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● *Original Contribution*

NEW FULLY AUTOMATED METHOD FOR SEGMENTATION OF BREAST LESIONS ON ULTRASOUND BASED ON TEXTURE ANALYSIS

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Abstract—The study described here explored a fully automatic segmentation approach based on texture analysis for breast lesions on ultrasound images. The proposed method involves two main stages: (i) In *lesion region detection*, the original gray-scale image is transformed into a texture domain based on log-Gabor filters. Local texture patterns are then extracted from overlapping lattices that are further classified by a linear discriminant analysis classifier to distinguish between the "normal tissue" and "breast lesion" classes. Next, an incremental method based on the average radial derivative function reveals the region with the highest probability of being a lesion. (ii) In *lesion delineation*, using the detected region and the pre-processed ultrasound image, an iterative thresholding procedure based on the average radial derivative function is performed to determine the final lesion contour. The experiments are carried out on a data set of 544 breast ultrasound images (including cysts, benign solid masses and malignant lesions) acquired with three distinct ultrasound machines. In terms of the area under the receiver operating characteristic curve, the one-way analysis of variance test (α=0.05) indicates that the proposed approach significantly outperforms two published fully automatic methods (p<0.001), for which the areas under the curve are 0.91, 0.82 and 0.63, respectively. Hence, these results suggest that the log-Gabor domain improves the discrimination power of texture features to accurately segment breast lesions. In addition, the proposed approach can potentially be used for automated computer diagnosis purposes to assist physicians in detection and classification of breast masses. (E-mail: wgomez@tamps.cinvestav.mx) © 2016 World Federation for Ultrasound in Medicine & Biology.

Key Words: **Breast ultrasound, Automatic segmentation, Texture analysis, Log-Gabor filters, Texture features.**

INTRODUCTION

Breast cancer is the most frequently diagnosed cancer and the leading cause of cancer death among women worldwide (Jemal et al. 2011). Early diagnosis is a crucial factor in breast cancer treatment, and hence medical images are important sources of diagnostic information. Today, breast ultrasound (BUS) is accepted as the most important adjunct to mammography for patients with dense breast tissue, palpable masses and normal or inconclusive mammograms (Kelly et al. 2010). BUS images are particularly effective in distinguishing cystic from solid lesions, with an accuracy approaching 100%. They are also useful for differentiating between benign and malignant tumors, which can be characterized by their shapes, borders, internal echo features and posterior acoustic behavior (Rahbar et al. 1999; Stavros et al. 1995).

Radiologists perform a BUS image interpretation by observing the sonographic features of breast lesions. Hence, the diagnosis depends on their expertise and training. Such subjectivity can lead to large variations in inter- and intra-observer image interpretation and, consequently, to distinct clinical conduct recommendations (Calas et al. 2010; Timmers et al. 2012). To overcome this inconvenience, computer-aided diagnosis (CAD) systems have emerged as a "second reader" for analyzing medical images by using computational approaches. Radiologists can thus take the CAD outcome as a second opinion and make a more conclusive diagnosis (Cheng et al. 2010).

An important step within a CAD system is the lesion segmentation, whereby the lesion should be accurately separated from its background and other structures. Then, from the segmented BUS images, textural and

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morphologic features are commonly extracted for further tumor classification into benign or malignant (Cheng et al. 2010).

Breast ultrasound segmentation is a difficult task owing to speckle artifacts, low contrast, shadows, blurry boundaries and the variance in lesion shapes (Kirberger 1995). To deal with these difficulties, a computerized segmentation approach should carry out two basic steps: detection and delineation. The former aims to find suspect regions in the whole image, whereas the latter performs the lesion outlining. In this regard, a segmentation approach can be semi-automatic or fully automatic; the lesion detection procedure is the main difference between these two approaches. In a semi-automatic method, a user defines a region of interest (ROI) containing a lesion or marks its location. In a fully automatic method, the ROI is automatically found by an algorithm based on image analysis and pattern recognition techniques. Lastly, once the ROI is determined, independently of the detection type, the lesion delineation is carried out by an algorithm that automatically outlines the tumor boundary.

Fully automatic segmentation methods are preferred today because the dependency on operators is virtually eliminated, and this ultimately leads to completely automated CAD systems (Xian et al. 2015). Therefore, several articles have addressed the fully automatic segmentation problem for BUS images. Drukker et al. (2002) employed radial gradient index (RGI) filtering to detect points of interest, and potential lesions from the surrounding tissues were determined by the average radial derivative (ARD) function. False-positive detections were discarded by a Bayesian neural network (BNN). A well-known method developed by Madabhushi and Metaxas (2003) used a seed point from which initial lesion boundary points are roughly detected. A deformable model then refined the initial solution to the final lesion contour. The method proposed by Liu et al. (2009) divided the input image into non-overlapping lattices to classify local textures into normal tissue and breast lesion classes using a support vector machine (SVM). Empirical rules were used to eliminate false-positive candidate regions to define a lesion-like ROI. Finally, the boundary of the ROI was refined to the final lesion contour using a deformable model. The fully automatic segmentation method proposed by Shan et al. (2012a) detected a seed point from which a region-growing algorithm determined a rectangular ROI around the lesion. An artificial neural network (ANN) classified each pixel in the ROI as either lesion or background. Another variant of this method employed a clustering approach based on neutrosophic *l*-means to partition the ROI in lesion and background pixels (Shan et al. 2012b). Recently, Xian et al. (2015) developed a fully automatic segmentation method in which a seed point placed inside the tumor was used to define a rectangular ROI. Next, by minimizing a cost function that combined space and frequency domain information, every pixel in the ROI was labeled as tumor or normal region.

These approaches usually employed texture features to depict the local variation of pixel intensities to detect abnormal regions within the BUS image. Also, they reported acceptable segmentation performance on their own data sets, which were acquired from only one ultrasound machine (excepting Xian et al. 2015). However, the quality of ultrasound images depends not only on the skills of the operator, but also on the parameters of the machine's setup (*e.g.*, transducer's frequency, gain, focusing). Thus, BUS images captured with different ultrasound machines could present distinct conditions of contrast and brightness, and consequently, the texture features could be sensitive to intensity changes (Masotti and Campanini 2008).

To overcome this inconvenience, we propose here a new fully automatic segmentation method in which the input BUS image is transformed into a texture domain before performing the segmentation procedure. Such a transformation attempts to extract texture features robust to variations in image contrast and brightness, aiming to improve the rate of detection of breast lesions. The performance of the proposed approach is compared with that of the automatic segmentation methods developed by Drukker et al. (2002) and Liu et al. (2009).

METHODS

Overview of proposed approach

The flowchart of the proposed fully automatic segmentation method for BUS images is illustrated in Figure 1. The original BUS image is decomposed by log-Gabor filters to obtain a set of texture channels, which are divided into overlapping lattices to describe the local textures. Spatial adjacency information and lesion location probability are also considered in the feature space. A linear discriminant analysis (LDA) classifier gives a score for each lattice to generate probable lesion regions from which potential lesion-like contours are evaluated by the ARD function to reveal the region with the highest probability of being a lesion. Lastly, the lesion delineation is a second ARD-based process applied to the detected region, and determines the final lesion contour.

BUS data set

In this study, the data set consisted of 544 BUS images from 371 patients, acquired during routine breast diagnostic procedures at the National Cancer Institute