Automated detection scheme of architectural distortion in mammograms using adaptive Gabor filter

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ABSTRUCT

Breast cancer is a serious health concern for all women. Computer-aided detection for mammography has been used for detecting mass and micro-calcification. However, there are challenges regarding the automated detection of the architectural distortion about the sensitivity. In this study, we propose a novel automated method for detecting architectural distortion. Our method consists of the analysis of the mammary gland structure, detection of the distorted region, and reduction of false positive results. We developed the adaptive Gabor filter for analyzing the mammary gland structure that decides filter parameters depending on the thickness of the gland structure. As for post-processing, healthy mammary glands that run from the nipple to the chest wall are eliminated by angle analysis. Moreover, background mammary glands are removed based on the intensity output image obtained from adaptive Gabor filter. The distorted region of the mammary gland is then detected as an initial candidate using a concentration index followed by binarization and labeling. False positives in the initial candidate are eliminated using 23 types of characteristic features and a support vector machine. In the experiments, we compared the automated detection results with interpretations by a radiologist using 50 cases (200 images) from the Digital Database of Screening Mammography (DDSM). As a result, true positive rate was 82.72%, and the number of false positive per image was 1.39. There results indicate that the proposed method may be useful for detecting architectural distortion in mammograms.

Keywords: CAD, Mammography, Architectural distortion, Gabor filter

1. INTRODUCTION

Consultation rate in breast cancer screening in Japan is increasing year by year. At the same time, also increasing the burden on physician interpretation, it is said that the oversight of the lesion and nearly 20%[1]. So computer-aided detection (CAD) technology for auxiliary interpretation by physician, has become development leaps and bounds, currently the automatic detection in mammography is a stage of practical use for mass and micro-calcification[2].

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However, the architectural distortion[3] have extremely difficult to identify the extent of invasion despite it is classified as more than third grade malignancy in the breast cancer if it identified. Therefore, it is important to detect and treat it at an early stage. As for the automatic detection of architectural distortion, Rangarai et al. proposed the mammary gland structure analysis using directionality index [4], and Nemoto et al. examined detection of spicula findings using the concentration index and Laplacian filter [5]. However, their detection rates were about 70%, the further improvement of the detection rate was desired. In order to improve the detection rate of these, it is essential to analyze more accurately the structure of individual differences mammary gland structure. In this study, we investigate a method to automatically detect detection for architectural distortion using adaptive Gabor filter for detecting the mammary gland structure.

2. METHODS

Detection method for architectural distortion in mammography consists of five steps: pre-processing, extraction of the mammary gland structure, post-processing, calculation of the degree of concentration, and false-positive reduction (Fig.1).

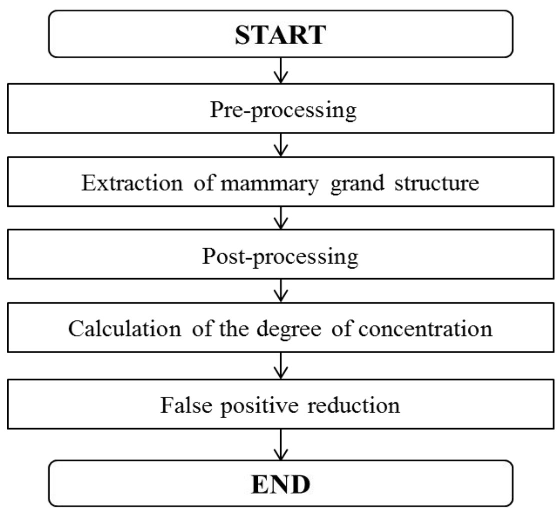

Fig.1 Flowchart of automatic detection method

2.1 Pre-processing

First, the breast region is extracted by the binarization using mode-based thresholding and labeling. Next, the relation between thickness of the breast and the pixel value are linearized by gamma correction. Finally the trend caused by the unevenness of the breast thickness and breast density of the image are removed by the Top-hat filtering.

2.2 Extraction of the mammary gland structure.

In order to detect of the mammary gland structure, Gabor filter is introduced. Gabor filter (Fig 2., eq.(1) and (2)) is one kind of line detection filter, which obtains the maximum value when matched the filter shape and the thickness of the line structure.

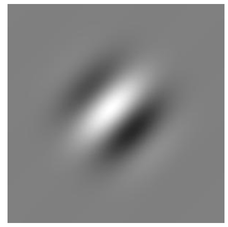

Fig. 2 Gabor filter function

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

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

where λ is the wavelength of filter function, γ is the aspect ratio, σ is the deviation of the Gaussian factor which determines the effective size of filtering, φ is the phase, θ is represents an angle, and $x' = x\cos\theta + y\sin\theta$, $y' = -x\sin\theta + y\cos\theta$.

In the conventional method [4], since only one type of filter shape is used, filter output is affected by the thickness of the line structure of mammary grand. However, there is a variety of thickness of the mammary gland structure in the breast. Therefore, in order to perform enhancement of the mammary gland structure for image pre-processing, the adaptive Gabor filter is developed (Fig 3.).

We have developed the adaptive Gabor filter that introduces several filters having different characteristic, and applying selectively and locally for the mammary gland structure with many individual differences. The processing of adaptive Gabor filter allows more accurate analysis of the mammary gland structure by selecting the appropriate Gabor filter that fit to the shape of the mammary gland structure.

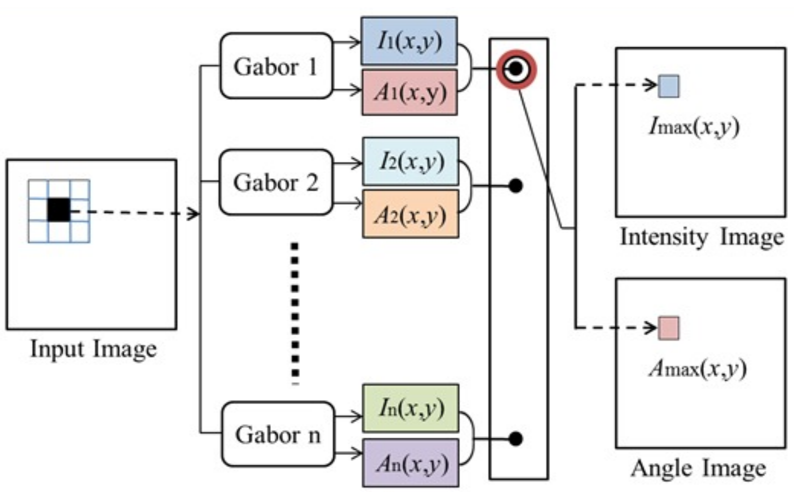

Fig. 3 Schematic of adaptive Gabor filter

As processing procedure of the adaptive Gabor filter, n types of Gabor filter function $g\mathrm{i}(x,y)$ (i=1,2…n) having different characteristics; the intensity image $I\mathrm{i}(x,y)$ and the angle image $A\mathrm{i}(x,y)$ are obtained by performing a filtering of the target pixel. Here, characteristics of filters are determined by changing the λ, γ and σ. From prepared filters, the best matched filter $g\mathrm{i}$ is selected so that $I\mathrm{i}(x,y)$ become the maximum value among all intensity images for each pixel; selected intensity image $I_{\max}(x,y)$ and angle output image $A_{\max}(x,y)$ are obtained.

2.3 Post-processing

At for the post-processing, the mammary gland structure involved in the formation of the architectural distortion (in this paper, we call it the primary mammary gland structure) is extracted by three steps described bellows.

(1) Determination of the primary mammary gland structure

To determine the primary mammary gland structure, we introduced NMS technique [4]. This method so that the intensity value which are included the intensity image were compared the target pixel and the pixels in the perpendicular direction of that pixel. Thus, only the primary mammary glands are extracted. These operations are performed for all pixels within the breast region. At the same time, the isolation pixels that produced by this process are also removed.

(2) Elimination of the normal mammary gland structure

The mammary gland structure which is traveling towards the nipple is removed by comparing the direction of the straight line connecting between the nipple and any target pixel using the angle obtained by $A_{\max}(x,y)$.

(3) Selection of the region of the primary mammary gland structure

Even if there is no region where the mammary gland, Gabor filter force to determine the direction. This may cause erroneous detection about the direction component in area without the mammary gland structure. Therefore, the region of primary mammary gland structure are selected by mode-based thresholding using the intensity image $I_{\max}(x,y)$.

2.4 Calculation of the degree of concentration

Spicula finding specific to the architectural distortion has concentration and distortion of the mammary gland structure. Thus, calculation of the degree of concentration is performed using the post-processed angle image $A_{\max}$.. Concentration index of $C(P)$ is defined as figure.4 and equation (3) [6].

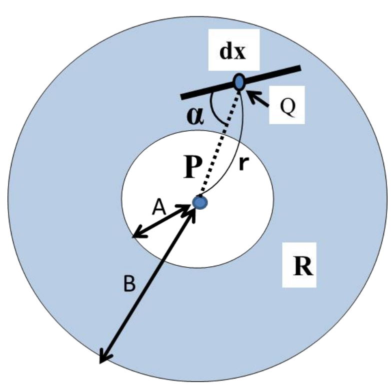

Fig. 4 Schematic of concentration index

$$C(P) = \sum_R \frac{dx\,|\cos\alpha|}{r} / \sum_R \frac{dx}{r} \quad (3)$$

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

2.5 False-positive reduction

The initial candidate regions of architectural distortion are obtained by performing thresholding which are determined based on each breast density. In addition, false-positive reduction process is performed using support vector machine with 23 types of characteristic features [7]. Finally, the outlines of the final candidate region are superimposed on the original image; they are used for the interpretation.

3. EXPERIMENTS

3.1 Image Database

In order to evaluate the effectiveness, we verified using 50 cases (200images) of mammography. 20 cases were the normal, and remained 30 cases contained the architectural distortion. And these images were introduced from the Digital Database of Screening Mammography (DDSM).

3.2 Results and discussion

Figure.5 shows an example of detecting the architectural distortion of spicula findings. The black border (g) is a candidate region for architectural distortion which was applied and detected our method; the red border (h) is pointed out by the physician. These results show that spicula findings is detected properly.

To evaluate the detection performance, the true-positive rate (TP rate) and the number of false positives per image (FPs/image) were calculated. As a result, TP rate was 82.72%, and FPs/image was 1.39.

4. CONCLUTIONS

We investigated an automated detection scheme of architectural distortion (spicula findings) using adaptive Gabor filter. We applied this method to 50 cases (200images) of clinical images, TP rate was 82.72%, and FPs/image was 1.39. These results indicate that proposed method may be useful of automatic detection method for architectural distortion.

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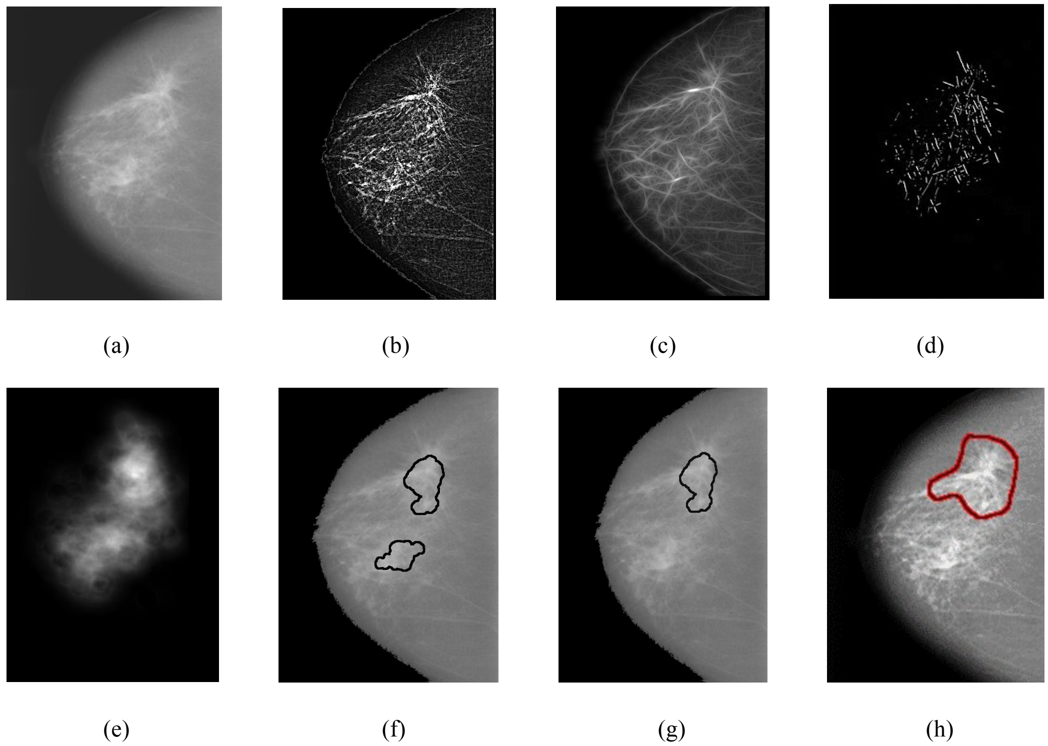

Fig. 5 Automated detection of architectural distortion,

(a)Input image, (b)Pre-processed image, (c)Extraction result of the mammary gland structure using adaptive Gabor filter, (d)Post-processed image, (e)Calculation result of the degree of concentration using the concentration index, (f)Initial candidate regions, (g)Result of after process of false positive reduction, and (h)Physician's interpretation

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