Feature Analysis for Abnormality Detection in Breast Thermogram Sequences Subject to Cold Stress

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Abstract—Breast cancer is the most commonly diagnosed form of cancer in women. Early diagnosis of Breast cancer is the key to improve survival rate. Due to the potential hazards of conventional breast imaging modalities, alternate techniques such as breast thermography are being evaluated. Breast thermography is a non-invasive diagnostic procedure that images the breasts to aid in the early detection of breast cancer. Breast thermal image is a visual representation of skin surface temperature of the breast. Abnormality detection by conventional breast thermography is less accurate as the imaging is done in a limited number of views. Also the segmentation of breast region from the chest wall is difficult. Hence classification of a breast thermogram as normal or abnormal is a challenging task by direct visual interpretation and image processing techniques as well. Rotational thermo mammography overcomes these difficulties as the imaging protocol incorporates complete imaging of each breast and application of external cold stress. This paper features an exhaustive analysis on spatial domain image features for automatic detection of breast abnormality in rotational infrared breast thermograms from the perspective of cold stress. Statistical features and Haralick texture features are extracted and fed to the support vector machine for automatic classification of normal and abnormal breast conditions.

Keywords—Rotational Breast Thermography, cold stress, Haralick Texture features, statistical features, Support Vector Machine(SVM).

I. Introduction

Breast cancer has been known for decades to be the most common type of cancer among women. Thermography (Infrared imaging) has been shown to be well suited for the task of early detection of breast cancer, especially in young women with dense breasts. Early detection is important as it provides significantly higher chances of survival. In this respect thermography outperforms standard mammography which can detect tumors only when they exceed a certain size. The increase in local temperature due to high metabolic activity of cancer cells can be picked up by the infrared camera. Thus tumors that are small in size can also be identified. Breast thermography is a diagnostic procedure that images the breasts to aid in the early detection of breast cancer. The procedure is based on the principle that chemical and blood vessel activity in both precancerous tissue and the area surrounding a developing breast cancer is almost always higher than in the normal breast. This process results in an increase in surface temperature of the breast. Temperature variations and vascular changes may be among the earliest signs of breast cancer and precancerous state of the breast. State of the art breast thermography uses ultra sensitive infrared cameras and sophisticated computers to detect analyze and produce high resolution images of these temperature variations. The procedure is comfortable and safe as it does not need painful breast compression or exposure to ionizing radiation. Unfortunately, it has not become widely used in the medical community due to the highly subjective nature of thermogram interpretation. Researchers are currently attempting to obtain quantifiable measures to help thermogram interpretation become more objective.

A. Conventional Breast Thermography

In conventional breast thermogram imaging technique the patient is made to sit in front of the camera at a particular distance. The thermographer takes the infrared images of the breast at three different positions namely Contralateral, Medio Lateral Oblique and Axillary. With these three views certain features may be missed resulting in wrong diagnosis. These images are highly operator dependant. Cold stress is not effective as the procedure is done in a room and not in a controlled chamber. The imaging protocol causes discomfort to the patient and the method is error prone due to patient movement.

B. Rotational Breast Thermography

In Rotational breast thermography, breast images are taken at many angles so that abnormality is not missed. A special setup is designed for taking infrared breast thermogram images. The subject lies in prone position on the Mammary Rotational Infrared Thermographic System(MAMRIT) with one breast freely hanging through a small aperture. Inside the MAMRIT chamber, the infrared camera is fixed at the end of robotic arm. The robotic arm rotates the infrared camera and takes images of breast at different angles. In this way complete imaging of the breast at all angles is taken. The ambient temperature during IR acquisition is controlled with an in-built air conditioner. Temperature information of the entire breast is captured including the nipple along the sides of the breast. With a 360 degree acquisition it has been observed that there is a continuous band of temperature that extends across the normal breast. An abnormal condition is detected, when this temperature pattern is disturbed.

C. Literature Review

Different approaches have been proposed for the classification of conventional breast thermogram images. T.Jakubowska, et.al [1] proposed the method based on wavelet transform and non linear neural network classifier for the classification of the thermal images in order to discriminate between healthy and pathological cases during breast cancer screening. E.Y.K.Ng, et.al [2] introduced advanced technique for the analysis of thermograms with the use of Bio-statistical methods and Artificial Neural Networks (ANN).The advanced technique, is a multi-pronged approach comprising of Linear Regression (LR), Radial Basis Function Network(RBFN) and Receiver Operating Characteristics (ROC). Pragati Kapoor, et.al [3] proposed an automated approach for classifying breasts by asymmetry analysis, using edge detection and Hough transform for segmentation.

N.Scales et.al [4] have proposed segmentation algorithm and Bartosz Krawczyk et.al [5] have built multiclass classifier for the purpose. Hairong Qil et.al [6] have also used asymmetry approach for automatic detection of breast abnormality. Acharya U, et.al [7], Sheeja Francis, et.al [8] have used texture features for classification of conventional breast thermograms in contralateral view. This paper conducts a detailed analysis of spatial domain features such as Haralick's texture features and statistical features extracted from rotational breast thermograms. The features are fed to the support vector machine classifier for automatic classification of normal and abnormal breast conditions.

II. Methodology

Breast thermogram images of 8 normal cases and 8 abnormal cases are taken for analysis. In rotational thermography, the breasts are imaged in the following order. Left Pre-Cool, Left Post-Cool, Left Frontal, Right Frontal, Right Pre-Cool, Right Post-Cool. In each of these, images are obtained in 12 views at an angular interval of 30 degrees. The differential temperature is maintained at 2 degrees between pre and post cool conditions, for the same breast, while ambient temperature is not held constant. The images are taken with informed consent of the patient and approved protocol using ICI7320P uncooled camera. The flow diagram of the methodology is as shown in Fig 1.

Fig 1. Flow chart of the project

III Pre-Processing:

Thermogram breast images are taken according to the above mentioned sequence. It is converted to gray scale. One normal and one abnormal thermogram are shown in fig 2 and fig.4. It has been observed that the temperature variation in a normal breast follows a layered pattern with nipple being the coldest region and an increase in temperature is observed in layers closer to the chest wall. The central 30% area of the total breast is cropped as shown in the Fig 3 and Fig 5. As this process is repeated in all 12 views, it is ensured that no information is lost. Features are extracted from this region of interest (ROI), for further analysis.

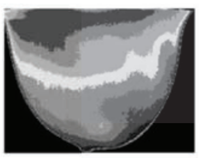

Fig. 2: Normal Image

Fig. 3: Normal ROI

Fig. 4: Abnormal Image

Fig. 5: Abnormal ROI

IV Feature Extraction

Feature extraction is the process of defining the set of features or image characteristics which will most efficiently represent the information that is important for analysis and classification. In this work a series of statistical features are extracted from the normal and the abnormal regions of interest. A statistical method of examining texture that considers the spatial relationship of pixels is the gray-level co-occurrence matrix (GLCM), also known as the gray-level spatial dependence matrix. Haralick texture features such as Angular Second Moment (ASM), Contrast, Correlation, Sum of Squares, Inverse Difference Moment, Sum Average, Sum Variance, Sum entropy, Entropy, Difference variance, Difference entropy, Information Measure of correlation1, Information measure of Correlation2 and statistical features like mean, variance, skewness and kurtosis are computed from the normalized GLCM matrix of the ROI.

V Results

The Features extracted were analysed to study the effect of cold stress on human breast conditions. Features were extracted from both left and right breasts before and after the application of cold stress and were analysed in the normal group. The same was extended for the abnormal group also.

A. Feature Analysis in Normal Group:

Study was carried out at all views for the normal group and the average feature values are given for left and right breasts in Table1 and Table2. These tables show the average value of each feature before and after the cooling process in each breast. The individual differences in feature values due to the cooling process are averaged and presented for the normal group. For all 8 normal patients, features were extracted in all 12 angles in pre cool and post cool conditions from both breasts. The ability of each feature in discriminating between the cooling conditions was studied using student's t test, in all the views. Most of the features were found to be insignificant ($p > 0.05$) as shown for angle 0 degrees in Table 3. Therefore it is inferred that these features do not differentiate between the cooling conditions in normal breasts.

Table1.

Average Feature Values and Average Feature Differences of The Normal Left and Right Breast Due to Cold Stress

Feature	Average of feature values at all angles for Left Breast			Average of feature values at all angles for Right Breast		
	PREcool	POSTcool	Diff	PREcool	POSTcool	Diff
ASM	0.28	0.25	0.03	0.25	0.25	0.0
Contrast	0.20	0.20	0.0	0.23	0.20	0.03
Correlation	0.95	0.96	-0.01	0.95	0.96	-0.01
Sum of Squares	29.80	29.51	0.29	26.55	26.15	0.40
Inverse Difference Moment	0.94	0.93	0.01	0.94	0.94	0.0
Sum Average	10.27	10.25	0.02	9.67	9.60	0.07
Sum Variance	89.30	86.90	2.40	76.59	74.74	1.85
Sum Entropy	1.61	1.69	-.08	1.71	1.74	-.03
Entropy	1.73	1.81	-.08	1.84	1.86	-.02
Difference Variance	0.20	0.20	0.0	0.23	0.20	0.03
Difference Entropy	0.39	0.40	-0.01	0.39	0.39	0.0
Information Measures of Correlation1	-0.73	-0.73	0.0	-0.74	-0.74	0.0
Information measure of correlation2	0.92	0.93	-0.01	0.93	0.94	-0.01
Mean	0.57	0.57	0.0	0.52	0.53	0.01
Variance	0.03	0.03	0.0	0.03	0.04	0.01
Skewness	0.05	0.07	-0.02	-0.03	0.09	-0.06
Kurtosis	3.04	2.85	0.19	3.21	2.81	0.4

Table 3.

Student T-Test for Normal Left Breast at Angle 0.

Feature	P-Value
ASM	0.055
Contrast	0.571
Correlation	0.371
Sum of Squares	0.522
Inverse Difference Moment	0.343
Sum Average	0.655
Sum Variance	0.819
Sum Entropy	0.035
Entropy	0.058
Difference Variance	0.571
Difference Entropy	0.407
Information Measures of Correlation1	0.924
Information measure of correlation2	0.010
Mean	0.707
Variance	0.288
Skewness	0.295
Kurtosis	0.863

B. Feature Analysis in Abnormal Group :

For all 8 abnormal patients, features were extracted in angles where the abnormality is seen most, in both pre cool and post cool conditions. The ability of each feature in discriminating the cooling conditions was studied using student's t test. Most of the features were found to be significant ($p < 0.05$) as shown in Table 4. Hence it is inferred that these features are able to differentiate between the cooling conditions when the breast is abnormal .

Table 4.

Student's T-Test for Abnormal Cases.

Feature	P-Value
ASM	0.00
Contrast	[illegible]
Correlation	0.01
Sum of Squares	0.01
Inverse Difference Moment	0.54
Sum Average	0.01
Sum Variance	0.01
Sum Entropy	0.00
Entropy	0.01
Difference Variance	0.52
Difference Entropy	0.55
Information Measures of Correlation1	0.04
Information Measure of correlation2	0.01
Mean	0.01
Variance	0.01
Skewness	0.24
Kurtosis	0.16

The association between features is analysed in the normal as well as abnormal groups by computing their correlation matrices and regression graphs.

VI. Discussion

Normal breast thermogram is generally found to follow butterfly pattern with a temperature gradient hotter near the chest wall and lowest at the nipple for a suspended breast. Abnormal breast thermograms deviate from this normal pattern, with the hotter bands protruding into the cooler bands in subtle way. These pattern changes are extracted in the form of statistical and texture features. It is observed from the correlation analysis that features of a normal breast were mostly better correlated with each other (ρ> 0.5), given a particular cold stress condition and also between the cooling conditions. Also features which showed higher degree of correlation in normal breasts were largely the least correlated in abnormal breasts. Correlation matrix was computed for the abnormal class of thermograms between precool and post cool conditions. As most of the features exhibited lesser correlation between these conditions, all features are considered to carry significant discriminative information. Thus it is inferred that all the features extracted responded quite well to cold stress in abnormal breast thermograms.

It is observed from line plots in Fig 6 and Fig 7 that the features obtained from normal group before and after cooling generally overlap each other. Hence they do not respond well to cold stress when compared with line plots in Fig 8, Fig 9 and Fig 10 of the abnormal group. The graphs are shown for angle 0 degrees. Almost similar over lapping plots were obtained in the other angles for normal breast whereas abnormal breasts show non overlapping plots in pre-cool and post-cool condition.

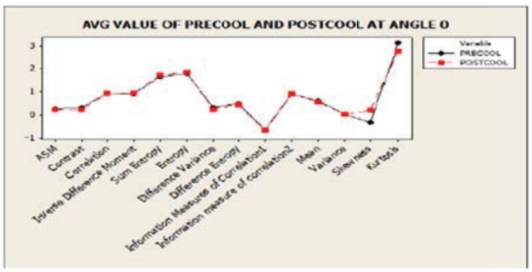

Fig. 6. Line plot-I of average feature values for pre-cool and post-cool conditions in Normal breasts.

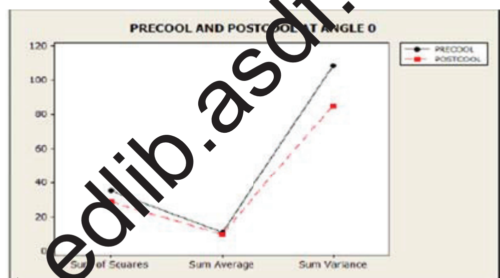

Fig. 7. Line plot-II of average feature values for pre-cool and post-cool conditions in Normal breasts.

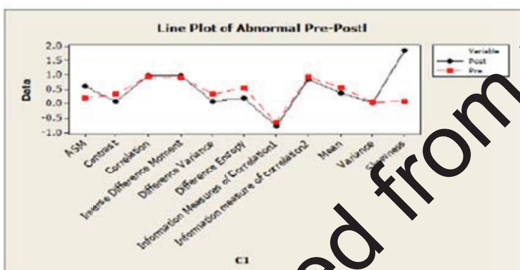

Fig. 8. Line plot-I of average feature values for pre-cool and post-cool conditions in Abnormal breasts

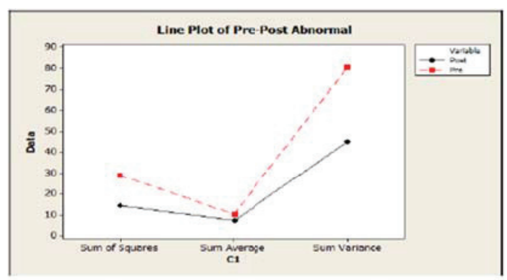

Fig 9. Line plot-II of average feature values for pre-cool and post-cool conditions in Abnormal breasts

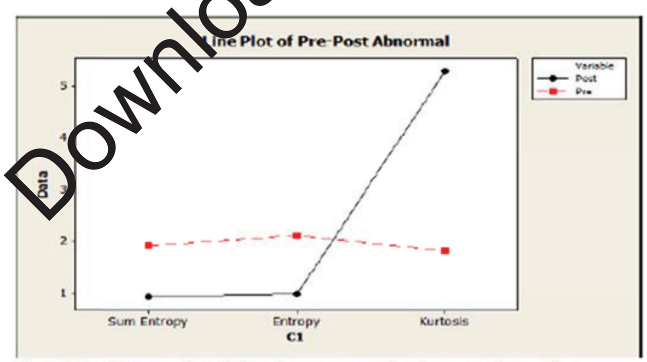

Fig 10. Line plot-III of average feature values for pre-cool and post-cool conditions in Abnormal breasts

VII Conclusion

To conclude, exhaustive feature analysis has been carried out in the spatial domain to identify features that best describe breast abnormality in rotational thermograms. The results of the study indicate that abnormal breasts respond well to the application of cold stress from an image processing view point. This is observed in the significant differences in feature values extracted from abnormal thermograms that have been acquired before and after the cooling process. Thus these feature differences may be used to train a SVM classifier for automatic detection of breast abnormality.

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