Research Article

Enhancement of mammogram images by using entropy improvement approach

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Abstract
Breast cancer in women has been the most often diagnosed cancer. Digital mammogram becomes the most effective imaging method to detect breast cancer in early stage. In breast cancer screening, radiologists typically miss about 10–30% of tumors due to the speculated margins of lesions. Mammogram is a low contrast image whose quality needs to be improved for better interpretation. The performance of the validation of pre-processing methods for mammogram image enhancement is done by performance metrics such as peak signal to noise ratio (PSNR) and mean square error (MSE). Good filtering technique having higher PSNR and low MSE value. Experimental results on the digital database for screening mammography images shown that the non-local mean filter is better for mammogram image enhancement. Further we proposed mammogram images enhancement by entropy improvement method by considering non-local filtered images. These methodologies could add to the effective discovery of masses and micro calcifications in mammograms.

Keywords Mammogram · DDSM · MSE · PSNR · Breast cancer · Entropy

1 Introduction

Mammography is the important tool for screening to find the tumor by using X-rays to form a picture of the breast. Breast cancer has turned out to be one of the usual happening types of malignancy in female, particularly in growing countries. It represents around 30% of all sorts of malignancies in ladies of urban India [1]. Breast cancer in India around 1 lakh cases/year, in the age group of 55–59 years. According to the International Agency for Research on Cancer, 27 million of new cases of this disease are expected before 2030. The survey of the National Cancer Institute shows that 1 in 8 women in the United States have the chance of getting breast cancer at a certain point in their lives [2]. The American Cancer Society [3] prescribes that female over the age of forty are screened once a year for mammography. Mammography plays an important role to notice abnormalities in the breast.

It offers elaborated information regarding anatomy, morphology and also the pathologies of breast for diagnosis of breast cancer. Irregular shapes or speculated margins have a higher likelihood of being malignant and regular shapes have a probability of being benign. The dense breast tissue on the mammogram looks white or light gray. This will create mammograms tougher to interpret in younger ladies [4]. Image enhancement is a crucial step in enlightening the quality of the picture for clear understanding and recognition. The enhancement processes are classified as spatial and frequency domain [5].

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2 Image pre-processing techniques

Normally impulse (salt and pepper) [6] and quantum noises [7] will degrade the mammogram images. The quantum noise will be observed in the images while capturing, because of reduced count X-ray photons, and affects whole image pixels. In salt and pepper noise model one pixel is allocated either lowest or highest intensity value. Remaining pixels will have any value from allowed dynamic range. Image filtering finds applications in smoothing, sharpening, removing noise and edge detection. Pre-processing techniques like mean, median, wiener, wavelet denoising, non-local mean and power law transformation are analyzed in our work.

2.1 Mean filter

Mean filtering [8] is a strategy to smooth pictures by reducing the intensity difference among adjacent pixels. This method operates by moving through the picture, pixel by pixel, substituting every value with adjacent pixels average value, including themselves. This method is optimal for removing Gaussian noise, but poor in edge preserving. Averaging operations [9] makes the image blur, which disturbs the correct feature localization. Consider S_{xy} is the set of coordinates in the MXN size rectangular sub image box (neighborhood) centered at point (X, Y). The grey value of pixel (X, Y) in G, will be substituted by the gray level f (X, Y) by considering the surrounding detail into account.

$$\hat{f}(X,Y) = \frac{1}{MN}\sum_{(S,T)\in S_{XY}} G(S,T) \tag{1}$$

2.2 Median filter

Median filter [10] performs the non-linear operation, frequently referred to reduce salt and pepper noise of the picture. Filter operates by moving pixel by pixel through the picture, substituting each value with the adjacent pixels median value. This filter maintains the sharper picture edges [11]. It is area invariant in nature, and therefore uncorrupted pixels also disturbed.

$$\hat{f}(X,Y) = \underset{(S,T)\in S_{XY}}{\text{MEDIAN}}\{G(S,T)\} \tag{2}$$

2.3 Wiener filter (WF)

The Wiener filter [8] technique utilizes a statistical approach to remove the noise from every pixel of an image. Wiener filtering is an optimum MSE filter [12]. This filter attempts to create an approximation of the original image by applying a MSE constraint between the approximated and the original image. The minimized error represented in Eq. (3). Wiener filter reduces the additive noise and simultaneously reverses the blurring. In frequency domain Eq. (4), provides a minimum mean square error (Wiener filter) function.

$$e^2 = E\left\{f(X,Y) - \hat{f}(X,Y)\right\} \tag{3}$$

$$\hat{F}(U,V) = \left[\frac{1}{H(U,V)}\frac{|H(U,V)|^2}{|H(U,V)|^2 + \frac{S_\eta(U,V)}{S_f(U,V)}}\right]G(U,V) \tag{4}$$

Here H (U, V) = degradation function; H * (U, V) = complex conjugate of H (U, V); $|H(U,V)|^2 = H^*(U,V)\,H(U,V)$; $S_\eta(U,V)$ = noise power spectrum; $S_f(U,V)$ = power spectrum of undegraded picture.

2.4 Wavelet denoising filter

The wavelet transform plays vital role in image processing. The transform uses a multi-resolution [13] technique. In DWT, the signal passes through two complementary filters that give signal approximation and detail component. The process is referred to as the decomposition or analysis. The reconstruction or synthesis is the opposite of this process. First, the image is divided into different subbands and then thresholding algorithms are applied to the wavelet coefficients in image denoising. Inverse wavelet transform is finally applied, which provides denoised image. The thresholding techniques [14] can be soft or hard thresholding. Hard thresholding can be represented as function.

$$\begin{aligned} f_h(x) &= x \quad \text{if } x \geq T \\ &= 0 \quad \text{otherwise} \end{aligned}$$

Above function selects the wavelet coefficients which are greater than the given threshold T and sets zero otherwise. Soft thresholding can be represented as function.

$$\begin{aligned} f(x) &= x - \lambda \quad \text{if } x \geq T \\ &= 0 \quad \text{if } x < T \\ &= x + \lambda \quad \text{if } x \leq -T \end{aligned}$$

Wavelet transform [15] has certain disadvantages such as the absence of clear edge information and lack of shift invariance.

2.5 Non-local mean

This method substitutes the local comparison of pixels with a non-local patch comparison [16]. This filter will not make assumptions about the locality of the most significant pixels used to reduce the noise of the current pixel. This filter [17] considers the patterns around the pixels. The NL-mean filter not only compares the grey value at one point, but also the geometric structure in an entire neighborhood. Thus, this filter is more robust than other neighborhood filters [18].

Consider a noisy image v = {v(i) | € I} and calculated value for NL[V](i) for pixel i, is weighted average of all the pixels in the image [19]. Weights defined based on similarity between pixels i and j.

$$NL[V](i) = \sum_{J \epsilon I} w(i,j)v(j) \tag{5}$$

2.6 Power law transformation

Power law transformation [5] is applied to increase an image's contrast by adjusting the gamma and constant C value for a gray scale image, r and s are intensities of low contrast (input) and high contrast (output) images respectively. The transformation is given by Eq. (5).

$$s = c \cdot r^{\gamma} \tag{6}$$

where $\gamma > 0$ and c is constant.(1) If gamma = 1, there would be no changes to the processed image. (2) If gamma < 1, dark pixels range will be expanded and the bright pixels range will be compressed. (3) If gamma > 1, the range of dark pixels range will be compressed and the bright pixels range will be increased.

3 Proposed approach for entropy improvement

Entropy [20] measures the information content of the image. Entropy allows us to consider the neighborhood of the pixel and hence more appropriately texture is considered. The proposed approach has been shown in Fig. 1. It first follows image acquisition of medical images, may suffer from low-illumination and contrast issues which may lead to the inappropriate analysis and faulty diagnostic recommendations by clinicians. In order to deal with this issue, an approach for image enhancement by entropy maximization is proposed. Maximize the amount of information content in the enhanced image is aimed in the study.

For enhancement of mammogram, various filter's performance has been evaluated. As per the result analysis non-local mean filter performance is better. Hence, non-local mean filter has been considered in the proposed approach. In the flow diagram contrast enhancement is carried out with histogram equalization [21, 22] on the mammogram image data set. Then the morphological operation has been carried out for image smoothing. After that, non-local mean filter has been applied and entropy has been calculated. The improved entropy values shown in Table 2.

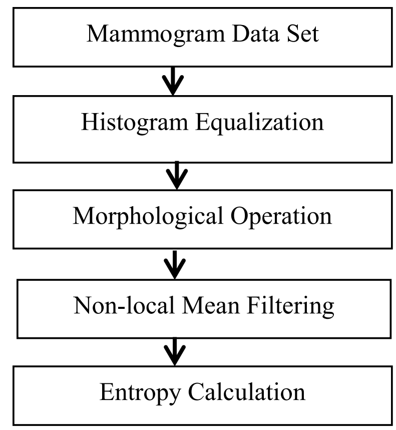

Fig. 1 Proposed methodology for entropy improvement

4 Experimental results

The techniques for pre-processing discussed in Sect. 2 have been developed using the Matlab version 2015a on a group of mammogram images. The techniques are tested with 20 mammogram images selected from the DDSM maintained by the South Florida University [23]. Mammograms were digitized with a size of approximately 200 × 200 pixels. Mammograms containing suspect areas contain information on the locations and types of those regions. The output of the preprocessed image is a noise reduced and enhanced. The single mammogram image as input and the output of the pre-processed images with different pre-processing techniques are shown in Fig. 2. Entropy improvement approach images are shown in Fig. 3.

The statistical measurements will measure the enhancement of the image. The MSE, PSNR and entropy are used to analyze the performance of the pre-processing methods.

4.1 MSE

The mean square error must be low for good quality image, can be calculated by following equation.

$$\mathrm{MSE} = \frac{1}{M*N} \sum_{X=1}^{M} \sum_{Y=1}^{N} (p(X,Y) - \delta(X,Y))^2 \tag{7}$$

Here M * N is image size, p(X, Y) input image pixel value and δ(X, Y) estimated image pixel value.

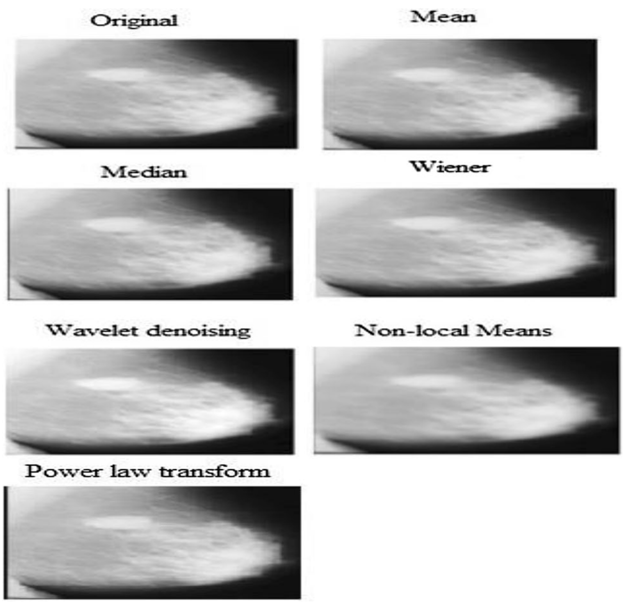

Fig. 2 Images of the pre-processing techniques output

4.2 Peak signal noise ratio

Higher PSNR indicates that difference between the original and reconstructed picture will be minimal. And smaller value of PSNR defines poor quality of image.

$$\mathrm{PSNR} = 10\log_{10} \mathrm{R}^2/\mathrm{MSE} \tag{8}$$

Here R represents the highest pixel value.

4.3 Entropy

$$\mathrm{E(n)} = \sum_{X=1}^{M}\sum_{Y=1}^{N} \mathrm{p(X,Y)} \log_2 (\mathrm{P(X,Y)}) \tag{9}$$

The Table 1 shows the preprocessed images PSNR, MSE and entropy values. The experimental results shows that the non-local mean filter is having more PSNR and less MSE value. Hence it is better suitable filter for mammogram image enhancement.

The Table 2 represents entropy values for the input and preprocessed mammogram. From the table it is concluded that our proposed approach improves the entropy of the mammogram image.

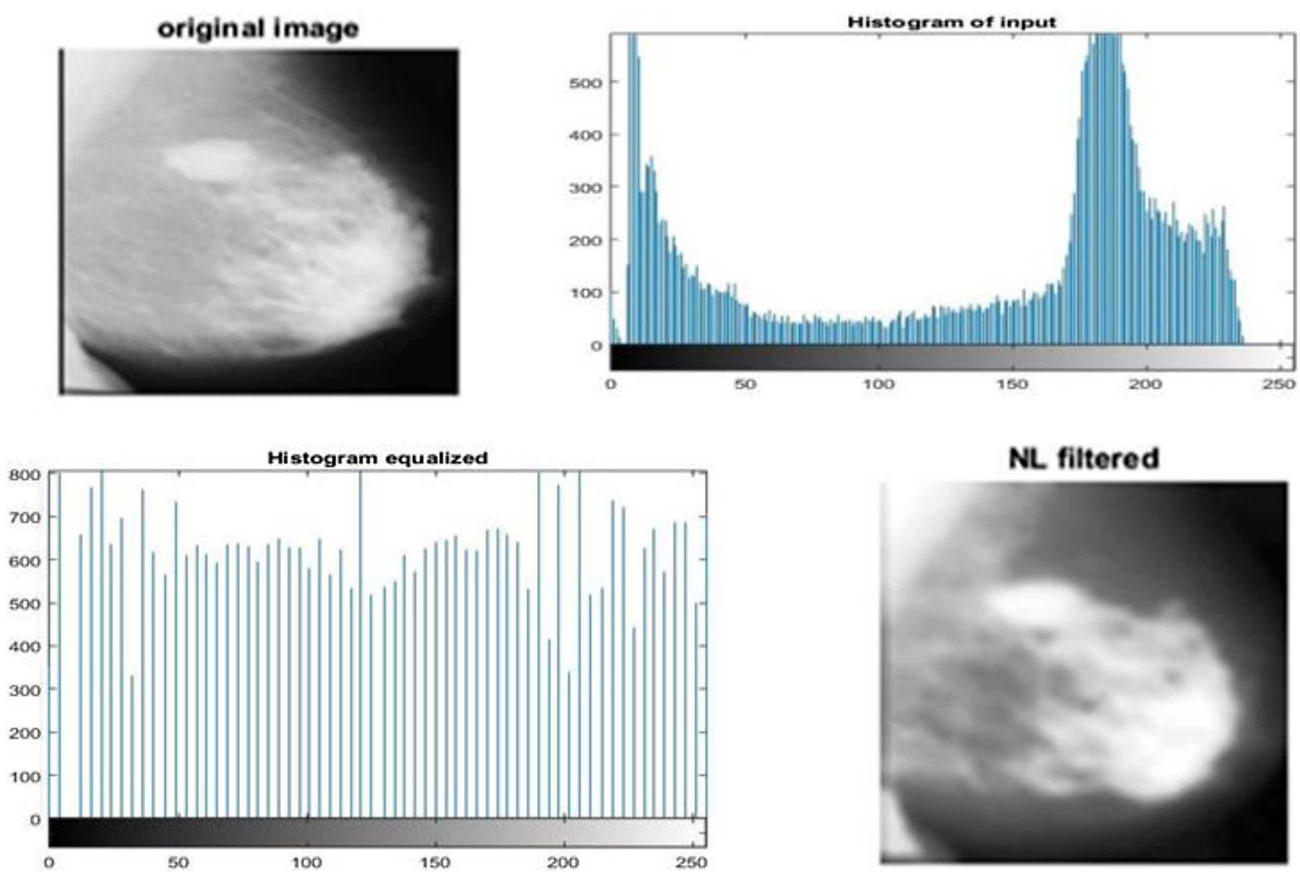

Fig. 3 Entropy improvement methodology in mammograms

Table 1 Comparison of different pre-processing techniques for the mammogram image

Si. no.	Pre-processing technique	Performance metrics		
		PSNR	MSE	ENTROPY
1	Mean filter	38.65	8.93	7.14
2	Median filter	47.15	1.33	7.08
3	Wiener filter	46.32	1.53	7.10
4	Wavelet denoising	42.07	4.06	7.11
5	Non local means	78.93	0.0012	7.10
6	Power law transformation ($\gamma = 0.5$)	63.94	0.026	6.60

Table 2 Entropy improvement for the mammogram image

Image	Entropy
Input mammogram image	7.2720
Preprocessed image with entropy improvement approach	7.92144

5 Conclusion

Breast cancer research is highly required nowadays. Pre-processing techniques are essential for enhancing the low contrast mammogram image. Here performance of the pre-processing techniques is measured using performance metrics such as MSE and PSNR. The comparisons of techniques are verified for mammogram images. Among all the techniques have been experimented non-local mean filter is appropriate for the mammogram image noise reduction because it gives high PSNR and low MSE. Entropy improvement for mammogram images is observed in our proposed methodology, which improves average information content of the image. Further research is being conducted in this area to identify and classify the breast cancer in accordance with Breast Imaging Reporting and Data System (BIRADS).

Compliance with ethical standards

Conflict interest The authors declare that they have no conflict interest.

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