Efficient Textural Model-Based Mammogram Enhancement

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Abstract

An efficient method for X-ray digital mammogram multi-view enhancement based on the underlying two-dimensional adaptive causal autoregressive texture model is presented. The method locally predicts breast tissue texture from multi-view mammograms and enhances breast tissue abnormalities, such as the sign of a developing cancer, using the estimated model prediction error. The mammogram enhancement is based on the cross-prediction error of mutually registered left and right breasts mammograms or on the single-view model prediction error if both breasts' mammograms are not available.

1 Introduction

Breast cancer is the most common type of cancer among middle-aged women in most developed countries. To lower the mortality rate, women can attend preventive mammography screenings. However, around 25% of radiologically visible cancers are missed by the radiologists at screenings. To improve the chance that they will not miss suspicious regions, radiologists can use computer enhancements of mammograms to help with the visual evaluation. Several mammogram enhancement methods have been published [1, 6, 5, 2]. Radiologists also regularly compare bilateral mammogram pairs during screening in search for breast asymmetry. The mostly used computer based techniques of bilateral comparison include thin-plate spline transformation and wavelet transformation [4, 7].

The novelty of the presented method is that whereas alternative methods usually use simple pixel difference to compare the bilateral images, we use the mammogram of one breast as a learning sample for the 2DCAR breast texture model [3] and then try to analyze the other mammogram based on the acquired information. This way we can achieve a result which is robust to inaccurate registration, and which gives improved enhancement results than single-view analysis even using similar local texture modeling.

2 Mammogram Enhancement

Our method presumes that left and right breasts are architecturally symmetrical, for radiologists frequently compare bilateral mammograms to find asymmetrical parts, which could indicate a developing cancer. The texture based asymmetry detection neither needs to assume a pixel-wise correspondence of both breast images, nor their ideal subpixel registration inside the breast area. The method consists of three major steps: registration, model parameters adaptive estimation, and the cross-prediction error estimation.

Mammogram Registration

Since we compare the images based on textural features rather than pixel-wise, we do not require as precise registration as other methods, and can use simple affine transformation based registration. As the three reference points needed for affine transformation, we chose the nipple and one point above and one below it which are closest to the pectoral muscle.

2.1 Predictive Textural Model

The mammographic tissue texture is locally modeled by an independent Gaussian noise-driven autoregressive random field two-dimensional model (2DCAR) [3] which can be expressed as a stationary causal uncorrelated noise-driven 2D autoregressive process:

$$Y_r = \gamma X_r + e_r \ , \tag{1}$$

where γ is the parameter vector, I_r^c denotes a causal contextual neighborhood (i.e., previously visited and known support pixels), e_r is a white Gaussian noise with zero mean

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and a constant but unknown variance, and X_r is a support vector of Y_{r-s} where $s \in I_r^c$. The method uses a locally adaptive version of the model, where its recursive statistics are modified by an exponential forgetting factor, i.e., a constant smaller than 1 which is used to weight older data.

Prediction

The conditional mean value of the one-step-ahead predictive posterior density for the normal-gamma parameter prior is $E\left\{Y_r \mid Y^{(r-1)}\right\} = \hat{\gamma}_{r-1} X_r$. The predictor is used only for single-view mammogram enhancement.

For multi-view mammograms where there are available both left and right breasts mammograms the method uses the cross-prediction. Let us denote two mutually registered (e.g., left and right breasts' mammograms) Y and $\tilde{Y}$, their local 2DCAR model parameters estimates $\hat{\gamma}_{r-1}$ and $\tilde{\gamma}_{r-1}$ and the corresponding support vectors X_r and $\tilde{X}_r$. The cross-predictions between images $Y, \tilde{Y}$ are

$$E\left\{\tilde{Y}_r \mid Y^{(r-1)}\right\} = \hat{\gamma}_{r-1} \tilde{X}_r \quad (2)$$

$$E\left\{Y_r \mid \tilde{Y}^{(r-1)}\right\} = \tilde{\gamma}_{r-1} X_r \quad (3)$$

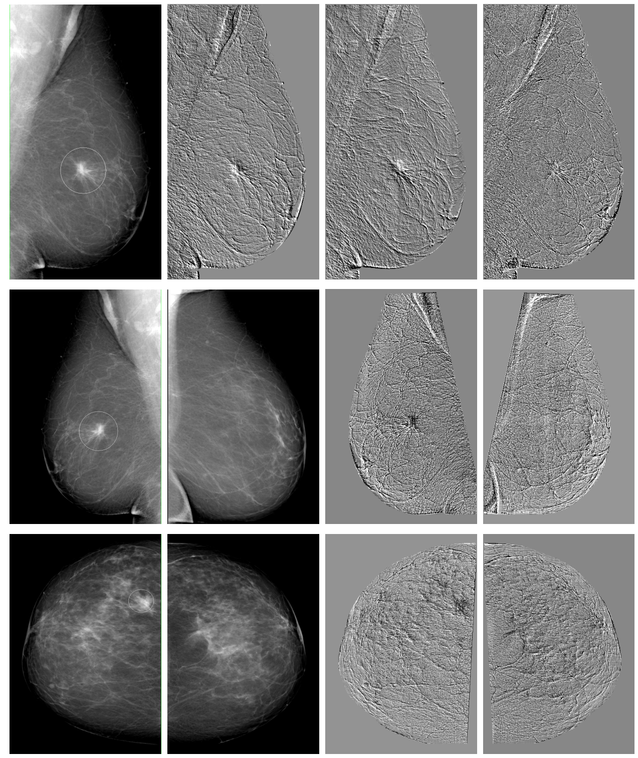
The enhanced mammograms are then the corresponding prediction error images.

3 Experimental Results

The algorithm was tested on mammograms from the Digital mammograph Senographe 2000 D which produces high resolution (0.1 mm) 1920×2300 images with 14 bits pixel quantization. The upper row of the figure shows a single-view MLO mammogram enhancement using one directional rightward or downward or omnidirectional 2DCAR model, respectively. In the lower two rows there are MLO (middle row) and CC (bottom row) cross prediction enhanced results. Comparing the cross-prediction enhancements in the middle row with the same breast single-view enhancement in the upper row, the benefits of the cross-prediction are clearly visible.

4 Conclusion

We proposed the novel fast method for completely automatic mammogram enhancement which highlights regions of interest detected as textural abnormalities. Cancerous areas typically manifest themselves in X-ray as such textural defects. This way the enhanced mammograms can help radiologists to decrease their false negative evaluation rate. This method is based on the two-dimensional adaptive CAR texture model and benefits from mutual textural information in the registered bilateral breast pairs. Contrary to simple



pixel difference or cross-correlations, textural feature comparison brings increased robustness to registration inaccuracies inevitably encountered due to the elasticity of breasts.

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