Identification of Pre-processing Technique for Enhancement of Mammogram Images

Jaya Sharma[1], J. K. Rai[2]
Amity School of Engineering and Technology
Amity University, Noida, India
jsharma1@amity.edu[1]
jkraius@rediffmail.com[2]

R. P. Tewari
Applied Mechanics Department,
M.N.N.I.T, Allahabad, India
rptewari@mnnit.ac.in

Abstract—This paper presents an analysis and identification of image pre-processing techniques suitable for mammogram images. Pre-processing is one of the preliminary stages used for mammogram image enhancement to aid an early identification of suspicious lesions and micro calcifications. Nine image pre-processing techniques are considered here for mammogram images. These techniques are implemented using Matlab. The results obtained are compared on the basis of Peak Signal to Noise Ratio (PSNR) for a set of 30 mammogram images. A high value of PSNR indicates better suitability of the pre-processing technique for further image processing. Anisotropic diffusion and Median filtering are suitable for noise removal. Power-law transformation, morphological processing, and un-sharp masking are giving better enhancement results in terms of achieved PSNR values as compared to other pre-processing techniques analyzed here. These identified pre-processing techniques, chosen carefully may give better results for further identification of masses, calcification, architectural distortion, bilateral asymmetry and aid in early detection of breast cancer.

Keywords—Image enhancemen; Mammogram;Preprocessiong; PSNR.

I. Introduction

Breast cancer has become one of the commonly occurring forms of cancer in women, particularly in developing countries. It accounts for about 25% to 33% of all type of cancers in women of urban India [1]. Early identification of breast cancer would result in timely diagnosis of the disease thus providing better chances of survival**.**

Image enhancement is a crucial step in most of the image processing applications. Enhancement means improving the visual quality of image for better interpretation and human perception. A number of image enhancement techniques exist but as far as mammogram processing is concerned, the techniques of interest are the ones that do not degrade the quality of image or modify existing information content in the image. One or more attributes of the image are selected and modified in the enhancement process.

The enhancement processes are categorized in two domains: spatial domain and frequency domain. Techniques belonging to the first category [2] are directly applied to the image pixel values to get desired enhancement. For the second category, Fourier transform is obtained for its frequency domain representation. After doing enhancement operations in frequency domain, Inverse Fourier transform is carried out to get the resultant image in spatial domain.

Image enhancement may include manipulation of image intensity and its contrast, reducing the levels of noise present, background removal in order to avoid any artifacts, filtering, edge sharpening etc. Enhancement may involve operations that are applied only on the selected region i.e. Region-of-Interest (RoI), in the image. Pre-processing of mammogram is essential for increasing the contrast between image background and selected RoI and to sharpen the edges or boundaries of suspected lesions.

In this paper nine image pre-processing techniques are explored for better results suitability in case of mammogram images. The rest of the paper is organized as follows: section II presents review of related literature. Image pre-processing techniques considered are presented in Section III. Results are presented in Section IV. Finally, conclusions and future work are given in Section V.

II. Review of Related Work

The common anomalies indicative of cancer in breast are masses, micro-calcifications (MCs) and architectural distortion. A breast mass could be defined as space occupying lesion seen in at least two different projections or as a localized lump in the breast [3]. A mass is parameterized according to its shape, size, location margins and density etc. Circular or oval shaped mass are generally considered as benign whereas masses with spicules tend to be malignant. Micro-calcifications represent one of the earliest signs of breast cancer. These are small deposits of calcium (and related) salts representing either warnings of malignancy or just benign formations. They are encountered in approximately 25% of mammograms and appear as bright spots or clusters of such spots, due to the high X-ray attenuation factor of calcium [4].

Numerous approaches for image enhancements using Histogram processing are available. It includes histogram equalization, adaptive histogram equalization and local histogram processing [5]. Adaptive histogram equalization is explored in this paper because of improvement in the appearance of images. For a dark image histogram would be oriented towards the lower gray scale values. It means the

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entire image detail lie in the dark end of the histogram. To obtain uniform distribution of gray levels, stretching of gray levels at the dark end is required.

Direct application of this method often results in the enhancement of noise present in the image. Contrast-limited adaptive histogram equalization (CLAHE) could be used to solve this over enhancement problem [6]. Histogram Modified Contrast Limited Adaptive Histogram Equalization (HM-CLAHE) is another variation of this technique proposed in [7]. It adjusts the level of enhancement giving a strong contrast image and also highlights the local information present in the original image for better interpretation. In [8] an image enhancement algorithm based on edge detection is used to preprocess mammograms. The proposed algorithm was applied on preprocessed mammograms. It helped to get more details from images and lesions were clearly differentiable from background.

Morphology is the science of structure and shapes. It could be used as a tool for image processing by extracting and representing regions and shapes of objects in images. Image enhancement, detection and segmentation of objects are some of the application areas of morphology [9]. There are two simple operations called erosion and dilation on the basis of which a large number of filters can be designed and expressed.

Many image processing operations involving enhancement makes use of oriented filters. In this same filter is applied over again by rotating it at different orientations under adaptive control. One can remove noise and enhance oriented structures by angularly adaptive filtering. In [10] authors have used the steerable features of derivatives of Gaussian for image enhancement.

III. IMAGE PRE-PROCESSING TECHNIQUES

The pre-processing techniques described in this section have been applied on 25 images. RoIs are marked on the images by radiologists. These marks don't contribute or affect the outcome of pre-processing techniques considered in this work. It is indicated that the test images are taken from [11].

A. Contrast Stretching

Image may result into low contrast because of poor background lighting, lack of dynamic range in the imaging sensor, improper setting of focus etc. at the time of image acquisition [2]. Contrast stretching is used to increase the dynamic range of gray levels in the image being processed. Contrast stretching is considered here because mammograms generally have low contrast. It aids in identification of suspicious regions in the mammogram

Contrast stretching is done on the basis of (1)

$$s = \begin{cases} l.r, & 0 \le r < a \\ m.(r-a)+v, & a \le r < b \\ n.(r-b)+w, & b \le r < L-1 \end{cases} \quad (1)$$

where, s is the output gray level, r is the input gray level, l, m and n are slopes in the respective regions and L-1 is the maximum intensity value in the original image. Figure 1 (a) and 1 (b) shows one of the original and contrast enhanced image as a sample output.

B. Power-Law Transformation

The power law transformation can also be used for improving the dynamic range. It can be expressed as a set of nth power and nth root curves. The transformation is represented mathematically by (2)

$$s = cr^{\gamma} \quad (2)$$

where, s is the output gray level, r is the input gray level, c is constant and γ is the correction factor. It is also called as gamma correction [2]. Varying the values of γ will give transformations corresponding to different enhancements levels. Figure 1 (c) shows one of the power law transformed image as a sample output.

C. Histogram Processing

Histogram of an image provides enormous information about the image. It gives an idea about the appearance of the image and is defined as a plot of the relative frequency of occurrence of various gray levels. Histogram of a digital image with intensity levels in the range [0, L-1] is a discrete function given by (3)

$$h(r_k) = n_k \quad (3)$$

where, r_k is the kth intensity level in the interval [0, L-1] and n_k is the number of pixels in the image whose intensity level is r_k.

Histograms are generally normalized by dividing all elements of $h(r_k)$ by the total number of pixels in the image and is given by (4)

$$p(r_k) = \frac{h(r_k)}{n} = n_k/n \quad (4)$$

For k = 0, 1, 2… L-1

D. Un-sharp Masking

It is a common method of pre-processing employed for sharpening. It works by subtracting the smoothed image from original. Thus it enhances high frequency components like edges in the image and attenuate low frequency information giving a much sharper image [12]. This may make micro-calcifications more prominent in the processed mammogram image. Un-sharp masking is performed using (5)

$$g(x,y) = f(x,y) - f^s(x,y) \quad (5)$$

where, f(x,y) is the original image, $f^s(x,y)$is a smooth version of the original image. $g(x,y)$is the enhanced image after un-sharp masking.

Figure 1 (e) shows image after un-sharp masking as a sample output.

E. Morphological Processing

To improve the contrast of mammograms, two operations, the top-hat transform and bottom-hat transform are applied sequentially. Top-hat transform is the difference between the original image and its opening. It is used to remove uneven illumination in darker background. The bottom-hat transform is the difference of the closing of the original image with original image. Both the steps require defining a structuring element based on the particular application [13]. This gives much clarity to the appearance of micro-calcifications. This morphological processing is expressed in (6) and (7)

$$f_{TH}(x,y) = f(x,y) - f \circ s \tag{6}$$

$$f_{BH}(x,y) = f \bullet s - f \tag{7}$$

where $f_{TH}(x,y)$ and $f_{BH}(x,y)$ denote the top-hat and bottom-hat transforms of original image $f(x,y)$. $f \circ s$ and $f \bullet s$, represent the opening and closing operations of original image with a structuring element s.

Figure 1(f) shows an image after morphological processing as a sample output.

F. Median Filtering

Median filtering is mainly used to reduce or eliminate noise present in the image. Median filter not only reduces the noise but also preserves useful information in the image. Each pixel is considered and is replaced by the median value of its surrounding pixels. Different neighborhood size could be chosen for filtering. Here, median filter of size of 3x3 is taken. Figure 1(g) shows median filtered image as a sample output.

G. Anisotropic Diffusion Filtering

An important aspect of preprocessing mammograms is to remove noise without affecting the other features present in it. Anisotropic diffusion filtering is based on a physical diffusion process [14]. It provides edge smoothing without the loss of significant details. The image is iteratively smoothed through the diffusion process. This diffusion process is expressed by (8).

$$\frac{\partial I(x,y,t)}{\partial t} = \Delta\big(c(x,y,t)\big)\nabla I(x,y,t) \tag{8}$$

where, t=0 corresponds to the original image. C(x,y,t) controls the strength of diffusion process. To be more effective, c needs to behave according to location i.e. diffusion will be smooth within the region as compared to boundary. Figure 1(h) shows a sample output for anisotropic diffusion.

H. Bilateral Enhancement

Bilateral filters are easily adaptable filters that provide reliable smoothing for images. They provide enhancement and also preserve the edges by considering the spatial closeness and similarity of nearby pixels in the image [15]. The output depends on the weighted combination of nearby pixels. This function is given in (9)

$$g(i,j) = \frac{\sum_{k,l} f(k,l)w(i,j,k,l)}{\sum_{k,l} w(i,j,k,l)} \tag{9}$$

The weight coefficient w depends on the product of a domain and range kernel. The filter function is given by (10) as:

$$I_f = \frac{1}{k_S}\sum f(\rho - s)g\big(I_\rho - I_S\big)I_\rho \tag{10}$$

where, ρ and s denote the current and center pixel coordinates. f(ρ − s) is generally a Gaussian function to measure the geometric distance between ρ and s. The function $g(I_\rho - I_S)$ is used to measure the photometric similarity between the two neighboring intensities I_ρ and I_S.

Bilateral filtering has been applied here to get enhanced mammogram image with smooth boundary. Figure 1(i) shows a sample image after bilateral enhancement

I. Homomorphic Filtering

Homomorphic filter is based on the separation of illumination and reflectance components of an image. Illumination represents slow spatial variations i.e. low frequency components whereas reflectance represents abrupt variations i.e. the High frequency components, particularly at the edges. This is expressed by (11).

$$f(x,y) = i(x,y).r(x,y) \tag{11}$$

where, i(x,y) and r(x,y) are the illumination and reflectance components respectively.

Thus homomorphic filter effect low and high frequency components in different manner. It reduces the low frequency dynamic range and increase the contrast in high frequency. These varied illumination levels can be considered as multiplicative noise that can be reduced by filtering in the log domain [16]. So, homomorphic filtering is preferred in case of multiplicative noise.

Figure 1(j) shows image after applying homomorphic filter as a sample output.

IV. Results and Discussion

The pre-processing techniques described in Section III have been implemented using Matlab on a set of 30 images obtained from [11]. Since only visual inspection of pre-processing is not very prominent, PSNR has been calculated for comparison of all these techniques. Average, minimum and maximum PSNR values obtained for the set of 30 mammogram images are listed in Table I. The results clearly help in identifying better suited pre-processing techniques for mammogram images. It is evident from Table I that Anisotropic diffusion, power-law transformation, un-sharp masking, morphological processing and median filtering are having higher values of PSNR as compared to other pre-processing techniques considered in this work. Even the minimum PSNR values for the identified techniques i.e. Anisotropic diffusion, power-law transformation, un-sharp masking, morphological processing and median filtering are greater than the maximum values of rest of the four pre-processing techniques. So, the small number of test images may not affect the result in general.

TABLE I. AVERAGE, MINIMUM AND MAXIMUM PSNR VALUES

S. No	Pre-processing Technique	PSNR Values (in dB)		
		Average	*Min*	*Max*
1	Contrast Stretching	17.84	13.43	20.52
2	Power-law Transformation	27.67	21.07	31.03
3	Adaptive Histogram Equalization	18.30	17.35	20.46
4	Unsharp Masking	25.02	23.74	26.85
5	Morphological Processing	28.71	25.58	31.6
6	Median filtering	36.29	32.14	38.6
7	Anisotropic Diffusion	43.08	41.23	44.61
8	Bilateral Enhancement	16.37	12.66	18.92
9	Homomorphic Filtering	19.75	16.91	22.75

V. CONCLUSION

In this paper, nine image pre-processing techniques namely contrast stretching, power law transformation, histogram processing, un-sharp masking, morphological processing, median filtering, Anisotropic diffusion, Bilateral enhancement and Homomorphic filtering have been considered to identify its better suitability to mammogram images. These pre-processing techniques have been tested on a set of 30 images and the result shows that anisotropic diffusion, power-law transformation, un-sharp masking, morphological processing and median filtering are giving higher PSNR values. So these techniques will be more suitable in pre-processing stage of mammogram images. The identified pre-processing techniques may be followed by segmentation, post processing, texture analysis, feature extraction and classification to yield better results. The future research will be carried out to improve the early identification of masses, calcification, architectural distortion and bilateral asymmetry for detection of breast cancer by using these identified pre-processing techniques.

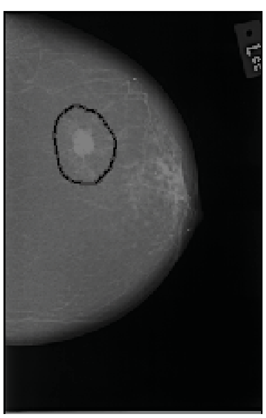

Figure 1(a): Original mammogram

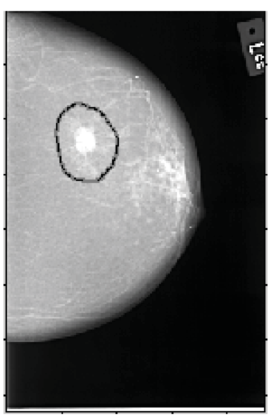

Figure 1(b): Contrast enhancement

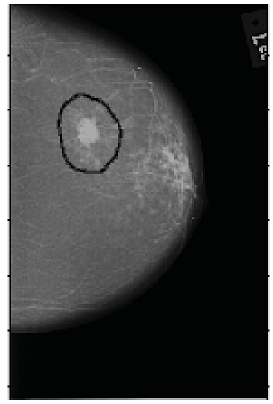

Figure 1(c): Power-Law transformation

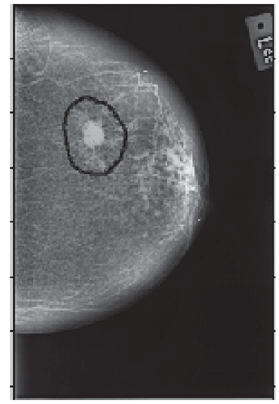

Figure 1(d): Histogram equalization

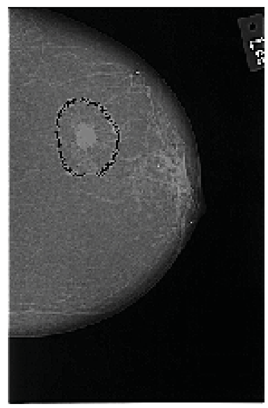

Figure 1(e):Un-sharp masking

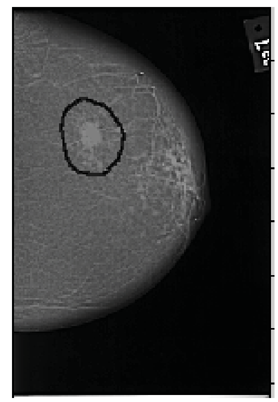

Figure 1(f): Morphological processing

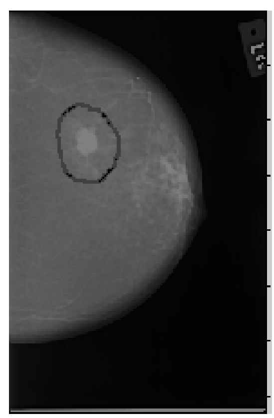

Figure 1(g): Median filtering

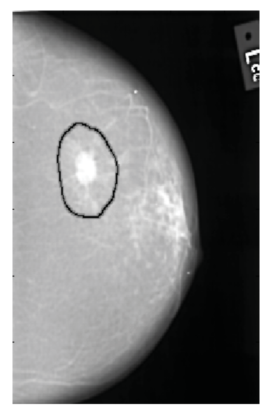

Figure 1(h): Anisotropic diffusion

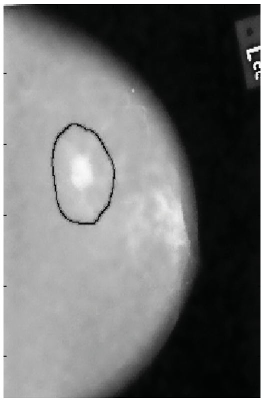

Figure 1(i): Bilateral enhancement

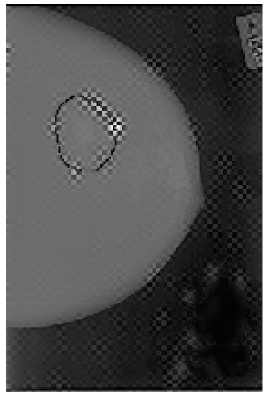

Figure 1(j): Homomorphic filtering

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