Detecting Breast Cancer from Infrared Images by Asymmetry Analysis

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Abstract—**Infrared imaging of the breast (also called thermography) has shown effective results in both risk assessment and prognostic determination of breast cancer. This paper proposes an automated approach to detect asymmetric abnormalities in thermograms. Canny edge detector is first used to derive the edges from the original image. Hough transform is then applied to the edge image to recognize the four feature curves, which include the left and the right body boundary curves, and the two parabolic curves indicating the lower boundaries of the breasts. Segmentation is conducted based on the intersection of the two parabolic curves and the body boundaries. Bézier histogram is then derived from each segment. Curvature information is finally computed from the histogram to be used to easily indicate the asymmetry.**

Keywords— **asymmetry analysis, thermography, Hough transform, Bézier histogram, curvature analysis**

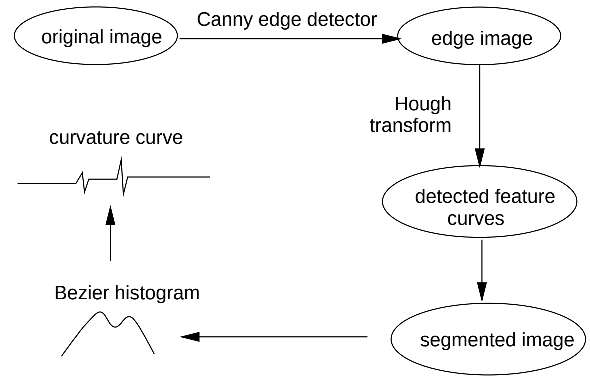

Fig. 1. Procedure of automatic asymmetry analysis of thermogram.

I. Introduction

MAKING comparisons between contralateral images are routinely done by radiologists. When the images are relatively symmetrical, small asymmetries may indicate a suspicious region. This is the underlying philosophy in the use of asymmetry analysis for mass detection [1].

There have been a few papers addressing techniques for asymmetry analysis of mammograms [1], [2], [3], [4], [5]. [6] also proposed an interesting approach which used computer-generated mammogram-like images to compare images from two viewing modalities. [7], [8] recently analyzed the asymmetric abnormalities in infrared images. In their approach, the thermograms are segmented first by operator. Then breast quadrants are derived automatically based on unique point of reference, i.e. the chin, the lowest, rightmost and leftmost points of the breast.

In this paper, we propose an automated asymmetry analysis technique on thermograms, which include automated segmentation and automated asymmetric abnormality detection. It involves 5 steps: (1) Edges are first detected by Canny edge detector. (2) Four feature curves in the edge image are distinguished: the left and right body boundary curves, and the two lower boundaries of the breasts. Hough transform is used to detect the parabolic shaped lower breast boundaries. (3) Segmentation is based on a line and an intersection. The line is formed by the two armpits which can be obtained by curvature analysis of the left and right body boundaries. The intersection is the point that intersects the two parabolic curves. (4) After segmentation, Bézier histogram is derived from each segment. (5) Curvature can then be computed from the two histograms which can easily indicate the asymmetric hot pattern if there are any.

Testing images are obtained using the Inframetrics 600M camera, with a thermal sensitivity of 0.05^0K.

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II. Approach

Figure 1 is a system guideline of the steps involved in the proposed approach: *edge image* obtained by Canny edge detector, *feature curves* detected by Hough transform, *segmentation* based on the feature curves, *Bézier histogram* derived from the segments, and *curvature curve* computed from the histograms.

A. Edge detection by Canny edge detector

Edge image is first derived by using Canny edge detector [9]. The standard deviation is chosen to be equal to 2.5 so that only strong edges can be detected.

B. Feature curve detection by Hough transform

There are four most important curves appeared in the edge image which we called the feature curves: the left and right body boundaries, and two lower boundaries of the breasts. The body boundaries are easy to detect. Difficulties lie in the detection of the lower boundaries of the breasts. We observe that the breast boundaries are generally in parabolic shape. Therefore, Hough transform [10] is used to detect the parabola.

C. Segmentation

Segmentation is based on three key points: the two armpits (P_L, P_R) derived from the left and right body boundaries by picking up the point where the largest curvature occurs, and the intersection (O) of the two parabolic curves derived from the lower boundaries of the breasts. The line goes through point O and is perpendicular to line $P_L P_R$ is the line to separate the left and right breasts.

D. Bézier histogram of segments

Histogram provides us a view of brightness distribution. But pure histogram would not help us much in asymmetry analysis because the curve usually zig-zags a lot. To make it smoother, we use Bézier splines [11].

We have 256 rounded brightness levels, and the histogram values of these levels are used as the control-point positions: $\mathbf{p}_k = (x_k, y_k)$, with k and x_k varying from 0 to 255. These coordinate points are blended to produce the position vector $\mathbf{P}(u)$ (Eq. 1), which describes the path of an approximating Bézier polynomial function between $\mathbf{p}_0$ and $\mathbf{p}_{255}$.

$$\mathbf{P}(u) = \sum_{k=0}^{255} \mathbf{p}_k BEZ_{k,255}(u). \quad (1)$$

Here $0 \leq u \leq 1$. The Bézier blending functions $BEZ_{k,255}(u)$ are the Bernstein polynomials (Eq. 2):

$$BEZ_{k,255}(u) = C(255, k)u^k(1-u)^{n-k} \quad (2)$$

and the $C(255, k)$ are the binomial coefficients (Eq. 3):

$$C(255, k) = \frac{255!}{k!(255-k)!} \quad (3)$$

E. Curvature curve of Bézier histogram

The vector equation in Eq. 1 represents a set of two parametric equations for the individual curve coordinates, as shown in Eq. 4,

$$\begin{array}{c} x(u) = \sum_{k=0}^{255} x_k BEZ_{k,255}(u) \\ y(u) = \sum_{k=0}^{255} y_k BEZ_{k,255}(u) \end{array} \quad (4)$$

Once the Bézier histogram is represented as the form of $x(u)$ and $y(u)$, local curvature (κ) can then be computed by Eq. 5,

$$\kappa = \frac{\dot{x}(u)\ddot{y}(u) - \dot{y}(u)\ddot{x}(u)}{(\dot{x}(u)^2 + \dot{y}(u)^2)^{3/2}} \quad (5)$$

where $\dot{x}(u)$ and $\dot{y}(u)$ represents the first derivatives, and $\ddot{x}(u)$ and $\ddot{y}(u)$ represents the second derivatives.

The two curvature curves from the two histograms are compared. A threshold is chosen based on testing images which can be used to decide if a difference is large enough to indicate the abnormality.

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