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Appropriate Feature Vectors (Metrics) for Effective Representation and Description of Abnormality from Breast Thermographs

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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 interpretation and classification of abnormality from breast thermographs has been developed. It involves suitable techniques for abnormality isolation, effective features for describing the abnormality, soft computing tool for classifying abnormality. In this paper, slope based gradient method has been used for abnormality isolation, and selection of suitable statistical and regional descriptors for quantitatively characterizing the abnormality. This paper exploits various descriptors that can be used for describing the abnormality.**

Index Terms – **slope gradient, segmentation, regional descriptors, statistical descriptors.**

I. 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 cannot detect cancer at the early stage [1]. Clinical Infrared thermography is now accepted as the reliable technique for early detection of breast cancer. Infrared thermography is a non-contact, non-invasive and non-hazardous technique that maps the temperature distribution into thermographs. For normal cases, temperature is uniform throughout the region and is symmetrical for left and right halves. On the other hand, an abnormality results in abrupt temperature variation and hence introduces asymmetry [1-5].

The underlying principle for thermal asymmetry is that cancer cells require large amount of nutrients for its growth hence resulting in higher metabolic activity around that region. As a result temperature increases in that area when compared to the other regions [4].

Severity of the disease can be determined by measuring the temperature variations in the abnormality region.

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Due to recent advances in Infrared technology, specifically designed focal array planes are available for obtaining high quality thermographs.

These thermographs are sent to human interpreters for abnormality characterization. However human interpretation of thermographs results in abnormality detection. But human interpretation of thermograph is subjective in nature as it is 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. It involves three phases namely suitable feature extraction techniques for abnormality region isolation, proper choice of statistical parameters for abnormality detection, and development of soft computing tool for decision making and classification of cancer (normal, benign or malignant). However an image segmentation technique that could isolate only the abnormality region by completely removing the undesirable artifacts (similar characteristics) has not yet been developed. Though considerable research is done in describing the abnormality with feature vectors, suitable descriptors are yet to be defined. This paper presents slope based image segmentation technique that has completely removed the artifacts by retaining the abnormality region and four different metrics namely abrupt temperature rise metrics, asymmetry metrics, shape metrics and size metrics.

Section II discusses the related work. Section III describes the image dataset used in this work. Section IV describes the proposed segmentation technique and set of descriptors used for describing the abnormality. Results and Discussion is dealt in Section V and Section VI concludes the work.

II. RELATED WORK

In recent years automated analysis tools for breast thermograph interpretation and description are developed. Negin et al (1977) proposed a computerized breast thermographic interpreter that takes decisions through linear discriminant classifiers based on extracted features [6]. Head et al (1997) used second generation Amber Indium Antimonide focal plane staring array system to acquire breast thermographs. Sensitivity and resolution of these thermographs are high and hence asymmetric analysis can be performed more easily on these thermographs [7]. They also found that the upper outer quadrant of the breasts is the most probable area for tumor growth. Qi et al (2000) found that the difference in histogram curvature of the left and right breasts is used as a measure for abnormality identification [8]. 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 [9]. Tang et al (2008) proposed an automated analysis technique for breast cancer detection based on measuring Localized Temperature Increases (LTI). LTI is calculated as the difference between the pixel temperature and the corresponding background temperature. They found that there is a significant difference between benign and malignant cases in terms of LTI amplitude [10]. 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 [11]. Scales et al (2010), Kapoor et al (2010), Wang et al (2010) proposed automated analysis for breast cancer detection which involved Hough Transform, boundary detection and asymmetry analysis based on skewness, kurtosis and histogram [12-14]. Nurhayati et al (2011) developed an automated breast cancer classification tool by combining five statistical parameters namely mean, variance, entropy, Skewness, kurtosis, eigen values, eigen vectors and covariant matrix (Principal Component Analysis) [15]. Zadeh et al (2011) 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 and blue intensities G_T&B_T<20 [16]. 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. From the literature, it is found that better results can be obtained if the abnormality is isolated properly and is described with suitable parameters.

III. Image Dataset

An image dataset has been initially created with nine breast thermographs (2 for normal cases, 3 depicting cancer and 4 depicting fibroadenoma). The size of these thermographs is 165x220. From rigorous subjective analysis of these thermographs it is understood that thermographs of normal cases is symmetrical and uniform in nature. On the other hand, if there is an abnormality either as fibroadenoma or breast cancer, the temperature distribution between the left and right breasts and also there is an abrupt variation in the affected regions. Also from the analysis it is found three degree rise in temperature from the surroundings corresponding to the abnormality. Intensities of tumor/ fibroadenoma are Fr(x,y)=255 and Fb(x,y)>=33 and Fg(x,y)>=33. The color coding used for pseudocoloring is shown in Fig. 1. Abnormality is coded with red and white intensities. Fig. 2 describes the cancer and fibroadenoma thermographs. The desirable regions are shown by arrow marks. Fig. 3 represents the normal person. It does not show any significant variation in temperature and the left and right halves are symmetrical.

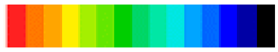

Figure1.Ccolor Coding

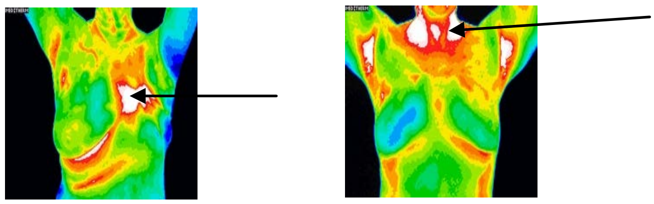

Figure 2. Cancer and fibroadenoma thermographs

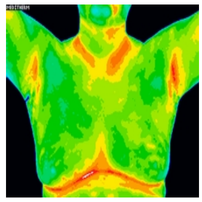

Figure 3. Thermograph of a normal person

IV. Slope Based Segmentation And Abnormality Descriptors

The proposed method involves developing a suitable segmentation algorithm for detecting the abnormality and identifying the effective set of statistical and regional descriptors for describing the abnormality. In the proposed work, slope based segmentation technique has been used for extracting the abnormality region. After a rigorous literature survey, a set of statistical and regional descriptors have been identified. In addition to the conventional descriptors, central moments and histogram based parameters were also used for effectively describing the abnormality.

A. Slope Based Segmentation

In the proposed technique, the edge points are determined by exploiting the fact that every 3 degree rise in temperature results in abnormality. The intensity slope corresponding to 3 degree rise in temperature is determined. Using this threshold, all the points corresponding to a possible abnormality region are then determined. Though there is an abrupt intensity variation in the beginning of the abnormality region, the pixels inside the abnormality region are of nearly same intensity. Hence the similarity slope is also determined. Later the pixels satisfying this threshold are determined and the number of pixels is calculated. If the number of pixels is greater than a threshold it indicates an abnormality and these pixels are retained. If there is more than one region, then these regions are xored in order to indicate the complete abnormality region. In this way only the abnormality regions are determined.

B. Representation and Description

Quantitative characterization of abnormality should describe the abrupt rise in temperature and hence the intensity variation (if any) in the affected region, asymmetry due to abnormality, shape of the abnormality region, size of the abnormality region. The metrics used for the above are entropy of histograms of the left and right halves (indicates the rise in temperature), absolute difference in entropy, mean, variance between the left and the right halves, skewness and kurtosis (asymmetry metrics), second order central moments (shape metrics) and area, major axis length and minor axis length (size metric) After isolating the abnormality regions, they are quantitatively described using the region descriptors namely area, major axis length and minor axis length. These parameters provide an idea about the severity of the abnormality region.

V. RESULTS AND DISCUSSION

The proposed slope based segmentation algorithm is applied on all the eight thermographs and the abnormality regions are isolated. The gray scale and the corresponding output thermographs are shown for normal, cancer and fibroadenoma thermographs in Fig. 4-6. The proposed segmentation technique has effectively removed the undesirable artifacts and has retained only the abnormality region in its original form. The histograms for the left and right halves for normal, fibroadenoma and cancer thermographs are shown in Fig. 7-9. From the Subjective analysis, while left and right histograms are similar for normal cases, it is not so for thermographs depicting abnormality.

Figure 4. Gray scale and segmented images (normal)

Figure 5. Gray scale and segmented images (Fibroadenoma)

Figure 6. Gray scale and segmented images (cancer)

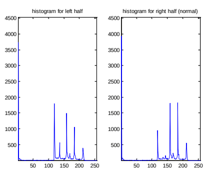

Figure 7. Histograms of left and right halves (normal)

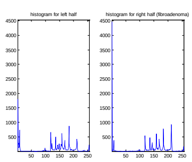

Figure 8. Histograms of left and right halves fibroadenoma)

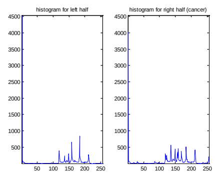

Figure 9. Histograms of left and right halves (cancer)

Entropy is calculated for the left and right halves of the gray scale thermographs which indicate the intra-temperature variation within that half. It is shown in Table 1. Though a general pattern could not be derived from these values (as the temperature is dependent on individual's body temperature), it can be found that entropy of the affected half is greater than that of the normal half. Asymmetry metrics are difference in entropy, mean and variance between left and right halves and skewness and kurtosis as shown in Table 2. From the table it can be found that more asymmetry is predominant in cancer and fibroadenoma thermographs.

Table 1. Temperature rise metrics

Images	**Entropy for left half**	**Entropy for right half**
Ab_n1	-0.0023	-5.4030e-004
Ab_n2	-0.0085	-5.4030e-004
Ab_n3	-0.0078	-0.0026
Fibro2	-0.0118	-0.0010
Fibro3	-0.0126	-5.4030e-004
Fibro4	-0.0026	-0.0010
Norm1	-0.0038	-5.4030e-004
Norm2	-0.0023	0

Table 2. Asymmetry metrics

Images	Entropy	Mean	Variance	Skewness	Kurtosis
Ab_n1	-0.0017	18.0258	2.5005e+005	1.8151	44.9183
Ab_n2	-0.0079	10.2319	2.1590e+006	0.3657	5.3025
Ab_n3	0.0052	32.9190	2.1181e+006	1.5840	17.9087
Fibro2	0.0108	1.2876	7.0082e+006	1.8364	14.1123
Fibro3	0.0121	8.6493	8.4223e+005	-0.2344	2.6970
Fibro4	0.0016	27.1470	2.6480e+005	0.1260	4.9335
Norm1	0.0032	5.7247	2.1086e+006	0.2295	2.6756
Norm2	0.0023	8.5499	2.2191e+006	0.1142	4.4381

The size of the abnormality region is described in terms of area, major axis length and minor axis length and is shown in Table 4. From Table 4, abnormality region has significant values of these metrics. Second order central moments, used for describing the shape of the abnormality are shown in

Table 3. It relates to the direct diagnosis of the abnormality. All these metrics are measured in terms of pixels.

Table 3. Abnormality size Metrics

Images	Area	Major Axis Length	Minor Axis Length
Ab_n1	964	87.3820	59.2730
Ab_n2	0	0	0
Ab_n3	498	40.6191	22.8757
Fibro2	0	0	0
Fibro3	854	71.2971	44.5903
Fibro4	0	0	0
Norm1	0	0	0
Norm2	0	0	0

Table 4. Abnormality shape Metrics

Images	Cm11	Cm20	Cm02	Cm21	Cm12	Cm30	Cm03
Ab_n1	0.0912	0.0720	0.0611	-1.4953	-0.9307	2.9530	-1.4541
Ab_n2	0.1366	-0.0015	0.0380	0.1095	-0.4963	-1.3138	-3.3243
Ab_n3	0.0932	-0.1039	-0.0818	-0.8041	1.0468	0.9281	-2.2234
Fibro2	-0.0048	-0.0072	-0.0036	0.7605	-1.1891	4.8382	-0.9821
Fibro3	0.1815	0.0305	0.0228	0.2737	0.2393	-0.7701	-3.0976
Fibro4	0.1461	0.1034	0.0569	-0.7513	1.0109	-4.1552	-2.1715
Norm1	0.1384	0.0017	-0.0062	2.1345	-0.0689	-0.1785	-3.7662
Norm2	0.1748	-0.0293	-0.0274	-0.7926	0.2410	-2.6395	-3.9119

VI. CONCLUSION

In this paper, an effective slope based segmentation technique has been developed for isolating the abnormality and appropriate metrics were identified for describing the abnormality. These metrics provide complete information about the abrupt temperature rise with the affected half, asymmetry between left and right halves, shape and size of the abnormality. It serves as the prerequisite for developing automatic breast cancer classification system using Artificial Neural Networks. The descriptors (metrics) determined from this paper can be used as input parameters for exemplar generation in developing such classification systems.

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