Analysis of bilateral asymmetries in breast MR images based on texture and directional statistics of the breast parenchymal

R. J. Ferrari[1], and A. L. Martel[1,2]

[1]Imaging Research, Sunnybrook Health Sciences Centre, Toronto, ON, Canada, [2]Department of Medical Biophysics, University of Toronto, Toronto, ON, Canada

Introduction: Bilateral asymmetry analysis of mammograms of a given subject is an important clinical procedure often used by radiologists to help in the diagnosis of breast cancer. A recent study of bilateral asymmetry analysis of mammograms has shown evidences that breast asymmetry is higher in healthy women who are free of breast disease but subsequently go on to develop breast cancer than in women who remain disease-free in the same period [1]. In the context of Computer-Aided Diagnosis (CAD) systems, such an analysis may provide additional information about the presence of early signs of breast cancer that are not detected by other methods, including areas of increased density, parenchymal distortion, and small asymmetric dense regions. Despite the potential clinical significance of this analysis, its application to analysis of mammograms is compromised due to the tissue superposition as a result of breast compression and 2D image projection, which is inherent to mammography [2]. Breast MR imaging, on the other hand, does not required breast compression and provides 3D images. In addition, MRI does not use ionizing radiation and presents better image contrast compared to mammography, including dense breasts. In this work, we proposed a new method for asymmetry analysis, which is based on the hypothesis that the development of a tumor in one of the breasts will increase the degree of asymmetry between them by changing the normal parenchymal flow pattern and the image texture, and that these changes can be detected by bilateral comparison, despite the normal natural asymmetry that may exist between the breasts.

Methodology: A total of 40 cases, 20 benign and 20 malignant, from patients who had previously obtained bilateral breast MRI were randomly selected from a large screening population of high-risk women and used in this work. The study consisted of bilateral T1-weighted sagital images acquired from a 1.5T Signa GE scanner with 28 slices of 256x256 pixels resulting in an in-plane resolution of approximately 0.7mm and slice separation of 2-3mm. The images used in this analysis were obtained prior to contrast enhancement by Gd-DTPA. Image contrast enhancement was applied to the left and right MR images by using a global histogram equalization algorithm. The effective region of the breasts were segmented by using the Otsu's threshold algorithm and used as image masks for posterior processing. The phase congruency algorithm [3], which is a frequency-based model used for detection and characterization of singularities (edges, lines, and ridges) in an image, was used to detect curvilinear edge structures within a specific width-range in a breast image, see Figure 1. In contrast to edge intensity based methods, that search for points where there are sharp changes in intensity, this model searches for patterns of *order* in the phase component of band-pass quadrature filters, and therefore, it is less sensitive to changes in image intensity and threshold selection. In this work, a bank of complex log-Gabor filters (quadrature filters) was used for the implementation of the phase congruency algorithm. The number of scales and orientations of the bank of Gabor filters were set to 3 and 24, respectively, and the frequency center of the filters were adjusted to achieve fairly even spectral coverage with a minimal overlap between the filters and minimum aliasing artifacts. After applying the phase congruency algorithm to the left and right breast MR images, an angular histogram was obtained for each breast by summarizing the phase information computed for all individual slices, as illustrated in Figure 1. A set of three directional statistical features, including preferential orientation (F1), circular variance (F2), and entropy (F3), were extracted from the difference of the angular histograms. These statistics were further used to detect possible distortions on the normal oriented breast tissue patterns. In addition, a measure quantifying the difference in the amount of curvilinear edge structures from the left and right breasts (feature F4) was computed from the magnitude images. Texture characterization was performed by using local energy maps computed from the complex images resulting from the convolution of a bank of log-Gabor filters (the same bank of filters used for the phase congruency algorithm) with the original image. The mean and standard deviation of the magnitude of the complex filtered coefficients were computed for each 2D image subband over the entire MR image volume. A feature vector for texture representation was created using the calculated mean and standard deviation as feature components. A normalized distance between the feature vectors (feature F5) along with a correlation measure (feature F6) computed from the left and right breasts were used for the classification. Classification of the images in cancer and non-cancer using the directional statistical and texture features was performed using linear discriminant analysis and the leave-one-out methodology, implemented in the SPSS statistical package [4]. Due to the limited number of samples, a pooled within-groups covariance matrix, obtained by averaging the separate covariance matrices, was used in the classification.

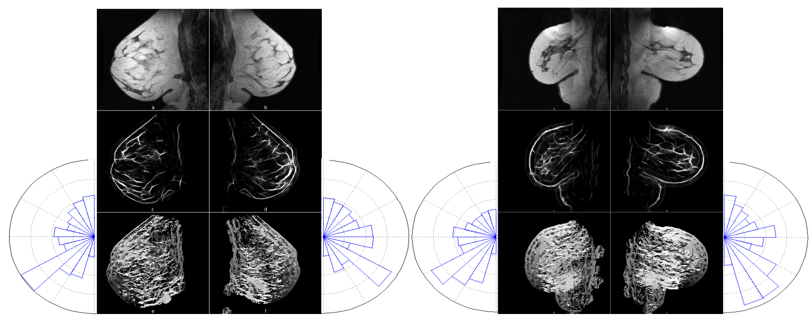

Figure 1: Left: Normal case. Right: Cancer case (invasive ductal carcinoma). Original images are presented on the first row. Second and third rows show the magnitude and phase images, respectively, obtained using the Phase Congruency algorithm. Original and magnitude images were contrast-enhanced for better visualization of the edge details.

Results and Discussions: Average accuracy, sensitivity and specificity values were obtained for exhaustive combination of all six derived features. The best results in terms of average accuracy are summarized in Table 1. A second analysis was performed by using separate covariance matrices for each class. In this case, the best result obtained was: average accuracy = 78.1%, sensitivity = 73.3%, and specificity of 82.4% using features F2, F5, and F6. Due to the complexity of the breast tissue distribution, effects of the breast segmentation (especially in the pectoral muscle region) as well as the proper alignment of the angular histograms may introduce bias to the results. These effects are under investigation at the moment.

Features	Sens. %	Spec. %	Aver. %
F5	70.6	60.0	65.6
F2, F4	53.3	94.1	75.0
F2, F6	**73.3**	**76.5**	**75.0**
F1, F2, F4	40.0	94.1	75.0

Table1: Best results of classification using linear discriminant analysis and leave-one-out method for the exhaustive combination of all six features. Only combinations of up to 3 features are presented here.

Conclusions: Despite the small number of images assessed in this study, preliminary results from our proposed method for bilateral asymmetry analysis of breast MR images are very encouraging, given the small number of features and the simple classifier used in this work. The phase congruency algorithm has been shown to precisely detect curvilinear edge structures in the breast and may further be used to assess local parenchymal distortions.

Acknowledgements: We thank to Dr. Ellen Warner and Dr. Donald B. Plewes for providing the clinical data. This project is partially funded by CBCRA.

References:

1. Scutt D, Lancaster GA, Manning JT, *Breast asymmetry and predisposition of breast cancer*, Breast Cancer Research., 8, 1-7, 2006.
2. Ferrari RJ et al, *Analysis of asymmetry in mammograms via directional filtering with Gabor wavelets*, IEEE Transactions on Medical Imaging, 20(9), 933-964, 2001.
3. Kovesi P, *Phase congruency: A low-level image invariant*, Psychological Research., 64, 136-148, 2000.
4. Sweet SA, *Data Analysis with SPSS*. Boston, MA: Allyn & Bacon, 1999.