Detecting Region-of-Interest (ROI) in Digital Mammogram by using Morphological Bandpass Filter

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Abstract

Microcalcifications are early sign of breast cancer appear as isolated bright spots in mammogram images, which are difficult to detect due to their small size. In this paper, morphological bandpass filter (MBF) is introduced to detect microcalcifications, which is implemented by opening the original image two times with two different structure elements respectively, and subtracting one opened image using another one that can decompose the image into interest details domain image where microcalcifications tend to appear. Series of MBFs are tuned for the detection task, and binary image contained microcalcifications region-of-interest (ROI) will be obtained. Experimental results show that the proposed method with these bandpass filters can recognize ROI with a true positive of 93.07% and a false positive of 4.34%. Comparing to the well-known discrete wavelet transform (DWT) method, this method is more accurate in positions and sizes of microcalcifications.

1. Introduction

Breast cancer is still one of main mortality causes in women, but the early detection can increase the chance of cure [1]. Microcalcifications are small size structures, which can indicate the presence of cancer since they are often associated to the most different types of breast tumors. However, they very small size and the X-ray systems limitations lead to constraints to the adequate visualization of such structures, which means that the microcalcifications can be missed many times in mammogram visual examination. In addition, the human eyes are not able to distinguish minimal tonality differences [2], which can be another constraint when mammogram image presents poor contrast between microcalcifications and the tissues around them. Computer-aided diagnosis (CAD) schemes are being developed in order to increase the probabilities of early detection [3-4].

A general CAD system can be divided into three parts as shown in Fig.1. The first part is to find region-of-interest (ROI) which have high possibilities of breast cancer. Finding ROIs with high accuracy can be very important for correct diagnosis. The second part is to extract appropriate features from ROIs for the next part. And the last part of a CAD system is to determine whether a region contains malignant symptoms or not based on the feature values.

Some morphological methods for detecting microcalcifications are based on top-hat transform to elaborate all the bright blobs of small size which are the suspected microcalcifications [5-8]. But top-hat transform enhance not only the microcalcifications but also other type of bright narrow elongated areas due to the connective tissue of the breast. Other methods for detecting microcalcifications using multiresolution approaches are based on wavelet transform [13-15]. Since wavelet transform can decomposing image into subimages through subband decomposing filterbank. In [14], a low-high (LH), high-low (HL) and high-high (HH) sub-bands at full size are obtained, which correspond with horizontal, vertical and diagonal details. Sum of the detail bands (LH+HL+HH) gives an image containing small elements (microcalcifications) detected in each direction. But this assembling has the problem of locating as small details objects that have a small size in only one
direction [12]. In [12], the author uses Gussianity test for next classification, but Gussianity test is not an accurate approach for determining microcalcifications positions but only for determining microcalcifications areas, it is not deserved spreading. In [15], given that the microcalcifications correspond to high-frequency components of the image spectrum, detection of microcalcifications is achieved by decomposing the mammograms into different frequency subbands, suppressing the low-frequency subband, and, finally, reconstructing the mammogram from the subbands containing only high frequencies. But noises also remain in the left subbands.

To conquer the drawbacks of those above approaches, in this work we describe a method to detect the microcalcifications by using morphological bandpass filter (MBF), which is implemented by opening the original image two times with two different structure elements respectively, and subtracting one opened image using another one to obtain a bandpass image [9]. The structure element’s sizes of MBF are tuned automatically. Then adaptive threshold method is applied in the bandpass image to segment the microcalcifications into binary image. By this method, noises in the high frequency subbands are removed by morphological bandpass filters, but microcalcifications are remained in the frequency subbands, which is an improvement of the above methods.

This paper is organized as follows: In Section 2, we describe the morphological bandpass filter and Section 3 explains the proposed detection method. Experimental results are explained in Section 4 and Section 5 shows the conclusion.

2. Morphological bandpass filter

Morphological filters are nonlinear signal transformations that locally modify geometric features of signals. The basic morphological operations are dilation and erosion, other operation like open and close operation can derived from the dilation and erosion operation. In general, signals can be represented either by sets (binary) or functions (multilevel) [9]. Since the mammography is gray level image, we have to take multilevel morphological operations which are defined as algebraic operations using the concepts of the umbra (U[]) and top (T[]) surface [11]. The multilevel dilation of function f by a multilevel structuring element s is denoted by f (+) s, and is defined by

\[ f \oplus s = T[U[f]] \Theta U[s] \]  

From this definition, multilevel dilation can be computed in terms of a maximum operation and a set of addition operations.

\[ (f \oplus s)(x) = \max[f(x - z) + s(z)] \]

for all \( z \in s \) and \( x - z \in F \)  

Where, F and S is the domain of functions f and s, respectively.

The multilevel erosion of a function f by a multilevel structuring element s is defined by

\[ f \Theta s = T[U[f] \Theta U[s]] \]

Using the above definition, the erosion can be evaluated in terms of a minimum operation and a set of subtraction operations.

\[ (f \Theta s)(x) = \min[f(x + z) - s(z)] \]

for all \( z \in s \) and \( x + z \in F \). 

Multilevel open is implemented by first erosion and then dilation using the same structure. It is defined

\[ A \circ B = (A \Theta B) \oplus B \]

Morphological filters can be defined use the multilevel open operations, which are used to image processing well. Since the multilevel open operation just like a lowpass filter, it eliminates those structures of the image that are smaller than structure element. A morphological bandpass filter is defined as the difference of two multilevel open operations with two different structuring elements as in Fig.2 [9].

3. Microcalcifications detecting method

Microcalcifications found in a digital mammogram have a cone-shape with local maximum gray-level values. Fig. 3 shows examples of microcalcifications. Tissues, which occupying most of the breast area, from wide mountain-like shape, while microcalcifications are appeared as local peaks on the mountains. Morphological bandpass filter is a good tool for getting the peaks of the image. Here we use it to detect the microcalcifications in this work. Due to mammogram’s inhomogeneous background, there are noise and all kinds of small isolated structures in it,
which can be removed by a smaller structure element, while microcalcifications are removed by using an appropriate bigger structure element for their bigger size structures than noise and small isolated structures in the digital mammogram. The sketch processing and final labeled binary image are shown as in Fig.4. The structure element using in this work is a $3 \times 3$ squares for one open operation, which contained elements all are number 1 (if different $z$ is used in formula (2, 4), different result will be got, here we use $z=1$), and the $5 \times 5$ or $7 \times 7$ or $9 \times 9$ squares for another ($z=1$) to implement the corresponding morphological bandpass filters $MBF_I$, $MBF_{II}$ and $MBF_{III}$.

![Fig.3](image1.png)

Fig.3: (a) Original image. (b) The 3D view image.

![Fig.4](image2.png)

Fig.4: (a) One open operation. (b) Another open operation (c) Subtract the one opened image by another. (d) Labeled binary image.

The detection flow is showed in Fig.5. The algorithm starts with a smaller opening size of morphological bandpass filter, usually $MBF_I$, then tuning to $MBF_{II}$ and $MBF_{III}$ to detect all microcalcifications. Adaptive threshold methods are used to determine whether the remained regions belong to ROIs. Regions resulted from the above steps may contain very small size regions, component of 1~2 pixel(s), from tissues and noises. To improve the correct recognition rate of microcalcifications in a CAD system, tiny regions and holes must be removed by an enhancement process. We use the mathematical binary morphology operators for this purpose at the refinement step [16].

![Fig.5](image3.png)

Fig.5: ROI detection flowchart.

4. Experimental results

The database of digital mammogram used in this work is form MIAS (Mammographic Image Analysis Society [10]) database. In these database images, microcalcifications have been marked by the veteran diagnostician. Each image in the database has the resolution of $50 \mu m$ with 256 gray levels. 60 images that contain microcalcifications (30 benign and 30 malignant microcalcifications) are selected for this experiment.

Two examples of resulted images, malignant and benign, are shown in Fig.6 (a) and (b), respectively. It shows that all ROIs are detected and malignant microcalcifications tend to be easily affected variations of tissues.

![Fig.6](image4.png)

Fig.6 Result images ($MBF_{III}$, $T=10$)
Here discrete wavelet transform method is discussed for comparing with our morphological bandpass filter method. We used DWT method introduced by Wang and Karayiannis in [15]. The processed image by DWT is showed as Fig.7. As in the figure, some small microcalcifications are eliminated and others are shrunken, so the performance of using MBF method to detect ROIs is better.

Fig.7 DWT processed result.

Microcalcifications numbers are detected by using MBF₀, MBF₁, MBF₂ and DWT for 2 different mammograms (mdb209 and mdb219) in Table1. Testing with our database and comparing with the marked microcalcifications, we consider taking MBF₂ and threshold value 10, can achieve the best result, the true positive is 93.07% and false positive is 4.34%.

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<th>mdb209</th>
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<td></td>
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5. Conclusion

In this work, we describe a new method for the detection of microcalcifications by using morphological bandpass filter. Comparing to DWT method, this method is more accurate in positions and sizes of microcalcifications. However, some tissues which have similar characteristics with microcalcifications in digital mammogram exist. More intelligent stages are needed to delete and to minimize the effect of normal tissues. This work should be refined and further proceeded to complete an efficient CAD system.

6. Acknowledgment

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7. References