Detection of Focal Asymmetry Based on Pair of Mammographic Images

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Abstract--**Human breasts are not exactly symmetry to each other. However, asymmetry breast tissues reveal risk of abnormality or even cancer. This paper introduces a scheme to detect area of focal asymmetry based on pair of mammographic images. Our scheme consists of transformation process and detection process. In transformation process, the proposed scheme integrates edge detection, curvature computing, and dynamic time warping for estimation of transform matrix. In detection process, we apply histogram matching to target breast image in advance for intensity consistency to pair of images. After transforming reference breast image using the estimated matrix, we then compute image difference between the target and the trans-reference breast images. Eventually, pixels with large differences are treated as a portion of focal asymmetry. The experiment results will demonstrate our scheme achieves good performance in detection of focal asymmetry.**

I. INTRODUCTION

Due to effects of gene and environment, human organs have various growth rates. For paired organs, they are not exactly symmetry to each other. However, asymmetry paired organs reveal risk of abnormality or even cancer, such as, breast. According to clinical reports, breast cancer became the most common cancer in women worldwide. Early diagnosis and detection on digital mammography are helpful to increase women's survival rate in breast cancer. The four common abnormalities in digital mammography, namely, mass, calcification, asymmetry, and architectural distortion. In this paper, we emphasize on detection of focal asymmetry. According to [1], the characteristics of focal asymmetry have three: (1) area of asymmetry is smaller than a quarter of breast; (2) area is free of characteristic of tumor; and (3) edge is concave outward in area of asymmetry.

In [2], Miller and Astley proposed a method to detect all types of asymmetry in breast images. Three features were employed in detection of asymmetry, including, brightness distribution, shape, and topology. In [3], Ferrari et al. computed linear directional components using Gabor wavelets-based multiresolution representation. Applying Karhunen-Loève transform to the selected principal components, rose diagrams were yielded by referring to filter responses. Their method analyzed rose diagrams as well as detected asymmetry. The similar study was addressed in [4], Rangayyan et al. combined directional information, morphological measures, and geometric moments for detection of bilateral asymmetry. In [5], Casti et al. employed Moran's index to measure angular convariance between rose diagrams, and then detected bilateral asymmetry. In [6, 7], the authors addressed the importance of breast alignment before detection of bilateral asymmetry. In [8], Bozek et al. aligned right and left breast images using B-interpolation, and then computed the difference. Consequently, area of asymmetry is illustrated by colors on mammographic images.

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In this paper, we introduce a scheme to detect area of focal asymmetry based on pair of mammographic image. Our scheme consists of transformation process and detection process. In transformation process, edges between breast and background are detected on pair of breast images. Subsequently, curvature computing and dynamic time warping are applied to pixels on edges for alignment and estimation of transform matrix. In detection process, histogram matching is applied to target image by referring to histogram of reference image for intensity consistency. Subsequently, the reference image is transformed using the estimated transform matrix, and then the difference between the target and the trans-reference images. Finally, pixels with large differences are considered as a portion of focal asymmetry. The rest of this paper is organized as follows: the proposed scheme is introduced in Section II. The experiment results will be revealed in Section III, and the conclusion will be drawn in Section IV.

II. THE PROPOSED SCHEME

A. Transformation Process

Fig.1 shows the block diagram of the proposed scheme, which is composed of transformation process and detection process. The objective of transformation process is to estimate transform matrix for breast alignment. Edge, E_b, between breast and background is a key feature, which is determined by,

$$E_b = A_b - (A_b \circ s), \qquad (1)$$

$$A_b(x,y) = \begin{cases} 1, & g(x,y) > \tau \\ 0, & \text{otherwise} \end{cases}$$

where the symbol '$\circ$' represents erosion operator of morphology, s is a structural element, and $g(x,y)$ denotes the intensity of the (x,y)-th pixel. Area of breast, A_b, is a binary image determined by a threshold τ. The (x,y)-th pixel is considered as a portion of breast as $A_b(x,y)=1$.

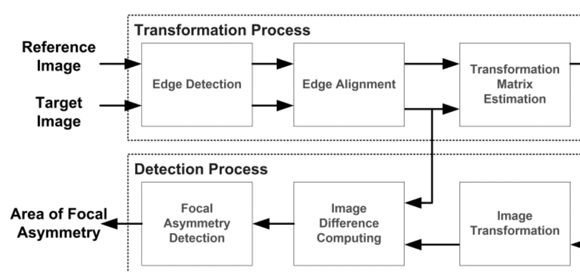


Fig. 1. Block diagram of the proposed scheme

The proposed scheme computes curvature of pixels on edges in advance. Let c_i be the absolute curvature of the i-th pixels on edge according to,

$$c_i = \left| \frac{x_i' y_i'' - y_i' x_i''}{\left(x_i'^2 + y_i'^2\right)^{\frac{3}{2}}} \right|, \qquad (2)$$

where x_i and y_i represent the coordinates of the i-th pixel at x-axis and y-axis, respectively. Moreover, z_i' and z_i'' denote the first-order and the second-order differentials of the i-th pixel at z-axis, respectively, where $z \in \{x, y\}$.

Let $\mathbf{I}^T$ and $\mathbf{I}^R$ be, respectively, the target and the reference breast images. Integrating curvature and dynamic time warping [9], our scheme obtains the connection of pixels, such as the (x_i^R, y_i^R)-th pixel of $\mathbf{I}^R$ corresponds to the (x_j^T, y_j^T)-th pixel of $\mathbf{I}^T$. A transformation matrix is estimated based on (x_i^R, y_i^R) and (x_j^T, y_j^T), which is defined as follows,

$$\begin{bmatrix}\hat{x}_j^T\\ \hat{y}_j^T\\ z\end{bmatrix} = \begin{bmatrix}a & b & c\\ d & e & f\\ g & h & 1\end{bmatrix}\begin{bmatrix}x_i^R\\ y_i^R\\ 1\end{bmatrix},\quad x_j^T = \frac{\hat{x}_j^T}{z}, \text{ and } \; y_j^T = \frac{\hat{y}_j^T}{z} \qquad (3)$$

where a, b, c, d, e, f, g, and h are unknown coefficients. Furthermore, (3) is reformulated as,

$$\begin{bmatrix}x_1^T\\ y_1^T\\ \vdots\\ x_k^T\\ y_k^T\\ \vdots\\ x_N^T\\ y_N^T\end{bmatrix} = \begin{bmatrix}x_1^R & y_1^R & 1 & 0 & 0 & 0 & -x_1^T x_1^R & -x_1^T y_1^R\\ 0 & 0 & 0 & x_1^R & y_1^R & 1 & -y_1^T x_1^R & -y_1^T y_1^R\\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots\\ x_k^R & y_k^R & 1 & 0 & 0 & 0 & -x_k^T x_k^R & -x_k^T y_k^R\\ 0 & 0 & 0 & x_k^R & y_k^R & 1 & -y_k^T x_k^R & -y_k^T y_k^R\\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots\\ x_N^R & y_N^R & 1 & 0 & 0 & 0 & -x_N^T x_N^R & -x_N^T y_N^R\\ 0 & 0 & 0 & x_N^R & y_N^R & 1 & -y_N^T x_N^R & -y_N^T y_N^R\end{bmatrix}\begin{bmatrix}a\\ b\\ c\\ d\\ e\\ f\\ g\\ h\end{bmatrix} \qquad (4)$$

where N is the total number of pixels in $\mathbf{I}^T$. Finally, we estimate the eight coefficients.

B. Transformation Process

Intensity inconsistency in pair of mammographic images results in incorrect detection of focal asymmetry. In order to make intensity consistent, the proposed scheme utilizes histogram matching to $\mathbf{I}^T$ referred to the histogram of $\mathbf{I}^R$. Furthermore, $\mathbf{I}^R$ is transformed to the trans-reference image $\mathbf{I}^{tR}$ using (3). Computing absolute difference, Δg, between $\mathbf{I}^T$ and $\mathbf{I}^{tR}$, the area of focal asymmetry is detected by,

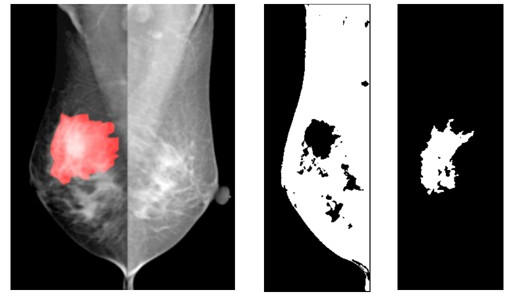
$$\Phi(x, y \mid T) = \begin{cases}1, & \text{if } \Delta g(x, y) > T\\ 0, & \text{otherwise}\end{cases} \qquad (5)$$

where $\Phi(x,y|T)$ represents the characteristic of the (x,y)-th pixel given the condition of the threshold T. In our study, pixel with large-difference is considered as a portion of area of focal asymmetry. Therefore, the pixels with $\Phi(x,y|T)$=1 are grouped together as area of focal asymmetry.

The proposed scheme compares to the approach that directly detects focal asymmetry without edge alignment and contrast consistency processing. Focal asymmetry and non-focal asymmetry are treated as positive case and negative case, respectively, in the experiments. Based on confusion matrix [10], five kinds of measures are computed to evaluate performance of detection, including, recall, precision, accuracy, specificity, and F_1 score.

III. THE EXPERIMENT RESULTS

There were eight pairs of mammographic images tested in the experiments, which were derived from [11-14]. The ground truth of focal asymmetry was labeled in advance. Two parameters were set to τ=5, and T=32. TABLE I lists the five kinds of average measures using the compared approach and our scheme. The experiment results show that our scheme achieves higher measures than the compared one does. High accuracy demonstrates the proposed scheme detects area of focal asymmetry and non-focal asymmetry accurately. Fig.2(a) shows the bilateral image synthesized by a pair of tested images, the red area represents ground truth of focal asymmetry. Obviously, intensities of the right and the left breast images are inconsistent. Fig.2(b) and Fig.2(c) show the detection results of the compared approach and our scheme, respectively. Our scheme overcomes influence of intensity inconsistency, and achieves better performance than the compared approach does in detection of focal asymmetry.



(a) (b) (c)

Fig.2. Detection Results of Focal Asymmetry: (a) bilateral image with ground truth, (b) detection result of the compared approach, and (c) detection result of our scheme.

TABLE I

PERFORMANCE EVALUATION OF TWO METHODS: THE AVERAGES OF FIVE MEASURES ARE COMPUTED, INCLUDING, RECALL, PRECISION, ACCURACY, SPECIFICITY, AND F_1 SCORE.

Measures	The Compared Approach (A)	Our Scheme (B)	Difference (C=B-A)
Recall	0.5955	0.6825	0.0870
Precision	0.4595	0.7018	0.2423
Accuracy	0.8541	0.9548	0.1007
Specificity	0.8599	0.9816	0.1217
F_1 Score	0.4768	0.6673	0.1905

IV. CONCLUSION

We propose a scheme for detection of focal asymmetry based on pair of mammographic images. Our scheme not only overcomes influence of intensity inconsistency on pair of images, but it also detects area of focal asymmetry accurately. The experiment results show that our scheme has higher measures than the compared approach does, and accuracy of detection is increased over 0.1.

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