

**Research Article** 

# A Dynamic Interconnected Cuboid Localization Algorithm in WSN using Projected Point Circle Method

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## Abstract

Knowledge of precise location of sensor nodes plays vital role for applications of wireless sensor network (WSN). Many algorithms are purpose to reduce cost, complexity, localization error and dynamic structure. However, existing protocols shows good performance in each terms. In this paper, we purpose a novel dynamic algorithm that is free from RSSI, Zigbee, and Hop distance that produces a minimum localization error as compared to existing system. A uniform distribution of anchor node and its triangulated Centre of Gravity (COG) holds interconnected forward and backward cuboid space. Position of cuboid space is obtained by anchor-centroid pair. Any random estimation node falls on interconnected space is tracking with the help of cuboids vertex. Projections of estimated nodes are transferred to the line joining of two vertices by using projecting factors. In 3D, a circumference point that is 45 degrees apart in a unit radius circle is taken as Q-matrix. Euclidian error distance between estimated node and its projection is applying to enlarge Q-matrix. A considerable iteration is implemented to reduce presenting error distance with the help of Q-matrix. The purpose system greatly reduces localization error, cost, and complexity. It is also free from fixed length 3D space and flooding number of anchor nodes.

Keywords: Wireless sensor networks (WSNs); Localization project point circle

#### Introduction

Wireless sensor networks (WSNs) are the one of the key means of advancing in application of surveillance and monitoring. Sensor networks are made up by shelf material which identifies the change in particular sensing area of surveillance and monitoring. The periodically reported changes or movement of animals, decrease or increase in temperature, rainfall etc., are reported to aggregation point or central server. Changing areas are distinguished by central server or aggregation server with the help of sensor node sending as reference localization. Localization of nodes are responsible for location information that play significant role in many areas such as routing, surveillance, monitoring, identifying minute changes like pressure, temperature, gas leak etc., as well as military operation, and robotics detection. An efficient node localization system conducted many challenges in wireless sensor network for finding location information of the objects within a given co-ordinate system. Deployment in the three dimensional space without any infrastructure is one of the key facing issues of WSN. Global Positioning System (GPS) receivers can be used by the nodes to determine their location in the area of deployment, but putting GPS receiver on each node is not feasible due to cost factor.

A self-organizing, fast and easy deployment, fault-tolerance capability of WSN makes up promising on wide range of applications. Cheap hardware cost, little energy consumption, and less scalability are the key factor of Range free localization rather than Range based localization. Nowadays, sensor node of WSN is localized by finding coordinate of target nodes under Range-free algorithm due to the cost factor [1-3]. In range free schemes, unknown or target nodes position are calculated using path information from the known or anchor node positions. As number of known nodes increases, localization error decrease but many research utilizes large number of hops for reducing localization error. Some research is conducted by assuming anisotropic networks [4], heterogeneous networks [5] etc. However, due to random nature of change in monitoring and surveillance area, range-free approach is still facing with high localization error and accuracy. Toady's WSN required an introduction to new concept in WSN which greatly reduces the localization error and maximizes its

J Electr Electron Syst, an open access journal ISSN: 2332-0796 accuracy than existing system in random 3D earth space. An improved DV-hop localization of sensor node is free from RSSI, LQI, gateways system which turns very cheap mechanism for localization.

To overcome random change in object tracking, monitoring and surveillance of system, we introduce a novel, dynamic three dimensional localization algorithm which accepts any distance, any number of estimation node and provide actual localization position of target node. In this paper, we purposed two virtual forward and backward 3D spaces at specified pair of anchor-centroid points. Each anchor has nearest centroid points and make-up anchor sensor pair that track the nearest estimated points which falls between them. 3D displacement space is calculated between anchor and centroid points which provide particular working space. The displacement space looks like as a rectangular based 3D object as shown in Figure 1. Forward and backward spaces are interconnected in such a way that produces as possible as lower in distance between two vertexes. Vertex difference becomes constant when 3D space is similar to cuboid. However, presenting space is not always cuboid. To maintain this, we calculate Euclidian distance between anchor-centroid pairs and take half of that distance as a size of cuboid with balancing factor. Depending upon displacement, forward and backward cuboid is added to each of anchor or centroid points respectively. Forward space has positive co-ordinate of vertex which is added to lower bounds in other hand backward space has negative, added to upper bounds. Lower and upper bounds are either centroid or anchor depending upon displacement. Placement of such cuboid space produces an interconnected network between each

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of anchor-centroid pair. Three consecutive anchor nodes produce one centroid making up triangulation phenomena of WSN localization as shown in Figure 1.

Each vertex of cuboid space is treated with randomly estimated coordinate point which falls within interconnected network. Projected point is calculated on exact position of the line joining each cuboid nearest vertex with the help of projecting factor, tracking by two nearest vertexes with projecting factor produce a circle in 3D space. The division of circle in 45 degrees apart provides 8 different circumference points co-ordinate with the help of radius that can be denoted as Q-matrix. The error distance between estimated node and its projected point is used to enlarge Q-matrix, considering the projected point of origin. Each iteration origin is transferred to the nearest Q-matrix co-ordinate elements and error distance is calculated. As iteration method needs complex hardware structure, we choose only a considerable iteration. The location of Q-matrix nearest elements is our purposed actual node co-ordinate.

# **Related Work**

Distance between two nodes is most necessary for all localization algorithms. Depending up on distance estimation technique localization can be divided into Range based localization and Range free localization [6-8]. Range based Localized uses estimated distance between two nodes by using physical properties of communicated signal. The Physical properties of the signal are known as Received Signal Strength Indicator (RSSI) [8], Time of Arrival (ToA) [6], Time Difference of Arrival (TDoA) [7] and Angle of Arrival (AoA) [9]. In RSSI system receiver sends signal strength with respect to sender and sender calculate distance depending up on signal strength. With proper time synchronization factor, TOA and TDOA calculate range for localization by using anchor nodes [10]. A GPS with triangulation technique is used to identify localization [11] is another scheme of Range based system. However, the indirect technique for localization is known as Range Free Localization in WSN which is common and cost effective technique that compute range based on DV hop or DV distance. Probability Grid [12], Kcd location [11] works with anchor based distance localization whereas Convex Position Estimation technique [13] works without anchor node.

A range free, proximity-based, coarse-grained centroid algorithm is proposed on [14] where all positions of sensor nodes calculate their own position by using n anchor range position but suffer from high localization error conventionally. Development of centroid algorithm [15,16] in 3D positioning algorithm, location accuracy has been improved in some extents using co-ordinate-tetrahedron in the volume co-ordinate system. Ad-hoc sensor network which record unknown node position from anchor node position by using DV-distance or Euclidian distance, has no fixed infrastructure and adapted rapidly [17-21] but it put more strains on some node close base station/server due to changing topology. A point in Triangulation (APIT) method find-out movement of nodes presence inside or outside of triangle has problem of PIT test, anchor selection and times complexity [22]. APIT accepts Centre of Gravity (COG) to find number of sensor within a large network. Flood of anchor node and broadcasting their location information by running hop count at each node is used on DV-hop algorithm but it works under consideration of heterogeneous network [5]. Today's WSN localization networks seeking an algorithm which is free from flooding number anchor node, fixed infrastructure and node strains under lower cost and complexity. Minimization of localization error require high amount of hop distance, iteration calculation over some specified area that continues hardware complexity. The trade of between finding actual node position and localization error is greatly reducing by our purpose system.

## ICL Algorithm

The COGs becomes centroids when it has equal effects from corresponding anchor nodes. A dynamic WSN network of Ad-Hoc algorithm can be implemented on centroid based as well as APIT COG concept. Any number of target nodes can be find-out by using anchor position on APIT, Ad-hoc and centroid based algorithm. A uniform distribution of anchor nodes produces a known uniform centroid node [23]. Any number of random estimation points is located at random deploying space which turns purposed system has dynamic structure of localization. For simplicity and less localization error, our purpose algorithm views closer anchor nodes and centroid nodes using independent estimation nodes [24]. The displacement and distance between anchor-centroid pair help to bring the projected point  $P_r$  of estimation point along line joining of vertex. The error distance between them enlarge the unit-circle point matrix and make up Q-matrix. Each Q-matrix element adds the projected co-ordinate  $P_{\mu}$  and calculates error distance [25]. The minimum error distance co-ordinate of Qmatrix becomes  $P_{E}$  and resulting minimum error distance enlarges the unit circle. Circumference point and make up Q-matrix. This process continues considerable iteration.

## Algorithm 1: Actual node and localization error calculation

**Input:** anchor-centroid pair  $[A_i, C_i]$ , random estimation point  $[E_i]$ 

• If 
$$M_{idisp} > 0$$

 $A_i$ =upper bound point  $(U_p)$ 

$$C = lower bound point (L)$$

Else

 $A_i$ =lower bound point  $(L_p)$ 

$$C_i$$
=upper bound point ( $U_p$ )

Calculate Size of 3D cuboid space

$$(a) = \frac{D_{iEu}}{2}$$

Take a 3D cuboid space (C) with size a

Forward 3D space  $S_F = L_P + C$ 

Reverse 3D space  $S_{R} = U_{P}$ -C

- Repeat
- Calculate Euclidian distance between  $[E_i]$  and  $[S_{iF}]$
- Calculate Euclidian distance between  $[E_i]$  and  $[S_{IR}]$
- Is  $DF_{iEui}$  is minimum

Is  $DR_{iEui}$  is minimum

- Until
- $DF_{iEui}$  and  $DR_{iEui}$  is minimum
- Calculate  $S_{JF} S_{JR}$  from  $S_F$  and  $S_R$  and at  $DF_{jEui}$  and  $DR_{jEui}$
- Projecting factor :

a) 
$$P_{fF} = \frac{1}{DR_{jEul}}$$

b) 
$$P_{jR} = \frac{1}{DF_{j Eui}}$$

• Projected point:  $P_{iE} = P_{fF} \times S_{IF} + P_{fR} \times S_{IR}$ 

## Output

Projected point  $P_{iE}$ 

Lower and upper bound points are also vertex of forward Cuboid space and backward cuboid space. Any two or more negative displacement co-ordinate points obtained from co-ordinate subtraction between anchors -centroid pair, puts one of them to lower bounds and others in upper bounds points. The half of Euclidian distance between them is size of our cuboid space which needs balancing factor to maintain low localization error. The addition of forward and backwards space makes interconnected network as shown in Figure 2. Any random estimation points fall between centroid and anchor nodes should lie nearer to the any one of each vertex of cuboid spaces. The nearest vertex of each cuboid is selected and calculated by using corresponding projecting factor [26]. Projecting factor of each selected vertex can be obtained as shown in Algorithm 2.

## **Algorithm 2: Calculation of Projected point**

**Input:** An uniform anchor nodes matrix A, random estimation matrix E,

Random deployment region in length L



- Calculate centroid matrix C from A
- Deploy estimation matrix over 3D region
- Find-out nearer anchor node and centroid node of each elements of E

#### Repeat

- Calculate displacement  $M_{idisp} = A_i C_i$
- Calculate Euclidian distance (D) anchor-centroid pair.
- Calculate projected point  $P_{_{F}}$  of E by using algorithm 2:
- Transfer co-ordinate of  $P_F$  with help of Q-matrix
- Locate the actual node  $A_{iact}$  at minimum error distance  $l_{ie}$
- Until<sup>1</sup> reaches to random estimation points.

**Output:** A<sub>act</sub> and l<sub>e</sub>

# System Model

ICL algorithm allows to each estimation node that takes one anchor node and centroid node. Let number of anchor nodes A, and estimated nodes E in 3D space within large deployment region L [27]. To minimize localization error, anchor nodes are uniformly varied in 3D space whereas estimation nodes are randomly varied. Each of three consecutive anchor nodes formed a triangular region and provides Centre of Gravity (COG) points. From the uniform distribution of Anchor node, centroid nodes are uniform distributed by nature.

$$A_{i,cen} = (A_i + A_i + 1 + A_i + 2)/3 \text{ where } i = 1, 2, \dots N$$
(1)

Equation (1) tells that available centroid nodes are two less then available anchor nodes. Each of random estimation nodes can choose its corresponding nearest anchor and centroid node which is known as centroid localization error distance in WSN [28]. The purpose mathematical model assumes estimate point is the function of nearest anchor centroid pair as shown in Figure 1. Mathematically it is closest to distance vector method as

$$f(T_i) = D_{min}(A_i, C_k) \tag{2}$$

Due to dynamic nature centroid localization error and anchor error distance is very large although it is free from RSSI, Zigbee that turns to lower cost and complexity [29]. For simplicity, estimation nodes choose one nearest anchor node and centroid node then Euclidian distance and displacement between them can be calculate as

$$D_{i \, Eul} = \sqrt{\left(A_{i \, cen} - A_{i}\right)^{2}} \tag{3}$$

$$D_{i\,disp} = A_{i\,cen} - A_i \tag{4}$$

**Appendix I:** If we assumed  $C_k$  is located far from  $A_i$  then it should consists two positive values in displacement or vice-versa. Using Appendix I, if we assume  $C_k$  is far than  $A_i$  from origin that gives rectangular space if we take displacement between them.

The size of Cuboid is taken from half of the Euclidian distance and each axis displacement is calculated from Equation (4) as  $X_{cen}$ - $X_1$ ,  $Y_{cen}$ - $Y_1$ ,  $Z_{cen}$ - $Z_1$ . Co-ordinate axis is mutually perpendicular by nature, lines of same axis are parallel and lines of other axis line are perpendicular [30]. Then difference in displacement space is similar to 3D regular rectangular based object as shown in Figure 2. Citation: Acharya SK (2018) A Dynamic Interconnected Cuboid Localization Algorithm in WSN using Projected Point Circle Method. J Electr Electron Syst 7: 261. doi: 10.4172/2332-0796.1000261

#### Selection of cuboid

By nature, displacement can be positive or negative that help to distinguish which node is far from a reference point in axial basis. As ICL algorithm follows uniform distribution, any anchor-centroid pair space taken as working and origin as reference point. Appendix I help to distinguish either centroid is far from origin or anchor node is far from origin [31]. The far point is taken as upper point and near point is taken as lower point of working space. Windowing is the procedure of selecting some portion from large portion whose side is calculated from 2D on regular object where D is dimension. If D=2, selected portion becomes window whose has 4 side and If D=3, then it becomes rectangular object which has 8 side. Let us consider two cuboids with side a, first cuboid has all positive co-ordinate with origin whereas second has all negative co-ordinate with origin. The volume of both spaces can be written as

$$\left|S_{F}\right| = \left|S_{B}\right| \tag{5}$$

A long rectangular space can be divided in two parts which are also rectangular objects. If we choose two rectangular spaces with size more than half of big rectangular space size, then some space is overlapped. For this we have to add that space in lower co-ordinate point and upper co-ordinate point carefully. The positive co-ordinate space is added to lower co-ordinate and negative co-ordinate is added to upper co-ordinate then we found our working space and respective their co-ordinate as shown in Figure 3. We can apply such forward space and backward space theory to our anchor centroid pair. As per our assumption  $C_k$  has far co-ordinate value then  $A_i$  then we can apply as

$$S_{F} = A_{i} + S_{jF} \text{ where } j = 1, 2, \dots, 8$$
  

$$S_{B} = C_{k} + (-S_{jB}) \text{ where } j = 1, 2, \dots, 8$$
(6)

**Appendix II:** The value of  $\beta$ - factor lies between 0 and 1.

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Each anchor-centroid pair has different rectangular shape in 3D space that leads to develop a balance side factor  $\beta$  to obtain better result. At first, Co-ordinate of matrix has chosen as unit volume structure which has side length is unit. After that, cuboid is enlarging by a scalar as obtain from multiplication of  $\beta$  and half of distance between anchor-centroid pair (Appendix II).

$$a = \beta \times \frac{D_{Eul}}{2} \text{ where } 0.5 < \hat{a} < 1 \tag{7}$$



#### Interconnection analysis

Interconnection of cuboids can be obtained by addition and of forward and backward cuboid space to the lower bounds and upper bounds points in 3D space. Over-lapped between Cuboids space occur when addition of forward space cuboid on lower bound points and backward cuboid space on upper bound points. ICL ensure to selection of cuboid that makes each vertex of interconnected cuboid network lies in same distance. Interconnection can be visualizing as per 3D, 2D with a reference size as shown in Figures 3 and 4, respectively.

#### Nearer vertex calculation

A random estimated node can be located randomly at everywhere of 3D space, each of them have nearest anchor-centroid pair (Figure 5). Randomly generated estimation matrix find corresponding nearer element from forward space matrix  $S_F$  and backward space matrix  $S_B$  through with the help of Euclidian distance. A cuboid with size  $\alpha$ makes nearer vertex of  $S_F$  and  $S_B$  can be expressed as

$$f(T_{i}) = min\left(\sqrt{\left(C_{k} - S_{jF}^{'}\right)^{2}}, \sqrt{\left(A_{i} - S_{kB}^{'}\right)^{2}}\right) \dots where \ j, k = 1, 2, \dots .. 8$$
(8)

From equation (8) we can say that,  $S_{jB}$  and  $S_{jB}$  be the nearest point from random target node. Let calculate distance between that nodes

$$D_{s} = \sqrt{\left(S_{jFx}^{'} - S_{jBx}^{'}\right)^{2} + \left(S_{jFy}^{'} - S_{jBy}^{'}\right)^{2} + \left(S_{jFz}^{'} - S_{jBz}^{'}\right)^{2}}$$
(9)







#### Projection of estimated node

The error distance between vertex and random estimation points works as weight of projection which has unit sum. Lower in distance vertex co-ordinate get higher in weight that shifts projecting co-ordinate nearer to the random estimation points. To obtain correct positioning, ICL choose two projecting factor  $P_{fF}$  and  $P_{fR}$  which are calculated from opposite cuboid vertex error distance dividing by distance between that selected vertex. In eqn. (10) we have two minimum error distances we can say it  $D_{\min F}$  and  $D_{\min B}$ . If we compare both error distance, anyone of them will be lower in its magnitude. The proposed model suggests that to locate the estimated point near to the lower error producing vertex as

$$D_{\min F} < D_{\min B} \tag{10}$$

In 3D space if we have any error distance it means it is radius of sphere. The target point can lies in every direction. But if we calculate two errors distance from two fixed point, the locus of target point is a circle as shown in Figure 6.

Appendix III: If we have two points that lies opposite end of wall in 3D space then a co-ordinate of circle in a wall remain always same distance from those points (Appendix III).

The projecting factor is that we used for both vertex is obtained by opposite error distance divide by distance between two nodes.

projecting factor of each node = 
$$\frac{\text{Opposite vertex error of distance}}{\text{distance between two vertex}}$$
 (11)

Let  $P_{fF}$  and  $P_{fR}$  be distance between nearest nodes and estimated





Figure 7: Random deployment of large number of anchor, estimation and actual nodes over a huge 3D space.

node, a is middle vertex node and estimated node is b and C be distance between selected vertex node and middle vertex node. We take difference between sum of two lower sides and longer side which will be radius of our creating circle in 3D.

$$\left(P_{fF}, P_{fR}\right) = \left(\frac{D_{Smin B}}{D_S}, \frac{D_{Smin F}}{D_S}\right)$$
(12)

Any point in 3D lies randomly in space with Euclidian distance r, it can be treated as a sphere and that point lies in surface of sphere. A sphere contains large number of circle however there is only one circle which all points lies same distance from both cuboid vertices. It gives transformation 3D to 2D-plane that make us easy to transfer co-ordinate along some fixed points of circle with radius r, rotation angle  $\theta$  and deploying angle  $\Phi$  as shown in Figure 5. After Cartesian co-ordinate transformation we pick some points of circle which lies 45 degrees apart by making origin as projecting point. For this, we picked up a unit circle and calculate has unit area and spreading over interconnected network by multiplying error distance r and taken as Q-matrix.

### Sphere division

Now our error distance is minimized to the circle radius. But we finding that circle locus needs complex designing. We need to find only two axis co-ordinate in 3D structure. An alternative way to find such point by taking error distance is a radius of sphere. A Q-matrix is obtained by multiplying unit cuboid whose center point is origin and obtaining error distance to the target nodes. The Q-matrix consists same magnitude co-ordinate which has consecutive difference is  $\pm \frac{r}{\sqrt{3}}$ 

as shown in Figure 6.

Now our target node is shifted by Q-matrix elements. It means we add all co-ordinate of Q-matrix to projected point individually and find -out which point has lower error distance. Then eqn. (8) can be written as

$$T_i = min(T_i + Q_{rm})$$
 where m = 1, 2...8 (13)

Projected Point  $P_E$  is transferred to our localizing area with the summation of  $P_E$  and Q-matrix. Since we used sphere we use this step three times because as iteration increase the hardware cost will increase automatically.

$$f(T_i) = \operatorname{argmin}_{\sum} \left( T_i' + Q_{rm} \right)$$
(14)

Minimum in Euclidian error distance element of that matrix becomes our next projected point and again calculating error distance becomes r and its works on iteration wise. As iteration method needs complex hardware system, a perfect iteration time is selected and locates the actual localization points.

$$T_{i} = argmin\sum_{i}^{3} \left( \left( \left( \left( \frac{D_{SminB}}{D_{S}} \right) \times S_{jF} \right) + \left( \frac{D_{SminF}}{D_{S}} \right) \times S_{kR} \right) + Q_{rm} \right)$$
(15)

#### **Simulation Result**

As purposed system works under dynamic structure, we can have deployed any distance with any number of anchor and sensor nodes. Randomly selecting number of estimation points choose its corresponding nearest anchor -centroids pair by using Euclidian distance. As number of anchor nodes increase in deploying area, number of centroid increases that reduces repetition of selection on anchor or sensor node. For simulation, the number of anchor nodes are taken between 10- 20% of the network that shows ICL method works

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similar to DV-Hop but it has lower in the network size and complexity of the network. Figure 7 shows a huge ICL WSN network which has anchor-sensor ratio is 1: 10 over each axis distance of 500 m in 3D network.

#### Localization error

As similar to DV-Hop, it accepts more random sensor node but not as a flooding of sensor node to produce same error distance. Proper selection of each axis distance in 3D, number of anchor and sensor nodes provides below 1% localization error. We observe the localization accuracy variation by deploying number of anchor and sensor nodes with in randomly selected each axis distance. Simulation starts with random deploying ranging up to 100 m on each axis with constant anchor-sensor ratio of WSN networks. Each time position of anchor nodes are taken randomly over deploying area shows more dynamic phenomena in WSN. Figure 8 shows the localization error plotting with error-bar at number of anchor nodes are 20 and 25 with constant anchor-sensor ratio 1:5. To reduce localization error, simulation shows that balancing factor used  $\beta$  when transformation of rectangular to cuboid space has a scalar value. For simplicity, ignoring a random distance phenomena we choose a suitable balancing factor  $\beta = 0.7696.$ 

## Localization accuracy

The sum of errors calculated by multiplication of average error and number of deploying anchor nodes, WSN localization has good Accuracy when it has no effect of radio range. Figure 9 shows proposed system accuracy that has distribution of anchor nodes are 20 and 25 respectively. However, the accuracy is almost constant. Accuracy result is compare with existing improved MDS and MDS-MAP that shows around 20 % accurate. Purpose system has less effect of radio distance then existing system.

#### Network connectivity

The range free DV-hop localization maintains good localization accuracy when network size is very large. Algorithm work with iteration method needed a complex hardware structure for localization. The complexity of implementation effectively minimizes by selecting proper value of N. For simulation, we take N=3 which helps to solve localization equation in real environment. The 3D DV-Hop and 3D MDS-MAP [27] are improved version of 2D WSN network. Different configuration of WSN network simulation is carried out at 60 m × 60 m









 $\times$  60 m space with constant anchor nodes. The anchor ratio is decreasing when network size increases but localization error also decreasing in ICL algorithm as similar to DV-Hop as shown in Figure 10. The results show the averages values are obtained from 5 independents each case simulation. As Node density of network increases then it decreases the localization error, but purposed system reduced the flooding number of sensor nodes to achieved desired accuracy.

## **Conclusion and Future Work**

Localization is suffering from accuracy and error distance. Our purposed dynamic ICL algorithm ensures that improves certainty of randomly deploying sensor nodes within WSN network. As proper selection of anchor- target ratio of the WSN network, considerable uniform distribution of anchor result error occurs at lower bounds. Flooding number of sensor nodes reduced to some extent and provides better localization error distance in 3D network. Future works encompasses study of accuracy, uniform distribution analysis and reduction of localization error. In particular, we will study about lower bounds error by using different method and make flexible dynamic modeling that assemble lower sensor network deploying over higher 3D distance with considerably small localization error.

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