Advanced Enhancement Method for Micro Calcification in Mammography

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Abstract: ***Microcalcification is important for early breast cancer detection. But due to the low contrast of microcalcifications and same properties as noise, it is difficult to detect microcalcification. In this paper, we propose a robust contrast enhancement method for microcalcification. The proposed method is modified homomorphic filtering in wavelet domain based on background noise information. By using the proposed method, the mammogram contrast can be stretched adaptively thereby enhancing the contrast. Experimental results show that the proposed method improves the visibility of microcalcifications. The contrast improvement index (CII) is increased while noise standard deviation is decreased.***

Keywords: Mammography, Homomorphic filtering, Contrast Enhancement

1. Introduction

Breast cancer is currently the leading causes of death among middle-aged women. In the medical perspective, the earliest symptom of breast cancer is the appearance of micro calcifications. Thus, the detection of micro calcification is a major part of diagnosis in early stage breast cancer. However, micro calcification is too small to detect by palpable breast diagnosis. Mammography is known as the best modality to detect micro calcification.

The small size of micro calcification results in poor visualization in mammograms. Therefore, to provide the improved visibility of breast cancer to medical doctors as well as automatic breast-cancer detection systems, mammogram contrast should be enhanced. In doing so, denoising is considerable for image enhancement. Especially for mammogram, the size of micro calcification is close to noises. Noise should be reduced while micro calcifications are enhanced.

Some enhancement methods for mammogram have been proposed. However, in these methods, noise properties of mammogram were not considered properly. Some mammograms are taken from different environments such as different noise condition, X-ray intensity and concentration of sensitizer of mammogram films. Mammography in different noise conditions should be considered. In this paper, we propose a robust image enhancement and noise reduction by using noise characteristics in background region of each mammogram.

2. Contrast Enhancements in Wavelet Domain

The basic idea of wavelet transform is to analyze different frequencies of the signal using different scales. High frequencies of the signal are analyzed using low scales and low frequencies are analyzed in high scales. This is a far more flexible approach than the Fourier transform, enabling analysis of both local and global features. Left box shows the part of signal decomposition while right box is signal reconstruction part.

In Fig. 1, G (ω) is a high pass filter and H(ω) denotes a low pass filter. G*(ω) is construction filter of high pass components and H*(ω) is a reconstruction filter of low pass components. The variable of 2ω and 4ω indicates a sub sampling of input signal. 1-D signal can be decomposed into three high pass channels (G(ω), G(2ω) and G(4ω)) and one low pass channel (H(4ω)). E0(x), E1(x) and E2(x) are gains of each wavelet channel.

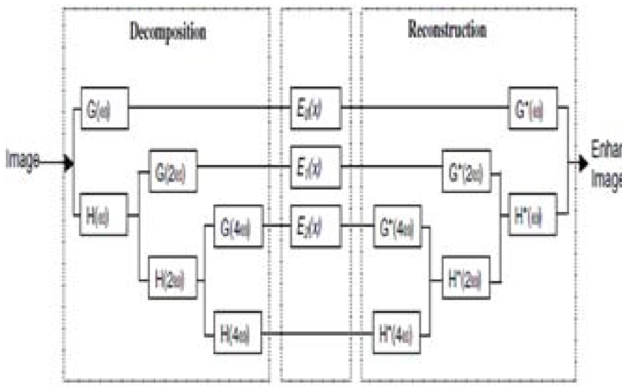
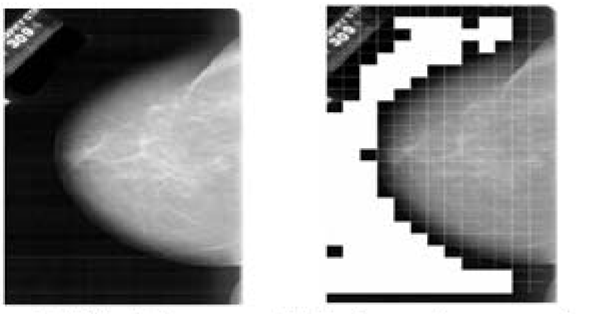


Figure 1: Dimensional contrast enhancement in wavelet domain

3. Robust Image Enhancements in Wavelet Domain

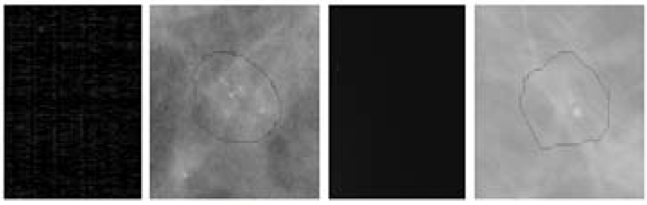
A mammogram is divided into three distinctive regions: the breast region, the background (non-breast) region, and the regions of artifacts. The breast region is created when X-ray is absorbed in breast. Background is the region where X-ray has no obstacle. Artifacts are objects such as labels. Background segmentation is useful for computer-aid-system because it significantly reduces the checking area. Moreover, the background region gives us information of noise that is used for processing the breast region.

In the previous contrast enhancement methods, the parameters such as gains of filtering and thresholds of denoising are usually the fixed value that is same for all mammograms. The propose method, in this paper, noise characteristics of each mammogram is considered in homomorphic filtering as well as denoising process. Properties of noise are obtained from the background region.



(a) Original image (b) Background segmentation

Figure 2: Result of background segmentation



(a) (b) (c) (d)

Figure 3: Examples of background noise and microcalcification areas (indicated by white arrows)

(a) and (b) are high noise (var>40) in background and breast, (c) and (d) are low noise (var<20) in background and breast area (12 bit gray level)

3.1 Robust Mammogram Enhancement Using Homomorphic Filtering

The homomorphic filter function decreases the energy of low frequencies while increases those of high frequencies in the image. The homomorphic filter is used to find the gain Km [3]. With the mammogram, the homomorphic filter gives contrast stretching for lower gray level by compressing dynamic range of the gray level. Based on the characteristics of homomorphic filter function, we determined the gain of mapping function, i.e., weighting wavelet coefficients of channels corresponding to homomorphic filter function. Fig. 4 represents the gain Km that is determined decoding to the discrete homomorphic filtering. In mammogram contrast enhancement, noise reduction is a considerable issue. One method of denoising is wavelet shrinkage that was presented in. Each mammogram contains its own noise characteristics because mammograms are taken from different environments. Therefore, applying the same parameters in noise reduction and the gain Km for every mammogram are not efficient. Taking into account noise properties of each mammogram, we propose robust method for mammogram enhancement.

To obtain noise characteristics of the mammogram, the background is segmented by thresholding the values combining the gray-level, mean and variance of pixels. The segmented background areas are supposed to contain the noise of image .Therefore; we can take noise characteristics in this area. The noise characteristic is measured by background noise variance (varb), which can be written as

$$var_b = \frac{1}{N_b}\sum_{(x,y)\in background}\{(I(x,y)-mean(x,y))^2\},$$

Where Nb is the number of pixel in background are. I(x, y) and mean(x, y) are calculated using background pixels only. If high variance of background noise exists, we need to reduce the gain of homomorphic filter in high frequency domain

$$K_m' = K_m \times \frac{A}{var_b + A}, \quad if\ m = 0\ and\ m = 1$$

Where A is constant value to normalize noise variance, m is a level of wavelet and Km means the gain of each wavelet level. In equation (2), m=0 means highest frequency level in wavelet and m=1 means second highest wavelet level. In high noise mammograms, the gains are reduced whereas, in low noise mammograms, higher gain of contrast enhancement is acceptable. Fig. 5 is a diagram of modified homomorphic filtering approach in the proposed framework.

Fig. 5 shows 3 level wavelet decomposition and reconstruction with one dimensional signal. Here, we first take logarithmic function for input signal. It also inverts the exponential operation caused by the radioactive absorption, which is generated in the process of obtaining mammography image. Km` is linear enhancement gain of each wavelet channel. It is suited for enhancement of microcalcification because it emphasizes strong edge much more than the weaker edge.

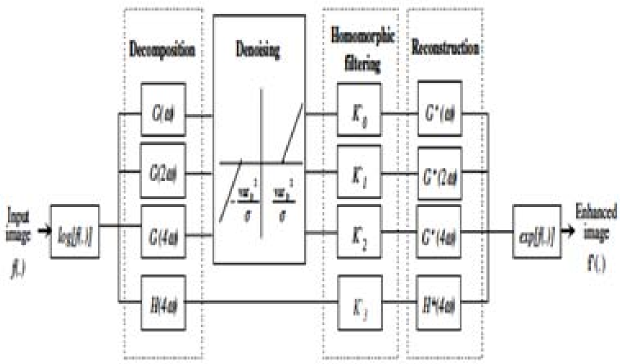


Figure 4: Robust contrast enhancement with denoising and modified homomorphic filtering

Further, an adaptive denoising is included in the enhancement framework in wavelet domain shown in denoising block of Fig. 5. To achieve the edge-preserved denoising, a nonlinear wavelet shrinkage method is applied. In denoising, wavelet coefficient values are reduced to zero according to a level-dependent threshold. Noise adaptive shrinking operator (S (u)) for the denoising can be written as

$$S(u) = \begin{cases} sign(u) \times \left(|u| - \mathrm{var}_b^{\,2}/\sigma\right) & if\ |u| > \mathrm{var}_b^{\,2}/\sigma \\ 0 & otherwise, \end{cases}$$

Where u is wavelet coefficient, and σ is variance of reconstructed image using wavelet coefficients in a sub-band. Sign (u) means positive or negative sign of u. Threshold in this wavelet shrinkage is called a nearly optimal threshold. Taking modified homomorphic filter gains of high frequency area in wavelet domain and optimal denoising operators, microcalcification can be enhanced and also noise can be reduced in breast area.

4. Proposed Method

To verify the proposed method, experiments are performed with DDSM mammogram database. In DDSM database, the resolution of a mammogram is 50 µm/pixel and gray level depths are 12 bits and 16 bits with various kinds of noise characteristics. In the experiment, three contrast enhancement methods are performed: linear enhancement in wavelet domain (Unsharp marking), homomorphic filter in wavelet domain (homomorphic filtering), and the proposed robust enhancement using modified homomorphic filter in wavelet domain (proposed enhancement).Because the proposed method is to enhance contrast of microcalcification and reduce noise, parameters of enhancement methods were chosen suitably for this purpose. If thresholds of denoising are small, much noise will remain after denoising and this noise is enhanced by filtering.

A quantitative measure of contrast improvement is calculated using contrast improvement index (CII). CII is defined as

$$CII = \frac{C_{enhanced}}{C_{original}},$$

Where Enhanced and Original denote for the contrast values of microcalcifications in the enhanced and the original images, respectively. The contrast C of a microcalcification in the image is defined as

$$C = \frac{f - b}{f + b}.$$

Where f is the mean value of the microcalcification, and b is the mean value of background. The standard deviation (std.) of pixels in background region is also measured in order to represent the level of noise. Fig. 5 shows enhancement results for a noise image. The contrast improvements of both homomorphic filtering and proposed enhancement methods are equivalent with center peak of profile in Fig. 6, and CII value of Figure 7.

However, Fig. 6 show that the proposed enhancement much better than the homomorphic filtering in denoising. This is also indicated by the standard deviation of noise (std. of noise) in Figure 7. Std. of noise of homomorphic filtering is 8.55, while the Std. of noise of proposed enhancement is 6.67. The experiment proves that the proposed enhancement is more effective in denoising compare with previous enhancement in high noise condition.

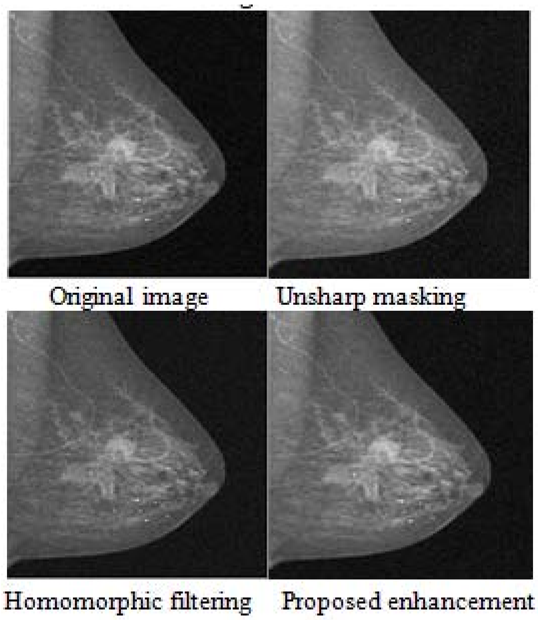


Figure 5: Contrast enhancement for noise mammography image

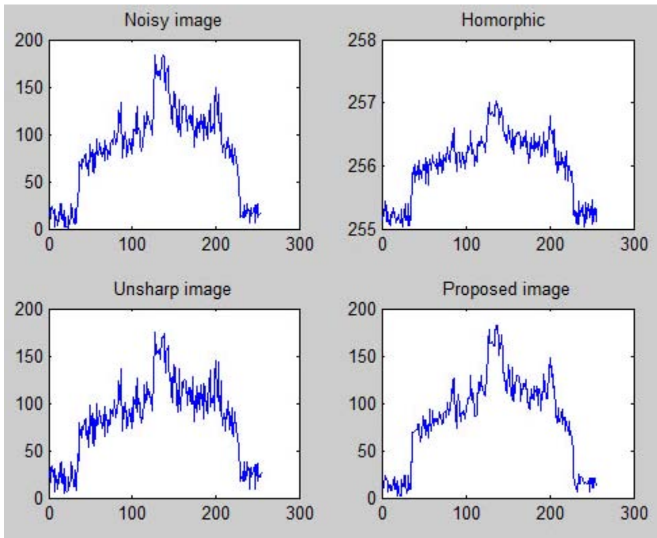


Figure 6: Results for All Enhancement Methods

	Original Image	Unsharp Masking	Homo marphic Filtering	Proposed Enhancement
C	0.0322	0.0307	0.0672	0.0430
CII		0.9321	1.0030	1.1085
Std Dev of Noise	21.3414	7.9613	8.5524	6.6761
PSNR		23.1265	18.8892	26.1079

Figure 7: Contrast Improvement Index and standard deviation of noise for noise mammogram

Figure 7 show that noise is reduced in the all enhanced images. However, the proposed enhancement increases the contrast of microcalcification better than the others. In Figure 7, the proposed enhancement obtains 1.1085 of CII while homomorphic filtering gets 1.0030. This example indicates that in low noise condition, proposed enhancement is better than the homomorphic filtering in contrast enhancement with similar denoising.

This is due to the higher gains in the high frequency channels. In conclusion, high noise mammograms have much fluctuation in breast region shown in profile of original image. Un sharp masking and homomorphic filtering enhance contrast of microcalcification with relatively high noise. On the other hand, proposed enhancement modifies wavelet gains and increases denoising threshold in high noise cases. Therefore, noise is reduced in breast area with high CII value. In low noise cases, proposed enhancement superior to other methods in denoising and improving contrast of microcalcification.

5. Conclusion

In this paper, we propose a robust contrast enhancement method for microcalcification. The proposed method estimates noise characteristic in background region and eliminates noise in breast area incorporation with contrast enhancement of microcalcification. Experimental results show that, the proposed enhancement significantly reduces noise in noise mammograms; contrast of microcalcification is increased while noise is decreased.

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