COMPUTER-AIDED DETECTION OF CLUSTERED CALCIFICATION USING IMAGE MORPHOLOGY

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Abstract

The presence of microcalcification clusters in the mammogram image is a significant sign for the breast cancer at an early stage. The early detection increases the chance for successful treatment and complete recovery of the patient [1]. At present, the detection of microcalcification is still difficult because of their fuzzy nature, low contrast and low distinguish-ability from their surroundings [2, 3]. The interpretations of their presence are very difficult because of their morphological features. Microcalcifications are very small, typically between 0.1 and 1.0 mm, which means that they can be easily overlooked by a radiologist [4]. The purpose of this paper is to identify the location of suspicious areas to assist radiologists for diagnosis. The proposed method is divided into four steps: (a) image preprocessing (b) image enhancement using image morphology (c) individual calcification detection using intensity threshold, where pixels with high intensity are considered as suspicious pixels; and finally (d) clustered calcification detection, where suspicious pixels in close proximity are grouped into clusters. 17 images with calcification marked by expert radiologists from MiniMIAS database [5] were tested to evaluate the detection of the proposed method. From the tested images that contain 3 types of breast tissue consisting of fatty, fatty-glandular and dense-glandular. There are 2 types of calcifications presented in the tested image, benign and malignant. From 17 images with calcification marked from MiniMIAS, all calcifications locations were correctly detected. At this point, this is just a preliminary experiment. The author cannot claim that this method can successfully detect for all mammographic images. Larger image database is needed to improve the proposed method. Request for more mammographic images from Thailand Breast Center is in processing.

Keywords: Calcification detection, breast cancer, image morphology

Introduction

Breast cancer is a heartless disease for women around the world. The victims of the disease will be very seriously jeopardized. Besides from losing their life, they also worry about lose of their femininity, and their role as wife and mother may be compromised. From the National Cancer Registry Report [6], stated that breast cancer is the number one incidence cancer in Malaysia. Unfortunately, almost a half of patients detected the disease at late stage III or IV. Most of treatments at the late stage haves little or no benefit [7]. So, early detection is very important increasing the chance for successful treatment and complete recovery of the patient. In the mammography screening programs, radiologists will look for signs of disease. The most common signs of breast cancer are masses and calcifications. Masses are big and clearly present in the mammogram. Unlike calcifications, which are very small and therefore hard to detect and see. The presence of calcifications may be easily missed or misinterpreted by radiologists while reading large amounts of mammograms provided in screening programs. Calcifications can be divided into two groups: macrocalcification and microcalcification. Macrocalcifications are large, while microcalcifications are tiny. Macrocalcifications are usually not linked with the development of breast cancer. On the other hand, microcalcifications are usually associated with the development of breast cancer especially if the microcalcifications are grouped into a cluster [1]. At this point, computer-aided detection of clustered microcalcifications is needed to support the diagnosis of radiologists increasing the early detection rates, and increasing the chance for successful treatment and complete recovery of the patient. Although the computer-aided microcalcification detection has been studied over two decades, automated interpretation of microcalcifications remains very difficult. Microcalcifications are very small and hard to be distinguished from inhomogeneous background of the breast tissue. They present in various sizes, shapes, and distributions;, therefore simple template matching is impossible. They are close to the surrounding tissues both for the intensity and location aspects, therefore simple segmentation algorithms cannot work well. Furthermore, simple enhancement will cause over-enhanced and under-enhanced producing false positive rate and false negative rate accordingly. Besides that, in the dense tissue microcalcifications are almost invisible [3]. Mathematical morphology has already been used for digital image processing. Morphological contrast enhancement methods have been shown to be very useful for emphasizing small sized bright details in an image, thus capable to enhance microcalcifications [8].

Materials and Methodology

A mammogram or mammographic image is a low dose x-ray of the breast. In order to conduct this experiment, the MiniMIAS database, provided by the Mammographic Image Analysis Society (MIAS) [5], was used. The MIAS database was digitized at a resolution of 50x50 μm and then has been reduced to 200x200 μm or 0.2x0.2 mm. All images are 1024x1024 pixels. In this paper, the images were cropped to be 400x400 pixels. This database was provided with the diagnosis from experts. In case the image contains calcifications, the location will be marked. As seen in Figure 1 (left), one of mammographic image in the MiniMIAS database called mdb219 is displayed with calcifications marked. There are 322 images in the database and about 20 images containing calcification. In this paper, 17 of images from MiniMIAS with clearly calcification location identified were used as testing images.

Figure 1 Original mammographic image from MiniMIAS database [5] called mdb219 with calcification marked by experts (left) and the image after preprocessing (right).

The overview of the proposed method is presented in Figure 2. The method can be divided into four stages: (a) image preprocessing (b) image enhancement using image morphology (c) individual calcification detection using intensity threshold, where pixels with high intensity are considered as suspicious pixels; and finally (d) clustered calcification detection, where suspicious pixel in close proximity are grouped into clusters. In the image preprocessing stage, digitizing images are manually manipulated with the intention to remove pectoral muscle, metal tag, and other obvious artifacts (please see Figure 1 (right)). In this context, researching phase, the input images were manually manipulated but in the future, in practical usage, automatic manipulation must be integrated into the system. In the image enhancement stage, images are enhanced using image morphology using the top-hat transform. In the individual calcification detection stage, the pixels with high intensity are considered as suspicious pixels. The final stage, is where clustered calcifications are detected, so that suspicious pixels in close proximity are grouped into a cluster.

Figure 2 Overview of the proposed method

Image Enhancement Using Image Morphology

Image morphology has already been used for digital image processing. Morphological contrast enhancement methods proved its efficiency for emphasizing small sized bright details in the image, thus capable to enhance microcalcifications. The morphological operations have been originally developed for the analysis of binary (black and white) image, and later extended to gray scale image [8]. Morphological operations are based on the relationships between an input image and a processing operator called a structure element. Two morphological operations, dilation and erosion are fundamental to morphological processing. Dilation adds pixels to the boundaries of objects in an image, while erosion removes pixels on object boundaries. The number of pixels added or removed from the objects in an image depends on the size and shape of the structure element used to process the image. In the morphological dilation and erosion operations, the state of any given pixel in the output image is determined by applying a rule to the corresponding pixel and its neighbors in the input image [9]. The rules for dilation and erosion are listed in Table 1.

Table 1 The rules for dilation and erosion

Operation	Rule
Dilation	The value of the output pixel is the maximum value of all the pixels in the input pixel's neighborhood coinciding with the value 1 pixel in the structure element.
Erosion	The value of the output pixel is the minimum value of all the pixels in the input pixel's neighborhood coinciding with the value 1 pixel in the structure element.

Opening and Closing Morphology

In image morphology, opening operation is the dilation of the erosion of input image *I* by a structure element *S* (as seen in equation 1). Closing operation is the erosion of the dilation of input image *I* by a structure element *S* (as seen in equation 2).

$$A \circ B = (A \ \Theta \ B) \oplus B \quad (1)$$

$$A \bullet B = (A \oplus B) \ \Theta \ B \quad (2)$$

Where $\circ$ denote opening operation, $\bullet$ denote closing operation, Θ denote erosion operation, and $\oplus$ denote dilation operation.

Top-Hat Transformation

In image morphology, top-hat transform is an operation that enhances small elements from the given image. There are 2 types of top-hat transform, white top-hat and black-top-hat. White top-hat is for small object that brighter than surrounding enhancement while black top-hat is for small object that darker than surrounding enhancement. In this paper, white top-hat is used to detect calcification that normally brighter than surrounding tissue. Top-hat transformation computes the morphological opening the image and then subtracts the result from the original image (as seen in equation 3).

$$\text{Top-Hat}(I) = I - (I \circ S) \quad (3)$$

The objective of top-hat transformation is to enhance objects or elements that are smaller than the structure element. In this paper, to enhance calcifications in the mammographic image, three iterations of top-hat transformation. In the first iteration, the image is performed using disk-shaped with radius = 1 structure element. In the second iteration, the result from the first iteration is the input and another top-hat transform is applied but using a disk-shaped with radius = 2 structure element. Finally, the result from the second iteration is performed using disk-shaped with radius = 3 structure element. The result of enhancement using this method is displayed in Figure 3.

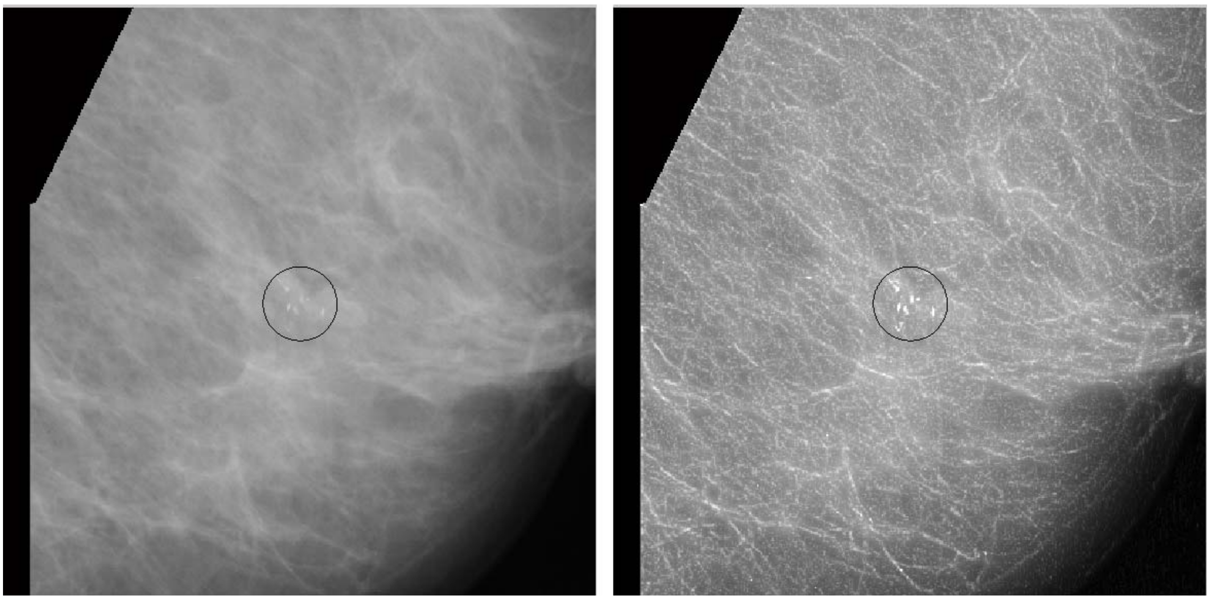

Figure 3 Original mammographic image from MiniMIAS database [5] called mdb252 with calcification marked by experts (left) and the image after three iterations of top-hat transformation (right).

Individual and Clustered Calcifications Detection

In order to detect individual calcification, simple threshold is used. The optimal threshold value is acquired from the empirical experiments. After three iterations of top-hat transformation, calcification pixels in all images always reached a maximum value of grayscale image. In this case maximum value of 8 bit grayscale images is 255. As seen in Figure 4 (left), the maximum pixels are marked by little circles and assumed as suspicious pixels to be individual calcifications. At this point, each pixel is considered to be the proper center of the cluster. The pixel that has minimum Euclidean distance from other remaining pixels is assumed as the center of the cluster. In order to group the pixels to form the cluster, the Euclidean distance from the center of the cluster is used. As implied from [3] the radius of a cluster can be one of these three distance, 0.5 cm, 1.5 cm., and 2 cm. From the empirical experiment, 1 cm is far enough to detect all calcification clusters. In this paper, the pixels that are in the range of 1 cm or 50 pixels are grouped into the cluster. So, in this paper, the cluster is always 2 cm diameter. The detected cluster is displayed in Figure 4 (right). From Figure 4, please note that there is an artifact vertical line presented. The detection efficiency is not interfered by this kind of artifact.

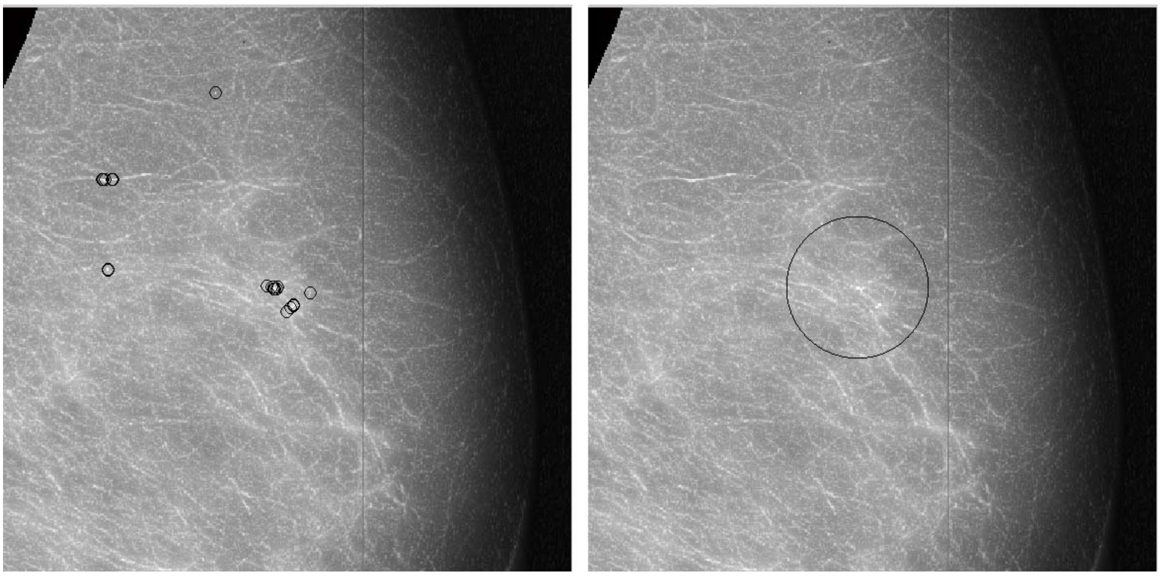

Figure 4 Enhanced image of mdb238 with individual calcification detection (left) and the clustered calcification detection (right).

Results

The enhancement and detection results are in Figure 5, 6, and 7. As seen in the results, the proposed method could work well for all types of breast tissues consisting of fatty breast tissue (see Figure 5), fatty-glandular breast tissue (see Figure 6) and dense-glandular breast tissue (see Figure 7). Furthermore, it could also work well for both types of calcifications; benign and malignant. From 17 images with calcification marked from MiniMIAS, all calcifications locations were correctly detected.

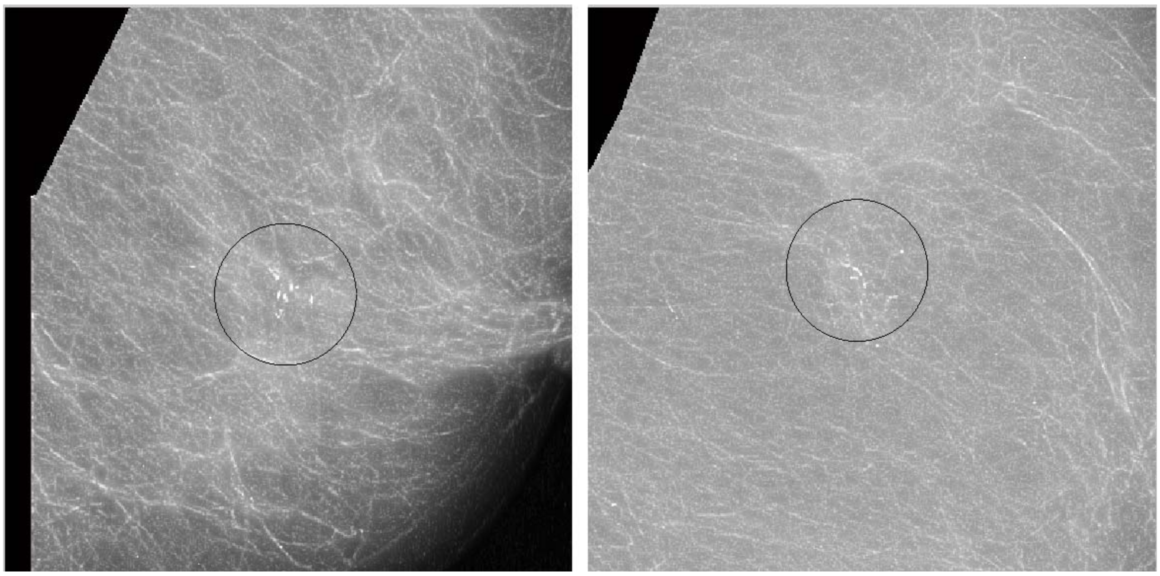

Figure 5 Calcification detection results from fatty breast tissue: mdb252 with benign calcifications (left) mdb256 with malignant calcifications (right).

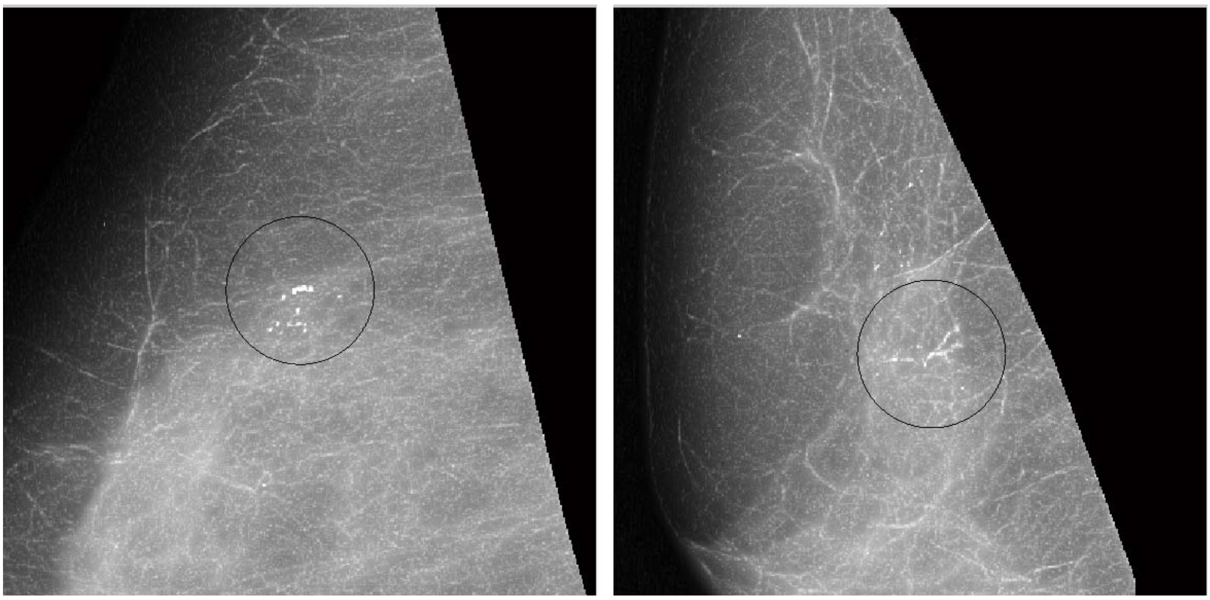

Figure 6 Calcification detection results from fatty-glandular breast tissue: mdb219 with benign calcifications (left) mdb213 with malignant calcifications (right).

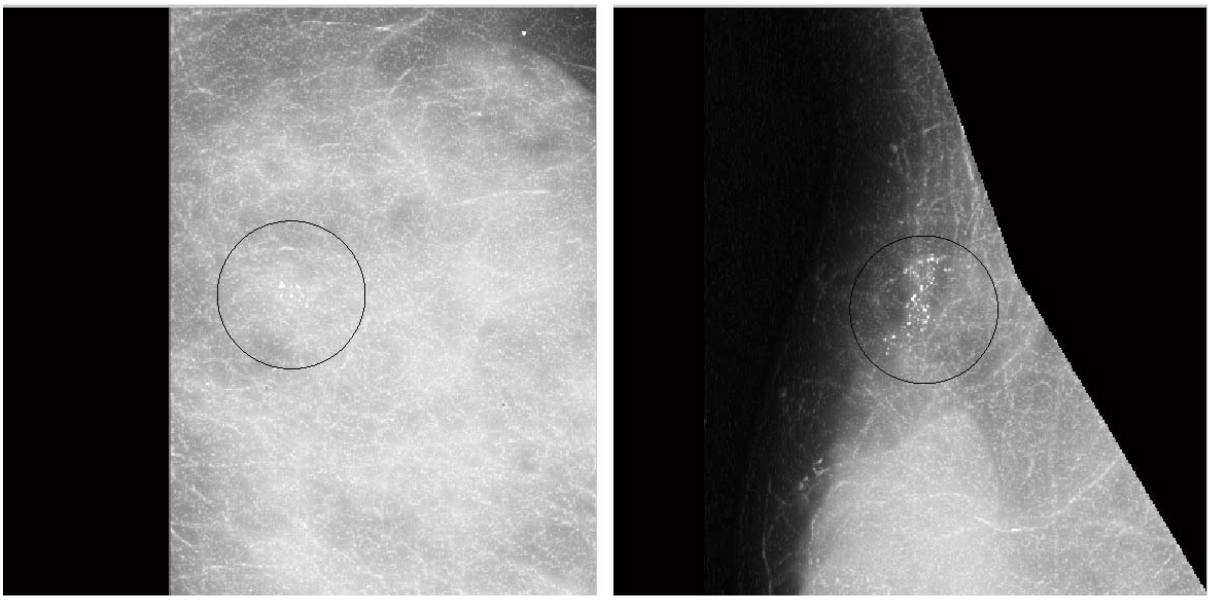

Figure 7 Calcification detection results from dense-glandular breast tissue: mdb219 with benign calcifications (left) mdb213 with malignant calcifications (right).

Discussion and Conclusion

Although the computer-aided microcalcification detection has been studied over two decades, automated interpretation of microcalcifications remains very difficult. The presence of calcifications may be easily missed or misinterpreted by radiologists while reading large amounts of mammograms provided in screening programs. Besides that, in the dense tissue microcalcifications are almost invisible. From the tested images that contain all 3 types of breast tissue consisting of fatty, fatty-glandular and dense-glandular. There are 2 types of calcifications presented in the tested image, benign and malignant. From 17 images with calcification marked from MiniMIAS, all calcifications locations were correctly detected. At this point, this is just a preliminary experiment. The author cannot claim that this method can successfully detect for all mammographic images. Larger image database is needed to improve the proposed method. Request for more mammographic images from Thailand Breast Center is in processing.

References

1. Bozek, J., Mustra, M., Delac, K., & Grgic, M. (2009). A survey of image processing algorithms in digital mammography. In Grgic, M., et al (Eds), Recent Advances in Multimedia Signal Processing and Communication, 631-657.
2. Mohanty, A. K., Champati, P. K., Swain, S. K., & Lenka, S. K. (2011). A review on computer aided mammography for breast cancer diagnosis and classification using image mining methodology, International Journal of Computer Science and Communication, 2, 531-538.
3. Cheng, H. D., Cai, X., Chen, X., Hu, L., & Lou, X. (2003). Computer-aided detection and classification of microcalcifications in mammograms: a survey, Pattern Recognition, 36, 2967-2991.
4. Yusof, N. M., Isa, N. A. M., & Sakim, H. A. M. (2007). Computer-aided detection and diagnosis for microcalcifications in Mammogram: a review, International Journal of Computer Science and Network Security, 7, 202-208.

5. Suckling, J., Parker, J., Dance, D. R., Astley, S., Hutt, I., Boggis, C. R. M., et al. (1994). The Mammographic Image Analysis Society Digital Mammogram Database, Exerpta Medica International Congress Series, 375-378.
6. Ariffin, O. Z. & Saleha, L. T. (2011). National Cancer Registry Report 2007, Ministry of Health, Malaysia.
7. Hisham, A., & Yip, C. (2004). Overview of breast cancer in Malaysian women: A problem with late diagnosis, Asian Journal Surgery, 28, 130-133.
8. Stoijic, T., & Reijin, Branimir. (2010). Enhancement of Microcalcifications in Digitized Mammograms: Multifractal and Mathematical Morphology Approach, FME Transactions, 38, 1-9.
9. Thapar, S., & Garg, S. (2012). Study and Implementation of Various Morphology Based Image Contrast Enhancement Techniques, International Journal of Computing and Business Research, 2229-6166.