

Automatic Mass Detection in Ultrasound Breast Images Using Computer Assisted Detection

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Abstract — *This work is concentrated on extraction of mass in Ultrasound breast images in to help doctors interpreting such images efficiently using Computer-Aided Detection. A set of six popular ultrasound machines were selected and images were acquired sweeping: modes of operation, transducer, frequency and contrast. To make a complete set of ultrasound images in B-Mode a multi purpose multi tissue Ultrasound Phantom was used. Gamma corrections, contrast stretching and filtering accompanied by morphological Image Processing were among the steps that were applied to find the final image. Two experienced radiologists were marked output. Statistical analysis showed a sensitivity of 100% and accuracy of 99% for solid mass and 99% and 98% for cystic mass respectively. It also showed that the same procedure can be use for cystic and solid breast masses with small change.*

Keywords — Computer Aided Detection, Ultrasound, Medical Image Processing, Breast Cancer, Ultrasound Phantom

I. INTRODUCTION

A group of rapidly dividing cells may form a lump or mass of extra tissues. These masses are called tumours. Tumours can either be cancerous (malignant) or non-cancerous (benign). Malignant tumours penetrate and destroy healthy body tissues. A group of cells within a tumour may also break away and spread to other parts of the body. The cells that spread from one region of the body into another are called metastases. The term breast cancer refers to a malignant tumour that has developed from the cells in the breast[1, 2]. Breast cancer is the second leading cause of death for women all over the world. Since the cause of the disease remains unknown, early detection and diagnosis is the key for breast cancer control, and it can increase the success of treatment, save lives and reduce cost.[3]

Breast cancer screening can be found as the evaluation of a population of women without symptoms, who have no signs of breast cancer, in an effort to detect the disease earlier in its growth. It is hinted that the cure is still possible when it detected in early stage. One of the primary reasons for screening of the breast is to scan for cancer. The most important feature of breast imaging is to prevent the premature and often prolonged, painful death of the individual.[4]

In general, pathologists classify breast lesions according to the microscopic architecture and cytologic features of the cells that compose the lesions. Breast lesions divided into two groups: Cystic lesions and Solid lesions. Breast cysts are accumulations of fluid in the breast. Cysts are non-cancerous and they typically present in the form of smooth, rounded lumps. Although they appear deep within the breast tissues, cysts are often moveable within the breast. Cysts are usually

confirmed with mammography and ultrasound (sonogram). In particular, ultrasound is excellent at quickly identifying whether a breast abnormality is in fact a cyst or a solid

mass.[5] Cysts are often differentiated by size and number. Sonographically, the simple cyst has the following characteristics: round or oval shape, anechoic, smooth and well-defined borders, posterior acoustic enhancement, a signal which will depend on the characteristics of the cyst (size and type), the glandular tissues, and the incidence angle of the ultrasound beam and lateral acoustic shadow.

One of the most frequently used diagnosis tools to detect and classify abnormalities of the breast is Ultrasound. As a second procedure after popular breast screening method such as Mammography, it may be suggested to patient's for following up's history of seen masses. Almost it's the best way of looking into lesions in heavy dense breast tissues. In addition, there are some advantages over other modalities. From instrument cost view, an ultrasound machine is a lot less expensive than other modalities instruments.

II. LITERATURE SURVEY

A physician is the person who acquired and examined medical images [6]. The purpose of image enhancement method is to process an acquired image for a better contrast and a visibility of the features of interest for visual examination, as well as for subsequent computer-aided analysis and diagnosis. The importance of image processing and computer graphics in medicine was shown in some researches [7]. For basic techniques in image analysis, they insisted on resolution

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conversion and digital signal processing, distance transform and shape processing, and data-driven image processing. A Fast Histogram Equalization for Medical Image Enhancement was presented [8]. A survey was done to review on the status of breast ultrasound among different imaging modalities [9]. Here are the summaries of this review: The well-defined breast anatomy with high frequency probes was achieved. The category of benign and malignant breast lesion was typically defined. It is also the most suitable modality in pregnancy and lactation. It is a complementary imaging technique to mammography, magnetic resonance and nuclear medicine. Based on this works, the importance of breast ultrasound among other breast imaging modalities was stated.

The role of ultrasound in detecting intraductal spread of breast cancer in comparison to mammography and magnetic resonance was assessed [10]. Based on this finding, it was concluded that ultrasound had a tendency to underestimate intraductal component of comedo type as compared to mammography and MRI. The importance of ultrasound in detecting breast disease was also explained in some research [11]. Based on these reviews, the use of ultrasound was indicated for any mammographically detected or clinically palpable mass. There are also some works on the automated segmentation of the breast lesions in ultrasound images [12]. It is worth highlighting that their limitations in doing segmentation came from the prior knowledge that the lesions tended to be located around the centre of images. For this reason, they just located the mass in the centre of the image and if the mass was shifted from centre, their algorithm could not apply. Previous studies shown that our proposed routine can enhance ultrasound images [13, 14]. It also can optimized processing times while extracting cystic masses [15].

III. PROCESSING REQUIREMENTS

A. Ultrasound Machines

This work includes six most popular ultrasound machines from different manufacturer. Each machine has its own image features and benefits. The following criteria were concentrated on each machine: frequency, contrast, transducers and modes of operation on machines. A set of images captured and categorized based on machine settings. There are four modes of operations, three types of transducers, four distinct frequencies and five separate contrast levels. The most common form of ultrasound imaging is B-mode ultrasound (Brightness-mode) that is the display of a 2D-map of B-mode data. In B-mode ultrasound, a linear array of transducers simultaneously scans a plane through the body that can be viewed as a two-dimensional image on screen. This mode commonly used by radiologists for breast screening.

Each ultrasound machine equipped with a set of transducers that are applicable to various fields of screening. As linear probes are applicable for breast imaging only these probes were tested. There are two or three types of linear probes based on the frequency range and level of beam penetration.

These linear probes covered frequency range. These are low frequency, medium frequency and high frequency probes. Contrast, as another factor, is rarely named directly in ultrasound machines. To have a complete set of the images, the steps for contrast or dynamic range were changed based on the modes of operation. Any change in this parameter can affect visibility (resolution).

B. Ultrasound Phantom

To improve the interpretation of the results, a multi-purpose multi-tissue ultrasound phantom was used to capture all the combinations of the possible functions in B-Mode. It contains dense and cystic masses in a range of sizes, one high-density target, and an assortment of nylon monofilament target groups. This was specifically formed to allow for assessments of linearity, depth calibration, axial and lateral resolution, dead-zone measurement, and registration within two different backgrounds [16].

As shown in Fig. 1, all these specifications and measurements can be used to calibrate an ultrasound machine. In our study, however, a fixed and calibrated machine was utilized to get the different shots.

For all machines, images were captured in all available modes of operations but Basic or Fundamental mode was selected as image sources of this study. Enhanced modes images of these machines were used for improving Basic mode images. Image set for this study contains 3400 ultrasound images covering above criteria. Although Digital Imaging and Communications in Medicine (DICOM) is a default format for output files, but other popular image file formats such as Joint Photographic Experts Group (JPG) can be used as input file format. Standardization of start point for pre-processing is one of the goals of this research. In this way all captured images were analysed and preset to a default level.

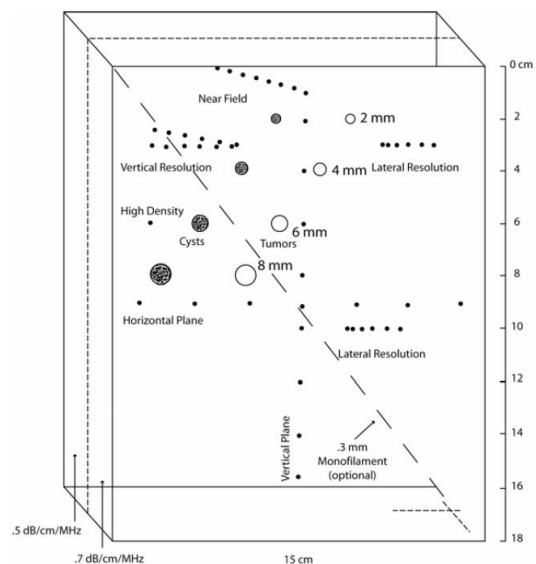


Figure 1. Ultrasound Phantom.

Referring Fig. 1 for ultrasound phantom, two sets of masses were prepared with different specifications: Cystic (black) and Solid or tumors (white). Our proposed routine can run for both by adding steps to the Cystic mass procedure in order to extract tumors also. To certify the similarities of these masses in ultrasound phantom images, a set of captured images for a variety of settings in case of Cysts and Solids were selected and analyzed. Results showed that except for the mass itself all other properties of the captured images with same settings would be same. As Cystic masses are black and Solid ones are white adding a simple image complement in the preprocessing section can provide the required input image for following stages.

IV. METHODOLOGY

A region of interest (ROI) in background was selected and its statistical specifications were collected and saved in a table. For each unidentified input image ROI was selected with same datum and specifications were acquired as sample images. Comparing each image with the best one, which is marked by experienced radiologists, was produced a table of difference for each machine setting. For an input ultrasound image, ROI must be selected, and its specification should be compared with data stored in table. Then the actual machine setting for this image was found from table. These data then applied to original image and Mean Square Error (MSE) was used to maximize their similarities. MATLAB image processing tool box and applied factors such as Signal to Noise Ratio (SNR), Peak Signal to Noise Ratio (PSNR) and MSE parameter were used to check the output image. As this work focused on B-Mode Ultrasound a 24 bit map was selected for each pixel.

A. Pre-processing

Second stage is Histogram equalization that is a widely used technique for image enhancement [8]. Then Median filters applied because of its popularity and its performance in excellent noise-reduction for certain types of random noise, with considerably less blurring than the linear smoothing filters of similar size [17]. This step can improve the contrast level of the input images. Contrast enhancement is one of the most important problems in both digital and analogue image processing [11].

An image is a discrete signal (digitized). As a discrete signal, digital filters may be used to reshape the spectrum of the input signal in order to produce the spectral characteristics desired in the output signal [18]. There are two types of such filters; the Finite-duration Impulse Response filter (FIR) and the Infinite-duration Impulse Response filter (IIR). As the low pass and high pass filters are used in sequence, carrying out the work using a band pass filter seemed to be a good idea. It would be straight forward and done in one step. Then a band pass filter was applied to continue the current work. In the context of this study, the FIR filter was used. There are

different types of Band Pass FIR filters but for this study window filters were selected.

For each ultrasound image, a set of coefficients that should be put on the corresponding filter was found to produce the best output at this stage. A lookup table (LUT) was then provided for all the images. This LUT was programmed in the subsequent process. Thus, for the real scene, the assigned data are found and then referred to LUT to find all the corresponding setup data needed for it.

The final stage is Segmentation which is the partitioning of an image into meaningful regions. [16] Thresholding methods, such as global thresholding, multiple thresholding, variable thresholding and multivariable thresholding were among the popular methods. As user interaction is not interested in this part, some MATLAB functions are used based on the recent methods; these are mixed to automatically find the threshold level [19].

To Smooth and fill holes and avoid near boundary pixels, some sort of Mathematics known as mathematical morphology is needed. [18] The basic binary morphological operations can be extended to use with greyscale images; the results of such operations are greyscale images. As in the case of the current study, the basic operations were combined to enhance the images. All these combinations were based on the set theory, whereby the images were assumed as the selected set of data.

B. Receiver Operating Characteristic (ROC)

A Receiver Operating Characteristic analysis was done as a part of evaluation of proposed study using MedCalc Ver. 12. A set of 548 input images in Basic mode was used as base input of statistical test. As a classification parameter was needed two experienced radiologists evaluated output images and their marks were considered as classification variable for ROC.

V. RESULTS AND DISCUSSION

The Low Frequency Probe (LFP) and High Frequency Probe (HFP) results were compared for both cysts and solids. Table I shows that the differences between cystic and solid mass data are rather negligible, so adding an image complement can provide required input file.

The maximum number of masses was detected in the lowest frequency range as shown in Fig. 2. All the detected masses have round shape and clear border as defined earlier for solid and cyst mass characteristics. This procedure can also be used for abnormal mass extraction. As stated before, this routine can extract cystic masses whose results also showed in Fig. 2. In part (a) black masses are cystic and white ones are solids or tumors that are complemented in (b) to be entered to proposed routine for mass detection.

TABLE I MASS COMPARISON TABLE

	Mass Type	
	Cyst	Solid
Min	37	40
Max	207	198
Average	87.21	85.91
edian	86	85
STD	0.0657	0.0665
Mode	0.3176	0.3215
SNR	20.622	19.62

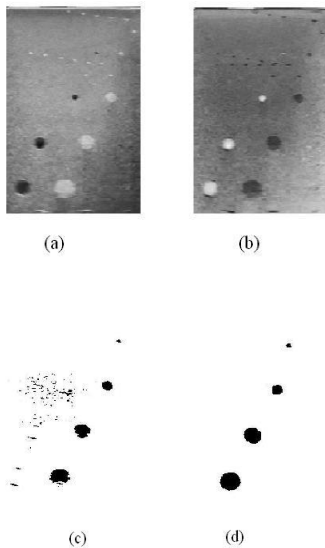
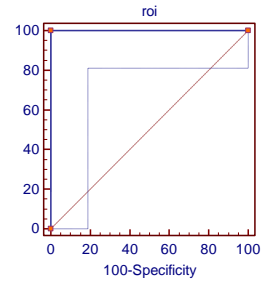


Figure 2. Ultrasound Phantom images (a) Solid (b) Complemented (c) Filtering and thresholding (d) Morphological imaging.

A Receiver Operating Curve analysis results were shown in Fig. 3 and Fig. 5 using MedCalc Ver. 12. Two experienced radiologists marked output images and their marks were considered as classification parameter (review). Resulting ROC is shown in Fig. 3. A sensitivity of 100% and an accuracy of 99% showed that accuracy of proposed work is quite acceptable for solid mass. These values for cystic mass are 100% and 98% respectively as shown in Fig. 5.



Variable	solid	
Classification variable	review	
Area under the ROC curve (AUC)	0.989	
Sensitivity	100.00	Specificity
		98.61

Figure 3. ROC analysis results (a) ROC, (b) ROC data

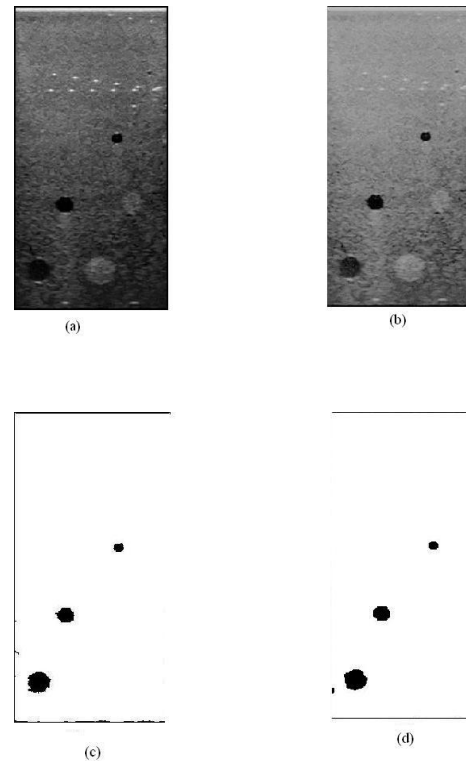
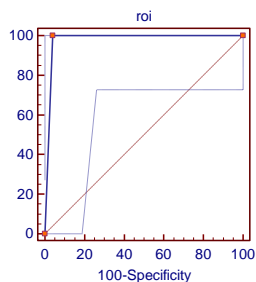


Figure 4. Ultrasound Phantom images (a) Cyst (b) Contrast enhancement (c) Filtering and thresholding (d) Morphological imaging



Variable			cyst
Classification variable			review
Area under the ROC curve (AUC)			0.979
Sensitivity	100.00	Specificity	97.83

Figure 5. ROC analysis results (a) ROC , (b) ROC data.

VI. CONCLUSION

Using phantom images for interpretation of ultrasound images is a goal of this work. Results obtained in previous section showed our routine can detect solid and cystic masses in ultrasound images. Comparing results of this work with radiologist idea about type of observed masses showed a good performance for proposed routine. This work can be applied for other body parts such as abdomen with small changes in specifications of desired masses.

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