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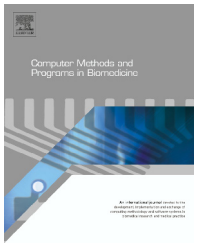

A novel breast ultrasound image segmentation algorithm based on neutrosophic similarity score and level set

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ABSTRACT

Breast ultrasound (BUS) image segmentation is a challenging task due to the speckle noise, poor quality of the ultrasound images and size and location of the breast lesions. In this paper, we propose a new BUS image segmentation algorithm based on neutrosophic similarity score (NSS) and level set algorithm. At first, the input BUS image is transferred to the NS domain via three membership subsets *T*, *I* and *F*, and then, a similarity score NSS is defined and employed to measure the belonging degree to the true tumor region. Finally, the level set method is used to segment the tumor from the background tissue region in the NSS image. Experiments have been conducted on a variety of clinical BUS images. Several measurements are used to evaluate and compare the proposed method's performance. The experimental results demonstrate that the proposed method is able to segment the BUS images effectively and accurately.

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1. Introduction

According to the statistics, breast cancer is one of the most common cancers among women and 232,670 new cases of invasive breast cancer were diagnosed among women in the US during 2014 [1], and an estimated 40,430 breast cancer deaths were expected in 2014 in US [2]. In statistics, breast cancer is indicated as the fifth most common causes of cancer death. However, these deaths can be reduced if cases are detected and treated early [2]. Breast ultrasound (BUS) is known to be a major imaging modality due to its low cost, real time and dynamical imaging, and without ionizing radiation [3]. BUS has also proved to be a suitable tool for large-scale screening addition to mammography in early detection of breast lesions [3]. However, clinical experience and expert knowledge are important factors to achieve accurate and fast diagnosis using BUS [3]. In other words, highly skilled physicians and radiologists are needed for interpretation of the BUS images.

In the last decades, several decision support systems have been proposed for helping the physicians in order to interpret the BUS images [4]. Generally these systems are using image processing and pattern recognition algorithms. Especially, image segmentation is vital to localize the lesions in these systems. However, speckle noise, poor quality and size and location of the breast lesions make this crucial step still challenging and difficult [3]. Up to now, a great number of

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automatic, semi-automatic and manual BUS image segmentation methods have been proposed.

According to the literature, the segmentation methods for BUS images are categorized into four groups [5]: histogram thresholding, active contour model, Markov random field, and neural network based methods.

Histogram thresholding is one of the widely used techniques for gray level image segmentation [6]. It is necessary to apply the histogram thresholding in BUS images segmentation. Although, the histogram thresholding methods are too simple and easy to implement, they generally do not perform well when the histograms are unimodal.

The active contour model, more widely known as snake [7], is a framework to delineate an object's contour from background, and an edge-based segmentation method. The snake model has been extensively used for BUS images [8,9]. A hybrid scheme combining region-based and boundary-based techniques was proposed for BUS image segmentation [10]. The seed points are automatically generated by empirical rules based formulation. The boundary points are then determined by region growing and directional gradient operation. Finally, a deformable model is employed for ROI segmentation. An active contour model based method is employed for BUS image segmentation [11]. The method is composed of two parts. ROI generation is followed by a ROI segmentation part. The authors reported improved accuracy according to their comparisons. Seed selection and subsequent contour initialization is carried out based on texture features and level set segmentation [12]. The deformation model based methods mostly handle only the regions of interest in the image (ROIs), not the whole image. In addition, automatically generating a suitable initial contour is very difficult, and the deformation procedure is very time-consuming.

Markov random field (MRF) model has been used for BUS image segmentation [13,14]. The MRF method provides a strong exploitation of the pixel correlations, and the segmentation results are further improved by the application of maximum a posteriori segmentation estimation scheme. However, it has complex iteration process and is time-consuming.

Classifier based methods [4,15,16] are popularly used in image segmentation. They generally convert the segmentation problem into classification decision based on a set of features. The BUS image segmentation method [4] is based on adaptive reference point classification algorithm, and tumor extraction is carried out based on a cost function, which is defined in terms of tumor's boundary and region information in both frequency and space domains. The classifier based methods are enough good but the algorithms would not perform well when the lesion was not compact and round-like. Moreover, the appropriate number of hidden units for the neural network was determined empirically. A ROI generation algorithm is combined multi-domain features to characterize the lesions in BUS image segmentation [17]. The lesion segmentation is carried out with neural network classifier. An object recognition based automatic lesion detection scheme is proposed for BUS images [18]. The method firstly filters the BUS image for speckle noise reduction and then a graph based segmentation method is applied to segment the image into a number of sub-regions. Tumor extraction is carried out based on object recognition methodology. A two stepped learning based algorithm is proposed for detection of breast tumor in ultrasound images [19]. The initial tumor localization is carried out with an AdaBoost classifier on Harr-like features and then the detected preliminary tumor regions are quantized using support vector machines. The segmentation is further completed with random walk method.

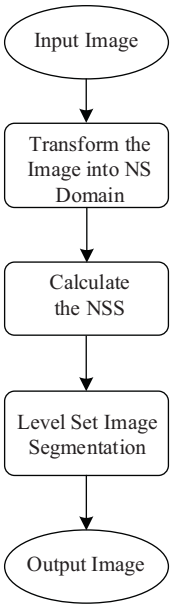

Fig. 1 – The flowchart of the proposed method.

Other methods were proposed recently for image segmentation. Pereira et al. [20] segmented breast masses on mammogram using multiple thresholding, wavelet transform and genetic algorithm. The method was quantitatively evaluated using the area overlap metric (AOM). The mean ± standard deviation value of AOM for the proposed method was 79.2 ± 8%. A marker-based watershed segmentation method [21] was proposed to segment background of X-ray images. The method includes image preprocessing, gradient computation, marker extraction, watershed segmentation from markers, region merging and background extraction. It yielded a dice coefficient of 0.964 ± 0.069.

Based on the reviewed literature, it is evident that image segmentation in BUS is still an open area for further research. In this paper, we propose a new breast ultrasound image segmentation algorithm based on neutrosophic similarity score and level set algorithm. A BUS image is represented in the neutrosophic set (NS) domain, and a neutrosophic similarity score (NSS) is defined and employed to measure the belonging degree to the true tumor. A level set method is finally used to segment the tumor from the background using the NSS value of the image. Experiments have been conducted on a variety of clinical BUS images. Several measurements are used to evaluate and compare the proposed method's performance. The experimental results demonstrate that the proposed method segments the BUS images effectively and accurately.

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