Digital Mammography: A Review on Detection of Breast Cancer

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Abstract: This paper is a survey of Digital image processing techniques that play a vital role in assisting the biopsies. The mammogram images are stored digitally and several image enhancement techniques are applied to get enhanced images. These enhanced images are segmented to obtain the ROI from which the features are extracted. On the extracted features the acceptance/rejection criteria are applied to determine whether the tumor is benign or malignant. The results of all the techniques mentioned here are studied and analyzed.

Key Words: Breast cancer, Digital mammography, Image pre-processing, Image segmentation, Feature Extraction, Classification.

1. INTRODUCTION

Breast cancer has become the second most common cause of death, especially for women of the age from 40 to 55. A survey by American Society of Cancer has revealed that by 2012, the death rate due to breast cancer has reached around 40,000 per year in America and 450,000 per year across the world. Since the causes of the disease are completely unknown, it's highly impossible to prevent it or take precautions for it. But an early detection of the disease may help to increase the chances/rate of survival.
Proceeding in this way, the Digital Mammography has proved itself as the best technique for early detection of breast cancer with a better performance than screen film mammography. The image processing techniques like pre-processing, segmentation, feature-extraction and classifications are used in Digital Mammography that provides clear mammogram images, which helps the radiologists to give the most accurate second opinion.

Breast cancer is an abnormal, un-controlled growth of breast cells where the cells get divided un-conditionally giving rise to tumor (mass). The tumor developed this way can be either Benign or Malignant. The Benign tumors are not cancerous. They just grow larger but do not spread to other parts of the body. Hence they do not cause much harm to the person. But malignant tumors are considered as cancerous. They grow larger and spread to other parts of body. Hence they are treated as very dangerous to the person, in whom they are found. Breast cancer is not a disease of today or yesterday. It's a disease causing death from 1600 BC. Since then researches are going on to avoid the deadliest outcomes of the disease. But still the researches have not got any fruitful result [1]. The main reason for these failures is the lack of knowledge regarding the causes of the disease. The reasons are completely un-known till today. Hence it's very difficult to get the precautions too. Although the disease cannot be avoided but the outcomes of the disease can be controlled by early detection of the breast cancer. Thereby the most deadly outcome of the disease (death) can be avoided.

A mammography exam called Mammogram plays a key role in early detection and diagnosis of breast cancer. This helps to increase the chances of successful treatment, since detected in its early stage. There are two ways to carry out the mammography exam. One is Screen film based mammogram and the other one is Digital mammogram. Both the ways are widely used by the radiologists to detect the breast cancer. But the Screen film based mammogram has got some drawbacks, like it suffers from the obscuring effect of over-lapping breast tissues due to the projection of 3-Dimansiional object onto a 2-Dimansional image [2]. Because of this the radiologists will not be in a position to give exact opinion about the existence of the cancerous tumor. Most of the time an asymptomatic woman gets false positive result and symptomatic woman gets false negative result. Since both of these false positive and false negative results are harmful, there exists a need for the accurate result from the radiologists.
Hence now-a-days in most of the hospitals the Screen film based mammography is being replaced with Digital mammography. In Digital mammography the breast image is captured using a special electronic X-ray detector, which converts the image into a digital mammogram for viewing on a computer monitor and also for storing as shown in figure 1 [3].
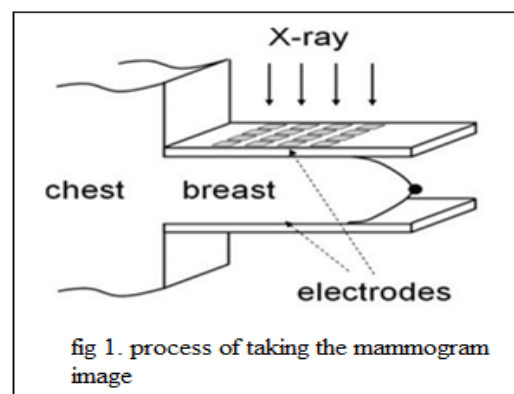

fig 1. process of taking the mammogram image

The main advantage of Digital mammography is the storage of mammogram images digitally and thereby reducing the no of patient biopsies. The image enhancement techniques applied to the digitally stored images helps to get clearer and contrast enhanced images which majorly helps the radiologists more than screen film mammography in diagnosing the patients.

In Digital mammography four important image processing techniques are used which all together helps the radiologists to give accurate results of the diagnosis. The techniques used are- preprocessing, segmentation, feature extraction and classification. In this paper all these techniques are discussed by taking different methods for each of them. The block diagram in figure 2 represents the flow of the process.

fig 2. Block diagram representing digital mammography steps
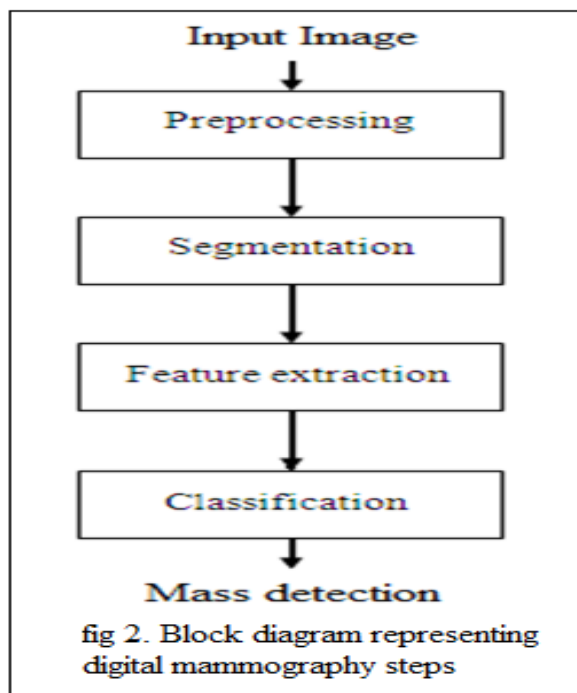
The final output will be the mass detected as either benign or malignant tumor.

2. METHODOLOGY

The fallowing discussion covers the methods used in digital mammography. All the methods are focusing on the early detection of breast cancer with a reduced false rates and increased performance.

1. Preprocessing of Digital Mammograms:

The process begins by obtaining the digital mammogram images at different quantization and sampling rates [4]. De-noising techniques are applied to remove the noise from the images and then contrast enhancement techniques are applied to enhance the mammogram images. At this level, several approaches have been adopted like wavelet transform, multi-resolution analysis, region growing techniques…etc. The following part highlights the different mammogram image de-noising and enhancement approaches.

A. Mammogram image De-noising using wavelet multi-resolution technique.

It has been revealed that, at the time of taking the breast images using X-rays, the radiation exposure caused by mammography exam can induce the development of breast cancer in some women undergoing the test [5,6]. One solution to this problem is the use of reduced radiation doses. But, the use of such reduced doses of radiations increases the quantum noise in the mammogram images due to the use of low photon count for the image formation process. The presence of such quantum noise reduces the visibility of subtle lesions in the mammograms [7].

To deal with this problem, new approach has been presented, using wavelet multi-resolution image analysis [8]. In this approach the mammogram images are obtained at different radiation dose levels: 100%, 85%, 70% and 50% of the standard dose. On these images the multi-resolution technique is applied. The steps are: i. Decompose the input signal with forward wavelet transform. ii. Apply a thresholding method to the vertical, horizontal and diagonal coefficients. iii. Apply the wavelet inverse transform in order to reconstruct the signal. The co-efficient shrinkage [9] in wavelet domain is used with the multi-resolution technique to de-noise the images.
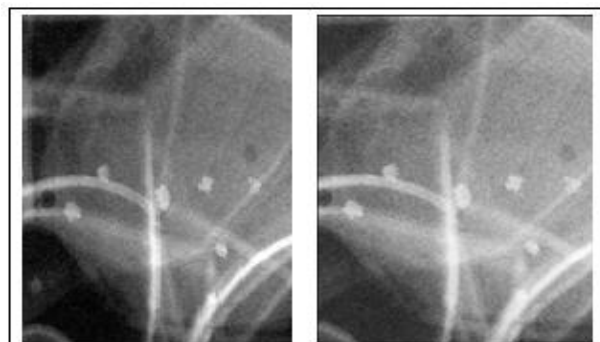

fig 3. result of applying multi-resolution technique to de-noise the mammogram image
original image(left) and de-noised image(right)

The image quality metrics like PSNR and MSSIM are compared both before and after applying the technique. The comparison of the metrics revealed that the quality of mammogram images acquired with lower radiation doses were preserved as that obtained with standard doses. And also the quantum noise was removed completely.

This work helped in a way to reduce the harmful effects of using the strong radiation doses just for the detection of the breast cancer. Once the noise is removed from the images the next step is to enhance the contrast of the mammogram images.

B. Image enhancement using Adaptive region growing technique.

An approach for the image enhancement has been proposed by using Adaptive region growing technique [10]. The whole algorithm in this approach is split into 4 major steps: i. Selection of the seed point from the image to be enhanced. ii. Based on the selected seed point, dividing the image into foreground and background region. iii.

Foreground region is enhanced using adaptive histogram equalization and then the background region is added to the enhanced foreground region. iv. Finally, the enhanced image is obtained by adding gradient of original image to the image obtained in the step iii.
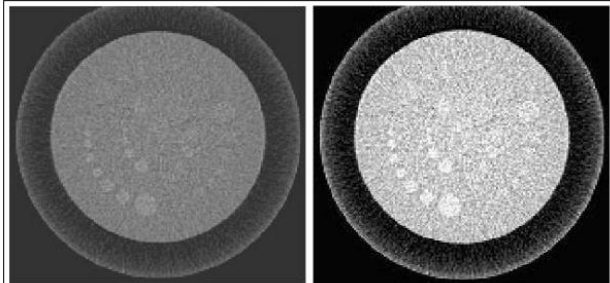

fig 4. result of applying adaptive region growing technique to enhance the images
original image(left) and enhanced image(right)

On comparing this approach with the other existing Image enhancement approaches, the region growing technique has come up with the best result as illustrated in the figure 4. The same process when applied on the mammogram images, it will result in highly enhanced mammogram images.

C. Mammogram image enhancement using dyadic wavelet transforms technique.

In this approach, dyadic wavelet transform is applied on the mammogram images to enhance the visibility of masses and micro-calcifications [11]. Wavelet analysis permits the decomposition of image at different levels of resolution. Mammogram images are decomposed up to 10 levels by applying dyadic wavelet transform with a decimation factor 2. The original 1024x1024 grayscale digital mammogram image decomposed to 10 levels by applying Daubechies4 wavelet transform. Finally the lowest approximation image S10 is of single pixel width. Since micro calcification appears as high frequency behavior in mammogram, the enhancement is achieved by setting the value of S10 as zero.
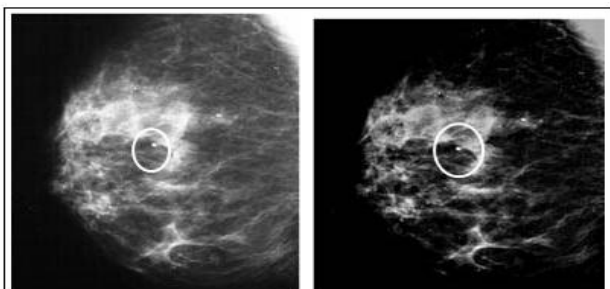

fig 5. result of applying dyadic wavelet transform technique to enhance hte image
original image(left) and enhanced image(right)

As shown in the figure 5, the visibility of masses and micro-calcifications in the enhanced image are clearer than the original image. Usually it's not easy to enhance the micro-calcification regions since the surrounding dense breast tissue makes the abnormality areas most invisible. But this dyadic wavelet transform makes it easy to enhance the micro-calcification regions too.

D. Mammogram image enhancement using wavelet based thresholding technique.

In this approach, the mammogram images are enhanced using wavelet based thresholding, where the thresholding is applied to the multi-scale products to compute the detail components. Applying this method reduces the insignificant features and increases the significant features in the mammogram images. Applying inverse wavelet transform at last provides a fine quality image which is more suitable for efficient diagnosis. Micro-calcification appears as nodular high frequency region is greatly enhanced compared to other breast areas.
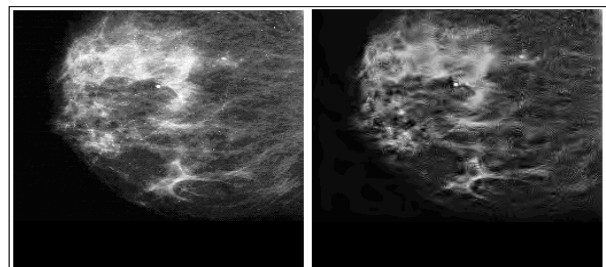

fig 6. result of applying wavelet based thresholding to enhance the mammogram images
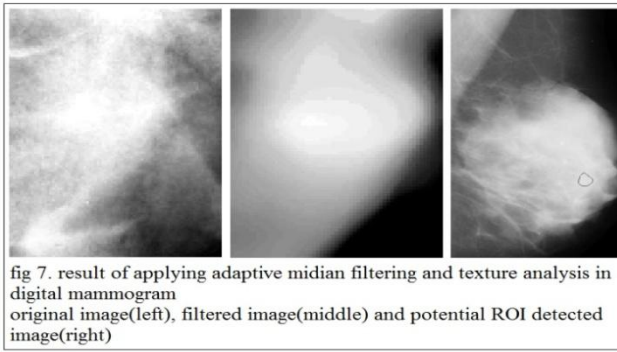original image(left) and enhanced image(right)

2. Segmentation of Digital Mammograms:

Segmentation is the process of dividing the image into its constituent parts or objects from which the regions of interest are selected. It is the second main stage of Digital mammography, in which the suspicious regions that may contain the masses are separated from the background parenchyma tissue [14]. The separation done in this way divides the mammogram image into several non-overlapping regions from which the Region of Interest (ROI) are extracted. From the selected ROI the suspicious mass candidates are located. Usually the brightness of the suspicious areas is higher than its surroundings and also they almost have uniform density, regular shape with varying size and fuzzy boundaries [14].

Since the mass characteristics vary from one image to the other image, the segmentation of masses is a complex process. The following discussion covers some of the approaches for the mammogram image segmentation. The approaches include digital image processing techniques like median filtering, texture analysis, nearest neighboring algorithm…etc.

A. Segmentation of breast masses in Digital mammograms using Adaptive median filtering and texture analysis.

In this approach, adaptive median filtering and texture analysis are used to divide the mammogram image into multiple segments in order to identify the Region of Interest (ROI) consisting of potential masses [13]. There are three steps involved in this approach: i. Small neighborhood removal - the test images after preprocessing consists of some small neighborhood pixels that create negative impact on the segmentation. Since these neighborhoods are not bright enough to be considered as potential masses, they must be removed first.

fig 7. result of applying adaptive midian filtering and texture analysis in digital mammogram
original image(left), filtered image(middle) and potential ROI detected image(right)

ii. Applying Adaptive Median Filtering – this makes gradual changes in the intensity skew for expounding the borders of any possible masses and clarifies the edges. Hence the boundaries of any object existing in the image are turned into fine, crisp straight lines that can be isolated directly later. iii. Border selection – the filtered image consist many closed curves encircling each other. These curves are the edges and boundaries highlighted by the filtering process. The last step of segmentation is to select one of these curves, such that the curve has to be the edge of potential mass region. The selection of such curve starts from innermost curve and moves towards the outermost curve. When the region enclosed by one of the curves has a proper texture and geometric feature, then that region is considered as the potential ROI.

B. Segmentation of Digital mammograms using supervised and Un-supervised methods.

In this method, the segmentation is performed on digital mammogram images using supervised and Un-supervised methods [15]. The labels of the data and their use during the training are used as distinguishing factors for these methods. The supervised method such as k-nearest neighbor (k-nn) algorithm [16] uses physical labels of tissue classes as selected by an operator from regions within the image prior to segmentation. These training pixels are then used to classify the remaining un-labeled text pixels. Un-supervised method such as Fuzzy c-means algorithm [17] relies on the human to label each tissue class appropriately once the algorithm has clustered all the pixels in the image into c-homogeneous regions.

In both supervised and un-supervised methods the intensity is used as the discriminating feature. These methods are able to significantly reduce the no of mis-labeled pixels with respect to certain regions within the image. These methods have also shown that the segmentation of digital mammograms (using these methods) will have higher ROI detection rate.

C. Segmentation of breast images using vector quantization technique.

In this approach Linde Buzo and Gray (LBG) was used for segmentation of mammographic images [18]. Initially a codebook of size 128 was generated for mammographic images. These code vectors were further clustered in 8 clusters using same LBG algorithm. These 8 images were displayed as a result. This approach does not lead to over segmentation or under segmentation. For the comparison purpose displayed results of GLCM and watershed

segmentation were used along with this method. Segmentation should be stopped when the regions of interest in an application have been isolated. Segmentation distinguishes objects from background.

3. Feature Extraction of Digital Mammograms:

It is an important step in the image processing technique that deals with extracting the image features that best describe quantitatively or qualitatively the objects in the image. It's a high level procedure in which shapes and structures of objects are described analytically. In comparison with the image processing technique while performing the digital mammography, the features of ROI obtained during the segmentation are extracted. The fallowing discussion covers some of the approaches for the feature extraction from digital mammograms.

A. Feature Extraction by calculating the Roughness value.

In this work, a mammogram image is used for the breast cancer detection. The roughness of each and every pixel is calculated [19]. The use of fractal analysis reduces the search region. If the roughness value calculated for a region lies between 2 to 3, then the region is considered to be having a potential mass. All the other sub-blocks with roughness value less than 2 or greater than 3 have to be discarded since they are not considered as masses. The various features selected in this approach to locate the regions that are suspicious of tumors are: area of the surface, compactness, mean gradient within current region, mean gradient of region boundary, gray value variance.

B. Feature extraction by Wavelet decomposition technique.

In this approach the mammogram image features are extracted from the selected ROI based on wavelet decomposition process [20]. There are five processing steps: i. Wavelet decomposition – this helps to avoid unreasonable maximum scale values. The maximum scale (N) decomposition of image is determined according to the no of scales that contain irredundant information. ii. Co-efficient extraction – the horizontal, vertical and diagonal detail co-efficient are extracted from the wavelet decomposition structure. It returns the horizontal H, vertical V and diagonal D, detail co-efficient vectors at scale N. These vectors are extracted at each scale except the scale one, since it contains high frequency details which are in-significant. The image quality is then computed after zeroing the co-efficient in scale-1. iii. Normalization – the co-efficient vectors (H, V and D) extracted in previous step are normalized to simplify their co-efficient values. iv. Energy computation – the energy is computed for each vector by squaring every element in the vector. The produced values are considered as features for the next process. v. Feature reduction – since the images are of large size, large no of co-efficient are produced. Therefore to reduce the no of features, predefined no of energy values are summed up together. Once the feature extraction is done completely, based upon the extracted features the mammogram is classified as normal or abnormal. The next step after the feature extraction is the Classification phase.

4. Mammogram Classification:

Based on the results obtained from the previous steps, the classification of mammograms is carried as whether the mass found in the mammogram is benign or malignant. If the mass is benign, then the mammogram is considered to be a normal one. If the mass is malignant then the mammogram is said to be abnormal. The fallowing approach helps to identify the mass as benign or malignant.
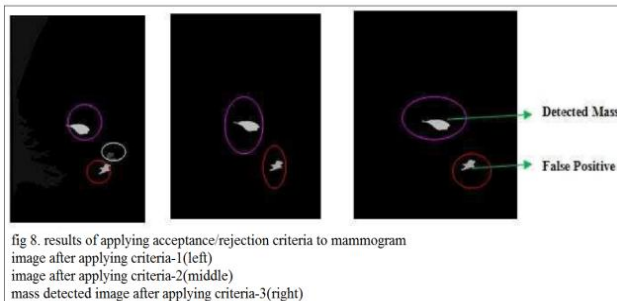
A. Mass detection by applying Acceptance/Rejection criteria.

In this approach the suspected ROIs are suspected to three acceptance/rejection criteria [21], which selects the most important candidate regions that strongly resemble a circumscribed mass in terms of their area and their statistical characteristics such as their pixel's intensity, higher order moment etc.

Criteria 1: From the ground truth given in the database, it is found that area of the mass ranges between 900 to 5000 pixels. So the region whose area lies between 900 pixels and 5000 pixels is considered to be suspicious. Regions that don't meet this requirement are rejected.

Criteria 2: Each remaining region is considered a suspicious region if its third order moment (skewness) is negative, otherwise they are rejected.

Criteria 3: Each remaining region is still considered suspicious if its mean intensity is higher than a threshold value Tm. The regions that do not satisfy this criterion are rejected.

fig 8. results of applying acceptance/rejection criteria to mammogram
image after applying criteria-1(left)
image after applying criteria-2(middle)
mass detected image after applying criteria-3(right)

All the regions that satisfy the above mentioned criteria are considered as the malignant tumors and hence they must be treated as early as possible to avoid the dangerous outcomes of it.

3. CONCLUSION

The paper is a survey of different digital image processing techniques used for the purpose of digital mammography. The four most important techniques (pre-processing, segmentation, feature extraction and classification) are performed using various methods to identify the mass as benign or malignant in its early stage itself. All the methods are intended to reduce the error rate in the detection breast cancer. Thus by reducing the error rate in the detection, the digital mammography has become the widely used technique for early breast cancer detection. Thus it is helping the physician especially pathologists to give effective treatment to the patients.

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