

Mammographic Feature Enhancement using Morphology and Spatial Filter

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ABSTRACT

The proposed method focuses on the prediction of breast cancer in its early stage. It is very difficult to detect microcalcification due to its small size and low contrast with respect to the surrounding tissues. A new, fast and simple enhancement technique is considered for early detection of breast cancer by enhancing microcalcification features using morphology and LOG filter. Target to background contrast ratio, Contrast and Peak Signal to Noise ratio are considered for performance evaluation of the enhancement algorithm. The mini-MIAS mammographic database was employed for testing the accuracy of the proposed method and the result was promising.

General Terms

Image Processing, Breast Cancer., Laplacian of Gaussian, Morphology.

Keywords

Gaussian filter, microcalcification, mammogram, CAD, Breast Cancer.

1. INTRODUCTION

Breast cancer is one of the leading causes of cancer death among women. According to the statistics in 2011-12, the expected mortality rate due to breast cancer is about 577,190 [1], even though there is decrease in death rates since 1990. According to the Indian Council of Medical Research (ICMR), breast cancer becomes the leading cause of cancer-related mortality among women and it will affect 2.5 lakh women in India by 2015. Mammographic image analysis is a complicated and difficult task which requires opinion of highly trained radiologists. Detection of microcalcification, a possible symptom of breast cancer is a complex task because of the inhomogeneous background and the high noise level in the images due to emulsion artifacts. Microcalcifications (MC) are of small size which appears as bright spots [2]. Image enhancement methods were based on the fact that MCs tend to be brighter than their surroundings. A threshold can be applied to separate them after increasing the contrast. El Naqa and Yang [3] suggested the four major groups of MC detection methods as basic image enhancement methods, stochastic modeling methods, multiscale decomposition methods and machine learning methods. Enhancement is the first stage in the process of microcalcification detection. While enhancing MCs, background structures as well as noise may get amplified. Radiologists can provide an efficient opinion regarding the presence of MCs if there is improvement in visual appearance as well as contrast. Exiguous enhancement may lead to missed MCs, while excessive enhancement may lead to substantial increase the amplitude of background resulting in false detection. Contrast can be improved by increasing the intensity of MCs from the background. The proposed method comes under the basic image enhancement method. The principal objective of the

proposed contrast enhancement method is to enhance detail that is blurred.

In the proposed method, we employ Top-Hat operation in morphology as well as LOG filtering [4] to enhance microcalcification features in mammographic images. The significant elements that correspond to significant features of the image are retained, while leaving out those that possibly correspond to image noise, such as those due to emulsion discontinuity. Figure 1 shows an example of mammographic image (mdb 241) in the mini-Mias database and its region of interest where microcalcification features are identified with the help of radiologists. The performance of the proposed enhancement method is verified using various performance measures. The purpose of our method is to enhance suspected microcalcification so that early stage diagnosis and treatment can be done in effective manner. The major advantage of our technique is its simplicity, fast and novel approach.

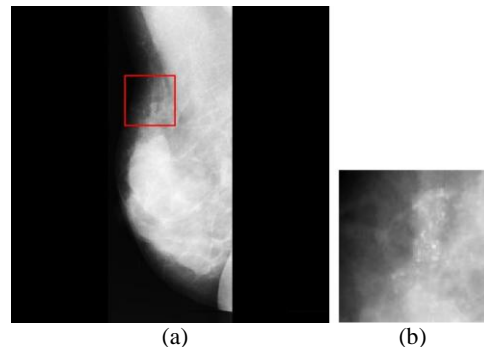


Fig 1. Example of a mammogram and its ROI with microcalcification features (a) mdb241 (b) ROI of mdb241 with microcalcification features.

2. PROPOSED METHOD

The proposed method is based on sharpening the edges in order to increase the contrast between image structure and background [5]. The major difficulties in identifying MCC in mammograms are due to very high frequency noise and background with low frequency components. In order to avoid these difficulties, the proposed method utilizes Top-Hat operation of morphology [6][7] along with spatial filtering. Morphological contrast enhancement was first suggested by Sollie[8]. The morphological Top-Hat transformation provides an excellent tool for extracting bright features smaller than a given structuring element. Even though it removes most of the low-frequency components, a smoothening effect occurs at the boundary of the individual MC. Noise reduction is not effective using Top-Hat operator. Noise reduction can be achieved very efficiently using Laplacian of Gaussian (LOG) filtering by pruning out artifact elements.

In the proposed method, the region of interest (ROI) is extracted from the mammographic image using the information provided by the radiologists in the mini-MIAS database. The extraction of ROI helps to reduce the complexity of our algorithm. The proposed method mainly consists of three steps. A morphological approach, Top-Hat transformation is employed to isolate the breast background from the MCs. In the second step, LOG filtering is performed to reduce noise and to enhance the MCs. In the final step, a logical AND operation is performed among the results obtained from step 2 and step3 to realize the enhancement of microcalcification features. The detail steps of the proposed algorithm are explained in section 6.

3. MORPHOLOGICAL OPERATION

Enhancement approaches using Morphological operations is of great importance as it is a powerful tool in extracting important information in an image. Dilation, one of the basic morphological operation results in growth or object or thickening while erosion shrinks objects based on the size of structuring element.

Erosion is defined as

$$I \ominus S = \{z / (S)z \subseteq I\} \quad (1)$$

where I is the image and S is the structuring element and z is the outcome when S is subset or equal to I.

Dilation is represented by

$$I \oplus S = \{z / [(S)z \cap I] \subseteq I\} \quad (2)$$

By combining erosion and dilation, the important morphological filter operations opening and closing are formed. Opening and closing are defined as follows.

$$I \circ S = (I \ominus S) \oplus S \quad (3)$$

$$I \bullet S = (I \oplus S) \ominus S \quad (4)$$

Opening operation represented by the symbol o, helps to keep the background (i.e., features that cannot hold the structuring element) which is not required for the proposed method. So a Top-Hat operation [9] is performed to remove the background in order to get the required microcalcification features. Top-Hat representation is given by

$$TH = I - (I \circ S) \quad (5)$$

where TH represents the resultant image after Top-Hat operation. In Top-Hat operation, the foreground objects can be highlighted by suppressing the dark background. Since the low contrast MCCs in mammograms appear as circularly bright spots, and a calcification has approximately a size of 20 pixels on each mammogram [10], the proposed method considers a structuring element larger than 20 pixels. So the detection of microcalcification is possible through morphological approach. The result image is threshold after morphological operation using the value of $8*\sigma$, where σ is the standard deviation of the result image.

4. LAPLACIAN OF GAUSSIAN FILTER

The LOG filter enhances high frequency components especially edges in an image. LOG filtering is defined as follows.

$$LOG(x, y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2} \quad (6)$$

The second derivative of the image is obtained by performing LOG filtering operation. Abrupt change in intensity indicating edge can be detected by LOG. Since the second derivative of image is susceptible to noise, the Laplacian is often applied after smoothing by Gaussian smoothing filter. In LOG filtering, a smoothed image is subtracted from the original

image. Zero crossings in the second derivative of image is utilized in LOG for finding out the high frequency elements. The sudden intensity variations are highlighted. In LOG, Gaussian smoothing operation is carried out first to curtail the noise. LOG operation removes the low pass components from the image.

5. LOGICAL AND OPERATION

Logical AND operation is performed on the results of Top-Hat operation and LOG filtering based approach. The logical and operation on the results of morphological and laplacian of Gaussian filtering operation utilizes the advantages of both operation.

6. ALGORITHM

Step1) The region of interest (ROI) is extracted from the mammographic image using the information provided by the radiologists in the mini-MIAS database.

Step2) Perform morphological operation, opening to get the unwanted background elements.

Step3) Resultant image obtained after opening operation is subtracted from the original image to obtain the probable microcalcification features using equation (5).

Step4) Threshold the resultant image using the value $8*\sigma$, where σ is the standard deviation of the resultant image.

Step5) Apply Laplacian of Gaussian filter to the original image.

Step6) Threshold the resultant image using the value $1.5*\sigma$, where σ is the standard deviation of the image obtained from step6.

Step7) Apply a logical AND operation with the results obtained from step 4 and step 7 to realize the detection of MCCs. Combine the result with the original image to get an enhanced image.

7. PERFORMANCE EVALUATION

In order to evaluate the enhancement results of the proposed method, contrast, the peak signal-to noiseratio (PSNR) [2], Target to Background Contrast (TBC) [11] were employed. The contrast C of a region is defined by

$$C = \frac{(f - b)}{(f + b)} \quad (7)$$

where f is the mean gray-level value of the foreground and b is the mean gray-level value of the background. The background noise level is measured by the standard deviation σ of the background:

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^N (b_i - b)^2} \quad (8)$$

where N is the total number of pixels in the surrounding background region. PSNR is defined as follows

$$PSNR = \frac{(p - b)}{\sigma} \quad (9)$$

where p is the maximum gray-level value and f is the average gray-level value of a foreground. High value of PSNR indicates better performance of enhancement technique. In order to evaluate the effect of visual appearance of our method, we are considering a quantitative measure, Target to Background Contrast Ratio using Variance (TBC). The expression for computing TBC is given below.

$$TBC_c = \frac{\delta_{\mu}}{\sigma} \quad (10)$$

where δ_μ is the difference between the ratios of the mean gray in the foreground and background areas in the original and enhanced images.

$$\delta_\mu = \left(\frac{\mu_f^e}{\mu_b^e} \right) - \left(\frac{\mu_f^o}{\mu_b^o} \right) \quad (11)$$

where $\mu_f^e, \mu_b^e, \mu_f^o, \mu_b^o$ represents mean gray-level value in the foreground of enhanced image, mean gray-level value in the background of enhanced image, mean gray-level value in the foreground of original image, mean gray-level value in the background of original image respectively.

$$\sigma = \frac{\sigma_f^e}{\sigma_f^o} \quad (12)$$

where σ_f^o and σ_f^e are the standard deviations of the target in the original and enhanced image. An efficient technique increase the contrast enhancement between foreground and background by increasing δ_μ without reducing the spread of gray scales in the enhanced foreground compared with that in the original image. This reduction can be measured by using σ . Efficiency of the algorithm can be indicated with high TBC value.

8. RESULTS AND DISCUSSION

The mini-MIAS mammographic database [12] was employed for benchmarking the proposed algorithm. Among these 25 images, 13 cases are diagnosed as malignant and 12 as benign. Figure 2 shows the inputs for logical AND operation obtained from morphological operation and LOG filtering technique before thresholding. The morphological operation extracts fine details with bright features while LOG filtering results in noise free edges. The common features among morphological and LOG filtering method can be obtained by logical AND operation. Figure 3 shows the enhanced results of various mammographic images obtained by the proposed method. The results are shown for the Mdb241, Mdb211, Mdb245 and Mdb249 images from the mini MIAS database. Mdb249 is a mammographic image having dense glandular background tissue with well-defined malignant microcalcifications. Mdb211 is a fatty glandular mammogram with a difficult to detect microcalcification cluster. Mdb245 represents a mammographic image with widely distributed calcifications. Mdb241 is a mammographic image having easy to detect microcalcifications. The result in figure 3 reveals that the proposed technique enhances the appearance of the microcalcifications against the surrounding dense tissue which may otherwise obscure these structures. The quantitative results of figure 4-6 substantiate the improvement in contrast and visibility with reduction in noise for the proposed technique. The results were promising on evaluation with the information provided by the radiologists in the mini-MIAS mammographic database. Execution time for the proposed method is around 1 second.

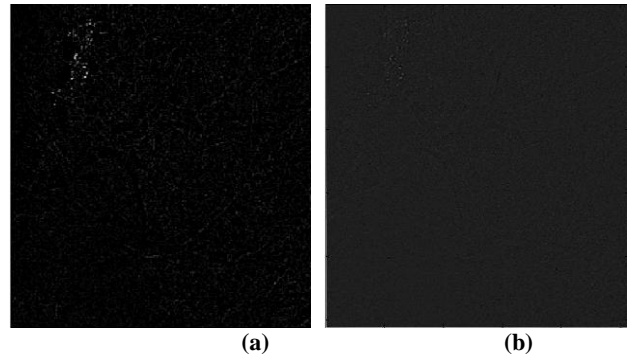


Fig2: Results after step3 and 6 (a) Tophat transform(b)LOG

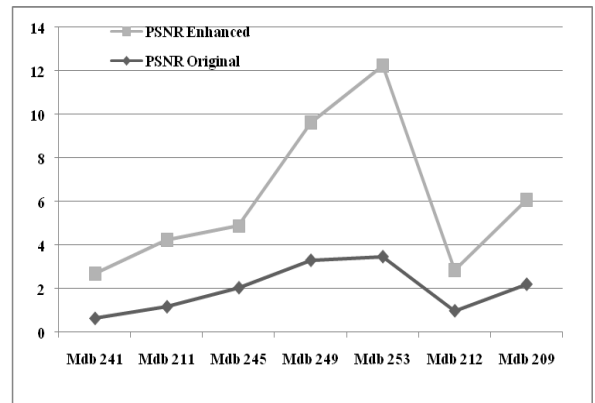


Fig4: Peak Signal to Noise ratio plot of original and enhanced image

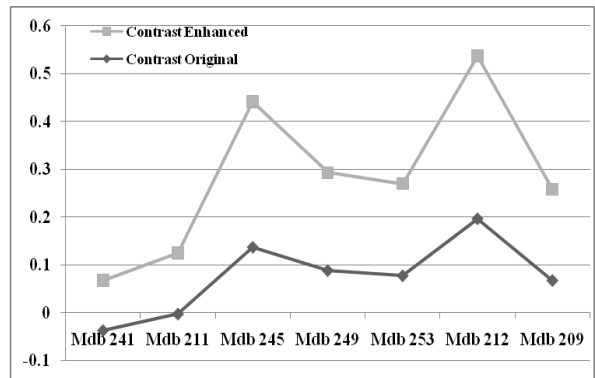


Fig5: Contrast plot of original and enhanced image

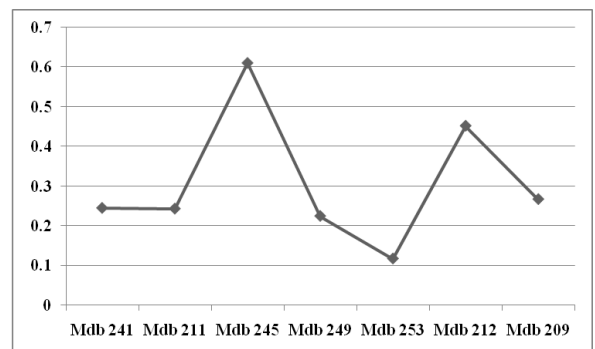


Fig6: Target to background contrast ratio plot of enhanced image

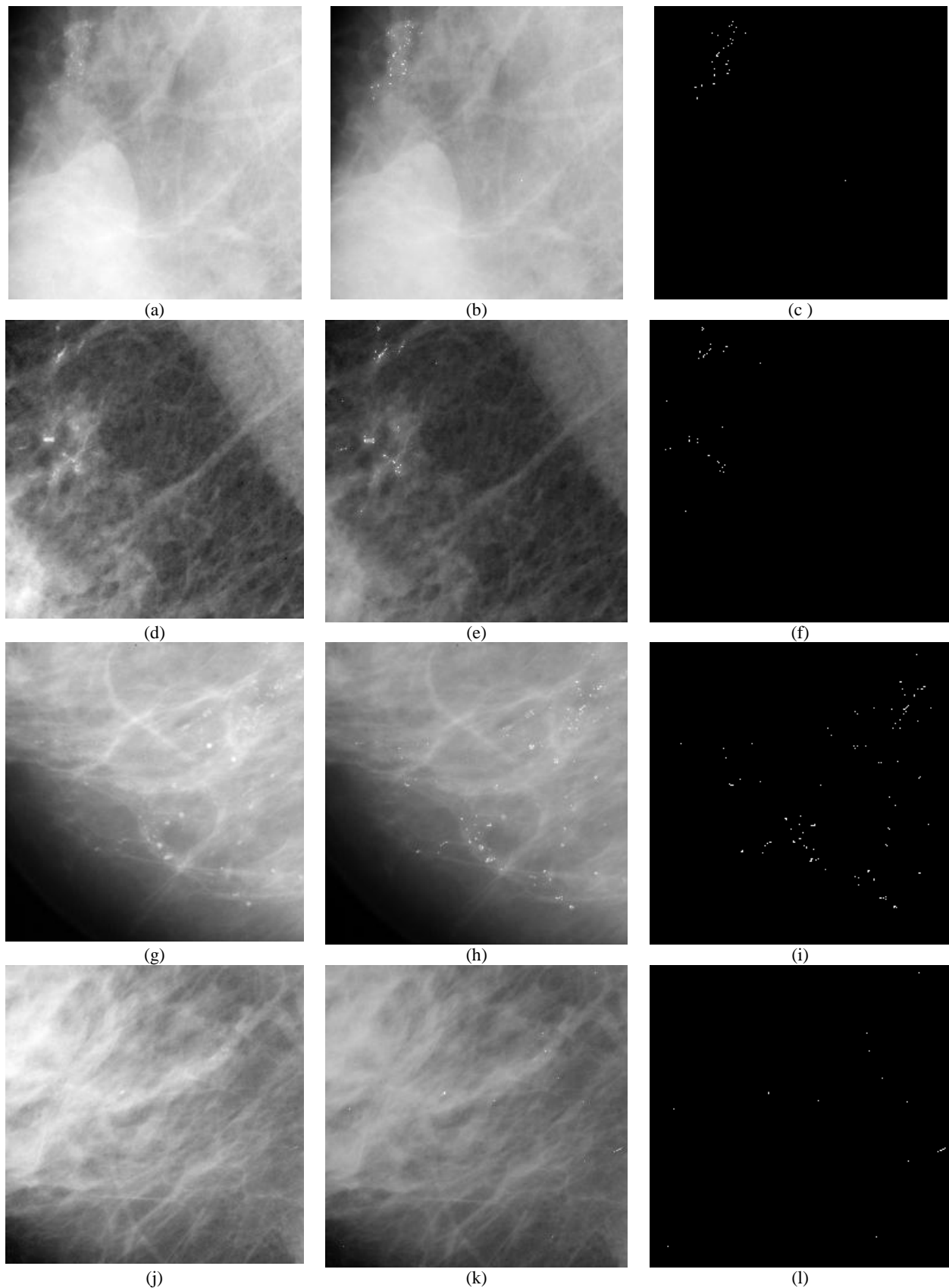


Fig 3: The enhancement and segmented results of microcalcifications on selected ROI's : (a)(d)(g)(j) original ROI of mdb241, mdb249, mdb245, mdb211, (b)(e)(h)(k) enhancement by proposed method (c)(f)(i)(l) segmented microcalcification

9. CONCLUSION

In this paper, a fast, novel method is proposed based on morphological operation and Laplacian of Gaussian filtering for mammographic image enhancement. Top-Hat morphological operation reduces the dark background while improving foreground microcalcification features. LOG reduces low pass components while reducing noise. Relevant edge features including microcalcification structures were enhanced while image artifacts were suppressed. Quality measures including contrast, PSNR and TBC were calculated to determine the efficiency of the proposed method. The proposed method takes an average execution time of 1.2 sec.

10. REFERENCES

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