Journal of Scientific Research and Development 3 (7): 59-64, 2016
Available online at www.jsrad.org
ISSN 1115-7569

Ultra wide-band imaging through human breast for domestic and reliable health screening system

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Abstract: Breast cancer is an abnormal cell locates in the breast tissue. Early detection plays an important role as it helps for long-term survival. The available systems are expensive and need expert to operate it. This paper presents a low-cost and user-friendly breast cancer detection system for end user at home. This system consisted of a pair of home-made antenna, Ultra wide-band (UWB) transceiver to receive signal and a Neural Network (NN) module for signal analysis. Transmitted UWB signals from one antenna were received by the other and saved in PC. Discrete Cosine Transform (DCT) was to use to convert the received analogue signal to discrete values integers 1632 points. Then through feature reduction only four points were achieved from 1632 point values, which were feded to NN module. The system's efficiency is tested on developed breast phantom before real clinical test. Breast phantom is placed in the center while two UWB antennas were placed diagonally opposite side of the breast phantom. K-fold cross validation based feed forward NN is used to train, validate and test the features. The system can screen the breast cancer with 100%, 82.62% and 90.69% using heterogeneous breast phantom and 100%, 89.06% and 83.96% using homogeneous breast phantom for existence, location and size respectively. The proposed breast cancer detection system will be very useful for home user to check breast health regularly.

Key words: Breast cancer detection; UWB; Feed forward back propagation; K-fold cross validation; Neural network

1. Introduction

Breast is consists of skin, fatty tissues, glandular tissue, lobules and duct (WHO, 2014). In human body, cells usually reproduce and replace the dead cells. When cells reproduce rapidly without control causes the abnormal growth and increase the number of cells. This causes the development of cancerous cells in breast tissue. A breast with lump at the beginning is usually only a benign tumor which is not harmful. However, if it grows, after certain duration it may press surrounding organ and causes pain. This may lead to the development of malignant tumors, which is cancerous and dangerous. In order to detect the cancer, many researchers have proposed breast cancer detection strategies (Breast, 2015).

Traditional methods like mammography, magnetic resonance imaging (MRI), ultrasound and so on are already available to be used in the clinic. However, these types of methods are expensive and have side-effect. At the same time, cannot be used at home for regular check-up and it needs trained doctor or expect the operator to operate. To overcome these shortcomings, a new method called microwave based imaging is proposed. Microwave UWB based imaging technology uses dielectric properties in order to distinguish cancerous and non-cancerous cell. Two approaches are available which are radar based imaging and microwave tomography (Baran et al., 2014). The UWB radar based imaging method is mostly used to detect breast cancer. UWB is a type of technology uses radio energy to transmit the information. UWB technology is widely used to detect breast cancer and popular among researchers. It is a low-power, high bandwidth and secure technology. Using this technology, UWB signal is transmitted and received. The received UWB signal contains the cancer signature and needs to process in order to detect the cancer. Various types of signal processing methods are available (Rakesh & Kshetrimayum, 2009).

Salleh et al. (2015) used Vector Network Analyzer (VNA) to detect the cancer. Backscattered signal is measured at frequency (1GHz to 10GHz). This research has proved that if the antenna position is closer to the tumor results, more signals is scattered. So, a tumor can be detected easily if the antenna is located close to the tumor. The signal is scattered more at 8.8 GHz (Salleh et al., 2015). Tiang et al. (2013) processed the received signal using VNA. Images are reconstructed using Delay and Sum (DAS) and enhanced version of the delay and sum (EDAS) algorithms. This algorithm can be used to detect the size of the cancer (Tiang et al., 2013). Ahmad et al. (2011) measured the size of the tumor

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by analyzing the transfer function of the received UWB pulse. Bode plots are used in order to determine the size of the detected tumor (Ahmad et al., 2011). Lai et al. (2011) first calibrated the received UWB pulse firstly uses subtraction method and average method. Received UWB pulses were then processed using real time oscilloscope. Image constructed using delay and sum beamforming algorithm. Using the subtraction method, a tumor can be detected more precisely rather than average method (Lai et al., 2011).

The above proposed methods like VNA and oscilloscope are only suitable for the clinic / hospital usage. This is because of the cost and manual operation of each system. To overcome this shortcoming, a user-friendly and low-cost breast cancer detection system is proposed in this paper. This enhanced system based on AlShehri et al. (2009) by making affordable and end user friendly to be used at home. Artificial neural network (ANN) is used to process the received UWB signal. K-fold cross validation is used to determine the efficiency of the proposed system.

2. Methodology

2.1. Overall system summary

Both hardware and software are used in order to detect the cancer in the breast. Hardware included a pair of home-made antenna and UWB transceiver. The software includes ANN module developed in Matlab, PC- hardware interface and full graphical user interface (GUI). Fig. 1 shows the overall system work flow to detect early breast tumor/cancer.

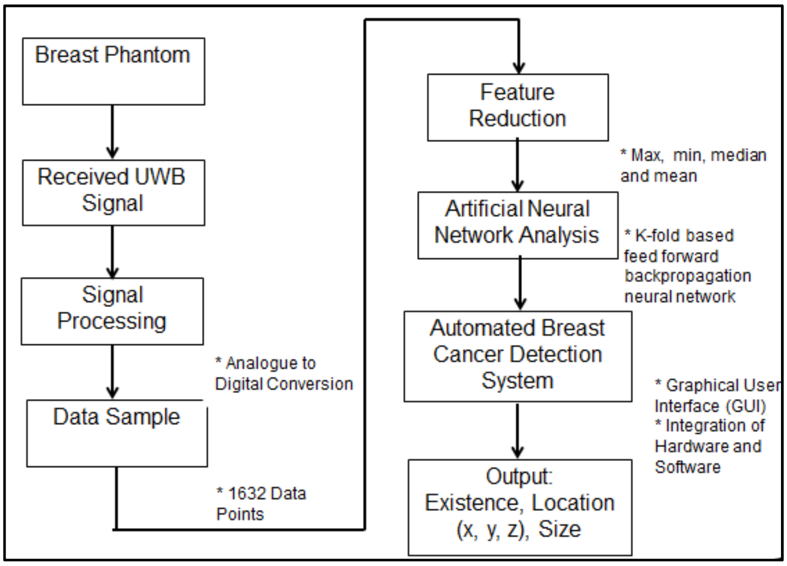


Fig. 1: Summary of Overall System

2.2. Breast phantom development

Two different breast phantoms which are homogeneous and heterogeneous were taken into account for this work. Homogeneous breast phantom is only a simple breast phantom which contains only skin and fatty tissues; whereas heterogeneous breast phantom is used to be more realistic and practical. Heterogeneous breast phantom contains skin, fatty tissue and glandular tissues. The preparation of the breast phantom is done as in (AlShehri et al., 2009, 2011, 2011a). Homogeneous breast phantom is developed using only petroleum jelly and heterogeneous breast phantom is developed using petroleum jelly, a mixture of water and flour and soy oil as shown on Fig. 2. Tumor is developed using the mixture of water and flour (55%) as shown in Fig. 3. Tumor is placed in the breast phantom in various locations. The size of tumor is varied. Fig. 4 shows the experimental set-up of this research. A pair of home-made antenna (biomedical pyramidal antenna) is placed diagonally opposite side of the breast phantom. One antenna transmitted the signal while another received the forward scattered signal. Transmitted signal and received signal for tumor size 2mm at location of 32.5mm, 62.5mm and 40mm for x, y, and z respectively as shown in Fig. 5. The received signal is different from transmitted signal because only forward scattered signal is captured. Since tumor size is small (2mm), most of transmitted signal is scattered forwards.

(a) Homogeneous Breast Phantom (b) Heterogeneous Breast Phantom

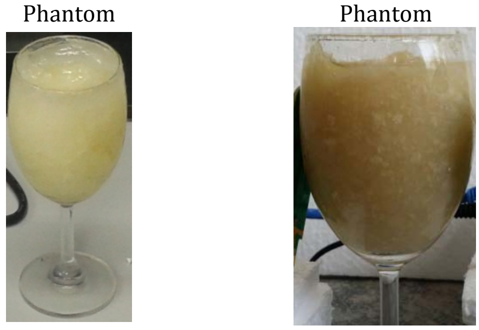


Fig. 2: Breast phantom

Fig. 3: 3mm tumor

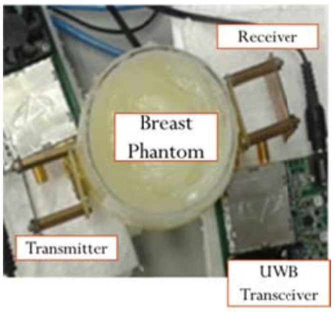


Fig. 4: Experimental set-up

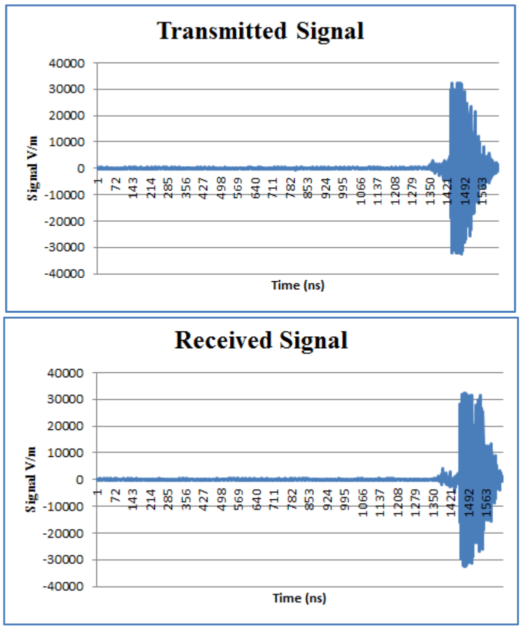


Fig. 5: Transmitted and received signal

2.3. Feature extraction

136 data samples were created after performing signal processing (analogue to digital conversion). Each data sample contains 1632 data points. Data sample with a large amount of data points will increase the processing time. After extracting the significant features and reducing the rest as necessary only four data points were kept (max, min, mean and median) from 1632 data points. 4 extracted values are maximum value, minimum value, median and mean. Mean and median are expressed as follows:

$$\mu = \frac{1}{N}\sum_{n=0}^{N-1}(X_n) \quad (1)$$

$$\sigma = \frac{1}{N}\sum_{n=0}^{N-1}(X_n - \mu)^2 \quad (2)$$

where μ is mean and σ is standard deviation. N is the total numbers of feature values and X_n is the input data points

2.4. Artificial neural network

The artificial neural network (ANN) is similar as the human brain. ANN is used to train the extracted features to detect the early breast cancer. The type of system can give approximate output with accuracy depending on how well training is performed. Fig. 6 shows the proposed ANN architecture used in this work which containing 4 input nodes, 2 hidden layer, 21 hidden neurons and 4 output nodes.

Four input node to fed the four features (max, min, mean and median) into the NN module. Training, validating and testing is performed using k-fold (5 fold) cross validation based feed forward back propagation NN where k=5. The data samples were divided into 2 groups.

Group (1): First data set contains 125 data samples (120 with tumor and 5 without tumor). These data samples were divided into 5 small subsets (fold) with 25 data samples in each.

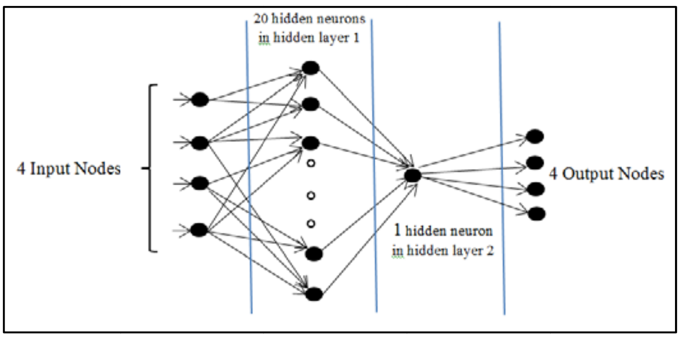


Fig. 6: ANN Architecture of Proposed System

These data sets used to train, validate and test the NN module. The data samples are divided for training and testing as shown in Table 1.

Group (2): Second data set contains 11 data samples (10 with tumor and 1 without tumor). These samples were used to perform real time testing to ensure the detection efficiency.

Table 1: Training and testing sets

K-	Training				Testing
1	1	2	3	4	5
2	1	2	3	5	4
3	1	2	4	5	3
4	1	3	4	5	2
5	2	3	4	5	1

Same problems like over fitting are rising during the training. Over fitting happened when NN start to memorize the training sample. This problem can be overcome by either reducing the number of neurons or changing the number of data sets (adding or reducing the data samples). Training of the NN is repeated until optimize performance is obtained and the real time testing gives the best result; NN parameters used in this paper as shown in Table 2.

2.5. Mean square error

Real time testing was done with testing data set to ensure the proposed breast cancer detection system's efficiency using data samples in Group (2). The smallest tumor used here is 2mm (diameter). This is to ensure the system can be used to detect breast cancer at a very early stage at home. The performance is described in terms of mean square error (MSE) which is expressed as follow:

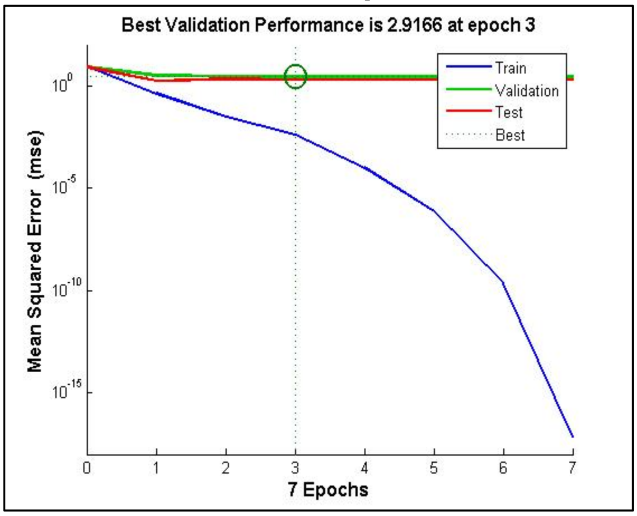
$$MSE = \frac{1}{j}\sum j\,(t_j - y_j)^2 \quad (3)$$

where j is number of input, t is actual target, and y is NN output. The training performance, validation performance, and regression curves are as shown in Fig. 7. The best validation performance is shown in Fig. 7 (a) for MSE value of 2.9166. 7 epoch is used since the data points are small.

Table 2: NN parameters used in Matlab

NN parameters used in MATLAB	NN parameters
Number of nodes in Input layer	4
Number of nodes in Hidden layer	21
Number of nodes in Output layer	4
Transfer function	tansig
Training function	traingdm
Learning rate	0.009
Momentum constant	0.6
Maximum number of Epochs	100000
Minimum performance gradient	1e-25

Performance plot



Regression plot

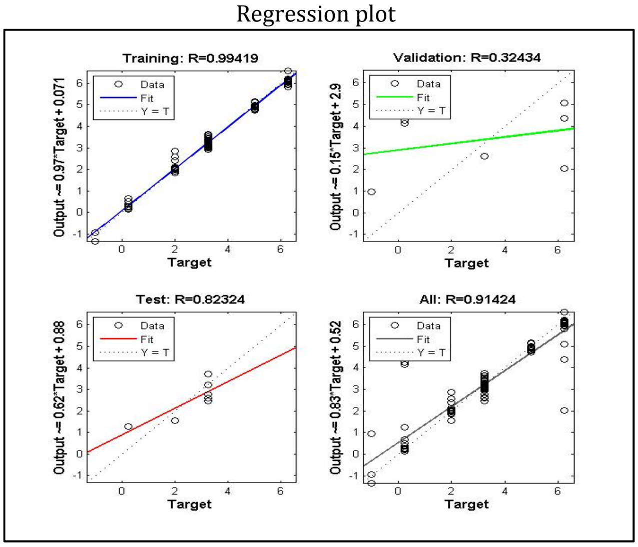


Fig. 7: Performance and Regression Plot

3. Results and discussion

Table 3 shows the output of the real time testing for homogeneous and heterogeneous phantoms. Negative value indicates the absence of the tumor while positive value indicates tumor presence. The proposed system is able to detect the breast cancer/tumor with 100%, 82.62% and 90.69% using heterogeneous breast phantom and 100%, 89.06% and 83.96% respectively using homogenous breast phantom for existence, location and size respectively.

Table 4 shows the comparison between the average detection accuracy for homogenous and heterogeneous breast phantom. Based on the Table 4 and Fig. 8, tumor can be detected more precisely using homogenous breast phantom (90.23%) compared to heterogeneous breast phantom (87.72%) which is as expected. But, the detection of tumor using heterogeneous breast phantom is not as easy as detecting in homogenous breast phantom because of its complex structure. Moreover, real human breast is glandular (heterogeneous) in nature. Hence, need to consider the heterogeneous one instead of homogeneous. Here, the results proved that the system is able to detect tumor with 87.72% accuracy. This system can be used to real patient for clinical testing in near future.

The detected breast cancer can be visualized in 2D and 3D environment through the GUI as shown in Fig. 9. This is to help non-trained end-user to check/screen their breast health at home without any difficulties. They may refer to medical doctor quickly if any abnormality (tumor) is detected for further treatment.

4. Conclusion

An UWB and NN based user friendly system performance is validated here for early breast health check-up and tumor detection (if any). The system is low-cost and works efficiently showing its usefulness practically. It is targeted for home users for their regular breast health check-up. This system may contribute to a knowledge women community followed by faster treatment process (from early detection to removal and survival) to save many precious human life in near future. The proposed system can be tested on real patients in order to justify its usability.

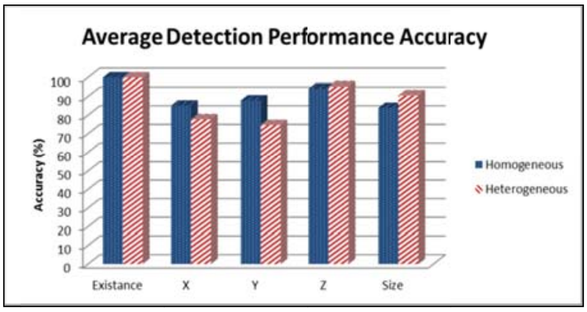


Fig. 8: Graph of average detection performance accuracy

Table 3: Detection performance accuracy

	Actual Target (mm)				NN output (mm)				Detection Performance Accuracy (%)			
	X	Y	Z	Size	X	Y	Z	Size	X	Y	Z	Size
HOMOGENEOUS	-1	-1	-1	-1	-1.12	-0.79	-0.99	-1	100	100	100	100
	32.5	20	50	2	14.37	21.21	52.24	20.1	44	94.3	96.71	99.5
	32.5	62.5	40	2	32.50	49.23	39.88	71.91	100	78.77	99.73	27.08
	32.5	2.5	30	3	32.67	2.64	12.75	28.59	99.69	94.7	42.5	98.04
	62.5	32.5	30	3	63.42	21.53	30.01	30.37	98.58	66.28	99.97	98.78
	2.5	32.5	40	4	49.02	43.49	40	68.18	5.87	74.73	100	58.67
	32.5	2.5	40	4	32.55	2.98	39.92	39.90	99.88	83.89	99.8	99.75
	32.5	32.5	40	5	32.62	32.58	40.03	45	99.63	99.75	99.93	90
	62.5	32.5	30	5	62.52	33.71	30.17	90.42	99.97	96.41	99.44	55.3
	32.5	50	30	6	32.55	50.48	29.96	58.49	99.85	99.05	99.87	97.48
	50	32.5	50	6	49.91	32.43	49.16	59.50	99.82	99.75	98.32	99.17
	Actual Target (mm)				NN output (mm)				Detection Performance Accuracy (%)			
	X	Y	Z	Size	X	Y	Z	Size	X	Y	Z	Size
HETEROGENEOUS	-1	-1	-1	-1	-0.95	-0.98	-0.89	-1	100	100	100	100
	32.5	20	50	2	25.6	15.3	50	1.5	78.77	76.5	100	75
	32.5	62.5	40	2	29.53	70.5	46.2	2	90.86	88.65	86.58	100
	32.5	2.5	30	3	47.06	25.65	31.23	2.6	69.06	23.15	96.06	86.67
	62.5	32.5	30	3	58.6	45.3	25.34	3.1	93.76	71.74	84.47	96.77
	2.5	32.5	40	4	28.3	39.53	41.25	3.6	25.8	82.21	96.97	90
	32.5	2.5	40	4	37.5	10.25	40.2	5.6	86.67	24.39	99.5	71.43
	32.5	32.5	40	5	25.1	25.53	35.69	5.3	77.23	78.55	89.23	94.34
	62.5	32.5	30	5	45.8	31.25	29.56	4.5	73.28	96.15	98.53	960
	32.5	50	30	6	25.67	46	30.93	5.7	78.98	90	96.99	95
	50	32.5	50	6	61.2	35.67	49.97	5.9	81.7	91.11	99.94	98.33

Table 4: Average detection performance accuracy

	Performance Accuracy %					Average Detection Accuracy
	Existence	Location			Size	
		x	y	z		
Homogeneous	100	85.17	87.89	94.11	83.96	90.23%
Heterogeneous	100	77.83	74.77	95.29	90.69	87.72%

This system can help user for regular breast health check-up at home. Type of tumor (benign or malignant) detection is still under investigation.

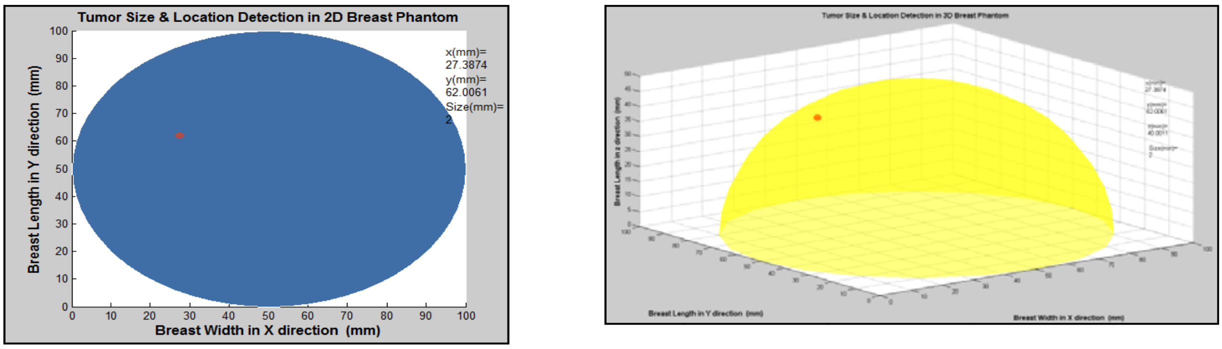


Fig. 9: 2D and3D environment

Acknowledgment

This work is supported by Ministry of Higher Education, Malaysia, Grant FRGS – 9003-00418.

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