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Abstract—Node localization that to be aware of the position of nodes is an essential part of wireless sensor network. One of the major requirement of localization in WSN is accuracy of location. Most of the work done is in two dimensional network. The aim of this paper is to reduce error in location estimation for 3D coordinate system. The proposed 3D-LRAGA in this paper is range based and anchor based algorithm. Initial step of algorithm is optimal placement of anchor nodes by using k-means and then encodes the sensor node in real coding. The fitness function is designed based on distances between anchor and non-anchor nodes. The Uniform crossover and a new three dimensional neighborhood mutation operator are applied. The three dimensional (3D-LRAGA) GA based algorithm is first time implemented and simulation result shows that, it show less RMSE value than previous 3D algorithm and algorithm shows faster convergence.

Keywords: WSN, Localization, Range based, Optimization, Genetic Algorithm (GA)

I. INTRODUCTION

A wireless sensor network has a number of different configuration sensors. Sensors are capable of sensing physical things like temperature, pressure of sound, humidity level, leakage of gas, light as in [1] and also can detect land mines. The job of each sensor is to identify the change which happens in its surrounding area according to range of sensor as in [2] and make notification of these changes at the base station. Now the job of base station is to find the location of that node. The recent technological development in wireless sensor network made feasible the development of low power, low cost, small size sensors which communicate over short distances.

Localization as in [3] is the major research area under wireless sensor network which identify the current location of sensor nodes. Localization means to calculate physical coordinates of a sensor node (or a group of sensor nodes) as in [4] and the spatial relationship among nodes. Sensor node do this either automatically or with the help of GPS device attached to it as in [5] or it is done manually. Manual estimation of the location may not be feasible in the context of large network and in inaccessible area.

To provide GPS with each sensor node is very costly, so the alternative is to use the concept of anchor node. Some nodes have GPS as in [6] called anchor nodes and other node identify location with the help of nearby anchor nodes. While the GPS is undoubtedly the well-known location sensing system, it is not accessible in all environments as in [7] (for example indoor environment) and may incur resource cost unacceptable for resource constrained wireless sensor network.

Localization covers a set of techniques as in [8] and methods that allow a sensor to estimate its own location based on information gathered from sensor’s environment. These technique include range based or range free, anchor based or anchor free, centralized or distributed. Range base technique (high accuracy, high cost) as in [9] include RSSI, TOA, TDOA. Range free technique (less accuracy, low cost) include hop count etc. Other methods are trilateration, multilateration, bounding box, probability based.

The requirement of location information in wireless sensor network is realized in these major areas as in [10], [22] for example, Navigation (To understand movement of objects and to guide path of the mobile objects to their destination), Track (It means understanding of the location of devices), Real time location (Virtual / Real time location and also orientation of sensor node), Optimize routing (Routing needs location information of each node in such a way that it optimized the routing).

In this paper efficient three dimensional (3D-LRAGA) node localization algorithm based on genetic algorithm is proposed. It works on the basis of uniform crossover and a new 3D neighborhood mutation operator. This paper also highlights the future research areas of localization in wireless sensor network.

Organization of the paper: Section 2 covers Review on localization algorithm which are based on GA. Section 3 Problem Statement. Section 4 Purposed algorithm. Section 5 present Simulation and Results. Section 6 present the Discussion and Future events. Section 7 Concludes the paper.

II. RELATED WORK

There are various algorithms in two dimensional network but there are no three dimensional algorithm which is based on GA, there are some algorithm in 3D GA, but they are target localization not node localization.

As in the paper [11] author proposed an improved DV-Hop (GADV-Hop) algorithm which is based on genetic system. In order to increase position accurateness or convergence rate, they restrain a population viable region. A combination of RSS and AOA based optimization which use genetic algorithm is introduced in paper [12] to accurately estimate the position of node.

A Genetic Algorithm in paper [13] for wireless sensor network localization with level-based reliability pattern is proposed to resolve the matter that the positioning correctness. Their proposed LRS-GA is made up of two stages. The node with excessive consistency is elected by level-based reliability pattern at the first stage and then acquires the measure distance by RSSI. At the second stage, GA localization procedure is used to approximation of the position of the unknown node.

An efficient algorithm in paper [14] that targets at minimizing the number of anchor nodes in a WSN, without...
threatening the job of locating all left behind nodes in the network.

The GA in paper [15], [16], [32] worked on the Euclidean distance objective function to discover the correct position of the sensor nodes. The objective function is predominant to minimize the difference between the actual and projected distance between the anchor node and the mobile sensor node.

The nodes in paper [17] of sensor system is two dimensional. \((x_i, y_i)\) as anchor node coordinates. Initially, the algorithm implement the decimal coding scheme of sensor. Agreeing to communication between nodes compute the distance between nodes.

The elementary idea of the algorithm PGA in paper [18] is that they present pattern search algorithm to the selection segment of genetic algorithm, so as to preserve a diversity of current population. In concept, PGA algorithm can reserve the best and the neighboring individuals of each generation.

The author proposed an enhanced genetic algorithm in paper [19] with a filter and replenishment approach FRGA, this algorithm can successfully evade the problems that the localization correctness of some nodes is not strict because of premature convergence. Algorithm in paper [20] avoid the impact of environmental aspects by pre-establishing the pattern. Likewise, the offered algorithm does not necessity of too much statistics about anchor nodes to pre-establish the pattern.

The algorithm in paper [8] is distributed into two stages, use sampling routine to gain initial location and polishes the initial location centered on genetic set of rules. A real-coded form of the generally used genetic process is presented in paper [31] in order to calculate the correctness of node localization problem in wireless sensor setups, in the meantime, the analogous fitness function and genetic machine are planned.

The work in paper [23] targets at determining the location of the sensor nodes with great correctness. The initial part of their work is supported out by localizing the nodes by means of Mobile Anchor Positioning (MAP), a range-free localization technique. Root Mean Square (RMSE) error has been used by them as a performance measure to compare between the two methodologies.

### III. PROBLEM STATEMENT

WSN localization problem can be defined as follows: There are \(m\) anchor nodes and \(n\) non-anchor nodes in three dimensional network. And initial coordinates of all the sensor nodes (\(m + n\)) are stored in a base station at the time of deployment. The coordinates of anchor nodes are known to us. The problem is to find coordinates of \(n\) non-anchor node based on the position of anchor node and distance between non-anchor node and anchor node.

\[
(x, y, z) = F (X_i, Y_i, Z_i, D_i), \text{ where } x, y, z \text{ is the position of non-anchor node and } X, Y, Z \text{ is the position of anchor node, } D \text{ is the distance between anchor and non-anchor node. }
\]

The assumptions of wireless sensor network are as follows, Nodes present in 3D space for 3D. Nodes are static. Two types of nodes anchor or non-anchor and nodes are homogeneous.

### IV. PROPOSED ALGORITHM

This algorithm is based on Darwin’s evolution of natural methods. Genetic Algorithm in [24], [25] is categorized as a global search technique. In order to get and obtain a global optimum solution, genetic algorithm is an evolutionary algorithm, that has advantage of simple conditions, strong ability as in [26], [27] to search, and it is appropriate for single and multi-objective, so it is suitable for wireless sensor network. Genetic Algorithm work on the random space as in [30] and real value encoding is used as in [31] through tournament selection as in [33], crossover and neighborhood mutation as in [21], [34] operations. One step in Genetic Algorithm is elitism. Its job is to keep the best chromosome for the next generation so that it cannot be lost. Genetic Algorithm is implemented using simulations and localization problem is converted into an optimization problem.

 Proposed localization algorithm 3DL-RAGA used genetic algorithm as optimization tool. In the algorithm anchors are distributed uniformly as in [28], [29] and for this \(k\)-means is applied. Two major stage of the algorithm are

1. **Stage 1** Network Formation or distance estimation which include step 1 and step 2.
2. **Stage 2** Genetic Algorithm or position estimation which include step 3 to 10.

#### Step 1. INITIALIZATION

Initialize all the sensor node with random coordinates in 3D network. Calculate Euclidian distance between all sensor nodes in an \(n \times n\) matrix, \(n\) is total number of nodes. For distance estimation RSSI method is used in the field where sensors are placed. \((x_1, y_1, z_1), (x_2, y_2, z_2)\) are coordinates of different node.

\[
d = \sqrt{(x_2 - z_1) + 2 + (y_2 - y_1) + 2 + (x_2 - x_1)} + 2
\]

#### Step 2. OPTIMAL PLACEMENT OF ANCHOR NODE

There are two types of nodes anchor node and non-anchor node. Anchor nodes are equipped with GPS and know their position. The position of non-anchor node is calculated with the help of anchor node. So uniform distribution of anchor node is must so that all non-anchor node must come in communication range of one of the anchor node. For this \(K\)-means algorithm is applied to make clusters. \(K\)-means provide node id with cluster number and center positions. It calculate distance between anchor and its neighbor. Then return center of cluster which has minimum distance.

#### Step 3. POPULATION GENERATION

Population contains individuals according to the population size. One individual contains randomly generated coordinates \((x, y, z)\) in 3DL-RAGA as the number of non-anchor.

#### Fig.1.1 : Individual 1

#### Step 4. ENCODING

As individual stores all coordinates of non-anchor nodes. Therefore Positions of sensor nodes are encoded with double values. It is called Value encoding.

#### Fig.2: Value Encoding
Step 5. FITNESS FUNCTION
Previously generated matrix (m X n) of distances which was stored in base station. Formulate a matrix (m X n) of distance of all nodes for each individual of population. Now calculate the difference of both the matrix. Here X, Y, Z is coordinates of anchor node and X, Y, Z are coordinates of unknown node and d is estimated distance by algorithm.

\[ F(x, y, z) = \sum_{i=1}^{n} \sqrt{(X-X_i)^2 + (Y-Y_i)^2 + (Z-Z_i)^2} - d_i \]

Step 6. ELITISM
It store best individual value from each generation in an array.

Step 7. SELECTION
For selecting best individuals from population Tournament selection is used. Tournament size is set to 4. It select 4 individual at a time, sort them. Then select top two parent for crossover and mutation.

Step 8. CROSSOVER
For this uniform crossover gives best result. It is rate based crossover. Rate can be changed to see the different result. Uniform crossover takes values from both of the parent.

\[ c_x = \text{random number} \]
\[ c_y = \text{random number} \]

Step 9. MUTATION
For this neighborhood mutation with some changes of boundary checking is applied on each coordinate of a node for example on x, y, z. It is rate based operator. Mutation operator take a random move around the single point with a specified radius and \( \Theta \in [0, 2\pi] \).

\[ r = \text{random} \ast \Theta \]
\[ C = \cos(r) \]
\[ S = \sin(r) \]
\[ v_1 = v_2 = v_3 = 0 \]

Ideal distance = \( \sqrt{\text{areaDimension}/n} \)

Radius = ideal distance \( \ast (1\text{-iter}/\text{max iteration}) \)

Rotation in Three dimensional Area

\[ v_1 = \text{radius} \ast C \]
\[ v_2 = \text{radius} \ast S \]
\[ v_3 = \text{radius} \ast \cos(r) \ast \sin(r) \]

\[ x_d = x + v_1 \]
\[ y_d = y + v_2 \]
\[ z_d = z + v_3 \]

Boundary Checking
If \( x_d < 0 \)
\[ x_d = x + \text{abs}(v_1) \]
elseif \( y_d > \text{areaDimension} \)
\[ y_d = y + \text{abs}(v_2) \]
End

If \( z_d < 0 \)
\[ z_d = z + \text{abs}(v_3) \]
elseif \( z_d > \text{areaDimension} \)
\[ z_d = z + \text{abs}(v_3) \]
end

Step 10. TERMINATION CRITERIA
The stopping condition for proposed algorithm is maximum number of iteration.

A. Design module
The flow chart represent the proposed algorithm as shown:

1. Initialize sensor network and initialize distance matrix
2. Optimal placement of anchor node
3. Population Generation and Encoding
4. Repeat until max iteration
5. Fitness calculation
6. Elitism and Selection
7. Crossover and Mutation
8. Stop

B. Advantage of Proposed 3DL-RAGA
For first step of localization algorithm: Distance estimation, when position of non-anchor node is calculated there is no need for requirement of three or more anchor node, proposed algorithm can predict location when non-anchor node come under communication range of at least one anchor node.

Second advantage is that GADV-Hop [5] require to calculate minimum of three distances between one non-anchor node and three anchor node predicted by algorithm. But the proposed algorithm place anchor node in such a optimize way by using k-means which already choose anchor node as a center of cluster with minimum distance of neighbor nodes.

For second step of localization algorithm: coordinate estimation Third advantage is that to calculate
coordinates of nodes by using distances from first step, this coordinate calculation is done by random generation method, which is the benefit of genetic algorithm, it reduce complexity of logic formation for localization algorithm.

For third step of localization algorithm: genetic algorithm, algorithm include a new three dimensional neighborhood mutation operator which result in faster convergence of fitness and maintain diversity of population.

V. SIMULATION AND RESULT

In order to evaluate location performance of the proposed algorithm, the experimental simulations are achieved by MATLAB 7.10.0, window 7, i3 processor. The sensor nodes are considered to be placed on a 100 X 100 X 100 cube for three dimensional network. The number of nodes are considered to be 100. Each node has transmission range of 30m.

Table1.1 : Simulation Parameters for 3DL-RAGA

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Network Size</td>
<td>100 X 100 X 100</td>
</tr>
<tr>
<td>2</td>
<td>No. of nodes</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>Population Size</td>
<td>120</td>
</tr>
<tr>
<td>4</td>
<td>No. of Generation</td>
<td>180</td>
</tr>
<tr>
<td>5</td>
<td>Transmission Range</td>
<td>40</td>
</tr>
<tr>
<td>6</td>
<td>Crossover Probability</td>
<td>0.5</td>
</tr>
<tr>
<td>7</td>
<td>Mutation Probability</td>
<td>0.5</td>
</tr>
<tr>
<td>8</td>
<td>Distance Estimation Method</td>
<td>RSSI</td>
</tr>
<tr>
<td>9</td>
<td>Position Estimation Method</td>
<td>Random Generation</td>
</tr>
<tr>
<td>10</td>
<td>Localization Algorithm</td>
<td>Genetic Algorithm</td>
</tr>
<tr>
<td>11</td>
<td>Classification of Proposed Algorithm</td>
<td>Ranged Based, Anchor Based</td>
</tr>
<tr>
<td>12</td>
<td>Observation Parameter</td>
<td>RMSE Value, Average Error, Complexity</td>
</tr>
<tr>
<td>13</td>
<td>Tournament Size</td>
<td>4</td>
</tr>
</tbody>
</table>

In order to compare location algorithm average error are defined as

**Error**: Error of single node,

\[ \text{Error}=\sqrt{((X_{est}-X_i)^2+(Y_{est}-Y_i)^2+(Z_{est}-Z_i)^2)} \]

**Average Error**: Average error are calculated as by given formula, for 3DL-RAGA,

\[ \text{Average Error}=\frac{1}{n}\sum_{i=1}^{n} ((X_{est}-X_i)^2+(Y_{est}-Y_i)^2+(Z_{est}-Z_i)^2) \]

Here \((X_{est}, Y_{est}, Z_{est})\) are estimated coordinates of sensor node given by genetic algorithm and \((X_i,Y_i,Z_i)\) are actual coordinates of sensor node, here \(n\) is the number of sensor node.

**Root Mean Square Error (RMSE)**: The formula for root mean square is:

\[ \text{RMSE} = \sqrt{\text{Average Error}} \]

General indicators [10] of localization method are Location accuracy (It is primary evaluation of localization algorithm and it is used to determine the proportion of error and the node’s wireless range) and Anchor node density (It is another sign for evaluation of localization algorithm. It should be least possible in order to decrease deployment cost).

The fig 6 shows placement of sensor node. Here blue dots represent actual position of sensor node, red circle represent position of anchor node and red dots represent position of sensor nodes predicted by proposed 3DL-RAGA when number of sensor= 100, transmission range =30, anchor node=30, area dimension= 100 X 100 X 100. More Red dot represent overlapping of actual position.

The fig 7 shows the fitness of best individual in one population size during all iteration of genetic algorithm when number of sensor= 100, transmission range =30, anchor node=30, area dimension= 100 X 100 X 100. The fig 8 shows error of each node, when number of node=100, transmission range=30, area dimension=100 X 100 X 100, number of anchor=30.

The fig 9 shows proposed 3DL-RAGA when number of sensor= 100, transmission range =30, area dimension= 100 X 100 X 100. Graph shows the average error when number of anchor node vary from 20 to 90. It shows that error are decreasing with increase in number of anchor node.

The fig 10 shows the proposed 3DL-RAGA when number of sensor= 100, anchor percentage =20, area dimension= 100 X 100 X 100. Graph shows the average error when transmission range of node vary from 30 to 90. It shows that error are increasing with increase in communication range.

The fig11 shows the comparison of proposed 3DL-RAGA and previous 3D [11] when number of sensor= 100, number of anchor =5, area dimension= 40 X 40 X 40 and crossover probability 0.5 and mutation probability 0.5. Graph shows the RMSE when transmission range of node vary from 25 to 50.

The fig 12 shows the comparison of proposed 3DL-RAGA and previous 3D [11] when transmission range= 25, number of anchor =5, area dimension= 40 X 40 X 40 and crossover probability 0.5 and mutation probability 0.6. Graph shows the RMSE when number of sensor node vary from 30 to 180.

VI. FUTURE EVENTS

The algorithm implement new 3D neighborhood mutation operator which mutate the coordinates of sensor node in sphere. Here an improvement can be made by setting the direction of mutation. It will further reduce errors in coordinate estimation.

There are many other issues with localization of sensor nodes in WSN, such as deployment of [3] sensor node in three dimensional space by the use of aircraft.

In another case, when there is mobility in sensor nodes then location estimation is done each time an event occur. There is another issue when some nodes leave the WSN and some new node join the system. The localization problem is further complicated by the non-uniqueness of the sensor node in the network.

Research may focus in area like accuracy, complexity, scalability, dependability, security, mobility [35] and energy conservation. As most of the localization method use adjacent nodes to identify their localization, there must be a confidence that position of nearby node is valid.

Anchor density Future work can be done to further reduce number of anchor node.

Resource constraint Energy concept can be applied while estimating the location.

- Fig. 6: Network Graph 3D-RAGA
- Fig. 7: Fitness vs Generation of 3D-RAGA
- Fig. 8: Error of each node of 3D-RAGA.
- Fig. 9: Average Error vs varying anchor node for 3D-RAGA.
- Fig. 10: Average Error vs varying Communication range for 3D-RAGA.
- Fig. 11: Comparison of 3D-RAGA and previous 3D algorithm

Comparison of proposed 3DL-RAGA and previous 3D algorithm

- Proposed 3DL-RAGA
- Previous 3D
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Fig.12: Comparison of proposed 3DL-RAGA and previous 3D

VII. CONCLUSION

Node localization is an important issue in wireless sensor network as many applications depend on knowing the position of sensor node. Most of the existing localization algorithm consider two dimensional coordinates with optimization to increase the accuracy and furthermore the location accuracy is relatively low. Localization in WSN is an optimization problem whose aim is to minimize the total estimation error of localization problem in WSN. In recent years, there have been several optimization based localization algorithm. In the proposed algorithm combine the optimization method to solve three dimensional localization problem and purposed algorithm is based on genetic algorithm.

The purposed GA based algorithm considered the three coordinates (x, y, and z) form individual of a population. Uniform crossover is applied on selected individual by tournament method. The algorithm implement new 3D neighborhood mutation with boundary checking to quickly converge the optimization problem and it maintain population diversity and show faster convergence. Three dimensional (3DL-RAGA) GA based algorithm is first time implemented and simulation shows that it show less RMSE value than previous 3D algorithm.

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