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ORIGINAL

Breast lump assessment: an IoT-Integrated framework with advanced localization techniques

Evaluación de tumores mamarios: un marco integrado en IoT con técnicas avanzadas de localización

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ABSTRACT

Internet of Things (IoT) influences many areas such as healthcare, transportation, agriculture, industry control, environment monitoring, and water management. Healthcare is a major area in which the IoT enables a more personalized form of healthcare through smart healthcare systems. Breast cancer is the second leading cause of death among women globally, and its incidence is increasing every year. Early-stage detection of breast cancer is an important research challenge in the medical field. The aim of this article is to design an IoT - Integrated framework with advanced localization techniques for breast lump assessment. Through the proposed framework, breast lumps are monitored periodically using sensor embedded wearable jacket. The lump position and its depth in the breast are evaluated using localization techniques in sensor organization. Model outcome is analysed for six periodic tests data. Results evidence that periodic monitoring of breast health using the designed framework is effective to fix abnormal lumps at the early stage.

Keywords: Breast Lumps; Internet of Things; Lump; Sensor; Wearable Jacket.

RESUMEN

Internet de las Cosas (IoT) influye en muchos ámbitos, como la sanidad, el transporte, la agricultura, el control industrial, la vigilancia del medio ambiente y la gestión del agua. La sanidad es uno de los principales ámbitos en los que el IoT permite una asistencia sanitaria más personalizada a través de sistemas sanitarios inteligentes. El cáncer de mama es la segunda causa de muerte entre las mujeres de todo el mundo, y su incidencia aumenta cada año. La detección precoz del cáncer de mama es un importante reto de investigación en el campo de la medicina. El objetivo de este artículo es diseñar un marco integrado de IoT con técnicas avanzadas de localización para la evaluación de tumores mamarios. A través del marco propuesto, los nódulos mamarios se monitorizan periódicamente utilizando una chaqueta wearable con sensores integrados. La posición del bulto y su profundidad en la mama se evalúan mediante técnicas de localización en la organización del sensor. El resultado del modelo se analiza para seis datos de pruebas periódicas. Los resultados demuestran que la vigilancia periódica de la salud de la mama mediante el marco diseñado es eficaz para detectar bultos anormales en una fase temprana.

Palabras clave: Tumores Mamarios; Internet De Las Cosas; Tumor; Sensor; Chaqueta Ponible.

INTRODUCTION

A sensor is a computing device that can measure or detect an event and record, indicate, or respond to it.[1] There is a significant record of sensor technology in healthcare and treatment. Sensors are embedded in a variety of medical instruments used in hospitals, clinics, and homes to closely monitor a patient's health condition. Wearable sensors have become very popular in many applications, such as the medical, entertainment, security, commercial fields and ensures a safe and sound living environment by providing accurate and reliable information on people's activities, behaviours, and health conditions.[2] Due to the evaluation of sensing tools, embedded systems, wireless communication, and nanotechnologies, it is possible to develop smart systems for continuous monitoring of human activities.[3] As per sensor technology literature, the pressure and position sensors are suggestable to detect lump and its position in breast.[4] The analysis of signals gets from these sensors possible to solve the current breast cancer research issue using localization technique.

Location - based services are among the most significant IoT applications. Localization is one of the key techniques used to provide accurate information about the target position in two or three-dimensional space. Localization techniques, such as triangulation and trilateration are frequently used to fix the object location in the environment. Usually, these techniques are used in various applications,[5] such as firefighters tracking, logistics, and military service. Why don't we apply localization techniques to health monitoring. In this Paper, we are proposing the localization technique to identify the lump area in the breast.

Triangulation and trilateration are two broadly used localization techniques to detect the location of the object.[6] These two are range-based positioning systems out of which lateration calculates a target position by considering the distance from various sensor points towards the target. Whereas angulation uses angle value from various sensor points towards the target. In a two-dimensional system, lateration requires three distance values assessed from three noncollinear sensors, whereas angulation requires two angles and one distance value.[7] The triangulation strategy is an angulation-based location estimation. The area of the target is evaluated by utilizing the edge of the entry signal that touches the base of the object from two sensor reference points in a two-dimensional system and three sensor reference points in a three-dimensional system. For both cases, one distance measure is mandatory to detect the location of the object.[8] Figure 1 represents a triangulation approach and figure 2 represents a trilateration approach.

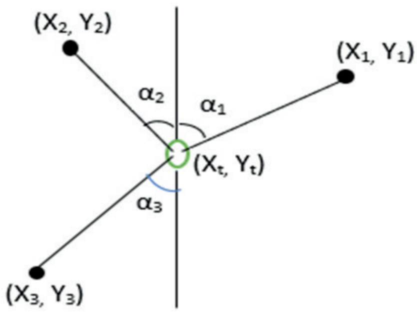

Figure 1. Triangulation

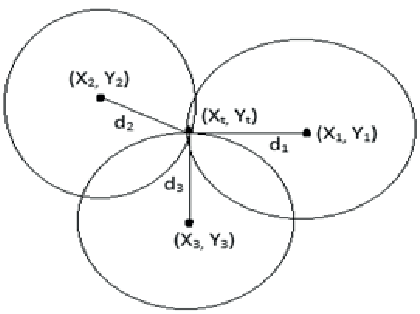

Figure 2. Trilateration

Valverde et al.[9] proposed the model of triangulation to inference the emotions of students while designing online learning applications. This computer-based active methodology uses the triangulation of three techniques facial expressions, pupil size, and student's self-assessment. This provides an effective assessment mechanism to design new online courses. Hyder et al.(10) proposed a solution to the brain sources localization problem using EEG signals. He also verifies the performances of various brain source localization techniques. Due to the non-availability of baseline, the evaluation of asymmetric activations is conducted using simulated dipolar source distributions constrained to the cortical surface in their research work. Balaji et al.(11) discussed the importance of localizing moving objects in wireless sensor networks related to IoT applications. To locate the moving object, a set of nodes are fixed at a predefined location which helps to detect moving object in WSN by using localization algorithms. The trilateration algorithm is a usual localization algorithm that needs distance calculation as the primary action. Here, the author uses beacon node placement to improve the distance calculation method. Paolini et al.(12), the author presented a model for fall detection using RFID readers in smart healthcare. The author uses signal strength indication and azimuth angle measurements for evaluation of target in radar concept. The author experimented with three-dimensional scanning of the room with decimeter accuracy using three reference points. The data is gathered over a predefined amount of time continuously and it is stored on an onboard microcontroller. The whole system is remotely controlled at smart homes and this experiment is done using Raspberry Pi 3B. The author presented his experiment on the detection of old people in indoor environments. Liu, H et al.(13) reported survey report on wireless indoor positioning mechanisms. Authors claimed that Time of arrival (TOA), angle of arrival (AOA), received signal strength (RSS) and time difference of arrival (TDOA) are various parameters used in localization techniques to fix the location of the object. Chalvatzaras et al.(14), discussed the survey report on map-based localization methods for autonomous vehicles. The authors discussed sensor organization with passive and active sensors. Various authors contributions on core, probabilistic and deep learning-based localization mechanisms are outlined. The author's contribution in this work helps us to understand and design better localization frameworks.

Alam, M. S et al.(15), reviewed RNN based camera localization for interior environments. Camera localization mechanism is proposed to detect the object from the image sequence produced from camera. Authors discussed the various applications of camera localization mechanisms and examined the key benchmarks set for evaluating V-SLAM based methodologies on considered datasets. Li, Z et al.(16), discussed indoor localization mechanisms using microwave reflections. In this author estimated the angle of arrivals and time of flight of propagation paths and uses the multipath triangle with its first order reflections to locate the object. The results are demonstrated using single AP-based localization system. Zou, Y et al.(17), discussed the angle of arrival mechanism to locate the object in three-dimensional space. Matrix representation is a generally used mechanism and requires large conditional number if the data is noisy. The authors evaluated iterative based methods without using matrix operations. Marquez, L. E et al.(18), discussed the review on basics and challenges of LoRA based localization mechanisms. Authors reviewed the work done by various authors and compared the results based on time and signal strength metrics. Discussed the testing scenarios under various conditions. This work helps the new researchers to explore different types of metrics considerably under model testing. Ren, Y et al.(19), designed a dynamic semantic aided localization structure. In this the classes are extracted from LiDAR scan and then map matching is performed using 2D key points corresponding. The results compared with non-semantic localization methods and proposed algorithm evidence the lowered positional fault. This work helps to design innovative algorithms. Panwar, K et al.(20), discussed the optimal sensor location methodology, which influenced the outcome of sensor organization. Authors discussed various parameters that influence the hybrid sensors outcome in calculating localization accuracy. Optimal placement algorithm is designed and tested under various noise conditions and various designs. This work helps to design hybrid sensors organized with optimal placement based on user application. Monji M. Zaidi et al.(21) proposed a digital design approach to optimize the TDOA algorithm performance in localizing forest fire in sensor network. The authors discussed a simple digital technique with iterative additions and shift SSD to find the location of node in two-dimensional wireless sensor network with reduced energy consumption. Alnakkash et al.(22) discussed an outdoor localization scheme for real-time IoT applications. The authors created an outdoor environment with 20 meters and 250 observations are generated based on the distance between anchor nodes and mobile nodes using AI system. The observations are trained using ANN and the results are analyzed. Aminu et al.(23), given the review work on localization approaches for object deletion from multiple points in wireless sensor network. Authors discussed various applications of localization approaches in multiple fields and discussed future work with respect to indoor and outdoor environments. Section 1 discussed the introduction part and related work which deals with various researchers' contributions. Section 2 handles the design part of the framework, sensor organization, target detection and data processing mechanism. Section 3 handles framework along with results discussion. Finally, the work ended with conclusion and future work discussion.

The referred work concluded that the localization techniques are helpful to identify the location of objects and sensors useful to sense the obects existance in the environment. In the proposed work, Lump is treated as an object inside the breast and localization techniques are applied to identify the target position inside the breast which is sensed using sensors. The integration of localization techniques with sensor-enabled jackets represents a significant advancement in breast health monitoring. By providing a non-invasive, accurate, and real-time method for detecting lumps, this technology has the potential to transform breast examinations and improve patient care.

METHOD

Wearable biomedical sensors play a vital role in patient health monitoring. Sensor vendors can provide inexpensive bio-medical sensors with preinstallation and with certifications as per the requirement of users. Through this wide usage of flexible sensors, an advancement happens in the patient health care domain.[24] Through this motivation, sensors are proposed here to sense the internal view of the breast, and we are using localization techniques to fix the approximate lump location using sensor angle and distance values. The architecture of the proposed framework is given in figure 3.

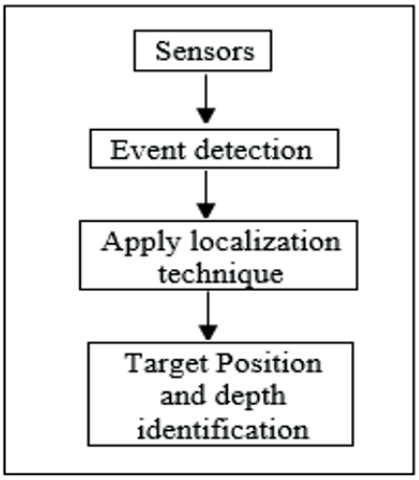

Figure 3. Block diagram of proposed work

Sensor Organization

Lumps are not formed at one fixed place in a breast part and these lumps are common in women during periods, pregnancy time, and hormonal exchange period. The uncontrolled duplicate of cells in the breast portion of the body causes lumps. All lumps are not caused by cancer. But some malevolent lumps which grow from breast lockups are cancerous.[25] Placing a sensor or a set of sensors at one place is not possible to fix all lumps in the breast. So, we are placing the sensors in the predefined probable area of lumps on the breast. Every sensor node has a specific range of observation for which it can dependably and precisely report the amount of data that it is watching. This assumption of a coverage area is difficult to justify in its simplest form generally. But in this proposed work we are trying to detect lumps at an internal view of the breast. That means breast internal lumps need to be sensed by sensors like detecting objects inside a bucket. We assumed, detecting abnormal lumps in the breast is a three-dimensional problem. That means we need at least 4 sensors to implement this work. The sensor network with 4 nodes {A, B, D, N}. The network is connected, and the routing protocol existed to provide the path from one node to the other node and to navigate from one node the other node. Means the path and hop-count (hc) lengths are not essentially same among the connections in the sensor network. Means path (A, B) and hc(A, B) may not be equal to path(B,A) and hc (B,A). The communication among the nodes done though beacons based on signal strength (ss (A, B)) of a sensor. The proposed sensor network is very small, the prototype of sensor placement is shown in figure 4. Breast is assumed as a circle shape surface and we are aware of the approximate size of common breast in women. That means the area of the probable region we are assuming. Using this assumption, we get a radius of the circle using equation (1).

$$A = \pi r^2 \qquad (1)$$

To draw a circle, we must identify the center point using equation (2). Here S refers sensing capacity of sensor, r means radius and μ refers approximate value to draw the circle in positive plane.

$$C = (Xcenter, Ycenter) = (s + r + \mu, s + r + \mu) \qquad (2)$$

On the circumference of the circle, we are fixing three sensors. The positions of sensors we are calculating using equations (3,4,5).

$Xi = Xcenter + rcos\theta$ (3)
$\text{Yi} = \text{Ycenter} - \text{rsin}\theta$ (4)
$Zi = 0$ (5)

- If θ= 360 degrees, then equation 3 gives, first reference point A= (X1, Y1, Z1).
- If θ= 180 degrees, then equation 3gives, second reference point B= (X2, Y2, Z2).
- If θ= 270 degrees, then equation 3 gives, third reference point D= (X3, Y3, Z3).

These three positions are three known sensor positions. The exact shape of sensor network we are assuming is cylinder shape. The fourth sensor we must place on the nipple to get the depth of target. Figure 4 depicts sensor network structure which depicts the predefined posions in sensor organization.

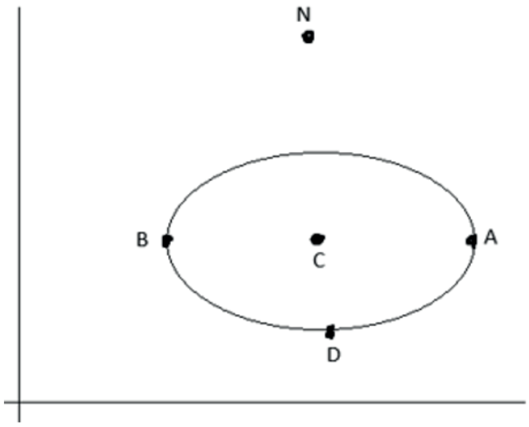

Figure 4. Sensor network structure

Target Detection in Sensor Network

Wireless sensors are available on the market to design smart healthcare applications. We are assuming sensor is capable to sense a lump in the breast and it can give the distance based on received signal strength indication (RSSI) and angle of arrival (AOA) towards target position from its position (fixed reference point). To identify the target location the angulation requires one distance and two angle values. If the sensor senses the target, it will store its distance, and the angle of arrival depends on the received signal strength indication.

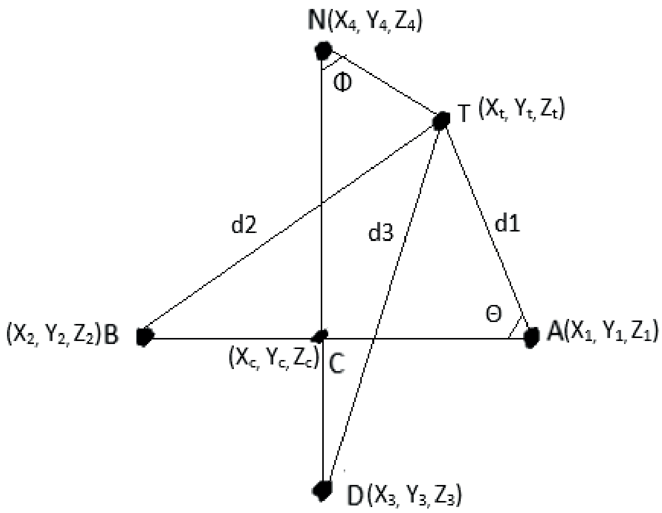

Figure 5. Triangulation to Locate the Target

Figure 5 depicts how the target is detected by sensors in a network. If the target is under the sensing range of sensor A, then this sensor will store angle, the distance towards lump from the sensor. To detect the location of the target we are considering fourth reference point N. The fourth reference point N gives an azimuth angle towards the target position. Figure 5 refers to the target T from sensor positions A and N. It shows the target is near to base sensor A compared to B and C base sensors. So, the distance given by sensor A is considered as

d. The angle of arrival (Θ) from sensor A to the target and azimuth angle (Φ) from top reference point N to the target is used to detect the target location T (Xt, Yt, Zt) using equations (6,7,8).

$$Xt = dsin\Theta \cos \Phi \qquad (6)$$
$$\mathrm{Yt} = dsin\Theta \sin \Phi \qquad (7)$$
$$\mathrm{Zt} = dcos\Theta \qquad (8)$$

The depth of the target position is calculated using center C and top reference point N. We must consider a point on the line between C and N exactly parallel to target to get the exact depth. The point M on the line is (Xc, Yt, Zt). Total distance between M and N is calculated using equation (9). P value refers to the depth of target in breast. Figure 6 depicts how the depth of target is calculated using point M and fourth reference point.

$$\mathrm{P2} = (\mathrm{Xc} - \mathrm{X4})^2 + (\mathrm{Yt} - \mathrm{Y4})^2 + (\mathrm{Zt} - \mathrm{Z4})^2 \qquad (9)$$

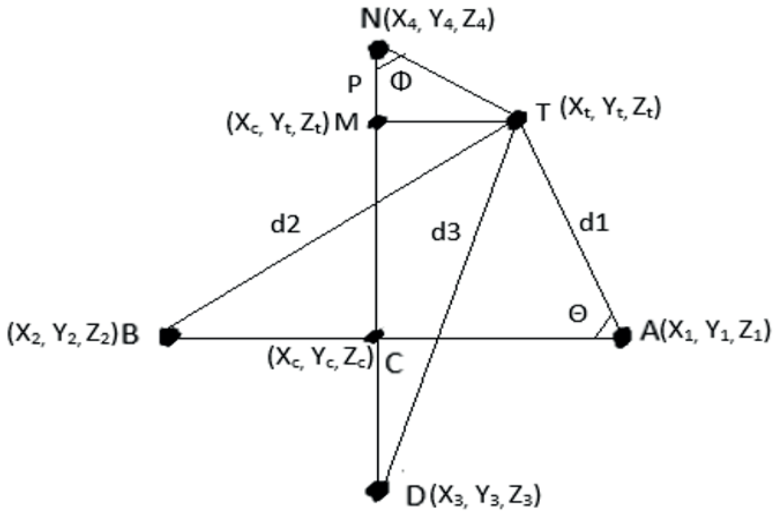

Figure 6. Target Depth Detection

Algorithm
Input: Sensor data
Output: Lump position

1. BEGIN
2. If lump is not sensed by any of the sensor, then
   2.1. Return 'lumps are not identified'.
3. If lump is noticed by sensor, then
   3.1. Sensor store distance d and angle of arrival Θ based on received signal strength indication.
   3.2. Sensor N gives azimuth angle Φ towards identified lump position.
   3.3. Calculate lump position T using equation (4)
   3.4. Return identified position and depth of lump in breast.
4. Repeat step 3 for all sensed targets (lumps) in breast
5. END

Generally, women's lumps are commonly observed in breasts during their mensural periods, pregnancy period, etc. But these casual lumps lifetime is very less. So, after some days these lumps will disappear. If the lump is malignant then it does not melt, and it increases the size or spreads to other tissues as per timeline. But this may take a month's period. So, using our proposed system we can observe the target periodically (monthly once after 10 days of the mensural period). If the target (lump) is detected constantly, we can report breast abnormality.

Implementation

The proposed work is exhibited in this section using a sample prototype build. The prototype is organized as a sensing module, communication and processing module, data storage module. Due to the non-availability of lump monitored bio-medical sensors in the market, the proposed work is demonstrating here by using infrared (IR) and ultrasonic sensors combination as sensing module, the components Arduino board, Wi-Fi module, LCD screen used in processing and communication module. An open-source thing speaks server is used as a storage module. Block diagram of proposed model is shown in figure 7.

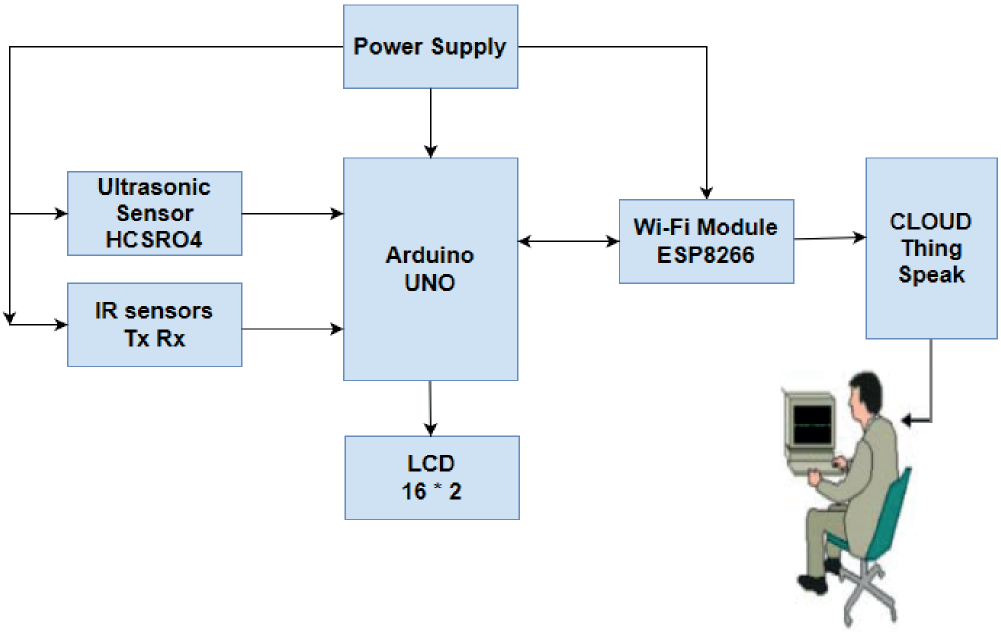

Figure 7. Block Diagram of Proposed Model

Figure 8 shows the prototype of the implemented work. Sensor enabled wearable jacket is proposed as sensing module. The sensed data is processed using a processing module available at Arduino and the results are stored at cloud using communication module and the status displayed using LCD monitor. During the test, if a lump is sensed then the angle and distance measures are sent to Arduino. The localization program stored at Arduino can process the data. The processed data is sent to the thing speaks cloud through a communication module (Wi-Fi). The thing speaks cloud is an open source and it allows to access the result at any time by authorized users. A synthetic dataset with expected test results is designed by applying localization techniques. This dataset serves to demonstrate the results of the proposed framework.

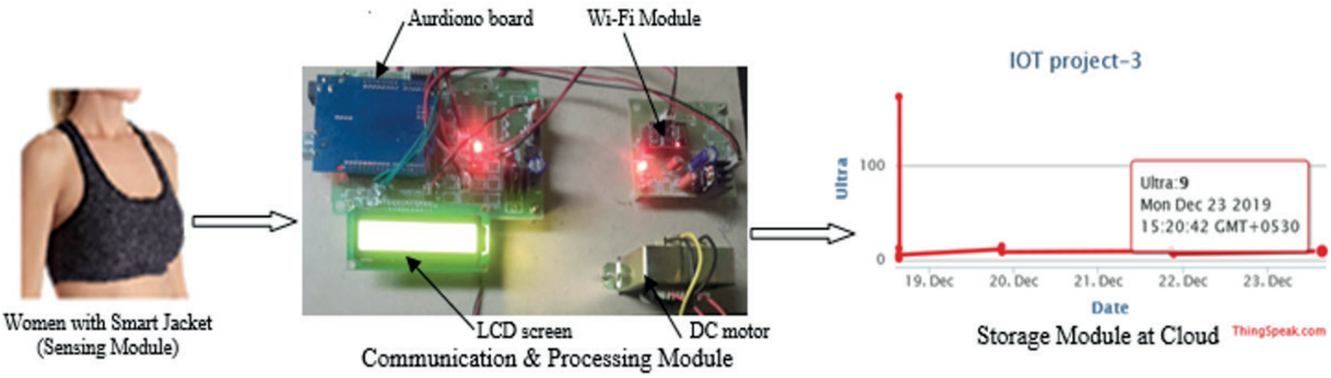

Figure 8. Implementation of Proposed Work

RESULTS AND DISCUSSION

Breast lumps are very common among women especially during mensural periods of younger women, pregnancy period of women, surgically altered breasts, and even for normal cases also. But these lumps may or may not be dangerous. As part of the proposed work in this article, the sensors sense the lump inside the breast and with the help of the triangulation localization technique, the position and depth of lump will be fixed. Normal lumps will disappear after a few days. But abnormal lumps are constantly detected by sensors in periodic tests. The simulation result shows the probable area of a lump in the breast. Table 1 shows the position coordinates of the target gets using a triangulation approach for six months of periodic monitoring of one abnormal patient.

Table 1. Target Coordinates of Patient Records (Estimations On 6 Periodic Tests)

Test No	X_t	Y_t	Z_t
1	2,09	0,37	2,12
2	2,41	0,78	1,78
3	2,18	0,46	2,01
4	2,85	0,82	1,85
5	3,09	0,83	1,16
6	3,35	1,15	0,62

Figure 9 shows the resultant graph. The graph is generated using a simulated tool, which shows the location of lump in three dimensional planes. If the lump position is detected periodically then we can confirm there is an abnormal lump in the breast. This result also helps the doctors to identify the lump position approximately and to give better treatment.

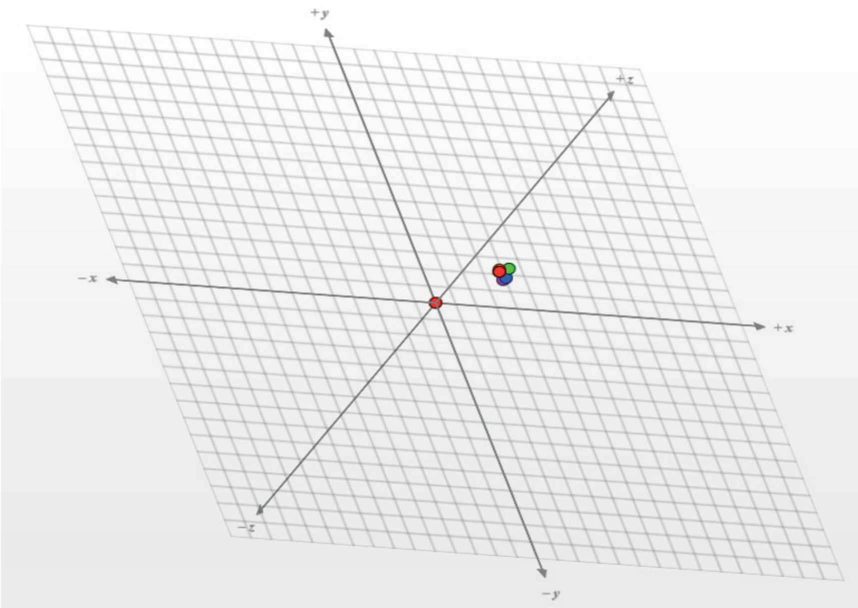

Figure 9. Probable Location of Target In Breast

CONCLUSIONS

Day to day sensor technology involvement is increasing in healthcare applications is increasing owing to its affordable cost in the market. Vendors provide advanced sensors with preinstallation and certifications according to user requirement. Tumor detection is a challenging task in medical science. Through this article, we claim that using sensor technology and localization techniques, it is possible to fix the location of the tumor in the breast. Periodic monitoring of breast health using this proposed framework, it is possible to fix abnormal lumps at the early stage. Early-stage detection of these abnormal lumps will help the people to attend the best treatment at premature stages of tumors and helps to increase their survival rates.

Future Work

While there are wide range of modalities available for the diagnosis of breast cancer, including breast self-examination, mammography, thermography, MRI, biopsy. In this work we proposed sensors to monitor breast lumps. Designing such sensors, which can sense the objects in three dimensional planes and embedding them in real-time wearable jackets is the future work.

Human and animal ethics

Designed wearable Tool is not yet applied on human beings or any animals.

For results discussion, synthetic dataset which is created using coordinate systems discussed in mathematics is considered.

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CONFLICT OF INTEREST
Authors declare that there is no conflict of interest.

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