ABSTRACT

Breast cancer is the second most deadly cancer among women and its early detection plays a significant role in improving the survival rate. Breast tissues undergo significant changes in morphology during physiological and pathological conditions. Breast thermography has emerged out as a potential method by providing early signs of the presence of precancerous or cancer cells. Its imaging procedure is to detect infrared radiation and generate temperature profile of surface of the breast called thermograms. The thermal variation is one of the most important indicators of an underlying dysfunction that can be measured and quantified. These variations are often subtle and are complex to analyze and interpret. Hence, a method for automated quantitative analysis is essential to accurately evaluate thermograms by detecting thermal variations due to pathological conditions. This requires segmentation of region of interest and efficient feature extraction techniques that could capture variations of thermal patterns.

Breast thermal images are inherently low in contrast and signal to noise ratio. The quality of the acquired thermal images is degraded due to addition of noises during acquisition and storage. The image quality needs to be improved to facilitate accurate segmentation. Segmentation of breast regions from other parts of the image remains an open challenge mainly due to its amorphous nature and absence of clear edges. Further complexity lies in the detection of lower breast boundaries and infra mammary folds. Feature extraction techniques that effectively analyze thermal variations from the regions of interest and provide quantitative information about pathological conditions of breast tissues is essential for proper diagnosis and interpretation.

In this thesis, an attempt is made to analyze the normal and abnormal breast thermal images using level sets and multidimensional phase
based transform methods. The images obtained from online database of the project PROENG are considered for this analysis. These images are subjected to two different denoising methods which include Block Matching and 3D filtering (BM3D) denoising method and Orthonormal Wavelet Transform Stein Unbiased Risk Estimate with Linear Expansion of Thresholds (OWTSURELET) denoising method. The performance of pre-processing algorithms is evaluated by estimation of SNR of raw and pre-processed images.

The segmentation of breast tissues is attempted on denoised images using reaction diffusion level set method and nonlinear adaptive level set method. The edge map generated as the intensity gradient of the Gaussian filtered image is used as stopping boundary for the level set function to settle in desired breast boundaries. To improve the segmentation accuracy, further experiments are carried out by incorporating the edge maps generated using coherence enhanced diffusion, total variation and phase congruence filters. The performance of segmentation of breast tissues is evaluated against ground truth images using overlap and regional statistics based similarity measures. Finally, the segmented breast tissues are subjected to Wavelet, Radon, quaternion, Riesz, steerable Riesz and multiscale quadrature filter analyses to capture texture signatures at any location, scale and orientation. The statistical texture features are extracted from these transformed coefficients and analyzed. Thus, a pipeline of processes that integrates the denoising, segmentation of the breast tissues and phase based feature extraction is proposed for thermal images.

The results show that the denoising method using OWTSURELET appears to be effective in removing the noise components by preserving the edge details. On an average, it gives reasonable SNR of 72.31 dB and gradient magnitude similarity deviation index value of 0.0057 indicating good smoothing and edge preservation. BM3D denoising method smoothens the image with consistent improvement of SNR to an average value of 61.16 dB,
however, this denoising method tends to lose important edge information corresponding to variations of thermal patterns.

Segmentation using reaction diffusion level set and adaptive level set methods could extract the region of interest properly irrespective of limitations such as absence of clear edges and low contrast. Gaussian edge map results in thick edges and level set contour is stuck to the false edge boundaries resulting in either over or under segmentation. As thermal images lack in sharp boundaries, intensity gradient based edge detection algorithms such as coherence diffusion and total variation diffusion fail to form distinct and meaningful boundaries. The phase congruence edge map displays the enhanced edge information and allows segmentation along weak or strong boundaries between anatomical structures.

Reaction diffusion level set with phase congruence method could achieve significant improvement in terms of both regional statistics and overlap measures with average performance greater than 94% when compared to various other edge maps. Significant improvement in the performance of the phase congruence based adaptive level set method is observed with average performance greater than 98%. It is observed that this method performs better than reaction diffusion level set with consistently high regional and overlap measures. This could be due to suppression of false boundaries by probability weighted stopping force. This method is able to identify and evolve perfectly near the lower breast boundaries and infra mammary folds using the obtained enhanced edge information.

The statistical texture features such as mean, kurtosis, skewness, coarseness, contrast and directionality derived from approximation coefficients of wavelet, Radon and quaternion Hilbert transforms could differentiate the normal and abnormal breast tissues. Among all features, the coarseness and directionality features derived from wavelet coefficients could provide distinct differentiation among various pathological conditions. The
kurtosis and skewness values derived from Radon coefficients show clear distinction between normal and abnormal breast tissues.

The values of statistical features extracted from phase component of Riesz transform exhibit high variation between normal and abnormal tissues than amplitude component. Among the six features, kurtosis, skewness, contrast and directionality derived from phase component could show the maximum variation between normal and abnormal conditions. The texture signatures derived from steerable Riesz coefficients allow analysis of thermal patterns on different scales and orientations. It is observed that the second scale representation shows better localization characteristics of image by steering the basis function in the direction of maximal response than first scale. Among the texture features, kurtosis, skewness, contrast and directionality features from second scale Riesz coefficients has enhanced the value between normal and abnormal conditions by 10%, 9%, 13% and 9% respectively.

Similarly, the statistical texture features derived from MQF coefficients are able to differentiate normal and abnormal tissues significantly. Among the texture features, kurtosis, skewness, contrast and directionality features from second scale MQF coefficients has enhanced the value between normal and abnormal conditions by 23%, 23%, 28% and 10% respectively. Thus, the results show that the steerable Riesz transform and MQF based statistical texture features could efficiently exploit the local organizations of scales and directions of thermal patterns. Thus it appears that the proposed pipeline of processes that integrates OWTSURELET denoising, phase congruence based adaptive level set with phase based transform techniques such as Riesz and MQF is found to be effective in evaluating breast thermograms for various pathological conditions and is found to be useful in the early diagnosis of breast abnormalities.