THE CHEETAH OPTIMIZER BASED SENSOR NODE LOCALIZATIONWITH JENKS NATURAL BREAKS DATA FUSION

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Abstract

Accurate localization of sensor nodes has a strong influence on the performance of a wireless sensor network. In this work, a node localization scheme using the application of nature-inspired metaheuristic algorithm, i.e., cheetah optimization algorithm, is proposed. In order to validate the proposed scheme, it is simulated on different sizes of sensor networks ranging from 25 to 150 nodes whose distance measurements are corrupted by gaussian noise. The performance of the proposed novel scheme is compared with performance of some well- known schemes such as particle swarm optimization (PSO) algorithm and genetic algorithm. The simulation results indicate that the proposed scheme demonstrates more consistent and accurate location of nodes than the existing PSO- and FA-based node localization schemes.

Introduction

The wireless sensor network (WSN) is composed of a large number of sensor nodes with wireless communications, computations, and sensing capabilities, which are densely deployed either inside the monitoring phenomenon or very close to it [1]. These tiny WSN nodes which are capable of communicating with each other, acquiring various physical values, performing computations can cooperatively achieve a desired task through specific protocol. This makes it possible for the WSN to a variety of monitoring and tracking applications in military, agriculture, and industry, etc. [2].

An important aspect in most of the WSN applications is the accurate localization of theindividual node [3]. WSN nodes are usually placed in different environment to accomplish different tasks, in which the locations of these nodes are random and unknown in advance. However, data acquired by these nodes are only available when connected with location information. Therefore, the node localization technology has aroused widespread attention and become one of the hotspots of WSN study. WSN node localization is that WSN node is locatedby a small number of known nodes in the networks, which means that coordinates are established with the location information of these known nodes and the coordinate of unknownnodes can be obtained using a special locating algorithm[4].

WSN node localization methods can be classified into two categories: the Range-free methods and the Range-based methods [5]. The former can realize node localization using onlythe information of network connectivity without the information of point-to-point distances, while the latter depends on the information of point-to-point distances.

In various disciplines of engineering, real-world problems are formulated as optimization problems. In the past, these optimization problems are tackled by traditional methods; however, these problems require huge computational efforts, which increase with theincrease in problem size. This motivated researchers to use optimization methods, which produce better results and use less computational resources [22]. Researchers have used nature-inspired metaheuristic algorithms as computationally better alternatives to traditional methods [23]. Examples of nature-inspired metaheuristic algorithms include particle swarm optimization (PSO) algorithm [24], genetic algorithm (GA) [25], butterfly optimization algorithm (BOA) [26], firefly algorithm (FA) [27,28], surrogate-based optimization (SBO)[29] and many more [22,30]. Various hybrid algorithms have been developed by the researchers to improve the solution quality and convergence [31,32].Ullah, Inam et al 2020 present a modified Kalman Filter (KF) for localization based on UKF and PF Localization. In the paper, all these algorithms are compared in very detail and evaluated based on their performance. The proposed localization algorithms can be applied to any type of localization approach, especially in the case of robot localization. Despite the harsh physical environment and several issues during localization, the result shows an outstanding localization performance within a limited time. The robustness of the proposed algorithms is verified through numerical simulations. Zazali et al 2020 et al proposes and develops an enhanced algorithm that can improve the region area for sensor nodes placement within the specific localization area. This researchaims to produce a longer network lifetime by reducing the energy used of the sensor nodes and at the same time minimize the localization error. This research describes the flooding control of the node’s placement for the localization of the DV-Hop algorithm. The placement of nodesis limited inside the region of the anchor nodes. The simulation environment setup comes withparameters such as the radius, area, number of nodes, types of nodes, the anchor proportion, and the value of the regions

Sabbella et al 2021 dopt a meta-heuristic algorithm known as Krill Herd (KH) inspired by the behaviour of krill. KH is selected to find the location of non-anchor nodes by using mobile anchor nodes. Mobile anchor nodes have GPS units and broadcast their exact locations at regular time intervals to find the location of no anchor nodes. The time-variant location of thenon-anchor node is calculated by movement generated by the existence of all sensor nodes in the neighborhood range, foraging motion of anchor nodes, and random diffusion of all the sensor nodes

Some swarm intelligence algorithms are based on animals’ hunting and foraging behaviours in nature. Some hunters can hunt the prey individually or in a herd with some numbers, and other members may not participate in the hunting process. Furthermore, in some cases, a small number of hunters can cover a large hunting area. These special features of the cheetah for hunting motivated us to study its behaviour more carefully and base it on the development of an optimization algorithm. The hunting processes are modelled in two simple sit and wait beside the attacking mode strategies. Indeed, despite other methods which use some complicated equations in the evolution process, the cheetah optimizer (CO) employs some simple techniques, while the hunting strategies help increase the algorithm’s effectiveness. Sitting and waiting to make the prey available, back to home in case of unsuccessful hunting process, return to last successful hunting if the prey not found for sometimes. These are the main strategies in CO. the algorithm performance confirms that the hunting process’s characteristics have been modelled in the proposed CO.Cheetah (Acinonyx jubatus) is the primary cat breed and fastest land animal living in the central areas of Iran and Africa56. the cheetah’s speed can reach over 120 km per hour. the cheetahs’ agility and speed are their physical characteristics like a long tail, long and thin legs, lightweight and flexible spine. Cheetahs are quick animals capable of stealthy movement, fast returning during predation, and specific spotted coats; however, these visual predators cannot maintain their high-speed action for a long time. Therefore, the chasing must be less than half of a minute57. Moreover, their speed significantly decreases from 93 km/h or 58 mph to 23 km/h 14 mph only in three strides after catching the prey. Due to the mentioned limitation of cheetahs in maintaining their speed, they precisely observe the environment after staying on small branches or hills to identify their prey. Furthermore, these big cats can effortlessly blend into the high and dry grass due to their specific coats58. These predators usually hunt gazelles, specifically Tomson’s gazelles, impalas, antelopes, hares, birds, rodents, and calves of more fabulous herd animals. First, theymove slowly toward the prey with a crouched posture to be hidden and reach the minimum distance, stopping hidden and waiting for the prey to approach the predator.

This is because they stop hunting if the prey observes the predator. the mentioned minimum distance is almost 60–70 m or 200–230 f; however, it is determined to be 200 m or 660 f if they cannot stay hidden appropriately. Specifically, the pursuit duration is 60 s with a mean distance of 173 m or 568 f to 559 m or 1834 f. Ten, the prey’s balance is lost after their rump is beaten with the cheetah’s forepaw, and finally, the predator brings down the prey usingtoo much force and turns it, which makes the prey try to escape59. Cheetahs’ muscular tails’ back and forth movement also helps them achieve sharp turns60.Generally, hunting the animals that move far from their herds or have less caution is much easier61,62. It should be noted that there are various determinants associated with predation, including maturity, gender, the number of predators, and the carelessness of prey. Also, coalitions or mothers with cubs tend to hunt more giant animals successfully. Accordingto the biological investigations, it has been found that cheetahs have remarkable spinal flexibility and long tails that lead to their physical balance. Moreover, they have collarbone-separated shoulder blades that facilitate the movement of the shoulders. All the characteristics mentioned earlier make these big cats considered remarkable predators; however, not all the predations are successful

Mathematical Model and Algorithm

When a cheetah is patrolling or scanning its surroundings, it is possible to detect prey.Seeing the prey, the cheetah may sit in its place and wait until the prey gets closer to it and thenstarts the attack. the attack mode includes rushing and capturing phases. the cheetah may give up the hunting for several reasons, such as its energy limits, fast prey feeing, etc. Ten, they maygo back home to rest and start new hunting. By assessing the prey, his/her condition, area anddistance to the prey, the cheetah may choose one of these strategies, as depicted in Fig. 163. Overall, the CO algorithm is based on intelligently utilizing these hunting strategies during hunting periods (iterations). • Searching: Cheetahs need to search, including scanning or activesearch, in their territories (search space) or the surrounding area to find their prey.

Sitting-and-Waiting

After the prey is detected, but the situation is not proper, cheetahs may sit and wait for the prey to come nearer or for the position to be better; • Attacking: Tis strategy has two essential steps:

- Rushing: When the cheetah decides to attack, they rush toward the prey with maximum speed.
- Capturing: the cheetah used speed and flexibility to capture the prey by approaching the prey.
- Leave the prey and go back home: Two situations are considered for this strategy.
  (1) If the cheetah is unsuccessful in hunting the prey, it should change its position or return to its territory.
  (2) In cases with no successful hunting action in some time interval, it may change its position to the last prey detected and searched around it. the mathematical models of the hunting mentioned above strategies are provided in detail in the following sections. Then, the CO is outlined.

Search Strategy

Cheetahs seek prey in two ways; either scan the environment while sitting or standing or actively patrols the surrounding area. Scanning mode is more suitable when the prey is dense and grazing while walking on the plains. On the other hand, choosing an active mode that needs more energy than the scan mode is better if the prey is scattered and active. Therefore, during the hunting period, depending on the prey's condition, the coverage of the area, and the condition of the cheetahs themselves, a chain of these two search modes may be selected by the cheetah. To mathematically model this searching strategy of cheetahs, let Xt i,j denote the current position of cheetah i (i=1, 2, …, n) in arrangement j (j=1, 2, …, D), where n is the number of cheetahs population and D is the dimension of the optimization problem. Indeed, each cheetah experiences different situations dealing with various prey. Each prey is a location of a decision variable corresponding to the best solution while the cheetah's states (other arrangements) construct a population. Ten, the following random search equation is proposed for updating the new position of cheetah i in each arrangement based on their current position,and an arbitrary step size as follows:

$$X_{i,j}^{t+1} = X_{i,j}^{t} + \hat{r}_{i,j}^{-1} . \alpha_{i,j}^{t}$$

where Xt+1 i,j and Xt i,j are the next and the current positions of cheetah i in arrangement j, respectively. Index t denotes the current hunting time, and T is the maximum length of hunting time. rˆ −1 i,j and αt i,j are the randomization parameter and step length for cheetah i in arrangement j, respectively. The second term is the randomization term, where the randomization parameter rˆi,j is normally distributed random numbers from a standard normal distribution.

Sit-and-Wait Strategy

During the searching mode, the prey may expose to a cheetah's field of vision. In this situation, every movement of the cheetah may make the prey aware of his/her presence and lead to the escape of the prey. To avoid this concern, the cheetah may decide to ambush (by lying on the ground or hiding among the bushes) to get close enough to the prey. Therefore, in this mode, the cheetah remains at his/her position and waits for the prey to come nearer (see Fig. 2b). This behavior can be modelled as follows:

$$X_{i,j}^{t+1} = X_{i,j}^{t}$$

where Xt+1 i,j and Xt i,j are the updated and current positions of cheetah I in arrangement j, respectively. This strategy requires the CO algorithm not to change all cheetahs simultaneouslyin each group to increase the success of hunting (finding a better solution) and hence can assistit in avoiding premature convergence.

Attack Strategy

Cheetahs use two crucial factors to attack their prey: speed and flexibility. When a cheetah decides to attack, he/she rushes to the prey at full speed. After a while, the prey noticesthe cheetah's attack and begins to fee. The cheetah rapidly pursues the prey in the interceptionpath with its keen eyes,

$$X_{i,j}^{t+1} = X_{B,j}^{t} + \check{r}_{i,j}.\beta_{i,j}^{t}$$

Simply, these all attacking tactics of cheetahs are mathematically defined as follows:

Attack Strategy

Cheetahs use two crucial factors to attack their prey: speed and flexibility. When a cheetah decides to attack, he/she rushes to the prey at full speed. After a while, the prey noticesthe cheetah's attack and begins to fee. The cheetah rapidly pursues the prey in the interception path with its keen eyes, In a group hunting method, each cheetah may adjust his/her positionbased on the feeing prey and the position of the leader or neighborhood cheetah.

Iterative Node Localization

The distributed range-based localization technique is used to estimate the coordinates of sensor nodes. The main objective of node localization in WSN is to determine the coordinates of the most of the target nodes by minimizing the objective function. The localization issue of WSN is considered as an optimization problem which is approached by various metaheuristic algorithms. The following process is used to localize the sensor nodes inWSN:

1. Initialize M target nodes and N anchor nodes randomly in the sensor field. Each anchor node has location awareness to find its location. Each anchor node and target node has transmission range R.
2. The distance between each target node and anchor nodes is evaluated which is alteredby the additive Gaussian noise.
3. The target node is known as localizable node if there are at least three anchor nodes within the transmission range of the target node. The underlying reason behind this requirement is that according to the trilateral positioning method, the coordinates of the three anchor nodes A (x1, y1), B (x2, y2), and C (x3, y3), and the distance between the target node di and three

anchor nodes are known. Then, by using the trigonometric laws of sines or cosines, the coordinates of the target node are calculated. Similarly, in multiliterate target node estimation method, distance measurements of three or more anchor nodes are used to minimizing the errorbetween actual distance and estimated distance.

4. For each localizable node, metaheuristic algorithm is run independently to find the position of the target node. The butterflies or agents are initialized with the centroid of the anchor nodes.
5. The metaheuristic algorithm helps to find the coordinates (x, y) of the target node that minimizes the localization error. The objective function of localization problem is the mean square distance between target node and anchor node which is minimized using an algorithm.
6. The optimal value (x, y) is estimated by metaheuristic algorithm after number of generations by minimizing the objective function. 7. The total localization error is computed after the position of all localizable target nodes NL is estimated.

Simulation Results

The proposed localization algorithm implemented using MATLAB. The total count ofthe target node is set 50 and deployed in a 100m×100m area. The locations of the nodes are denoted by randomly generated coordinates *(x, y)* within the boundary. The transmission rangeof every anchor node-set to 30U.The size of population and generations set 30 and 100, respectively. The percentage of localized nodes analyzed for varying node density, transmission range and a number of iterations. For fair comparison, the proposed technique compared with GA and PSO algorithms.

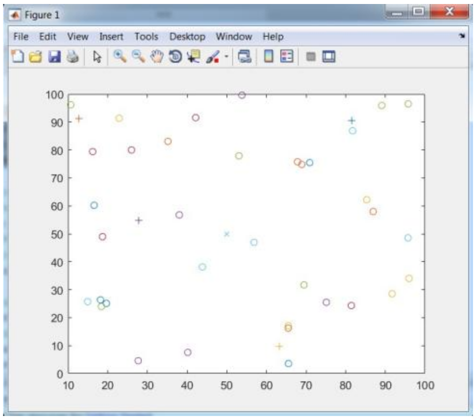

Figure 1 Node Creation

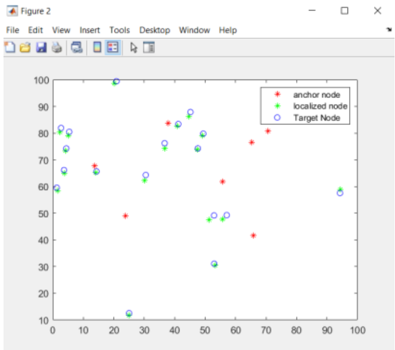

Figure 2 Localized Nodes

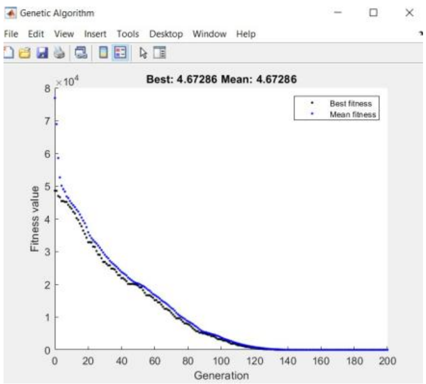

Figure 3 Fitness Valuation

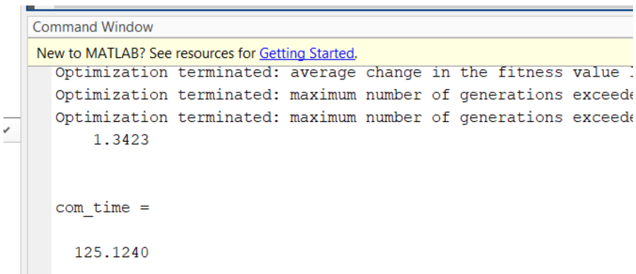

Figure 4 Accuracy and Computation Time Analysis

The localization of the target node is not possible when the count of the anchor node isless than three. Increasing the count of anchor nodes leads to increases in the percentage of localizing nodes. From the graph 3 observed that the proposed BWO optimization show higherpercentage localization by properly selecting anchor nodes. The number of localized node count increased by increasing the coverage or transmission range of the anchor node. The higher coverage avoids intersection problems. Gaussian noise is also the main parameter that actually affects the localization accuracy. This work gaussian noise set to zero. From Figure 4 and Figure 5 observed that the BWO optimization achieves higher localized nodes compared to other methods. Similarly, the increase in the number of iterations also used to increase a greater number of localized nodes.

Table 1 Optimization Results

Target node	Anchor node	PSO		GA		CO	
		LN	LE	LN	LE	LN	LE
20	6	19	0.2567	18	0.799	19.2	0.2245
40	12	37.6	0.4672	39	0.238	38.4	0.362
60	18	58.6	0.486	58	0.290	58.5	0.196
80	24	78.9	0.328	79.2	0.589	80	0.2164
100	30	95	0.6276	96	0.5135	96	0.292sni

The performance of localization error and localized node summarized in Table 1. The average values of LE and LN taken by performing 10 trials. Compared to GA and PSO, the proposed BWO optimization shows better results in error and localization rate.

Conclusion

Localization of sensor nodes is really important for the performance of WSN as many applications of WSN require localization information. The main objective of this optimization problem is to minimize the localization error with the help of nature-inspired optimization algorithms. In this work, FPA-based node localization algorithm is proposed to estimate the position of the sensor nodes in WSN. This paper has described the FPA-based localization technique and provides the summary of results by comparing the algorithm with the others like PSO algorithm and FA in terms of localization error, localized nodes and computing time. The simulation results show that the proposed technique is an effective refinement technique in nodes localization. BOA clearly outperforms other algorithms used in this study in terms of accuracy and computing time.

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