Using Texture Descriptors to Improve the Results of Breast Tumor Segmentations in Ultrasound Images: A Review

Abstract

Texture analysis in ultrasound images has been widely used in the medical field to extract relevant information that may help to differentiate several pathologies from healthy tissue, such as breast cancer. Some texture descriptors have been used to improve the results of breast tumor segmentations in ultrasound images. We present an evaluation of the ability of different texture descriptors to enhance the contrast between breast tumors and healthy tissue and how they affect the segmentation results. In this work we evaluate descriptors extracted from the analysis of the histogram, co-occurrence and run-length matrices, autocovariance and autocorrelation coefficients, and fractal dimension. The contrast between the tumor region and the healthy tissue was evaluated using the signal to noise ratio (SNR), contrast to noise ratio (CNR), the intersection between the tumor region and healthy tissue histograms and the difference between the histograms means. We implement a probabilistic segmentation method in order to evaluate the changes in the accuracy, sensibility, specificity, positive predictive value (PPV) and negative predicted value (NPV) of the method when using different texture descriptors.

Introduction

Since breast cancer has become the number one cause of death among women around the world, it is important to have accurate diagnostic methods to improve the prognosis of the patient (Jiao & Wang, 2011). Although biopsy is the gold standard for cancer diagnosis, minimal invasion methods for diagnosis are preferred in order to reduce further complications; for this reason, several diagnostic methods using ultrasound images have been proposed, currently ultrasound is responsible for about one in five of all diagnostic images (Halliwell, 2010). Visualizing lesions in ultrasound breast images is a difficult task due to some intrinsic characteristics of the images like speckle, acoustic shadows and blurry edges (D.-R. Chen, Chang, Wu, Moon, & Wu, 2003). Texture information provides a way to differentiate the lesion from other objects with similar intensities found in the images like acoustic shadows or glands (Liu et al., 2010). Several automatic and semi-automatic segmentation methods using pixel intensity along with texture information have been proposed (Madabhushi & Metaxas, 2003). Some of these methods use first-order texture descriptors obtained from histogram statistics (Huang, Chen, & Woo, 2008; Madabhushi & Metaxas, 2003), but these descriptors are not able to give a good texture description in ultrasound images because they do not take into account the spatial relation between pixels and gray-levels (Bader et al., 2000); because of this, other proposed methods use second-order texture descriptors extracted from co-occurrence matrices statistics (Liu et al., 2010), but the computational cost for computing the co-occurrence matrix is very high and much more demanding while working in per-pixel computation (F. Igual R. Mayo & M.Ujaldon, 2008). Other texture descriptors extracted from run-length matrices statistics (Lefebvre, Meunier, Thibault, Laugier, & Berger, 2000; Murmis, Gisvold, Kinter, & Greenleaf, 1988; Piliouras, Kalatzis, Dimitropoulos, & Cavouras, 2004), fractal analysis (Dar-Ren Chen et al., 2005), autovocariance and autocorrelation coefficients (Chang, Wu, Moon, & Chen, 2003) have been used for breast tumor classification in ultrasound images.

Except for the work done by Liao *et al.* in (Liao, Wu, Li, & Yeh, 2011), where they compare different texture descriptors extracted from co-occurrence matrices statistics, there is no work that evaluate the ability of different texture descriptors, extracted from first, second and higher order statistics, to improve the segmentation of tumors in breast ultrasound images by enhancing the contrast between the tumor region and the healthy tissue. Here we evaluate texture descriptors extracted from histogram statistics, co-occurrence matrices statistics, run-length matrices statistics, fractal analysis, and autocovariance and autocorrelation coefficients. To evaluate the ability of these descriptors to enhance the contrast between the tumor region and the healthy tissue, we obtained a texture image using per-pixel computation using different texture descriptors and compare the signal to noise ratio (SNR), contrast to noise ratio (CNR), the intersection between the tumor region and healthy tissue histograms and the difference between the histograms means in each image. Also we evaluate the ability of these descriptors to improve the segmentation results; we implemented a probabilistic segmentation method based on the work of Madabushi *et al.* in (Madabhushi & Metaxas, 2003) and compare the accuracy, sensibility, specificity, positive predictive value (PPV) and negative predicted value (NPV) of the method when using different texture descriptors.

Texture Analysis

Texture analysis refers to the characterization of regions in an image by their texture content, quantifying intuitive qualities described as roughness, smoothness, silkiness and bumpiness (Rajaei, Dallalzadeh, & Rangarajan, 2012). In ultrasound images echo patterns are generally referred as a kind of texture (Liao et al., 2011); a good breast tumor segmentation method in ultrasound images should take into account texture features in order to differentiate tumors from other objects with similar gray intensities like glands and acoustic shadows (Madabhushi & Metaxas, 2003), but texture analysis in ultrasound images is not an easy task, and many texture metrics have been used to model the echo patterns in breast tumors. The most used textures descriptors for tumor segmentation are extracted from histogram and co-occurrence statistics. The use of other texture descriptors extracted from run-length matrices, fractal analysis, autocovariance and autocorrelation have been proposed for the classification of breast tumors in ultrasound images.

Texture is a rich source of visual information and there are a number of methods for texture representation, because of this, it is difficult to define the properties that can be used to effectively distinguish textures found in a given image (Yassine, Belfkih, Najah, & Zenkouar, 2010). For this reason, it is important to evaluate which texture descriptor is the one that improves the outcome of the segmentation method. Except for the work made by Liao *et al.* in (Liao et al., 2011), there is no other work that evaluates the ability of different texture descriptors to enhance the contrast between tumor regions and healthy tissue while preserving the tumor edges in breast ultrasound images; the limitation of the work by Liao *et al.*, is that they only compare texture descriptors extracted form co-occurrence statistics, but other textures descriptors have been use for tumor segmentation and classification as mentioned before; in this work we evaluate some of these texture descriptors.

First-order texture descriptors are extracted from the original image values; they do not consider the spatial relationships with neighborhood pixels (Selvarajah & Kodituwakku, 2011). The most frequently used first-order texture descriptors are central moments of the histogram (Aggarwal & Agrawal, 2012). These descriptors have been used for the segmentation and classification of breast tumors in ultrasound images; Huang *et al*. in (Huang et al., 2008) use the Mean and Entropy of the histogram to characterize the texture of breast tumors, also the Kurtosis and Skewness of the histogram have been used for tumor classification by Pilouras *et al.* in (Piliouras et al., 2004). Other descriptors extracted from the image original values have been used, in (Madabhushi & Metaxas, 2003) they use the difference of the intensity of each pixel with the mean of its neighborhood.

Methods

The data base of breast ultrasound images were extracted from a set of 30 ultrasound scans acquired from GE Heatlhcare Voluson 73 in the Changhua Christian Hospital. The images have a size of 181x163 pixels. After manual localization of the breast tumor and the selection of the region of interest the images were inputted to open source software itk-SNAP for image enhancement and semi-automatic segmentation supervised by the specialist. All the texture and segmentation methods were implemented using Matlab in a MacPro with an Intel Xenon 2.8Ghz with 16 GB in RAM and Mac OSX 10.6 64bits operating system.