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Breast cancer detection in rotational thermography images using texture features

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HIGHLIGHTS

- This is the first study on rotational thermography – a complete breast imaging technique.
- Temperature reduction of 2–3° does not provide effective cold challenge.
- Texture features carry thermal signatures of abnormalities better than first order statistical features in breast thermograms.
- Abnormal breast quadrants have been located automatically.
- Malignant condition has been detected accurately by correlating with ultrasound findings.

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ABSTRACT

Breast cancer is a major cause of mortality in young women in the developing countries. Early diagnosis is the key to improve survival rate in cancer patients. Breast thermography is a diagnostic procedure that non-invasively images the infrared emissions from breast surface to aid in the early detection of breast cancer. Due to limitations in imaging protocol, abnormality detection by conventional breast thermography, is often a challenging task. Rotational thermography is a novel technique developed in order to overcome the limitations of conventional breast thermography. This paper evaluates this technique's potential for automatic detection of breast abnormality, from the perspective of cold challenge. Texture features are extracted in the spatial domain, from rotational thermogram series, prior to and post the application of cold challenge. These features are fed to a support vector machine for automatic classification of normal and malignant breasts, resulting in a classification accuracy of 83.3%. Feature reduction has been performed by principal component analysis. As a novel attempt, the ability of this technique to locate the abnormality has been studied. The results of the study indicate that rotational thermography holds great potential as a screening tool for breast cancer detection.

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1. Introduction

Breast cancer is the most common type of cancer leading to high mortality rates in women [1]. Early detection is of prime importance as it improves the chances of survival significantly. In a recent study the early detection capability of various breast imaging techniques have been compared [2]. Due to inherent limitations of conventional imaging modalities, alternate techniques are being evaluated for this purpose. Thermography is one such technique that has been documented to be well suited for early detection of breast cancer [3], especially in young women with dense breasts. It has been reported that small tumors (less than 1.66 cm in size), which are missed by mammography could be detected with breast thermography [4].

Breast thermography is a non-invasive diagnostic procedure that images the thermal variations of breast surface to aid in the early detection of breast cancer. This technique is based on the principle that chemical and blood vessel activity in the area surrounding a developing breast cancer is higher than in the normal breast. This process leads to an increase in surface temperature of the breasts [5]. These temperature variations and vascular changes may be among the earliest signs of breast abnormality. State of the art breast thermography uses highly sensitive infrared cameras and sophisticated software to produce high resolution images of these temperature variations [6,7]. The procedure is comfortable and safe unlike standard mammography, as it does

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not involve painful breast compression or exposure to ionizing radiation. The ability of temperature features in distinguishing an abnormal breast from a normal one has been demonstrated [8,9] and early detection capability has been analyzed [10,11].

A recent survey has compared various image processing approaches for breast cancer detection from conventional breast thermograms [12]. Several segmentation algorithms have been used to extract regions of interest with moderate success rates [13–20]. Texture features have been used to train artificial neural networks (ANN) for classification of breast thermograms [21]. Asymmetry analysis of texture features has been done to automatically classify thermograms [22,23]. The ability of texture features to represent surface temperature variations has been explained with thermal occulograms [24]. Acharya et al. extracted texture features to detect abnormality in conventional thermograms using support vector machine (SVM) [25]. First order statistical features [26], higher order statistical features like skewness, kurtosis and entropy [27] have also been used for automatic classification of abnormal breast conditions. Wiecek et al. [28] used features based on discrete wavelet transform with bi-orthogonal and Haar mother wavelets for the classification. Higher order spectral (HOS) features [29], bispectral invariant features [30] and features in fractal dimension [31] have been used recently for the problem. Fuzzy classifier [32], independent component analysis [33] and decision trees [34] have also been used for the classification purpose. Case studies, have established that the temperature profiles of normal, benign and malignant breasts differ significantly [35]. Texture features extracted in the wavelet [36] and Curvelet [37] domains have also been used for classifying thermograms. Sudharsan and Ng have conducted extensive study on breast cancer detection by numerical modeling of the breast [38–42].

Interpretation from conventional breast thermograms continues to be highly subjective, due to incomplete imaging of breasts and ineffective image segmentation algorithms. Rotational thermography is a novel technique, developed upon conventional thermography, in order to overcome these limitations. A pilot study has been carried out to assess the potential of this technique in automatic detection of breast abnormality. In this paper, spatial domain statistical features extracted from rotational breast thermograms, have been analyzed from the perspective of cold challenge. These features are fed to a support vector machine classifier for automatic classification of normal and abnormal breasts.

1.1. Rotational breast thermography

In conventional breast thermography, the patient is made to sit in front of the camera at a particular distance. Infrared images of the breast are captured in three different views, namely Contra-lateral, Medio-Lateral Oblique and Axillary. Due to normal breast sag, the lower posterior breast regions are not imaged completely in these views. Hence tumors in such regions are often not detected. In an attempt to make thermogram interpretation more objective, the imaging setup and protocols are modified, leading to rotational breast thermography. In this technique, breast is imaged from many views so that an abnormality is not missed. A special setup, called Mammary Rotational Infrared Thermographic System (MAMRIT) is designed for acquiring the breast thermogram images. The subject is made to lie comfortably in prone position on the MAMRIT unit with one breast freely suspended into a chamber through a small circular aperture. This ensures comfort to the patient and reduces e artifacts that may arise due to patient movement. Inside the MAMRIT chamber, a robotic arm rotates clockwise, around the suspended breast. An infrared camera fixed at its end, captures images of the breast from different views. Temperature information of the entire breast surface is thus captured, ensuring complete imaging of the breast. The ambient temperature and humidity inside the chamber are controlled with an in-built air conditioner. Black body calibration is performed for the camera as recommended by the manufacturer to ensure accuracy of measurements.

It has been observed that there is a continuous band of temperature that extends across the normal breast, from nipple to the chest wall. An abnormal condition is detected, when this temperature pattern is disturbed [43].

2. Materials and methods

2.1. Image acquisition

- The patients are disrobed to the waist and well rested before imaging in order to stabilize basal metabolic activity.
- The subject is made to lie in prone position on the imaging unit with one breast freely suspended into an air conditioned closed chamber.
- The images are acquired in closed dark chamber to eliminate interference from external IR sources.
- The ambient temperature inside the imaging chamber is set according to the comfort level of the patient at a humidity of 60%.
- The camera is placed at a distance of 30–47 cm s from the surface of the suspended breast. This ensures that the entire breast region from chest wall to nipple is imaged without compromising on image resolution.
- At this imaging distance, the effects of surface curvature of breasts have been neglected
- The robotic arm moves clockwise around the suspended breast and captures images at spatial intervals of 30° resulting in a series of 12 images.
- First the left breast is imaged at the chamber's ambient temperature resulting in a series of 12 images called as left precool series.
- Then the temperature inside the chamber is reduced by 2– 3° centigrade and imaging is resumed resulting in a set of 12 images called as left post cool series.
- Next the arm moves in a direction to image the nipple region. This image is called the left frontal image.
- This is repeated for the right breast, starting with right frontal image; right precool series and right post cool series.

Breast thermograms of 24 normal and 12 malignant patients are taken for the analysis. Only precool and post cool series of right and left breasts are used in the present study. The images are taken with informed consent and approved protocol using ICI7320P uncooled camera [44]. All patients referred to the breast clinic for suspected breast abnormalities were subjected to the rotational thermography procedure. All of them also underwent ultrasound scan to enable correlation of results.

When a normal breast is subjected to sudden cold challenge, the blood flow to its surface is redirected through deeper veins. This leads to an instantaneous reduction in surface temperature in this region. Breast surface overlying a tumor is not affected by this regulatory vasoconstriction.

Hence, unlike normal tissues, the surface temperatures in such regions are persistent even when subjected to cold challenge [45]. The infrared emissions from such hyper thermal surfaces will show subtle, yet, distinct patterns of abnormality on a thermo gram.

The present study is based on the hypothesis that application of cold challenge, will improve the efficiency of thermogram based, automatic breast cancer detection systems. Hence statistical image features are extracted from precool and post cool thermograms.

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