Chapter 2
Digital Image Processing and Machine Learning Techniques for the Detection of Architectural Distortion in Prior Mammograms[1]

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ABSTRACT

Architectural distortion is a subtle but important early sign of breast cancer. The purpose of this study is to develop methods for the detection of sites of architectural distortion in prior mammograms of interval-cancer cases. Screening mammograms obtained prior to the detection of cancer could contain subtle signs of early stages of breast cancer, in particular architectural distortion. The methods for the detection of architectural distortion are based upon Gabor filters, phase portrait analysis, a novel method for the analysis of the angular spread of power, fractal analysis via Fractal Dimension (FD), structural analysis of texture via Laws' texture energy measures derived from geometrically transformed regions of interest (ROIs), and statistical analysis of texture using Haralick's 14 texture features. The application of Gabor filters and linear phase portrait modeling was used to detect initial candidates of sites of architectural distortion; 4,224 ROIs, including 301 true-positive ROIs related to architectural distortion, were automatically obtained from 106 prior mammograms of 56 interval-cancer cases and from 52 mammograms of 13 normal cases. For each ROI, the FD, three measures of angular spread of power, 10 Laws' measures, and 14 Haralick's features were computed. The areas under the receiver operating characteristic curves obtained using the features selected by stepwise logistic regression and the leave-one-ROI-out method are 0.76 with the Bayesian classifier, 0.75 with Fisher linear discriminate

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analysis, and 0.78 with a single-layer feed forward neural network. Free-response receiver operating characteristics indicated sensitivities of 0.80 and 0.90 at 5.8 and 8.1 false positives per image, respectively, with the Bayesian classifier and the leave-one-image-out method. The methods have shown good potential in detecting architectural distortion in mammograms of interval-cancer cases.

INTRODUCTION

Breast cancer has been a major health problem in both developed and developing countries for the past 50 years and is one of the leading causes of deaths among women (Tang, Rangayyan, Xu, Naqa, & Yang, 2009). The success of treatment of breast cancer patients depends largely on the detection of breast cancer at early stages. Mammography is commonly used as a screening tool for the early detection of breast cancer. Mammographic screening has shown potential in reducing the mortality rates due to breast cancer by 30% to 70% (Jemal et al., 2004). However, the estimated sensitivity of screening mammography has been found to be between 85% and 90% (Bird,Wallace, & Yankaskas, 1992); misinterpretation of breast cancer signs accounted for 52% of the errors, and overlooking signs corresponded to 43% of the missed abnormalities. Computer-aided diagnosis (CAD) could provide a "second opinion" to the radiologist and help in increasing the sensitivity and accuracy of detection (Doi, 2006, 2007). Various CAD techniques and systems could be as effective as double reading (Doi, 2006, 2007) and have been shown to be efficient in detecting frequently observed signs of breast cancer such as masses and calcifications (Nemoto, et al., 2009).

Architectural distortion refers to the distortion of the architecture of normal breast parenchyma, which includes spiculations radiating from a point and/or focal retraction or distortion at the edge of the parenchyma without being accompanied by an increased density or mass (American College of Radiology, 2003). Architectural distortion can also be an associated finding and is one of the important indicators of early breast cancer. Architectural distortion could appear at the initial stages of the formation of a breast tumor (Matsubara et al., 2004) but may be similar in appearance to normal breast tissue overlapped in the projected mammographic image. At present, architectural distortion is the third most common mammographic sign of non palpable breast cancer (Knutzen & Gisvold, 1993) and is found to be associated with breast malignancy in one-half to two-thirds of the cases in which it is present (Matsubara et al., 2004). However, due to its faint, hard-to-detect, and variable appearance, architectural distortion is the most commonly missed abnormality in false-negative cases (Knutzen & Gisvold, 1993). Architectural distortion has been found to account for 12% to 45% of breast cancer cases overlooked or misinterpreted in screening mammography (Burrell, Evans, Wilson, & Pinder, 2001). Unlike masses and calcifications, CAD techniques and systems have been found to be not capable of detecting architectural distortion with a high level of accuracy (Baker et al., 2003). In this context, development of machine learning techniques dedicated to increasing the sensitivity and accuracy in the detection of architectural distortion could lead to an effective improvement in the prognosis of breast cancer patients (Broeders, et al., 2003).

In the context of a screening program, a "detection mammogram" refers to a mammogram on which cancer is detected, and a "prior mammogram" refers to a mammogram acquired at the last scheduled visit to the screening program prior to the detection of cancer (Rangayyan, Prajna, Ayres, & Desautels, 2008). When breast cancer is detected in a screening program in a particular individual, the case is referred to as "screen-

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