0.96$, $a = 0.22$, $\varepsilon = 0.3$, $L = 1.5$, $s = 0.7$ in firefly and flower pollination algorithms, respectively.

Conclusion. Wireless sensor networks are widespread and are being used more frequently every day. Global Positioning System is not contained in the sensor nodes due to their low cost and small size. It is crucial to locate these sensor nodes in order to carry out accurate and effective system monitoring and control. Here, the methods derived from the firefly and flower pollination algorithms play a major role to determine the unidentified sensor nodes. A detailed study with 40 sensor nodes is taken into account for this. Anchor nodes are used to identify unidentified sensor nodes. The sensor nodes' location is discovered by the clever algorithm. The flower pollination algorithm surpasses the other algorithms in the comparative research and recognises every node in the solution space. This study's use is in the improvement of mechanical engineering and designs for springs, pressure vessels, speed reducers, and robots. In the mechanical engineering stream, wireless sensor networks are typically applied to security, environmental sensing, structural health, equipment monitoring, condition monitoring, assessment, and process automation improvement.

REFERENCES

- [¹] HARIKRISHNAN R., V. JAWAHAR SENTHIL KUMAR, P. SRIDEVI PONMALAR (2016) A comparative analysis of intelligent algorithms for localization in wireless sensor networks, *Wireless Personal Communications*, **87**(3), 1057–1069.
- [²] BHAT SOUMYA J., K. V. SANTHOSH (2020) Is localization of wireless sensor networks in irregular fields a challenge, *Wireless Personal Communications*, **114**, 2017–2042.
- [³] MUNADHIL Z., G. K. SADIK, M. A. AMMAR, N. A. ALI, C. JAVAAN (2020) Neural network-based Alzheimer's patient localization for wireless sensor network in an indoor environment, *IEEE Access*, **8**, 150527–150538.
- [⁴] CHAI Q. W., S. C. CHU, P. S. JENG, Z. M. WEI (2020) Applying adaptive and self assessment fish migration optimization on localization of wireless sensor network on 3-D terrain, *Journal of Information Hiding and Multimedia Signal Processing*, **11**(2), 90–102.
- [⁵] SINGH A., S. SANDEEP, J. SINGH (2021) Nature-inspired algorithms for wireless sensor networks: A comprehensive survey, *Computer Science Review*, **39**, 100342.
- [⁶] SUJATHA S. R., M. SIDDAPPA (2020) Design of an intelligent based global optimiza-

- tion technique for localization in wireless sensor networks, *Contemporary Research in Electronics, Computing and Mechanical Sciences*, 181–213.
- [7] SRIDEVIPONMALAR P., S. K. JAWAHAR, V. R. HARIKRISHNAN (2018) Hybrid genetic algorithm–differential evolution approach for localization in WSN, *Advances in Intelligent Systems and Computing*, **695**, 263–271.
 - [8] HARIKRISHNAN R., S. K. JAWAHAR, V. P. SRIDEVI PONMALAR (2016) Firefly algorithm approach for localization in wireless sensor networks, *Smart Innovation, Systems and Technologies*, **44**, 209–214.
 - [9] WU J., W. G. YOU, B. KEVIN, T. C. YU, L. BRODIE et al. (2020) An improved firefly algorithm for global continuous optimization problems, *Expert Systems with Applications* **149**, 113340.
 - [10] CHENG Z., S. HAOHAO, W. JIQUAN, Z. HONGYU, C. TIEZHU et al. (2021) Hybrid firefly algorithm with grouping attraction for constrained optimization problem, *Knowledge-based Systems*, **220**, 106937.
 - [11] CHAKRAVARTHI K. K., L. SHYAMALA, V. VAIDEHI (2021) Cost-effective workflow scheduling approach on cloud under deadline constraint using firefly algorithm, *Applied Intelligence* **51**(3), 1629–1644.
 - [12] LAKSHMI D., R. ZAHIRA, C. N. RAVI, G. EZHILARASI, C. NAYANATARA (2020) Flower Pollination Algorithm in DPS integrated DFIG for controlling load frequency, *ICPECTS, IEEE 2nd International Conference on Power, Energy, Control and Transmission Systems, Proceedings*, 9337017.
 - [13] CHEN Y., P. DECHANG, X. YUE (2021) Neighborhood global learning based flower pollination algorithm and its application to unmanned aerial vehicle path planning, *Expert Systems with Applications*, **170**, 114505.
 - [14] ONG P., T. K. CHONG, O. K. MENG, E. S. LOW (2021) Tracking of moving athlete from video sequences using flower pollination algorithm, *The Visual Computer*, **38**(6), DOI: 10.1007/s00371-021-02060-2.
 - [15] KORKMAZ E., P. A. ALI (2021) Optimizing of phase plan, sequence and signal timing based on flower pollination algorithm for signalized intersections, *Soft Computing*, **25**(6), 4243–4259.
 - [16] BABU M., T. JESUDAS (2022) An artificial intelligence-based smart health system for biological cognitive detection based on wireless telecommunication, *Computational Intelligence*, **38**(4), 1365–1378.
 - [17] SENBAGAVALLI M., G THOLKAPPIAARASU (2016) Opinion mining for cardiovascular disease using decision tree based feature selection, *Asian Journal of Research in Social Sciences and Humanities*, **6**(8), 891–897.
 - [18] DEBNATH S., K. RAMALAKSHMI, M. SENBAGAVALLI (2022) Multimodal Authentication System Based on Audio-Visual data: A Review, *International Conference for Advancement in Technology (ICONAT)*, Goa, India, 1–5, doi: 10.1109/ICONAT53423.2022.9725889.

Anna University
Chennai, Tamil Nadu
600 025, India
 e-mail: himabhindykarthy@gmail.com

**Department of Mechatronics*
Mahendra Engineering College
Namakkal, Tamil Nadu
637 503, India
 e-mail: jesuphd@gmail.com