Segmentation of Breast Thermogram Images for the Detection of Breast Cancer – A Projection Profile Approach

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***Abstract*—Breast Thermography is an emerging medical imaging tool, used for early detection of breast cancer. The growing tumor in the breast will cause the occurrence of some asymmetric heat patterns in the left and right breast. Asymmetry analysis of left and right breast is used for detecting the breast cancer from the breast thermogram images. This paper presents a method for segmenting the left and right breast from breast thermogram images using Projection Profile Approach. Horizontal Projection Profile (HPP) method is used for locating the lower and upper borders of the breast by detecting the inframammary fold and axilla curves of the breast respectively. Vertical Projection Profile (VPP) method is used for locating the left and right borders of the breast thermogram image, which detects the parabolic shape of the breast. The results of segmentation are satisfactory. Generalization of this method can be done for various types of breast thermogram images by standardizing the height, background and removal of the noise present in the image.**

***Index Terms*—horizontal projection profile, vertical projection profile, edge detection, breast cancer, computer aided detection, Sobel operator, Canny operator, inframammary fold, asymmetry analysis**

I. Introduction

Breast cancer is the most common cancer in women all over the India. Population Based Cancer Registry (PBCR) report says that breast cancer accounts for 25% to 31% of all cancers in women in Indian cities. The breast cancer mortality rate of women correlates with the stage of the breast cancer when they are diagnosed. When breast cancer is diagnosed in its early stage and treated, the women have a greater chance of survival. Medical imaging techniques such as Mammography, Ultrasound and Magnetic Resonance Imaging, can detect early signs of breast cancer. Even though Mammography is known to be the gold method for detecting breast cancer, but its results are not effective for denser breast. It uses X-Ray radiation to form the images of the breast area. Mammographic procedure is painful for the patient due to the compression of the breast. So in search of other imaging techniques thermography has emerged as a potential method for detection of abnormalities in the breast. All bodies with a temperature above absolute zero emit infrared radiation. Thermal cameras can convert this infrared radiation into electrical signals, and present them as a thermal image. Breast thermography is based on the observation that malignant breast tumors emit greater heat than healthy breast due to higher metabolic activity of cancerous cells and angiogenesis i.e. Cancer tumor starving for nutrients produces a chemical that dilates the blood vessels [1]. Therefore, the cancerous tissue is highlighted and easily differentiated from a normal tissue in a thermogram. Thermogram can give highly dynamic information about tumors. In this method, in addition to normal tumors, very small tumors are also easily and very quickly detected [2]. Breast thermography is a non invasive, non radiating, passive, fast, painless, low cost, risk free imaging method and it is suitable for women of all ages, including pregnant and nursing women, with all sizes of breast, with or without breast implants, fibrocystic breasts and dense breast tissue.

To improve the accuracy of diagnosis of breast cancer, Computer-aided diagnosis/detection(CAD) techniques are used. The major method used by the physician to detect the breast abnormalities present in the thermogram image is by visual inspection of asymmetries in the left and right breast thermogram images. It is impossible to have a breast tumor growing symmetrically in the left and right breast. Due to the limitations of human visual system, it is not possible to detect all kinds of abnormalities present in the breast thermogram images. So there is a need to

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develop an appropriate segmentation technique to separate the left breast and right breast for the asymmetry analysis. The accuracy of detection of breast cancer using a computer aided detection system for breast thermography depends on the quality of the collected data and several image processing techniques such as Preprocessing, Segmentation, Feature extraction and Classification (final decision). Gathering a good informative and an adequate data is very important to get accurate results from the CAD systems. Preprocessing and appropriate segmentation are the essential requirements for the extraction of relevant features from the thermogram images. Development of a fully automated segmentation is a very difficult task due to their amorphous nature and lack of clear limits. It also depends on the distance from which the image is captured, height of the image, the size of the breast, image background, presence of noise etc.

II. Literature Review

Automatic segmentation of breast thermogram is a hard task. If the segmentation is inappropriate then entire CAD results are going to fail. For this reason some authors prefer manual segmentation or semi-automatic segmentation. Some researchers are working on automatic segmentation. Phani Teja *et al.* [3] uses hough transform for segmenting the breast, because the lower part of the edge image of the patient's breasts is approximated to the shape of a parabola. EDDIE Y. -K. NG *et al.* [4] proposed a new method to segment breast thermogram images and then extracted the region of interest. At first they used traditional snake and gradient vector flow snake. But the method was not successful in detecting the boundaries of the images. As a result, they modified the snake algorithm. They found the derivative of the image using Roberts cross-gradient operators. Then they used median filtering to process the gradient image. A high pass filter is used to sharpen the gradient image. Gerald Schafer *et al.* [5] describe the detection of breast cancer using a series of statistical features extracted from the thermograms coupled with a fuzzy rule based classification system for diagnosis. But left and right breasts were segmented manually by experts. Leonardo S. Motta *et al.* [6] presented a method for automatic segmentation of the region of interest of breast thermogram images. It is based on automatic thresholding, automatic border detection, mathematical morphology, curve extraction and interpolation. Hossein Ghayoumi Zadeh *et al.* [7] used a parabolic hough transform for Region of Interest (ROI) segmentation. For this purpose edges were detected through a logarithmic method. Their initial results of the edge detection were contaminated with high rates of noise. To remove this noise a Gaussian filter is used prior to edge detection. Dinsha D [8] presented a paper on breast tumor segmentation and classification of breast thermogram images. Here preprocessed breast thermogram image is enhanced by Contrast Limited Adaptive Histogram Equalization (CLAHE) technique. Then these images are filtered followed by segmenting the region of interest using k means and fuzzy C means. Various features are extracted from the segmented images. Finally a comparison has been made by using the SVM and Bayesian classifiers.

III. Proposed Methodology

The method used for segmenting the left and right breast is based on Projection Profile Analysis. It is used to find the upper, lower, left and right borders from the edge detected breast thermogram image. Horizontal (or vertical) projection profile is a histogram of a one-dimensional array with a number of entries equal to the number of rows (or columns). The number of black pixels or white pixels in a row (or column) is stored in the corresponding entry.

Horizontal Projection Profile (HPP) approach is used to locate the upper and lower borders. Vertical Projection Profile (VPP) approach is used to find the left and right borders. At first pseudo color breast thermogram image is converted into a grayscale image. Then the following sequences of operations are performed on the image. They are Image Filtering, Edge detection, Lower border detection, Upper border detection, Image thresholding, left and right border detection, find the central axis, and then segment the left and right breast. The images used for the study are collected from the open source available at www.advancedthermography.com. The block diagram of the proposed work is as shown in Fig. 1.

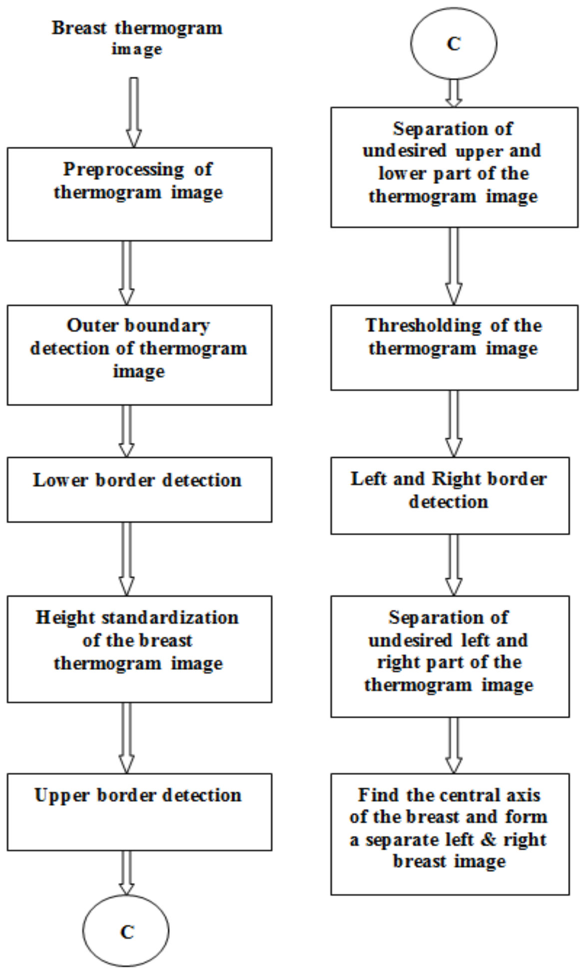


Figure 1. Block diagram of the proposed work

A. Edge Detection Using Sobel Operator

The Sobel operator performs a 2-D spatial gradient measurement of the thermogram image and so emphasizes regions of high spatial frequency that correspond to edges. Typically it is used to find the approximate absolute gradient magnitude at each point in an input grayscale image. The operator consists of a pair of 3×3 convolution kernels as shown in Fig. 2. One kernel is simply the other rotated by 90°. These kernels are designed to respond maximally to edges running vertically and horizontally relative to the pixel grid, one mask (kernel) for each of the two perpendicular orientations. The kernels can be applied separately to the input image, to produce separate measurements of the gradient component in each orientation (G_x and G_y). These can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient. The Sobel operator gives smoothing effect (averaging effect) and reduces the spurious edges. Theoretically, Gradient of the image f(x,y) is given by,

$$\nabla f = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial Y} \end{bmatrix} \quad (1)$$

where ∇ is the gradient operator.

The magnitude of the gradient is given by

$$\text{Mag}(\nabla f) = \sqrt{{G_x}^2 + {G_y}^2} \quad (2)$$

where, Mag (∇F) gives the strength of the edge at a particular location x-y.

Direction of the edge is found by

$$\alpha(x,y) = \tan^{-1}\frac{G_y}{G_x} \quad (3)$$

-1	-2	-1
0	0	0
1	2	1

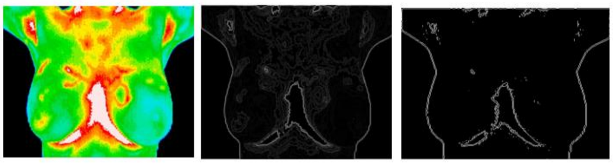
a

-1	0	1
-2	0	2
-1	0	1

b

Figure 2. a) Mask for computing Gx b) Mask for computing Gy

Fig. 3 shows the results of boundary detection of the breast thermogram image. The boundary of the breast thermogram image is detected satisfactorily using a Sobel operator as shown in Fig. 3c.



a b c

Figure 3. a) Original Image b) Filtered Image c) Boundary detected image

B. Inframammary Fold Detection of the Breast

To find the infra mammary fold, the edge detected image is scanned horizontally row-wise for the number of white pixels in each row from the bottom of the image. At the infra-mammary line, the number of white pixel count increases due to the infra-mammary fold of the breast. Scanning is repeated till we get the HPP value equal to or greater than the predetermined value. The value of HPP will be less below the infra-mammary fold of the breast, as shown in the Fig. 3c. The row number corresponding to the first high HPP is taken as the lower limit for the segmentation of the breast thermogram image.

C. Axilla Detection (Upper Border Detection) of the Breast

Horizontal Projection Profile approach is used again to find the axilla of the breast. Height standardization of the breast is needed due to the varying height of the images. Height of the breast thermogram image varies depending on the structure and size of the breast. To standardize the height of the image, distance between the detected lower border and the bottom of the image is measured. The distance value varies depending on the structure and size of the breast. The study found that the distance value will be high for small breasts and less for big breasts. As per the study and observation, the height of the breast is calculated as given below.

1) If the distance between the bottom of the image and lower limit of the breast is less than 100 pixels then

$$h = \frac{2}{3}m \quad (4)$$

where h is the height of the image and m is the total number of rows present in the image.

2) If the distance between the bottom of the image and lower limit of the breast is greater than 100 pixels then

$$h = \frac{1}{2}m \quad (5)$$

After the height standardization, HPP is applied from the h^{th} row towards the top of the edge detected image. The HPP value increases, when the scanning reaches the axilla of the breast. The line at which the HPP value is equal to or greater than the predefined value (Found by observing many images and chosen approximately), corresponding row value will be the upper limit for the segmentation of breast thermogram image. Detected upper and lower borders are shown in Fig. 4.

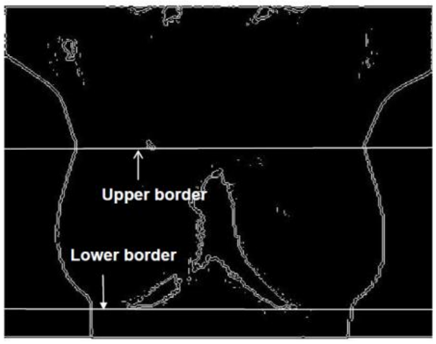


Figure 4. Detected upper and lower borders

D. Left and Right Border Detection

Breast thermogram image is segmented from the undesired top and bottom part, by using the upper and lower borders. Adaptive image thresholding is applied to the image to make the region of intrest white as shown in Fig. 5. Left and right borders are detected from the thresholded image using Vertical Projection Profile (VPP) method. In this algorithem VPP is defined as the number of white pixel count for each column. The steps followed for the detection of left border are given below.

1. Segmented image from the top and bottom part of the image is converted into gray scale.
2. Adaptive thresholding is applied, so that the region of interest becomes white as shown in Fig. 5.
3. Vertical Projection Profile (VPP) approach is applied from the left most column of the image towards the right of the image.
4. For each column VPP value is stored.
5. VPP value increases, when the scanning reaches the left most coloumn of the breast.
6. Now the scanning has been stopped and the corresponding column value is recorded as the left limit of the breast thermogram image.
7. A similar procedure is applied for detecting the right border of the breast thermogram image. Here the VPP is applied from the rightmost column towards the left of the image.

The detected left and right borders are used to form a desired thermogram image of the breast by removing the undesired left and right part of the breast. Central axis of the breast is determined by finding the maximum column value of the segmented image. Based on the central axis value breast thermogram image is segmented as left and right breast image, which can be used later for the asymmetry analysis for the detection of breast abnormalities. Breast thermogram image with highlighted lower, upper, left and right borders are shown in Fig. 6. The results of the above method are summarized in the Table I.

Figure 5. Segmented binary image from the top and bottom part of the breast

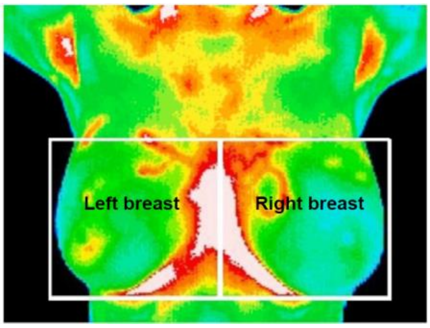


Figure 6. Breast thermogram image with highlighted upper, lower, left, right and central borders

TABLE I. RESULTS OF SEGMENTATION

Total number of samples considered	20
Number of samples with accurate segmentation	18
Number of samples with inaccurate segmentation	02

Some of the results of the segmentation method used for fibrocystic breast (Fig. 7a), inflammatory cancerous breast (Fig. 7b) breast and for normal breast (Fig. 7c) are shown in Fig. 7.

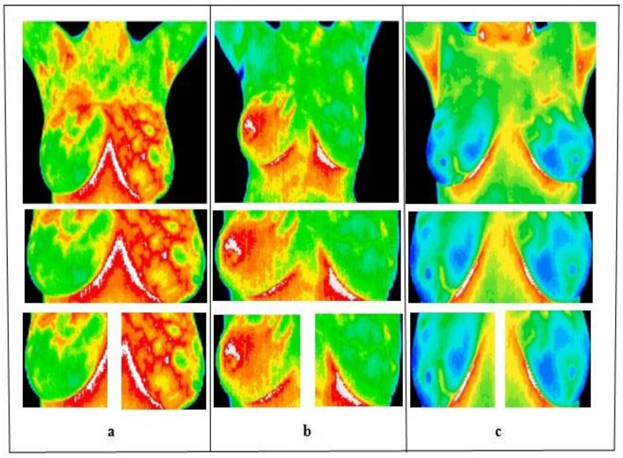


Figure 7. Segmentation results for a) Fibrocystic breast b) Inflammatory cancerous breast and c) Normal breast

IV. CONCLUSION

In order to detect breast abnormalities, an asymmetry analysis has been used. Improvement in accuracy of computer aided detection of breast cancer in breast thermogram images requires perfect segmentation of left and right breast. This study was aimed to the development of an automatic segmentation of left and right breast from breast thermogram images. A novel technique, called the Projection profile approach was used to locate upper, lower, left and right borders of the breast. The results are satisfactory. The method used in this paper can be generalized for other images with slight modifications like standardization of the image background, standardization of the height of the image and removal of the noise if present.

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