Breast Component Adaptive Wavelet Enhancement for Soft-Copy Display of Mammograms

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Abstract. A method that performs multiresolution enhancement, adaptive to breast components, for optimal visualization of the entire breast area is presented. The method includes an edge detection step to distinguish breast area from mammogram background and employs Gaussian mixture modeling to segment breast components (uncompressed fat, fat and dense). The original image is decomposed using a redundant discrete wavelet transform and magnitude coefficients corresponding to each breast component are linearly mapped for contrast enhancement. Coefficient mapping is controlled by a gain factor provided by the parameters of the modeled breast components. The processed image is derived by reconstruction of the modified wavelet coefficients. The algorithm is compared with two enhancement methods proposed for soft-copy display, in a dataset of 68 mammograms containing lesions. The proposed method demonstrates increased performance in accentuating lesions embedded in fatty or dense parenchyma, as well as in visualization of anatomical features in the entire breast area.

1 Background

Screen film mammography is the primary imaging technique for the detection and diagnosis of breast lesions. However, the high diagnostic performance of screen film mammography is challenged by occult disease signs (microcalcifications and/or masses) due to the masking effect of dense breast parenchyma, and the over-exposure of breast periphery.

Several computer-based algorithms have been proposed to enhance subtle features of interest in digital and digitized mammograms [1], [2]. These methods can be classified according to the type of processing used (global/locally-adaptive histogram equalization, region or neighborhood adaptive enhancement and wavelet enhancement) and to target area (dense tissue and/or breast periphery).

In the advent of Full Field Digital Mammography (FFDM), it is crucial to exploit the potential of image processing algorithms in enhancing the ability of radiologists to interpret images [1], [2]. To be eligible, candidate methods should also fulfill functionality requirements of robustness and computational speed for soft-copy display.

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In this study, an automated wavelet-based enhancement method is proposed adaptive to breast components. For this purpose we adopted the rationale of the Mixture Model Intensity Windowing (MMIW) technique [3], in order to derive linear mapping functions of wavelet coefficients for breast components. The method is demonstrated by means of a preference study including two additional image enhancement methods proposed for soft-copy display, in a pilot dataset containing lesions (masses and/or microcalcifications-MCs).

2 Method

2.1 Breast Border Identification

The breast border is identified using an edge detection technique which is performed in the following four steps:

i) The mean value of grey levels is calculated in the most homogenous rectangular region (164x164pixels) of the mammogram background (over-exposed area of the film). The most homogenous region is defined by means of quantitative criteria including the minimum grey level value and standard deviation.
ii) The gradient magnitude of the image is calculated using a derivative of Gaussian operator.
iii) An initial breast edge point is defined by the location of maximum gradient magnitude along a line passing horizontally through the center of a breast. Final acceptance of this point to the breast edge is subject to fulfillment of a similarity criterion of its rectangular neighborhood mean grey level value similar to that of the homogenous region of the mammogram background (± 0.2%).
iv) The rest of breast edge points are progressively defined by identifying adjacent points that fulfill the same two criteria.

2.2 Breast Components Segmentation

Segmentation of the three breast components (uncompressed fat-UF, fat-F and dense-D) is performed using Gaussian Mixture Modeling [4], [5]. Specifically, the breast area is modeled by a linear combination of *k* weighted Gaussian distributions (a mixture of Gaussians) given by:

$$f_k(x) = \sum_{j=1}^{k} \pi_j \varphi(x; \theta_j) \tag{1}$$

with:

$$\sum_{j=1}^{k} \pi_j = 1 \tag{2}$$