Automated Detection of Architectural Distortion Using Improved Adaptive Gabor Filter

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Abstract. Architectural distortion in mammography is the most missing finding for radiologists, despite high malignancy. Many research groups have developed methods for automated detection of architectural distortion. However, improvement of their detection performance is desired. In this study, we developed a novel method for automated detection of architectural distortion in mammograms. To detect the mammary gland structure, we used an adaptive Gabor filter, whichconsists of three Gabor filters created by changing the combination of parameters. The filter that is best matched to the mammary gland structure pixel by pixel in the mammogram is selected. After detecting the mammary gland, enhancement of the concentrated region and false positive reduction are performed. In the experiments, we verified the detection performance of our method using 50 mammograms. The true positive rate was found to be 82.45%, and the number of false positive per image was 1.06. These results are similar to or better than those of existing methods. Therefore, the proposed method may be useful for detecting architectural distortion in mammograms.

Keywords: Mammography, CAD, architectural distortion, Gabor filter.

1 Introduction

Mammography screening is carried out for detecting breast cancer early. The findings obtained from mammography are mass, micro-calcification, and architectural distortion. Among them, architectural distortion is the most elusive finding for doctors. Moreover, it is classified as having a high malignancy in breast cancer. Therefore, it is important to detect and treat architectural distortion at an early stage. Many research groups have developed automated detection methods for architectural distortion[1–3]subsequent to two other findings [4,5].However, conventional methods failed to produce acceptably low false positive and high true positive rates [1–3]. Therefore, further improvement of the detection rate is desired. In order to improve the detection performance, it is essential to analyze the mammary gland structure more accurately. In this study, we propose an improved detection method for architectural distortion using an adaptive Gabor filter, which uses three Gabor filters, and we evaluated its detection performance.

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2 Methods

The proposed method consists of 6 steps: pre-processing, detection of mammary gland structure, extraction of primary mammary glands, calculation of the degree of concentration, segmentation, and false positive reduction.

2.1 Pre-processing

Images of the breast area are extracted by automated thresholding and labeling. In order to emphasize the line patterns, trend removal using a top-hat filter and gamma correction is performed.

2.2 Detection of Mammary Gland Structure

In order to detect the mammary gland structure, a Gabor filter[6] is introduced. A Gabor filter [Fig. 1;Eqs.(1) and (2)] is a type of line detection filter. The maximum value of $h(x,y)$ is obtained at an angle that line structures of mammary gland andfilter shape is matched.

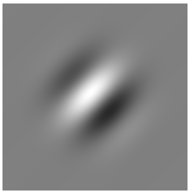

Fig. 1. Gabor filter function

$$h(x, y) = f(x, y) \otimes g(x, y), \tag{1}$$

$$g(x, y) = \exp\left(-\frac{x'^2+\gamma^2 y'^2}{2\sigma^2}\right)\cos\left(2\pi\frac{x'}{\lambda}+\varphi\right), \tag{2}$$

$$x' = x\cos\theta + y\sin\theta, y' = -x\sin\theta + y\cos\theta, \tag{3}$$

where λ is the wavelength of the filter function, γ is the aspect ratio, σ is the deviation of the Gaussian factor that determines the effective size of filtering, φ is the phase, and θ represents an direction of Gabor filter.

In this study, mammary gland structure is extracted using the adaptive Gabor filter as shown in Fig.2 [7].

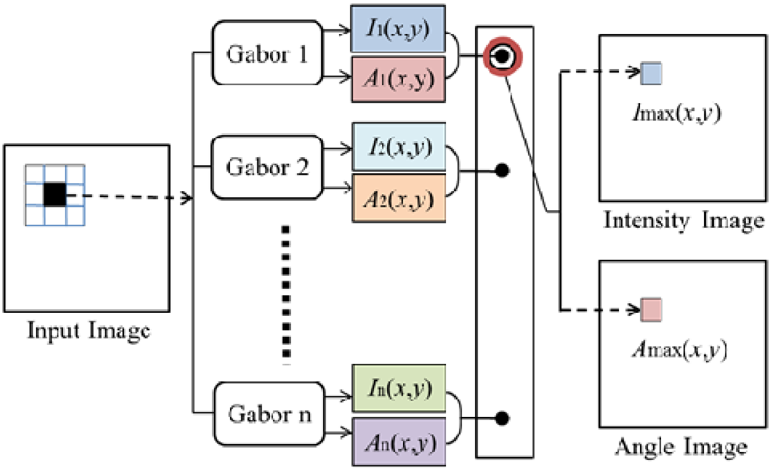

Fig. 2. Schematic of the adaptive Gabor filter

The n types of Gabor filter functions $g_i(x,y)$ (i=1,2…n) have different characteristics. The intensity image $I_i(x,y)$ and the angle image $A_i(x,y)$ are obtained by filtering the target pixel. Here, the characteristics of the filters are determined by changing λ, γ, and σ. From prepared filters, the best-matched filter g_i is selected such that $I_i(x,y)$ has the highest value among all intensity images for each pixel; the intensity image $I_{max}(x,y)$ and angle output image $A_{max}(x,y)$ are obtained.

In this study, we introduced three Gabor filters (n=3) and selectively and locally applied the filter most appropriate for the mammary gland structure.

2.3 Extraction of Primary Mammary Glands

The mammary gland structure involved in the formation of the architectural distortion (hereafter referred to as the primary mammary gland structure) is extracted in three steps in order to simplify the angle image. The steps are: (1) thresholding for narrowing the mammary gland region, (2) removal of non-primary line components, and (3) removal of mammary glands that have an anatomical normal orientation.

2.4 Calculation of the Degree of Concentration

A finding named spicula specific to architectural distortion indicates concentration and distortion of the mammary gland structure. Thus, the degree of concentration is calculated using the post-processed angle image $A_{max}(x,y)$. The concentration index $C(P)$ is defined as described in Fig.3 and Eq.(4) [8].

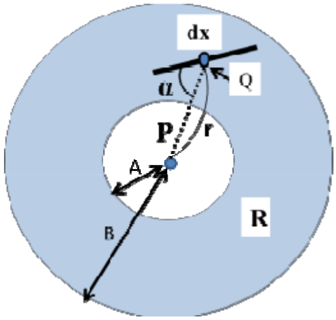

Fig. 3. Schematic of concentration index

$$C(P) = \sum_{R} \frac{dx\,|\cos\alpha|}{r}, \tag{4}$$

Where R is the range of processing coverage, dx is the length of a line element, Q is center of dx, r is the distance of line segment PQ, α is the angle between dx and PQ, and A and B are the inner and outer diameters of the region of interest, respectively.

2.5 Segmentation

The initial candidate regions of architectural distortion are identified by performing thresholding and are determined on the basis of individual breast density.

2.6 False-Positive Reduction

In order to reduce false positives, 23 types of characteristic features are calculated using the three images: the original image, intensity image, and concentration image. We calculated the following characteristic features: (1)area, (2)concordance rate of the filter, (3) density of the mammary gland, (4)position of the candidate region, (5) minimum pixel value, (6)maximum pixel value, (7)kurtosis of the pixel value, (8)skewness of the pixel value, and (9)standard deviation depending on the characteristics of each image. Finally, true positives and false positives are classified using a support vector machine [9,10]and these characteristic features.

3 Experiments

In order to evaluate the effectiveness of the proposed method, we evaluated its detection performance using 50 mammograms(200images),of which 20 were normal and 30 contained architectural distortion. These images were obtained from the digital database of screening mammography [11].

Figure 4 shows images that were detected by our method. Spicula and retraction findings were detected. Using this method the true positive rate was 82.45%,and the number of false positives per image was 1.06.

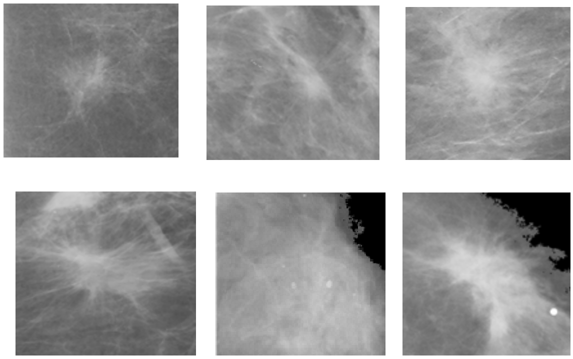

Fig. 4. Architectural distortions detected by the proposed method

4 Conclusion

We investigated an automated scheme for detecting architectural distortion (spicula) using an adaptive Gabor filter. We evaluated this method using 50 clinical mammograms (200 images).The true positive rate was 82.45%, and the number of false positives per image was 1.06. These results are similar to or better than those of existing methods. Therefore, the proposed method may be useful as an automatic method for detecting architectural distortion.

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