2021 International Conference on Information and Communication Technology for Sustainable Development (ICICT4SD) | 978-1-6654-1460-9/21/$31.00 ©2021 IEEE | DOI: 10.1109/ICICT4SD50815.2021.9396837

Coordinates Determination of Submerged Mobile Sensors for Non-parallel State using Cayley-Menger Determinant

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***Abstract*—In this paper the problem of localizing submerged sensors is observed and introduces a new method to ordain the coordinates of those sensors which are situated in underwater and they are mobile and only one beacon node is considered for the system. Collecting data of appropriate coordinate of the sensors in underwater wireless sensor networks (UWSN) is essential because the root contains confined value except the knowledge of real data. There is used trilateration technique to detect the submerged sensors and beacon is considered in six different positions. In this proposed model three sensors have been used. To find out the coordinates of the sensor nodes Cayley-Menger determinant is used for the proposed model. Here three mobile sensors and one beacon node that made six different volume tetrahedron shapes by making it in same volume through projection to apply Cayley-Menger determinant. Through enumerating of coordinates of sensors nodes, simulation results make out the proposed mathematical models with minimal errors.**

Keywords— Mobile sensor, Non-parallel State, Cayley-Menger Determinant, Localization, Euclidean Distance, Trilateration

I. Introduction

World Ocean provides monumental benefits for human being. Ocean provides half of the world's oxygen and soak carbon dioxide from our atmosphere. So, nowadays it is important to monitoring aqueous environments for the purpose of scientific exploration, underwater surveillance, marine ecology, offshore exploration and the most important thing is giving protection from enemy attack. Terrestrial applications are used in many fields but there still some challenges in submerged sensor fields. For this, comprehensive monitoring Underwater Wireless Sensor Network (UWSN) is important. It is important to develop an appropriate localization mechanism to collect accurate environmental data. Localization of sensor nodes is necessary because sensed data will be useful when sensor node is localized [1]. UWSN has been explored new type of sensors that provides novel opportunity to design and implement various new application field in water. Through this network (UWSN), different parameters in water like pH, turbidity, dissolved oxygen and temperature can be measured [2]. Location related application are being improving day by day like object position tracking in smart spaces, personal navigation which is necessary for indoor localization. Due to not available of Global Positioning System (GPS) in indoor, new technologies about localization is required. Wireless communication has been eminent in terrestrial applications, in submerged sensor field some challenges subsist yet. Underwater level is huge resourceful but is not developed in research field. Detecting underwater sensor from the surface of the water is chosen as a research study to upgrade the field. There are some applications which already exist for non-parallel situation of detecting underwater static sensor but non-parallel situation of detecting underwater mobile sensor is not considered yet. That is why, a proposed mathematical model has been simulated to determine the precise coordinate of underwater mobile sensor for non-parallel situation. To find out the coordinates of the submerged mobile sensors there is used Cayley-Menger determinant for non-parallel situation.

II. Background

In underwater environment, the problem of detecting automatically the position of mobile sensors, different techniques have been proposed which is known as auto-calibration or auto-localization problem. Through the pressure sensor, one can dynamically measure the depth of the sensor deployment. Moreover, due to the large scale and dense sensor deployment mobile UWSNs are different from Underwater Acoustic Network (UANs). Similarly, some new task is needed like localization and multiple access in mobile UWSNs [3]. To determine the location of beacon there is needed enough measurements. The whole system depends on both beacon and robot position [4]. Buoys moored with the waterbed and mobile nodes communicate with these buoys to know their location. But buoys need to be deployed in known location. So, this method does not support dynamic environment [5]. If positions are not known, there is a proposed formula to solve the multilateral equations by means of nonlinear least square optimization. This algorithm states that enough measurements from different positions will provide enough equations to solve the problem. This is called degree-of-freedom analysis [6]. In [4], same technique is used incorporating extended Kalman filter. But in the system of non-linear equation the degree-of-freedom analysis does not provide a unique solution, in trilateration distance is measured between the nodes [7]. In [8], only one beacon node is considered in the surface of the water and three sensor

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nodes are situated in underwater level which is in a parallel plane with the surface of the water.

III. Methodology

A. Problem Domain

In this proposed method assumed there are at least three submerged mobile sensors and one floating beacon node. The beacon node assumed to calculate the distance between beacon and sensors from six different positions of beacon node. The six different positions of beacon node create a plane which is situated at water surface. Three sensors and one beacon node create an irregular tetrahedron shape and the three sensors create a triangular bottom face of tetrahedron which is non-parallel with the water surface. The Cayley-Menger determinant is applicable to calculate coordinates of sensors where volumes of tetrahedron are same. The six different positions of beacon node will create six different volume of tetrahedron shape where bottom face areas are same but heights are different because sensors are mobile. Here proposed method assumed the velocity and direction of all three sensors are same. So here the Cayley-Menger determinant will not be applicable. In this proposed method a projected area has been created from the bottom face area of tetrahedron. So, the volume of new tetrahedron shape for six different positions of beacon node will be same. Because projected bottom face areas and heights of all tetrahedron are same. Characteristic of tetrahedron is described in section C. Then the Cayley-Menger determinant is applied to calculate coordinates of sensors.

B. Environmental Explanation

In this proposed method assumed all sensors are moving with same direction and velocity because normally an ocean current is a continuous and directed movement of sea water, which is generated by wind, temperature, salinity difference, movement of earth etc. Generally, underwater environment is more unfavorable than terrestrial environment. In spite of those boundaries, it asserts some benefits to determine the coordinates.

C. Characteristics of Tetrahedron

If the area of the base face of a tetrahedron is equal to the area of the base face of another tetrahedron and also their heights are equal, then their volumes will be same.

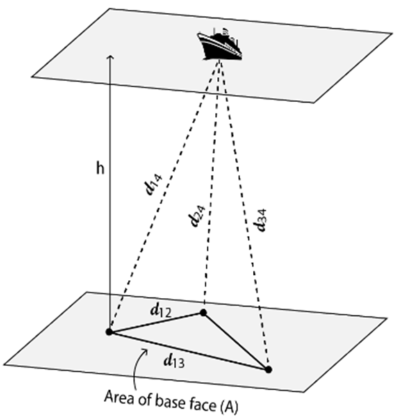

Fig. 1. Volume of a tetrahedron

$$Volume\ of\ tetrahedron = \frac{1}{3} * A * h$$

$$= \frac{1}{288} * \begin{vmatrix} 0 & 1 & 1 & 1 & 1 \\ 1 & 0 & d'^2_{12} & d'^2_{13} & d'^2_{14} \\ 1 & d'^2_{12} & 0 & d'^2_{23} & d'^2_{24} \\ 1 & d'^2_{13} & d'^2_{23} & 0 & d'^2_{34} \\ 1 & d'^2_{14} & d'^2_{24} & d'^2_{34} & 0 \end{vmatrix}$$

$$Where\ A = the\ area\ of\ base\ face\ of\ tetrahedron$$
$$h = the\ height\ of\ tetrahedron$$

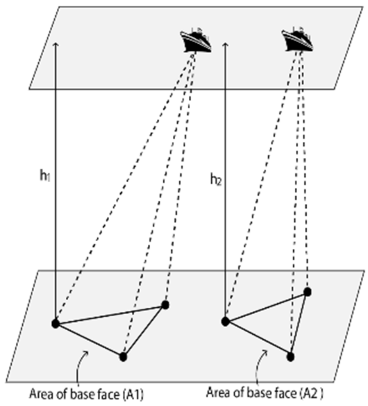

Fig. 2. Volume comparison between two different tetrahedron shapes

If,

A_1, h_1
$= the\ area\ of\ base\ face\ and\ height\ of\ a\ tetrahedron$

A_2, h_2
$= the\ area\ of\ base\ face\ and\ height\ of\ another\ tetrahedron$

And $A_1 = A_2 , h_1 = h_2$

Then, $\frac{1}{3} * A_1 * h_1 = \frac{1}{3} * A_2 * h_2$

D. Distance Measurement

Distance between beacon node and sensors can be measure by using signal and synchronous clock or radio and acoustic signal. While measuring distance, the disturbance that affect transmission error is considered.

E. Coordinates Computation

Here the localization algorithm is used to get exact coordinates. Since three sensors and one beacon node have been used here, they have created a tetrahedron shape. Since the sensors are mobile sensors and their speed and direction are same, so they have the same area of their base face every time. In our proposed algorithm, the base face is projected on a plane parallel to the plane of the beacon node. As a result, each of them has the same volume of tetrahedron. Then here the trilateration technique has been used to calculate the distance between the sensors.

In non-linear system trilateration or multilateral technique is used to obtain the sensors coordinates fully or partially. Initially S_j is considered as subset of the beacon node where $j = 4,5 \ldots 9$ and S_i is indicates three sensor nodes where $i = 1,2,3$. One of the sensor nodes S_i, $i = 1,2,3$ is consider as the origin (0, 0, 0) of the coordinate system to ascertain coordinate in general. Here, for distance measurement, trilateration technique can be written as a function of two groups of distance measurement. The distances from beacon to sensors are d_{14}, d_{24}, d_{34} which can measure data and inner distances between sensor to sensor are d_{12}, d_{13}, d_{23} and V_t is the tetrahedron volume. The depth from water surface to sensors are h_{11}, h_{12}, h_{13} respectively when reading is being taken from the first position of the beacon node. Similarly, h_{21}, h_{22}, h_{23} are the distances from beacon to sensors respectively when reading is being taken from the second position of the beacon node. Similarly, the rest is same procedure. From pressure sensors depth can be measured. According to water surface, sensor nodes d_{12}, d_{13}, d_{23} are deployed in non-parallel situation.

We are assuming a projection of the non-parallel situation which is parallel to water surface for applying Cayley-Menger determinant. The new distance from beacon S_j to projected sensor nodes are $d'_{14}, d'_{24}, d'_{34}$ respectively.

The expressions of distance measurement between beacon to projected sensors can be written as:

$$d'_{14} = \sqrt{d_{14}^2 - h_{11}^2 + h_{11}^2}$$
$$d'_{24} = \sqrt{d_{24}^2 - h_{12}^2 + h_{11}^2}$$
$$d'_{34} = \sqrt{d_{34}^2 - h_{13}^2 + h_{11}^2}$$

Similarly,

$$d'_{15} = \sqrt{d_{14}^2 - h_{21}^2 + h_{11}^2}$$
$$d'_{25} = \sqrt{d_{24}^2 - h_{22}^2 + h_{11}^2}$$
$$d'_{35} = \sqrt{d_{34}^2 - h_{23}^2 + h_{11}^2}$$
$$\vdots$$
$$d'_{19} = \sqrt{d_{14}^2 - h_{61}^2 + h_{11}^2}$$
$$d'_{29} = \sqrt{d_{24}^2 - h_{62}^2 + h_{11}^2}$$
$$d'_{39} = \sqrt{d_{34}^2 - h_{63}^2 + h_{11}^2}$$

Distance between beacon to projected sensors, inner distance and volume of tetrahedron which is formed by the beacon and sensors are unknown.

We need to know all the known unknown distances equations in local positioning system. We can find out those unknown values using Cayley-Menger determinant by applying the volume of tetrahedron V_t.

$$288V_t^2 = \begin{vmatrix} 0 & 1 & 1 & 1 & 1 \\ 1 & 0 & d'^2_{12} & d'^2_{13} & d'^2_{14} \\ 1 & d'^2_{12} & 0 & d'^2_{23} & d'^2_{24} \\ 1 & d'^2_{13} & d'^2_{23} & 0 & d'^2_{34} \\ 1 & d'^2_{14} & d'^2_{24} & d'^2_{34} & 0 \end{vmatrix} \quad (1)$$

By expanding known and unknown variables from Equation (1), we obtain;

$$\begin{aligned} & d'^2_{34}(d'^2_{12} - d'^2_{23} - d'^2_{13}) + d'^2_{14}\left(\frac{d'^4_{23}}{d'^2_{12}} - d'^2_{23} - \frac{d'^2_{13}d'^2_{23}}{d'^2_{12}}\right) \\ & +d'^2_{24}\left(\frac{d'^2_{13}}{d'^2_{12}} - \frac{d'^2_{13}d'^2_{23}}{d'^2_{12}} - d'^2_{13}\right) - \\ & (d'^2_{14}d'^2_{24} + d'^2_{14}d'^2_{34} - d'^2_{24}d'^2_{34} - d'^4_{14})\frac{d'^2_{23}}{d'^2_{12}} \\ & -\left(d'^2_{34}d'^2_{24} - d'^2_{14}d'^2_{34} + d'^2_{14}d'^2_{24} - d'^4_{24}\right)\frac{d'^2_{13}}{d'^2_{12}} \\ & +\left(144\frac{V_t^2}{d'^2_{12}} + d'^2_{13}d'^2_{23}\right) \\ & = (d'^2_{24}d'^2_{34} - d'^4_{34} + d'^2_{14}d'^2_{34} - d'^2_{14}d'^2_{24}) \end{aligned}$$

Here, $\left(d'^2_{12} - d'^2_{23} + d'^2_{13}\right)$, $\left(\frac{d'^4_{23}}{d'^2_{12}} - d'^2_{23} - \frac{d'^2_{13}d'^2_{23}}{d'^2_{12}}\right)$, $\left(\frac{d'^2_{13}}{d'^2_{12}} - \frac{d'^2_{13}d'^2_{23}}{d'^2_{12}} - d'^2_{13}\right)$, $\frac{d'^2_{23}}{d'^2_{12}}$, $\frac{d'^2_{13}}{d'^2_{12}}$, $\left(144\frac{V_t^2}{d'^2_{12}} + d'^2_{13}d'^2_{23}\right)$ are unknown terms.

The expression of known and unknown variable can be written as follows:

$$\begin{aligned} & d'^2_{14}X_1 + d'^2_{24}X_2 + d'^2_{34}X_3 - \left(d'^2_{14} - d'^2_{34}\right)\left(d'^2_{24} - d'^2_{14}\right)X_4 \\ & - (d'^2_{24} - d'^2_{14})(d'^2_{34} - d'^2_{24})X_5 + X_6 \\ & = (d'^2_{24} - d'^2_{34})(d'^2_{34} - d'^2_{14}) \quad (2) \end{aligned}$$

In fact, Equation (2) represents the linear form $a_1x_1 + a_2x_2 + \cdots + a_nx_n = b_1$. In Equation (2), we have six unknown variables, so that we need at least six different linear equation to calculate unknown.

After that, we get this formula from m-linear Equation;

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n &= b_1 , \\ a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n &= b_2 , \\ &\vdots \\ a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n &= b_m , \end{aligned} \quad (3)$$

Equation (3) can be represented as an array where all coefficients known as the augmented matrix of the system. Each row of the array defines the linear equation.

This expression can be written in linear form as $AX = b$.

$$A = \begin{bmatrix} d'^2_{14} & d'^2_{24} & d'^2_{34} & -(d'^2_{14} - d'^2_{34})(d'^2_{24} - d'^2_{14}) & -(d'^2_{24} - d'^2_{14})(d'^2_{34} - d'^2_{24}) & 1 \\ d'^2_{15} & d'^2_{25} & d'^2_{35} & -(d'^2_{15} - d'^2_{35})(d'^2_{25} - d'^2_{15}) & -(d'^2_{25} - d'^2_{15})(d'^2_{35} - d'^2_{25}) & 1 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ d'^2_{19} & d'^2_{29} & d'^2_{39} & -(d'^2_{19} - d'^2_{39})(d'^2_{29} - d'^2_{19}) & -(d'^2_{29} - d'^2_{19})(d'^2_{39} - d'^2_{29}) & 1 \end{bmatrix}$$

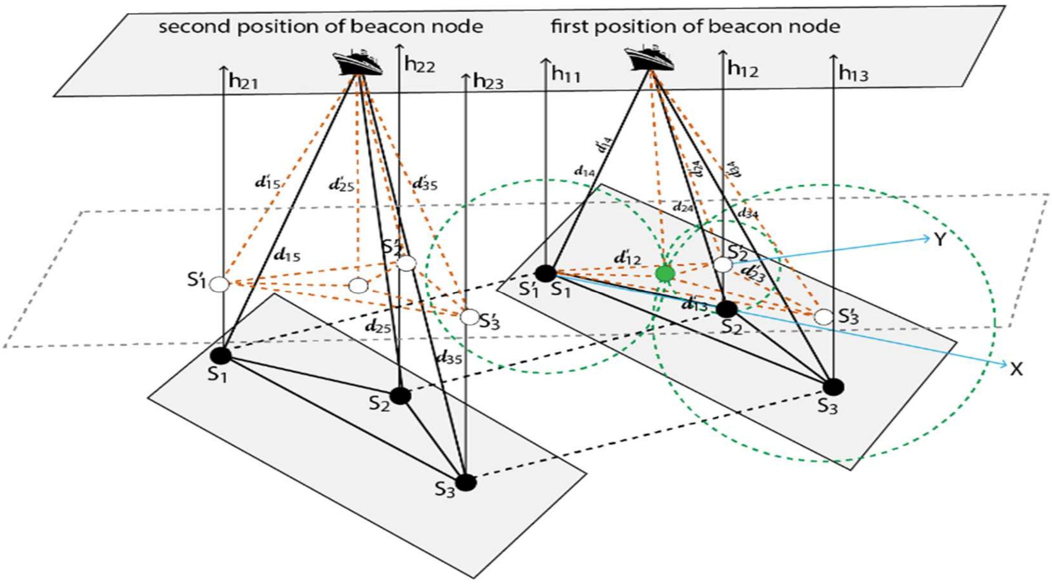

Fig. 3. Determination of coordinates

$$X = \begin{bmatrix} \left(\frac{d'^4_{23}}{d'^2_{12}} - d'^2_{23} - \frac{d'^2_{13}d'^2_{23}}{d'^2_{12}}\right) \\ \left(\frac{d'^4_{13}}{d'^2_{12}} - \frac{d'^2_{13}d'^2_{23}}{d'^2_{12}} - d'^2_{13}\right) \\ (d'^2_{12} - d'^2_{23} - d'^2_{13}) \\ \frac{d'^2_{23}}{d'^2_{12}} \\ \frac{d'^2_{13}}{d'^2_{12}} \\ \left(144\frac{V_t^2}{d'^2_{12}} + d'^2_{13}d'^2_{23}\right) \end{bmatrix}$$

$$b = \begin{bmatrix} (d'^2_{24} - d'^2_{34})(d'^2_{34} - d'^2_{14}) \\ (d'^2_{25} - d'^2_{35})(d'^2_{35} - d'^2_{15}) \\ \vdots \\ (d'^2_{29} - d'^2_{39})(d'^2_{29} - d'^2_{19}) \end{bmatrix}$$

From the above representation, after discovering the unknowns $X_1, X_2, X_3, X_4,$ and X_6 we calculate d'_{12}, d'_{13} and d'_{23} as follows:

$$d'^2_{12} = \frac{X_3}{(1 - X_4 - X_5)}, \qquad d'^2_{13} = \frac{X_3 X_5}{(1 - X_4 - X_5)},$$

$$d'^2_{23} = \frac{X_3 X_4}{(1 - X_4 - X_5)}$$

If we consider S_1, S_2 and S_3 as the coordinates of the submerged sensors then the coordinates will be $(0,0,0)$, $(0, y_2, 0)$ and $(x_3, y_3, 0)$ respectively. So, the inter-sensor distances could be written with respect to coordinates of the sensors as follows:

$$d'^2_{12} = y_2^2, \qquad d'^2_{13} = x_3^2 + y_3^2,$$

$$d'^2_{23} = x_3^2 + (y_3 - y_2)^2$$

By using above values, the unknown variable can be determined as follows:

$$y_2 = d'_{12}, \qquad y_3 = \frac{d'^2_{12} + d'^2_{13} - d'^2_{23}}{2d'_{12}},$$

$$x_3 = \sqrt{\left(d'^2_{13} - \left(\frac{d'^2_{12} + d'^2_{13} - d'^2_{23}}{2d'_{12}}\right)^2\right)}$$

Here, d'_{12}, d'_{13}, and d'_{23} are known distances.

F. Coordinates of the Sensors with respect to Beacon

In the following description above we have determined the coordinates of the sensor nodes with respect to S_1.
To find the coordinates with respect to the beacon node, the following steps are as follows:

TABLE I. COORDINATES OF THE SENSORS WITH KNOWN MEASUREMENTS

Sensors	Coordinates
S_1	$(0, 0, 0)$
S_2	$(0, d'_{12}, 0)$
S_3	$\left(\sqrt{\left(d'^2_{13} - \left(\frac{d'^2_{12} + d'^2_{13} - d'^2_{23}}{2d'_{12}}\right)^2\right)}, \frac{d'^2_{12} + d'^2_{13} - d'^2_{23}}{2d'_{12}}, 0\right)$

With the help of proper sensor, we can calculate the depth h between beacon node S_4 (x_4, y_4, z_4) and XY plane. Beacon node S_4 (x_4, y_4, z_4) is reflected on the plane XY which coordinate is P_4 $(x_4, y_4, 0)$. To find x_4 and y_4, we assume the distance between S_1, S_2, S_3 and P_4 are D_{14}, D_{24} and D_{34} respectively.

$$D_{14}^2 = x_4^2 + y_4^2 \qquad (4)$$

$$D_{24}^2 = x_4^2 + (y_4 - y_2)^2 \qquad (5)$$

$$D_{34}^2 = (x_4 - x_3)^2 + (y_4 - y_3)^2 \qquad (6)$$

From Equations (4), (5) and (6) we achieve our expected beacon's coordinates P_4 $(x_4, y_4, 0)$.

$$x_4 = \sqrt{\frac{1}{2D}\left(2d'_{12}D_{14}^2 - D_{14}^2 + D_{24}^2 + d'^2_{12}\right)},$$

$$y_4 = \frac{1}{2d'_{12}}\left(D_{14}^2 - D_{24}^2 + d_{12}^2\right)$$

As d'_{14}, d'_{24}, and d'_{34} are the hypotenuse of the $\Delta S_1P_4S_4$, $\Delta S_2P_4S_4$ and $\Delta S_3P_4S_4$ respectively. By using Pythagorean Theorem, we can find D_{14}, D_{24} and D_{34}. (x_4, y_4, h) would be the new coordinate of beacon node where all the elements are known.

$$\therefore S_4\,(x_4, y_4, 0) = \left(\begin{array}{c}\left(\sqrt{\frac{1}{2D}\left(2d'_{12}D_{14}^2 - D_{14}^2 + D_{24}^2 + d'^2_{12}\right)}\right), \\ \left(\frac{1}{2d'_{12}}\left(D_{14}^2 - D_{24}^2 + d_{12}^2\right)\right),\ \ h_{11}\end{array}\right)$$

It is also possible to obtain the coordinates of the other sensors if we change the Cartesian System to coordinate of the beacon node S_4. The result is shown in TABLE III.

TABLE II. COORDINATES OF THE SENSORS WITH RESPECT TO BEACON

Beacon	**Coordinate**
S_4	$(0, 0, 0)$
Sensors	**Coordinates**
S_1	$(-x_4, -y_4, -z_4)$
S_2	$(-x_4, y_2 - y_4, -z_4 - (h_{12} - h_{11}))$
S_3	$(-x_4, y_2 - y_4, -z_4 - (h_{13} - h_{11}))$

IV. Results and Discussion

From our simulation, we can take decision that, the x and y coordinates of the sensors will vary but z coordinates of the sensors will remain same. For this reason, keeping constant the distances between beacon to sensors and inner distances between sensors, it's seems that sensors are rotating with respect to beacon.

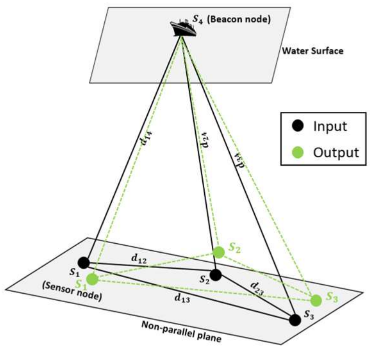

Fig. 4. Rotation of sensors

A. Error Generation

In our proposed mathematical model, there incorporates minimal error due to some environmental constraints. The sensors can be able to detect the signal when the shortest Euclidean distance is travelled. If we get more accurate distance from aqueous environment, we will be able to get more precise coordinates with less error.

B. Simulation Result Analysis and Discussion

To evaluate the proposed mathematical model, the proposed method has been implemented in Python. First of all, three sensors are deployed at (9, -6, -4), (-6, -9, -5) and (3, -12, -7) beacon is moved randomly in different position on the water surface plane. With respect to the plane of beacon, the sensors are deployed non-parallel situation. The coordinates of beacon are taken from six different position where first coordinate is considered (0, 0, 0). On the other hand, in underwater the coordinates of sensors are assumed randomly. While we are assuming the position of three sensors S_1, S_2 and S_3 with respect to first position of beacon (0, 0, 0). Here, three sensors are considered as mobile in the underwater. The calculated coordinates of the sensors when reading is being taken from the first position of the beacon node are shown in fig.4.

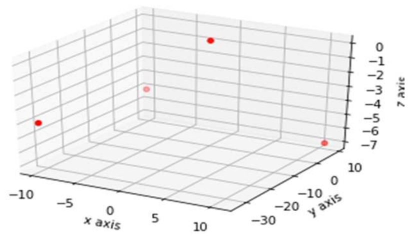

Fig. 5. Coordinates of sensors with proposed model

We have obtained coordinates of sensors for 100 iterations for calculating distance error where distance error is the difference of input coordinates and resultant coordinates of the sensors. For coordinates of sensors S_1, S_2 and S_3, we have computed errors for 100 iteration and calculated mean error which is shown in fig.6, fig.7 and fig.8 respectively.

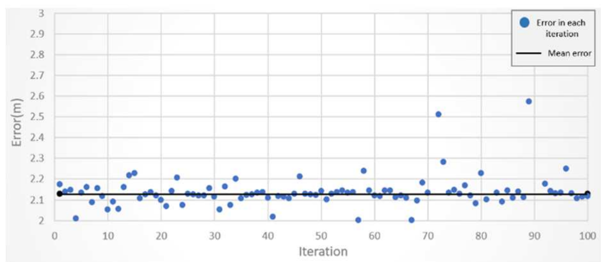

Fig. 6. Distance errors of sensor $\boldsymbol{S_1}$ between resultant and input coordinates

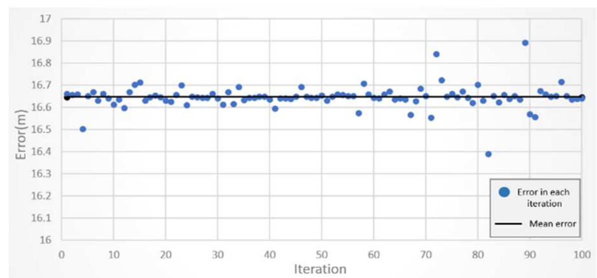

Fig. 7. Distance errors of sensor $\boldsymbol{S_2}$ between resultant and input coordinates

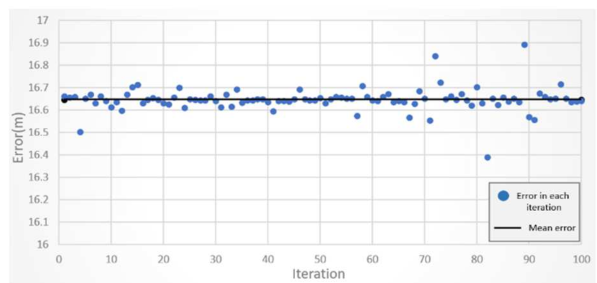

Fig. 8. Distance errors of sensor $\boldsymbol{S_3}$ between resultant and input coordinates

TABLE III. GENERATION OF DISTANCE ERROR (INPUT SENSORS TO OUTPUT SENSORS)

Sensors	Mean error(m)	Standard deviation of error distribution(m)
S_1	2.12769	0.027566
S_2	16.6473	0.009995
S_3	15.6849	0.01651

After getting output coordinates of sensors from our proposed model, the inner distances between sensor to sensor have come with a little bit error which is negligible.

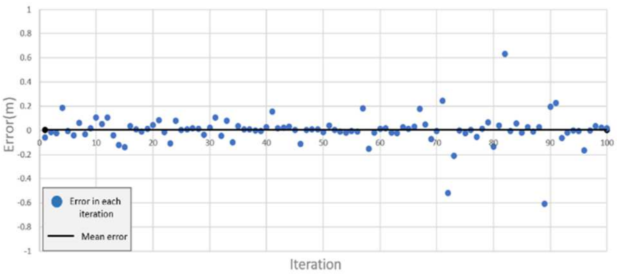

Fig. 9. Distance errors of sensor $\boldsymbol{S_1}$ to $\boldsymbol{S_2}$

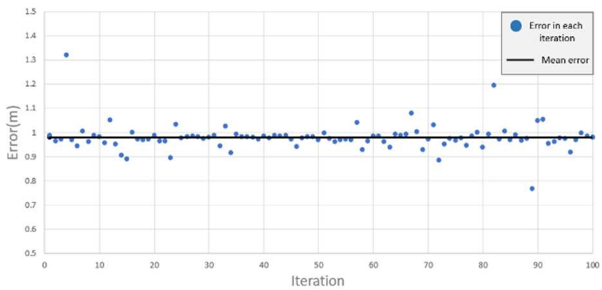

Fig. 10. Distance errors of sensor $\boldsymbol{S_2}$ to $\boldsymbol{S_3}$

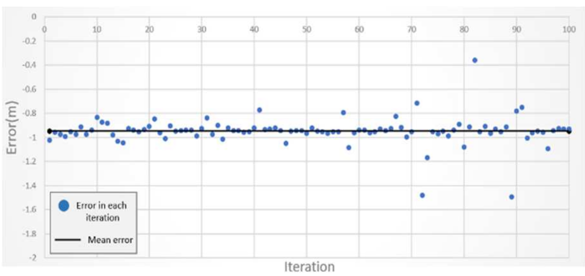

Fig. 11. Distance errors of sensor $\boldsymbol{S_3}$ to $\boldsymbol{S_1}$

TABLE IV. GENERATION OF DISTANCE ERROR (SENSORS TO SENSORS)

Sensors	Mean error(m)	Standard deviation of error distribution(m)
S_1 *to* S_2	0.003796	0.037179
S_2 *to* S_3	0.979097	0.004376
S_2 *to* S_1	-0.94655	0.04459

V. LIMITATION

We have moved the position of beacon in different shape like circle, triangle and linear line where for some input of shapes will not be applicable for our proposed model. For instance, from this input (0, 0, 0), (1, 0, 0), (2, 0, 0), (3, 0, 0), (4, 0, 0), (5, 0, 0) we do not get any output because this coordinates create a linear line where it makes a singular matrix. In our proposed method are considered the velocity and the direction of this mobile sensors are same. But if not the same, this proposed algorithm will not work.

VI. CONCLUSION

In this study we have explored the use of UWSN and we have presented a mathematical model by considering single beacon to obtain the coordinates of submerged mobile sensors for non-parallel situation. We have described the challenges of communicating underwater sensor nodes and have introduced a technique to localize them where localization technique is essential for collecting exact environmental data. This coordinate determination method eliminates numerous problems in the localization territory. By simulating our results, we can validate that our proposed mathematical model provides exact underwater sensors coordinates within adoptable error. Finally, we have concluded that it is a promising new model of determining the coordinates of underwater sensors. It could be a way to overcome some challenges in the field of deployment underwater sensors. It seems an efficient solution for many applications that involved monitoring of deployment in aqueous environments.

In future we plan to work with mobile sensors whose direction and speed are different.

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