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Automatic segmentation of breast lesions for interaction in ultrasonic computer-aided diagnosis

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ABSTRACT

Breast cancer is one of the most commonly diagnosed cancer types among women. Sonography has been regarded as an important imaging modality for diagnosis of breast lesions. Due to the speckle and the variance in shape and appearance of sonographic lesions, fully automatic segmentation of the breast tumor regions still remains a challenging task. In this paper, we propose an automatic interaction scheme based on an object recognition method to segment the lesions in breast ultrasound images. In this scheme, a 2D ultrasound image is firstly filtered with a total-variation model to reduce the speckle noise. A robust graph-based segmentation method is then used to segment the image into a number of subregions. An object recognition method incorporating the procedures of image feature extraction, feature selection and classification is proposed to automatically identify the regions which are associated with breast tumors. Finally, an active contour model is used to refine the contours of the regions that are recognized as tumors. This scheme is validated on a database of 46 breast ultrasound images with diagnosed tumors. The experimental results show that our scheme can segment the breast ultrasound images automatically, indicating its good performance in real applications.

1. Introduction

Breast cancer is a common disease and it causes death of millions of women every year all around the world. According to the cancer statistics of 2009 [21], breast cancer is one of the three most commonly diagnosed types of cancer among women. Breast cancer alone is expected to account for 27% of all new cancer cases among women every year. Therefore, the early detection is very important for the treatment of breast cancer [36].

Biopsy is the gold standard to determine whether a breast tumor is malignant or benign [31]. But less than 30% of the breast tumors referred for surgical biopsy is malignant. Therefore, it is obvious that quite a large number of biopsies are unnecessary and can be potentially avoided with screening techniques. Some well-established imaging technologies including magnetic resonance imaging (MRI) [28,29], mammography, and ultrasound [44,50] have been used for the early detection of breast cancer [35].

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In comparison with mammography and MRI, ultrasound has proven to be an important alternative for diagnosing breast cancers. Breast ultrasound (BUS) imaging has the advantages of no radiation, improved sensitivity, easy accessibility and low cost. Therefore, it has become one of the most important diagnostic tools for breast cancer detection. However, current diagnoses based on BUS are more operator-dependent than mammography and MRI, leading to a high inter-observer variation among different clinicians. To improve the usability of ultrasound, computer-aided diagnosis (CAD) is preferred to achieve more reliable and accurate diagnostic conclusions [10,22].

Generally, a CAD system based on BUS includes image preprocessing, segmentation, feature extraction and selection, and classification. Image segmentation is a key procedure in the CAD system. Automatic and accurate segmentation of breast tumor regions can significantly improve the performance of the CAD system. Because the speckle of sonograms and the presence of tumor like structures which produce some speckle noise, shadows, and the low or non-uniform contrast of certain structures in the ultrasound images [34], automatic segmentation of ultrasound images remains a difficult task.

In the last few years, a large number of segmentation methods have been proposed, such as histogram thresholding methods, active contour model methods, and region based methods. Histogram thresholding methods [30] have successfully been used to segment the monochrome images. Chen et al. [6] applied these methods to segment the masses in ultrasound images. Based on image preprocessing, binary conversion by histogram thresholding, and morphologic operations, the suspicious tumor region could be manually selected. The active contour model (ACM) also called Snake [5,7,24,41] is another popular segmentation method for ultrasound images. It attempts to delineate an object outline by minimizing the energy associated with an initial contour. The internal energy derived from the contour model is used to control the shape and the external energy derived from image features is used to extract the contour of the desired object boundary. Chang et al. [5] adopted the active contour model to segment the breast tumors in 3D ultrasound images. Level set method also traces the contours of objects and has been applied to image segmentation [11,33,46,49]. Sarti et al. [41] used the level set method to improve the active contour segmentation of ultrasound image. Their segmentation results show that the active contour model is efficient and flexible. However, the Snake and level set methods are sensitive to noise and heavily rely on the initial contour [18]. A poorly defined initial contour would lead to an inaccurate segmentation result. In addition, region based segmentation methods [3,17,39,51,53] have been applied to ultrasound image segmentation for a long time. Theories on Fuzzy sets have been proven to be useful for segmentation of medical images [12]. Combined with wavelet technology, a clustering method, Fuzzy C-Means (FCM) [27], was used to extract the boundary of carotid artery in ultrasound images [53]. Xiao et al. [51] used a combination of maximum a posteriori (MAP) and Markov random field (MRF) estimation techniques to estimate the multiplicative distortion field that is the dominant attenuation artifact in ultrasound images, and labeled image regions based on their corrected intensity statistics.

Although these segmentation methods mentioned above have shown applicable merit in segmentation of BUS, they are not fully automatic and their performance is highly operator-dependent. Using non-automatic methods, the interpretation of BUS images is time consuming, laborious and the diagnosis heavily depends on skill and experience of radiologist. Accordingly, development of fully automatic segmentation techniques for BUS images has become one of the most promising research topics.

In general, realization of a fully automatic segmentation method requires not only the segmentation of an image, but also the identification of region of interest (ROI) based on pattern recognition techniques incorporating a priori information of the nodule [1], which makes the fully automatic extraction of breast tumors from BUS images become a more challenging task. In recent years, a lot of research has been conducted to design automatic segmentation techniques for BUS images [4,19,32,38,42]. Liu et al. [32] used a normalized cut and clustering to segment the breast tumors. However, with an assumption that the tumor regions always appeared to be dark and located at the central part of the images, only the average gray value and the location were used as the features for classification of segmented sub-regions. Basically, using only the two features is not adequate in real applications because normal tissues can also appear to be dark or locate at the central part of an image, and therefore their algorithm is not sufficiently applicable. Poonguzhali and Ravindran [38] proposed an automatic segmentation method based on an automatic seed point selection. In this method, the seed point was automatically selected from the abnormal region based on analysis of textural features. A region growing algorithm was then adopted according to the selected point. Shan et al. [42] added two newly proposed lesion features, phase in max-energy orientation (PMO) and radial distance (RD) for locating the seed point and applied neural network classification to improve the segmentation performance. Although successful experimental results were presented, the accuracy of locating seed points was not reported. More specifically, if the seed point for targeting the ROI was incorrectly found, the subsequent work would be useless.

In order to overcome the problems existing in the popular segmentation methods, we propose a new automatic segmentation scheme for segmenting a BUS image in this study. Due to the complex image artifacts existing in BUS images, the total-variation model is firstly used. Subsequently, a robust graph-based (RGB) segmentation method is applied preliminarily to partition the filtered BUS image into different sub-regions [17]. Third, an object recognition method is proposed to detect the tumor regions. What is different from previous studies is that we adopt a graph-based clustering method instead of the region growing with a seed point location, and hence recognition of tumor regions can be achieved. Furthermore, a large number of features including gray feature, texture feature, gradient feature, shape feature and position feature are extracted to improve the classification accuracy. With well defined initial contours, an active contour model is finally applied to refine the contours of recognized tumor regions.