Image Processing Techniques and Neural Networks for Automated Cancer Analysis from Breast Thermographs-A Review

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Abstract

Clinical Infrared Thermography is the best suited technique for early detection of breast cancer. Interpretation of breast thermographs helps in identifying the abnormality in the region. In recent years, computer Aided analysis of breast thermographs has been developed to interpret the abnormality. In general, the analysis involves decision making based on the features describing the abnormality. Various image analysis techniques are developed to extract the abnormality region and different statistical parameters are used for describing it. Artificial Neural Networks (ANNs) are used for classifying abnormality based on its severity. Potential research is carried out in this area of developing a generalized procedure for automatic analysis and classification of thermographs due to complex nature of the thermographs. This paper provides a detailed literature review on the various image analysis techniques, choice of statistical parameters and application of ANN for classification.

Keywords: Breast thermography, image processing, Hough transforms, Statistical parameters, ANN

1. Introduction

Breast cancer is the most commonly occurring disease in women and the mortality rate due to breast cancer is high [1-3]. It is because tumor becomes fatal when detected in the last stages of development. On the other hand if it is detected earlier then it can be treated and mortality rate can be reduced. Though mammography is the well established technique for breast cancer diagnosis, it can not detect it at the early stage. Clinical Infrared thermography is now accepted as the reliable technique for early detection of breast cancer. Infrared thermography results in thermographs which are obtained by mapping the temperature distribution on the breast surface.

The underlying principle behind thermography is that cancer cells require large amount of nutrients for its growth and hence results in higher metabolic activity around that region. As a result, temperature increases in that area when compared to the other regions. It introduces asymmetry in the otherwise symmetrical distribution of temperature in left and right halves. Severity of the disease can be determined by measuring the temperature variations in the abnormality region. Better detection necessitates high end Infrared camera that gives a high quality thermograph. Due to recent advances in Infrared technology, specifically designed focal array planes are available for obtaining high quality thermographs. Later these thermographs can be quantitatively analyzed for abnormality detection and classification. Though human interpretation of thermographs can be done it is subjective in nature dependent on the expertise of the individual and may at times result in misinterpretations due to operator fatigue.

Hence automated analysis is aimed at and extensive research is carried out in computer aided interpretation of thermographs. In general it involves three phases namely, suitable feature extraction techniques for abnormality region isolation, proper choice of statistical parameters for abnormality description, and development of soft computing tool for decision making and classification of cancer regions (normal, benign or malignant). This paper reviews various image processing tools, statistical parameters and artificial neural networks for abnormality detection and classification. Section 2 reviews the various image processing and statistical parameters used for computer aided analysis. Section 3 discusses the applications of ANN in breast cancer analysis and classification. Section 4 is about the interpretation of thernmographs for normal and abnormal cases. Section 5 concludes the work.

2. Review of Image Processing Techniques and Statistical Parameters for Asymmetry Analysis in Breast Cancer

After acquiring the thermal images from the patients, various image analysis techniques are performed on these thermographs to isolate the abnormality region and to determine the suitable statistical parameters to describe the nature and severity of the disease. In general, all the proposed techniques involve the following steps: preprocessing thermographs for highlighting the Region of Interest (ROI), segmentation to isolate the abnormality and choosing proper statistical parameters for describing the abnormality. Though research started from 1970s, still intense research is carried out in these areas in order to obtain a generalized black box for automated breast cancer analysis.

Negin et al (1977) proposed a computerized breast thermographic interpreter that takes decisions through linear discriminate classifiers based on extracted features. They used a set of elemental parameters and compound parameters for describing the abnormal features. These parameters were then used for decision making and further classification of abnormality. Head et al (1997) proposed the use of second generation Amber Indium Antimonite focal plane staring array system to acquire breast thermographs. Such thermographs are better than that of conventional thermographs and can be interpreted easily. Sensitivity and resolution of these thermographs are high and hence asymmetric analysis can be performed more easily on these thermographs. They also found that the upper outer quadrant of the breasts is the most probable area for tumor growth. They also developed an automated algorithm for dividing the thermographs into four quadrants and calculated the mean, standard deviation, median, minimum and maximum temperature for each quadrant of the breast. Qi et al (2000) proposed an automated asymmetry analysis technique for abnormality detection from breast thermographs. It involved the following steps: Detecting the edges using Canny filter, identifying the left and right body boundary curves and two lower boundaries of the breasts using Hough Transform, identifying the point of intersection of the parabolic curves using segmentation, deriving the Bezier histogram for each segment and computing the curvature from the two histograms. The difference in curvature is used as a measure for abnormality identification. However the success of the proposed technique lies in effective edge detection and segmentation algorithms.

Frize et al (2003) proposed an automated breast cancer detection algorithm by implementing Head's methodology. Initially the difference in mean temperature between left and right breasts is determined. Thermograph is divided into four quadrants namely upper left, upper right, lower left and lower right. For each quadrant, scores are created as 0,5 if the mean temperature difference between the left and right halves is between 0.5 degrees to 1 degree. On the other hand the score is made as 1 if the difference is greater than 1 degree. An index is created by adding the scores for the four quadrants and if the index is greater than 1 then it indicated the presence of the abnormality. Yang et al (2007) analyzed the breast thermographs based on temperature distributions between the left and right breasts. In normal cases, the histograms of the left and right breasts are symmetrical in contrast to asymmetrical histograms in abnormal breasts. Also the temperature distribution curve obeys mathematical normal distribution while it deviates in the case of abnormality. From the analysis, they concluded that 0.5^{o} C differences in temperature between the two breasts of the patient can be considered as the threshold to distinguish abnormality from normal breasts. Wicek et al (2008) proposed imaging software for breast cancer diagnosis from breast thermographs. In the proposed method abnormality was described using three different sets of parameters. That includes first order moments such as mean, skewness and kurtosis, second order statistical parameters namely co-occurrence matrix and parameters such as entropy, energy based on image transformation using wavelet analysis. They also found that use of Artificial Neural Networks will provide better results.

Tang et al (2008) proposed an automated analysis technique for breast cancer detection based on measuring Localized Temperature Increases (LTI). The proposed technique involved two phases. Initially the suspicious focus regions in breast infrared thermographs are found visually. Later morphological approaches were used to determine the LTI and then decisions were made based on three measures. LTI is calculated as the difference between the pixel temperature and the corresponding background temperature. The key aspect of this analysis technique lies in determining the background temperature. A proper structuring element such as 'disc' is chosen and the opening at each radius is considered as the approximate background. They found that there is a significant difference between benign and malignant cases in terms of LTI amplitude. Nurhayati et al (2010) proposed an automated algorithm based on first order moments for abnormality detection in breast thermographs. Initially thermographs were deblurred using Weiner filter, contrast enhancement is done by histogram equalization, abnormality is detected by segmentation and is described using the first order moments namely mean, variance, skewness and kurtosis. Based on these parameters, abnormality detection is achieved. However the performance of the proposed technique can be improved if spectral and structural methods of analysis are performed. Wang et al (2010) proposed an automated algorithm for determining the severity of the abnormality from breast thermographs by using five different parameters. They are IR1, the difference in surface temperature at the lesion site from that at the mirror image site on the collateral breast, IR2, the temperature difference between the lesion site and the rest of the normal breast tissue of the ipsilateral breast, IR3, a combination of 8 various abnormal vascular patterns, IR4, an edge sign or bulge sign backed by heat, indicating loss of smooth contour of part of the breast due to skin retraction or bulging caused by a breast tumor and IR5, the presence of an asymmetric or heterogeneous vascular pattern at and around the lesion site, when the contra lateral breast did not reveal such a pattern. Based on these parameters decision about the severity of the abnormality is made.

Scales et al (2010) proposed three different techniques for detecting the boundaries of the breasts. In the first approach, modified Hough transform was used to detect the boundaries. In the second approach an algorithm used to detect the longest connected edges that are not part of the body boundary, and a third approach involving the density of detected edges in the breast region. They found that the last two methods provided better results in segmenting the edges. They also found that better segmentation techniques such as snake transform can be decided to improve their results. Kapoor et al (2010) proposed an automated computer aided analysis for breast cancer detection from breast thermographs. The proposed algorithm involves the following edge detection by Canny filter, Breast boundaries detection by parabolic Hough transform, feature extraction and asymmetry description using skewness and kurtosis and cumulative histogram. These parameters are then used for diagnosis of cancer regions. Nurhayati et al (2011) proposed an automated breast cancer classification tool by combining five statistical parameters with the principal Component Analysis. Pseudocolor breast thermographs were converted to gray scale thermographs of size 256x256, Five statistical parameters namely mean, variance, entropy, skewness and kurtosis and eigen values, eigen vectors and covariant matrix are calculated. Based on theses parameters decision about the severity of the abnormality was determined. However they found that the performance of the proposed system can be improved by using proper image preprocessing techniques. Zadeh et al (2011) proposed an automated image processing algorithm for abnormality extraction. The proposed algorithm involved the following steps: Converting Pseudocolor thermographs into gray scale, improving the brightness by thresholding, detecting the breast boundaries using Hough transform, removing the undesirable pixels using suitable filters, determining the parameters such as mean, variance skewness and kurtosis for histograms of the left and right sides of the breasts and finally decision making based on these parameters. They also found that for their set of thermographs from a specific IR camera, tumor cells correspond to pixels in Pseudocolor thermographs with Red intensity $(R_T)>100$, Green intensity and blue intensity $(G_T \& B_T<20)$. But thresholding based on this approach will result in few artifacts that belong to the same intensity level.

3. ANN for classification of tumor from Breast thermography-A Review

Classification of abnormality (cancerous, fibroadenoma, normal) from breast thermographs is a complex problem and is non-linear in nature. Also determining the severity of the abnormality from the temperature distribution is tedious. Both these problems require generalization and decision making based on repeated training and expert decision making. Hence Artificial Neural Networks are the best choice for these non-linear problems. Drosu et al (2006) proposed an ANN based approach for determining the shape of the abnormality from breast thermographs based on the principle that malignant tumor leads to a change of the volume distribution of the losses inside the breast tissue. They also inferred that the shape of the abnormality can be correlated to the temperature distributions on the breast surface. A square functional of the difference for tumor was obtained by minimizing the function through gradient procedure. They also used ANN for minimizing the gradient function.

Ng and Kee (2008) proposed an ANN based integrated approach for classification of abnormality from breast thermographs. In this method, linear regression, Radial Basis Function Network (RFBN) and Receiver Operating characteristic (ROC) curves were used to analyze thermographs. Linear Regression is used to decide the most significant features that can be used as inputs to the neural networks. After training RFBN gives an output as 1, if the abnormality is present and 0 if the abnormality is absent. ROC was used to evaluate the accuracy, sensitivity and specificity of the outcome of RFBN. Though the proposed method provided better results, it could not specify the actual location and size of the tumor. Wishart et al (2010) proposed an Artificial Intelligence based system for the interpretation of breast thermographs. They used a total of seven parameters for describing the abnormality. Of which four parameters described the temperature distribution between the left and right breasts, three parameters were used for determining the excess heat in individual breasts. They used Artificial Neural Networks to obtain the severity of the disease. However it is found that the performance of their method can be improved by defining more number of precise parameters for describing the disease.

4. Breast Thermograph

Thermograph is defined as a two dimensional function g(x,y) where x,y denotes the spatial co-ordinates and g(x,y) denotes the radiance at that pixel. Two different thermographs are shown in Figures 1 and 2 in order to understand the temperature variation in normal and abnormal cases. These thermographs are pseudo color thermographs in which red and white intensities correspond to the high temperature region and hence indicate the presence of the abnormality. By analyzing the normal and abnormal thermographs, it is found subjectively that thermograph of a normal person is symmetric and there is no abrupt variation in temperature. On the other hand, in abnormal thermographs there is an asymmetry in temperature between the left and right breasts and in there is an abrupt variation in temperature in the affected half.

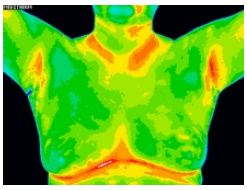

Figure 1: Normal thermograph

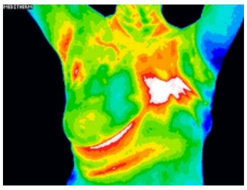

Figure2: Abnormal thermograph

This asymmetry can also measured in terms of skewness, kurtosis, and absolute difference in mean, variance between the left and right halves and is given in Table 1. From the table it is found that there is a significant variation in Kurtosis and Absolute difference in mean between normal and abnormal thermographs. Also for abnormal thermographs skewness and absolute difference in variance is greater than that of normal thermograph. Hence it is understood that asymmetry can be quantified using the statistical moments.

Table 1: Measure of asymmetry between left and right halves.

Images	**Skewness**	**Kurtosis**	**Difference in mean**	**Difference in variance**
Normal thermograph	0.2295	2.6756	5.7247	2.1086e+006
Abnormal thermograph	1.5840	17.9087	32.9190	2.1181e+006

3. Conclusion

Computer Aided Analysis can be used for detection of abnormality, classification of cancer and measurement of severity of abnormality. From the literature review the following conclusions can be arrived at.

- Asymmetry analysis can be done by measuring skewness, kurtosis, difference in mean and standard deviation or variance between the right and left halves.
- Histogram can be obtained separately for right and left halves and the curvature of histograms, mean, skewness, Kurtosis and variance of histograms can also be used for asymmetry analysis.
- Body boundaries can be identified using Hough Transform and gradient based Hough transform.
- Abnormality detection can be done with Canny detector, snake transforms.
- Artificial Neural Networks such as Radial Basis Function Networks and Back propagation Networks can be used for abnormality classification and severity detection.

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