Breast abnormality based early diagnosis of breast cancer using non-invasive digital infrared thermal imaging

Priya Tushar Hankare

Department of Electronics and Telecommunication,
K.J.Somaiya Institute of Engineering and Information Technology,
University of Mumbai, Somaiya Ayurvihar Complex,
Eastern Express Highway, Sion East,
Maharashtra 400022, Mumbai, India
Email: priya.h@somaiya.edu

Abstract: Breast cancer is one of the most leading and common cause of cancer. It can be detected by infrared thermal imaging Technique by observing the temperature distribution on the breast. Breast thermography is considered as a valuable tool for early breast tumours detection. The fast growing tumour has a higher metabolic rate and associated increase in local vascularisation. It will cause the occurrence of some asymmetric heat patterns. Clinical interpretation of a breast thermogram can be done on the asymmetry analysis of the heat patterns visually and subjectively. In this paper, a new approach for early detection of breast cancer is proposed using asymmetry analysis of breast thermograms. The heat patterns are segmented and the asymmetry analysis is performed by using histogram generation and feature extraction. Extracted statical features clearly indicate the abnormality of a breast thermogram.

Keywords: breast cancer; infrared thermal imaging; thermography; asymmetry analysis; feature extraction.

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Biographical notes: Priya Tushar Hankare is presently working as an Assistant Professor in the Department of Electronics and Telecommunication Engineering at the K.J. Somaiya Institute of Engineering and Information Technology, University of Mumbai. She received her BE and ME in Electronics Engineering with first class from the Walchand College of Engineering, Sangli, Shivaji University. Her research interests include image processing, neural network and communication engineering.

1 Introduction

Breast cancer is one of the most common cancer-related diseases among women worldwide. There were about 1.4 million occurrences of new cases in 2008, more than 100% increment compared to cases reported in 1975. The traditional method for diagnosing the disease relies on human experiences to identify the presence of certain pattern from the database. Other than that, this age old method is subjected to human error, is inaccurate, time-consuming and cause unnecessary burden to radiologists. By the time it is detected, it may already be at a critical stage.

The probability of developing breast cancer increases with age and the largest risk factors associated with its development, specifically age and gender, are not modifiable. Despite advances in treatment that have reduced breast cancer mortality over the past two decades, next to lung cancer, this disease still remains the second leading cause of cancer induced death in women (Sherring and Varsha, 2009). The average size of tumours undetected by thermography is 1.28 cm, while 1.66 cm by mammography. The result of thermography can be correct eight to ten years before mammography can detect a mass. Combining thermography with clinical examination and mammography can increase the relative sensitivity of breast cancer detection to 98%. Clinical interpretation of breast thermograms primarily depends on the asymmetry analysis. The higher metabolic rate of the fast growing tumours and the associated increase in local vascularisation will cause the occurrence of some heat patterns, such as focal hot spots and vascular heat. It is nearly impossible to have the tumour symmetrically in both the breasts. These heat patterns will occur asymmetrically. A new approach of asymmetry analysis is presented in this paper. The heat patterns are first segmented from the breast thermograms with mathematical morphology. The asymmetry is analysed according to the features extracted from the segmented heat patterns.

2 Infrared thermography

> "All objects above zero Kelvin emit infrared radiation. The Stefan-Boltzmann law gives the relationship between the infrared energy and temperature. Emissivity of human skin is high (within 1% of that of black body) therefore measurements of infrared radiation emitted by skin can be directly converted to temperature. This process is known as infrared thermography." (Lin et al., 2007)

2.1 Advantages of thermography

1. Thermography possesses many advantages, such as non-invasive, innocuous, non-contact, non-radiation and risk free and considerably less expensive.
2. The food and drug administration (FDA), Bureau of Medical Devices has already approved the thermography procedure of screening for breast cancer. In the recent reappraisal of its usage in medicine, it is considered particularly valuable for early breast tumours detection (Lin et al., 2007).

3 Image acquisition

A thermogram is an infrared thermal image. The images are taken using FLIR E30 infrared camera having a spectral response of 8 μm to 14 μm; and 160 × 120 IR resolution. The images are obtained in JPEG format. Skin surface temperature is greatly affected by numerous conditions (Kennedy et al., 2009).

3.1 Pre-thermographic imaging instructions

Skin surface temperature is greatly affected by various conditions. In order to reduce the errors due to thermal artefacts, images are taken using a recommended set of instructions to ensure the usefulness and consistency of thermal images. For thermal breast scan, certain protocols must be followed in order to ensure that the images convey accurate information (Ring and Ammer, 2000) is mentioned below.

1 No prolonged sun exposure to the chest and breast areas five days before the scan.

2 Use of lotions, creams, powders, or make up on the breasts should be avoided and there should be no use of deodorants or antiperspirants on the day of exam.

3 No shaving (or other types of hair removal) of the chest, breasts, or underarms for 24 hours before the scan.

4 No treatment (acupuncture, physical therapy, massage, electrical muscle stimulation, ultrasound, hot or cold pack use) of the neck, back, chest, or breasts before 24 hours of the scan.

5 No physical stimulation of the breasts before 24 hours of the scan.

6 No exercise before six hours prior to the scan.

7 No bath before four hours prior to the scan.

8 In case of nursing, try to nurse as far from two hours prior to the exam as possible.

9 Eat light and no coffee, green, or black tea.

10 No smoking or drinking alcohol before 24 hours prior to the scan.

11 If someone suffering from acute infection such as fever, or flu then it should be informed to doctor (Kennedy et al., 2007; Ring and Ammer, 2000).

3.2 Thermographic procedure

1 Breast thermography is a 15 min non-invasive test. It is an important procedure for alerting the doctor to the changes that can indicate early stage breast cancer.

2 The chest area must be cooled with an air conditioner for approximately 10–15 minutes during the process.

3 The room temperature is adjusted approximately 22 degrees Celsius and darkened during the test.

3.3 Sample thermograms

Figure 1 and Figure 2 shows the thermograms of volunteers with normal breast and with abnormal breast respectively. The thermograms are taken by following the previous pre-themographic uimaging instructions (Wakankar and Suresh, 2014). The colour bar present on the thermograms provides the temperature distribution indicating the coolest part (blue); intermediate temperature (yellow and red) and the warmest part of the image as white.

Figure 1 Thermograms of normal breast (see online version for colours)

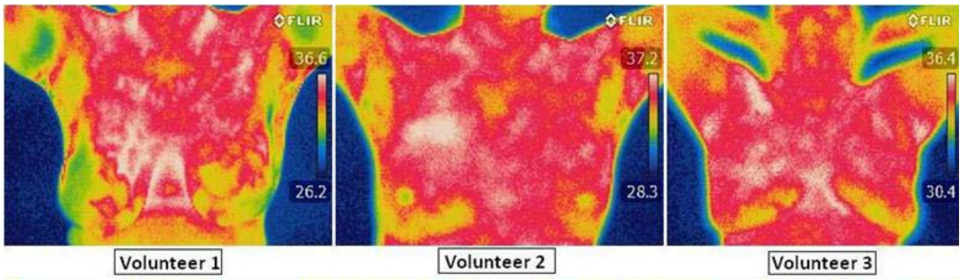
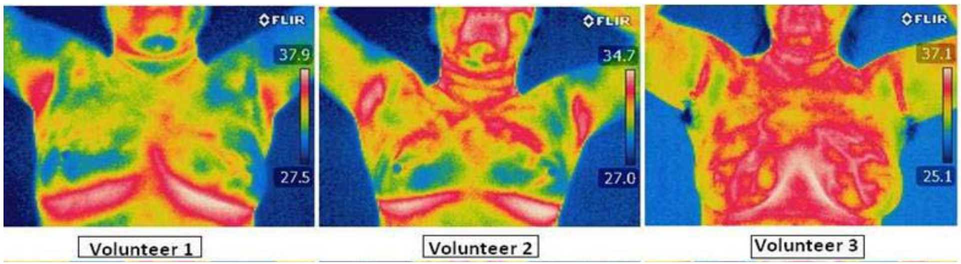


Figure 2 Thermograms of abnormal breast (tumour is present) (see online version for colours)



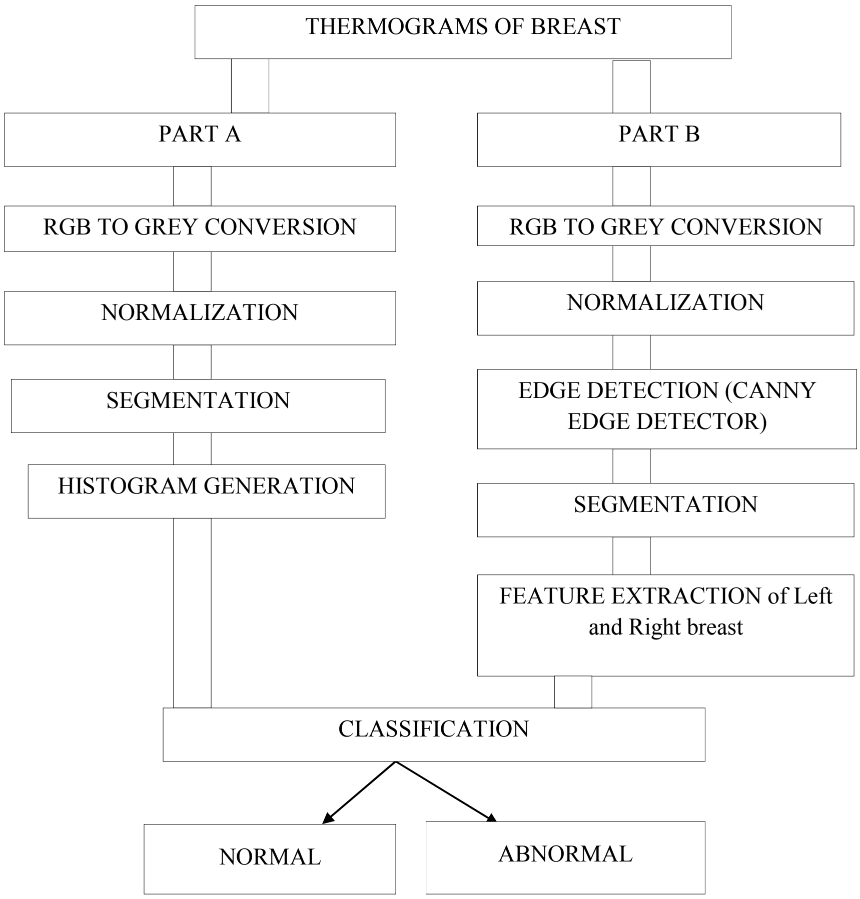
4 Methodology

Clinical interpretation of breast thermograms can be done by asymmetric analysis of thermograms. Figure 3 shows an outlined approach for the asymmetric analysis of breast thermograms is divided into two parts. It includes the following steps:

- Part A
  - breast thermogram taken using digital infrared thermal imaging camera
  - conversion of image from RGB TO GREY
  - pre-processing (normalisation)
  - segmentation
  - histogram generation
- Part B
  - breast thermogram taken using digital infrared thermal imaging camera
  - conversion of image from RGB TO GREY
  - pre-processing (normalisation).
  - edge detection
  - segmentation
  - histogram generation
  - feature extraction of left and right breast.

After the processing of Part A and Part B is done the breast thermogram is classified as normal or abnormal.

Figure 3 Flow for analysis of breast thermograms



4.1 Pre-processing

Pre-processing is background removal and then resizing the image to remove the undesired body portion; followed by normalisation.

Normalisation is the process of reorganising data in a database so that it meets two basic requirements:

1 There is no redundancy of data (all data is stored in only one place).

2 Data dependencies are logical (all related data items are stored together).

Normalisation is also known as contrast stretching.

Figure 4 Flow for normalisation of thermogram

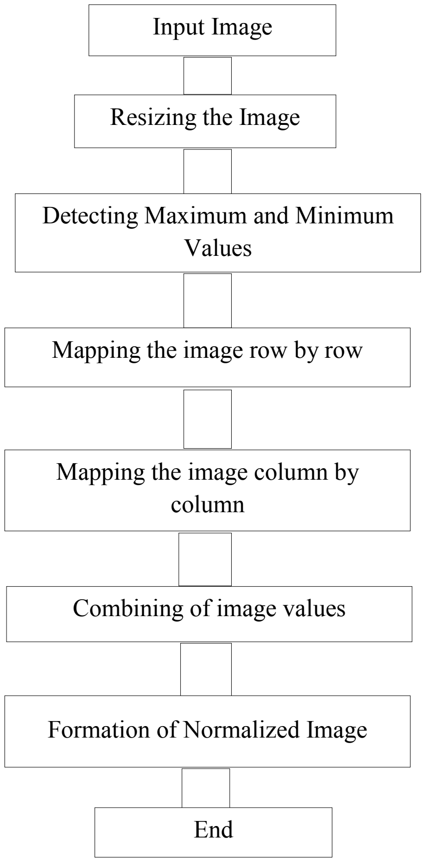


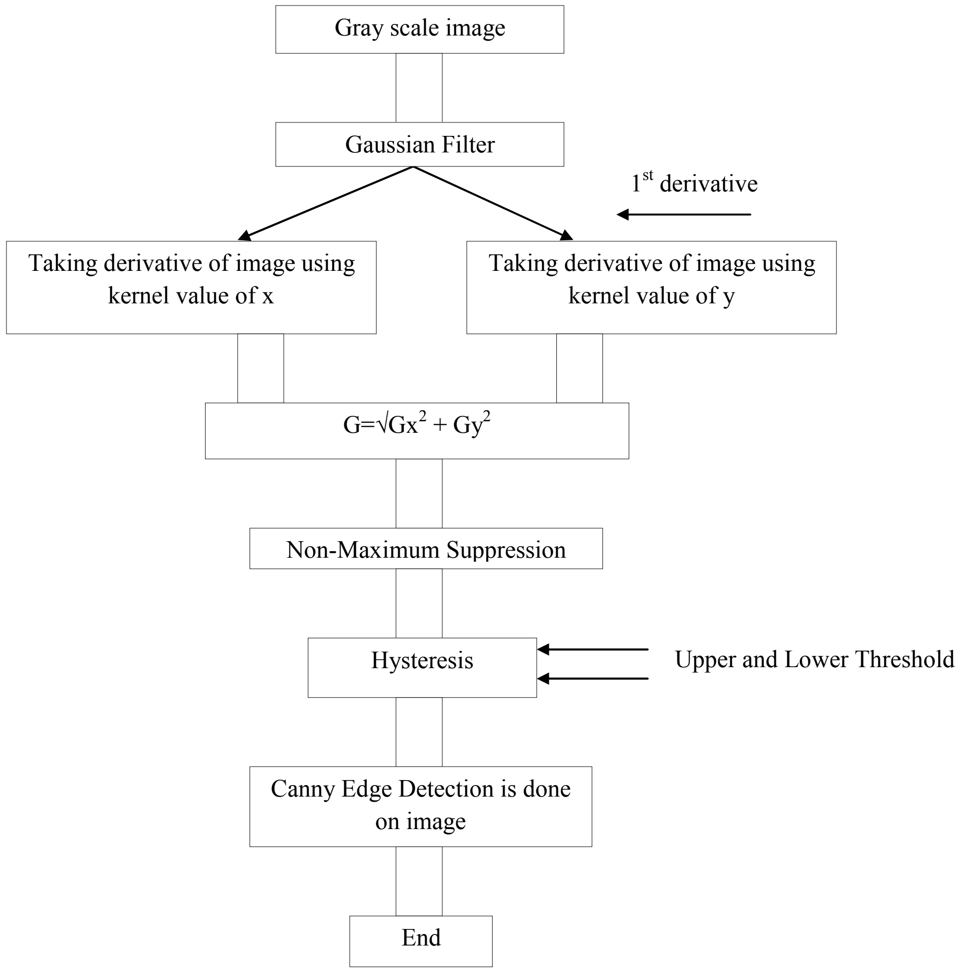
Figure 5 Pre-processing of breast thermogram

4.2 Edge detection

The purpose of edge detection in general is to significantly reduce the amount of data in an image, while preserving the structural properties to be used for further image processing.

Edge detection is a set of mathematical methods which aim at identifying points in a digital image at which the image brightness changes sharply or, more formally, has discontinuities. As a result, it is robust to noise and implements Gaussian function to smooth the image and to obtain the magnitude and orientation of the gradient for each pixel. Edge detection is performed using Prewitt, Sobel and Canny edge detector. Results obtained by canny edge detector are more prominent and appropriate. Hence canny edge detector is used for edge detection purpose (Wakankar and Suresh, 2014).

Figure 5 Flowchart for canny edge detection



The algorithm runs in five separate steps:

1 Smoothing: blurring of the image to remove noise.

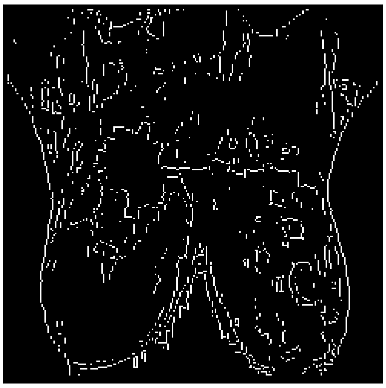
2 Finding gradients: the edges should be marked where the gradients of the image has large magnitudes.

3 Non-maximum suppression: only local maxima should be marked as edges.

4 Double thresholding: potential edges are determined by thresholding.

5 Edge tracking by hysteresis: final edges are determined by suppressing all edges that are not connected to a very certain (strong) edge.

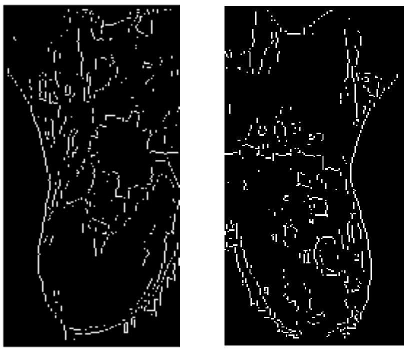
Figure 6 Canny edge detection



4.3 Segmentation

Image segmentation is the process of partitioning a digital image into segments. It is used to simplify and/or change the representation of an image into something that is more meaningful and easier to analyse to locate objects and boundaries.

Figure 7 Segmented ROI of thermogram, (a) left breast (b) right breast

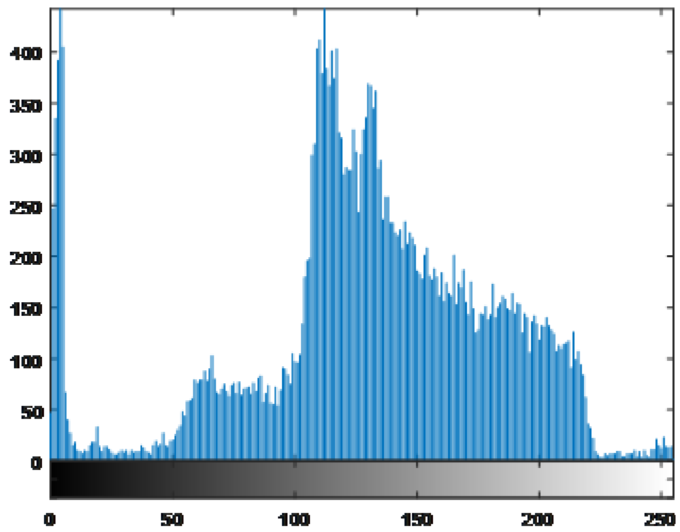


(a) (b)

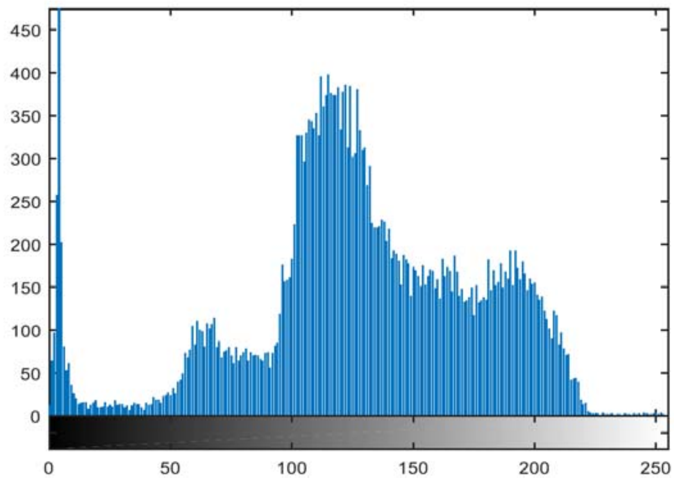
4.4 Histogram generation

A histogram is a graphical representation of the distribution of numerical data. An image histogram is a type of histogram that acts as a graphical representation of the tonal distribution in a digital image. It plots the number of pixels for each tonal value (Wakankar and Suresh, 2014).

Figure 8 Histogram of abnormal thermogram, (a) left breast (b) right breast (see online version for colours)



(a)



(b)

Note: The x axis indicates the gray scale values and the y axis indicates the number of pixels.

Histogram is generated for abnormal and normal thermograms. Figures 8(a) and 8(b) gives the histogram of abnormal thermogram respectively.

4.5 Feature extraction for asymmetry analysis

Feature extraction is performed on segmented thermograms which includes a comprehensive set of features such as skewness, entropy, kurtosis, variance, standard deviation and mean to capture completely the nature of temperature distribution in ROI (Kapoor et al., 2012; Kapoor and Prasad, 2010).

Table 1 Statistical parameters

Sr no.	*Parameters*	*Formulae*
1	Skewness	$S = 1/MN \sum_{i=1}^{M}\sum_{j=1}^{N}((P(i, j)-\mu)/\sigma)^3$
2	Entropy	$H(X) = -\sum_{k=0}^{L-1} P_{rk}(\log_2 P_{rk})$
3	Variance	Variance = √ SD
4	Kurtosis	$K = \{1/MN \sum_{i=1}^{M}\sum_{j=1}^{N}(P(i, j)-\mu)/\sigma)^4 - 3\}$
5	Standard deviation	σ = √ mean
6	Mean	$\mu = \sum_{i=1}^{M}\sum_{j=1}^{N} 1/MN\,(P(i, j)-\mu)^2$

Skewness — In statistics, skewness is a measure of the asymmetry. Skewness is a pure number that symbolises only the shape of the distribution. The skewness is given as a data set is symmetric if it looks the same to the left and right of the centre point.

Kurtosis — Kurtosis, K measures the peakness or flatness of a distribution relative to a normal distribution. Kurtosis is also termed as the fourth standardised moment.

Mean — In statistics the mean is the numerical value separating the higher half of the probability distribution.

Variance — It is the square of the standard deviation and also the second central moment of a distribution. It is a measure of statistical dispersions about the mean of the distribution.

5 Results

5.1 Output of abnormal thermograms

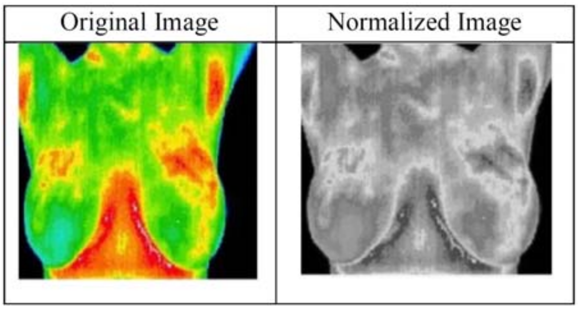
5.1.1 Part A

5.1.1.1 Pre-processing

Here the input images (breast thermograms) are taken from website.

- http://huddersfieldosteopathy.co.uk/clinicalthermal- imaging.html
- http://www.breastthermographync.com/wpcontent/ uploads/2012/06/Breast.jpg
- https://encryptedtbn1.gstatic.com/images?q=tbn:ANd9GcTsUpGgHV58KdS9iTo6O VMO5NawEtb6Dd- HUKz9zq4oeh8e8fG_

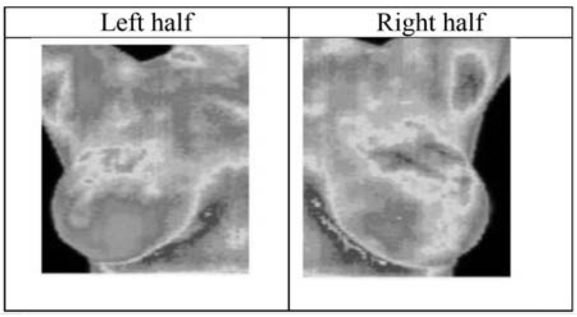
Figure 9 Normalisation of image (see online version for colours)



5.1.1.2 Segmentation

Here the number of rows and number of columns of normalised thermogram are calculated. Then the columns are divided into two halves.

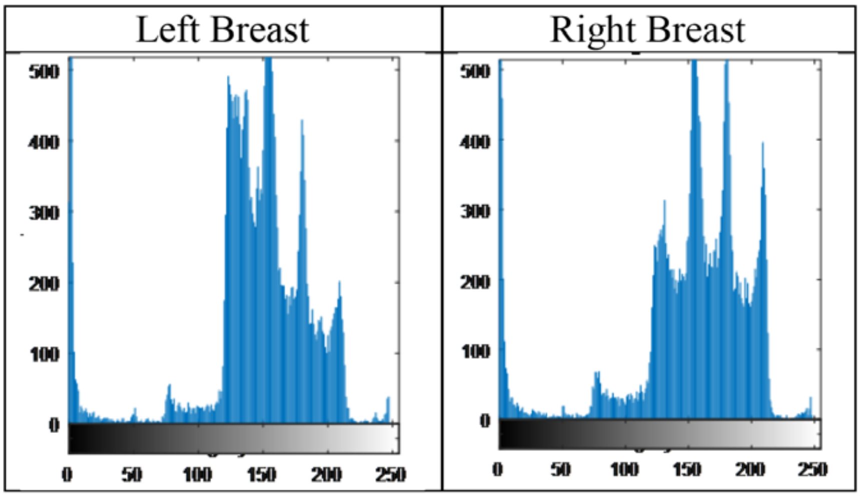
Figure 10 Segmentation of thermogram into left and right part



5.1.1.3 Histogram generation

In this case for abnormal images the histograms generated are asymmetrical. The graph of pixel values and grey scale values on y and x axis respectively will differ for left and right thermogram. If the histogram generated is asymmetrical then the thermogram is abnormal. There is a presence of cancerous tissues. Further the extraction statical parameters are done to confirm the presence of cancerous tissues in the thermogram.

Figure 11 Histogram of left and right breast (see online version for colours)



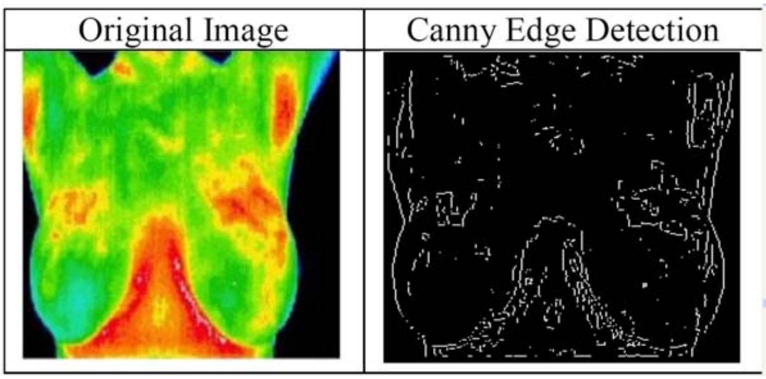
5.1.2 Part B

In part B the image is pre-processed. The RGB image is used for the purpose of edge detection of thermogram. Canny edge preserves the stronger edges of the image.

Further the thermogram is segmented into two halves to find the statistical parameters of left and right part.

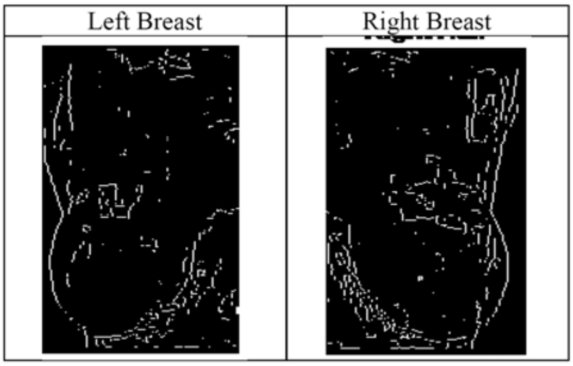
5.1.2.1 Edge detection

Figure 12 Canny edge detection of breast thermogram (see online version for colours)



5.1.2.2 Segmentation

Figure 13 Segmented of thermogram into left and right breast



5.1.2.3 Feature extraction (parameters)

The statistical features are extracted using mathematical formulae. The features of left and right part of thermogram are listed in Table 2.

Table 2 Values of Statistical features extracted for right and left part

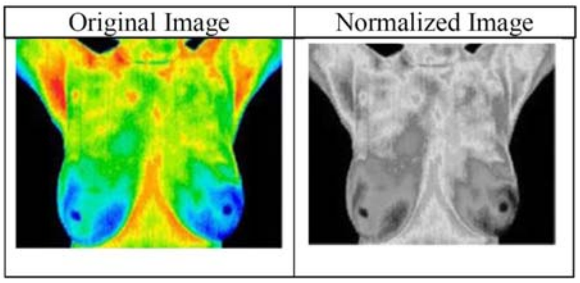
Parameter	*Image 3*		*Image 2*	
	Left breast	*Right breast*	*Left breast*	*Right breast*
Skewness	–0.2812	–0.2846	–0.2759	–0.2934
Entropy	0.2402	0.2446	0.2334	0.2562
Variance	2.8082e+07	2.6023e+07	3.1668e+07	2.1412e+07
Kurtosis	0.0791	0.0810	0.0761	0.0861
Standard deviation	5.2992e+03	5.1013e+03	5.6274e+03	4.6273e+03
Mean	1.6181e+03	1.5798e+03	1.6807e+03	1.4859e+03

5.2 Outputs of normal thermograms

5.2.1 Part A

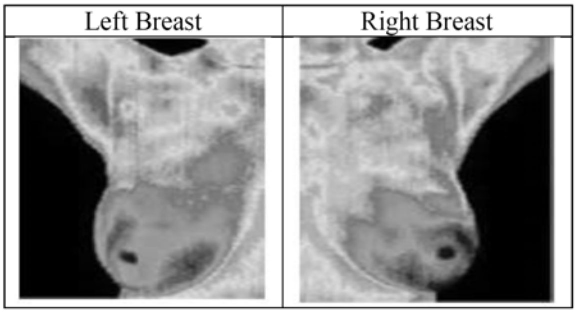
5.2.1.1 Pre-processing

Figure 14 Normalisation of image (see online version for colours)



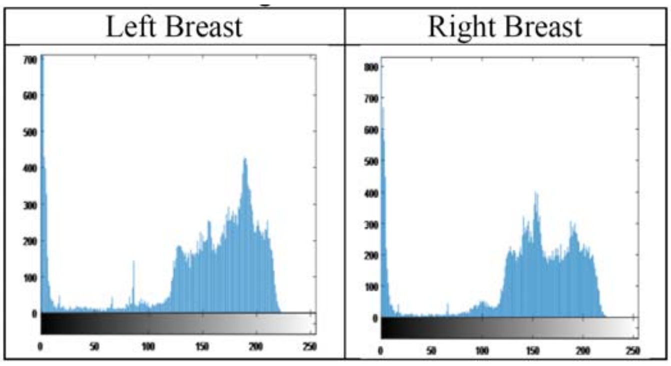
5.2.1.2 Segmentation

Figure 15 Segmentation of thermogram into left and right part



5.2.1.3 Histogram generation

Figure 16 Histogram of left and right breast (see online version for colours)

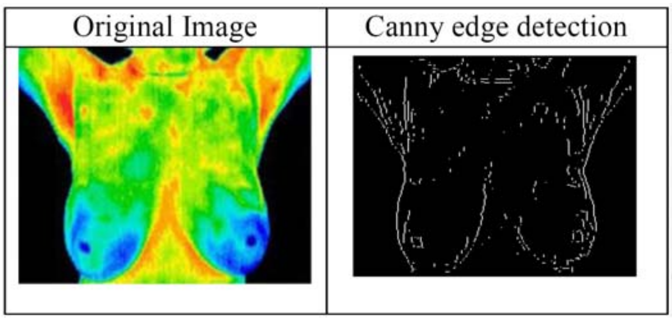


5.2.2 Part B

In this case the outputs for pre-processing remain the same.

5.2.2.1 Edge detection

Figure 17 Normalisation of image (see online version for colours)



5.2.2.2 Segmentation (edge detection)

Figure 18 Segmented of thermogram into left and right breast

Left half	Right half
	

6 Conclusions

Thus, this paper proposes an approach which deals with analysis of infrared breast thermograms based on asymmetry analysis. Canny edge detection is used for edge detection purpose. The breast thermograms are segmented into right and left part. Histograms are generated for left and right part. For abnormal images the histograms are asymmetrical. Also statistical features are extracted for the left and right part of breast thermogram for asymmetry findings. This kind of approach will help the diagnostics as a useful second opinion.

Analysis of breast thermography is a labour-intensive task that generally requires careful inspection of small temperature differences and abnormal vascular patterns. Future work can include more statical parameters for thermal imaging analysis. A back propagation neural network can be constructed and trained based on the statistical input parameters computed from breast thermogram for pattern recognition problems to assist in clinical decisions.

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