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Automatic multi-organ segmentation of prostate magnetic resonance images using watershed and nonsubsampled contourlet transform

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ABSTRACT

The watershed is an efficient algorithm for the segmentation of images. However, over-segmentation, which contains so many tiny regions that regions of interest cannot be identified easily, decreases the effectiveness. In this paper, pre-processing of images and the modification of watershed algorithm are both studied to restrain the over-segmentation. In the process of pre-processing, a kind of multi-scaled transform, contrast à trous wavelet based contourlet transform, is proposed and constructed to get sparse representation. In the aspect of modifying watershed, the "texture gradient" is defined, and the texture gradient is combined with marker-based watershed algorithm to reduce the number of segmented regions. The proposed method is tested by 36 prostate MR images and compared with several image segmentation algorithms; the experiment and comparison results show that the proposed method consistently restrains the number of segmented regions. The segmentation results correctly correspond to the main tissues in the images, and each tissue is integrally segmented, respectively with the elimination of small regions. The segmentation accuracy rate is 87.29%, which is higher than other methods under comparison.

1. Introduction

Prostate cancer is one of the most universal malignant tumors in the male reproductive system and a main kind of disease which causes of death for men [1]. Transperineal iodine-125 (125I) seed implantation is an effective approach for the treatment of localized prostate cancers, and the particle treatment planning plays an important role during the treatment [2]. In order to obtain precise treatment planning, virtual three-dimensional models of prostate and tissues around the target are generated in computer, and based on the model, particle treatment planning is set. Dose volume histogram (DVH) is used to evaluate and optimize the plan, which can cure prostate cancer and avoid damaging tissues around the prostate. The precision of models constructed based on image segmentation is the precondition of the seed implantation treatment. Because of the high contrast, MR images are chosen to perform the pretreatment of prostate cancer [3]. Therefore, a robust automatic segmentation of multi-organ technique for prostate MR images plays an important role in image guided brachytherapy treatment of prostate cancer.

However, automatic tissue classification of MR images is still a challenging task in applications [4]. The watershed segmentation [5] is an efficient tool for image classification and has been widely used in medical image segmentation and improved by combined with some classical algorithm [6]. The method regards image as a 3D topography surface, starts the region growing from the surface minima detected by image gradient, combines both the discontinuity and similarity properties effectively and finally obtains the segmentation results of one pixel wide, closed connected precise contours of objects [7]. Using gradient information of the actual image, watershed segmentation obtains accurate results for images containing connecting objects. The main courses of the algorithm are smoothing and extracting gradient image from the original image. However, the segmentation method has a major problem of over-segmentation [8], as shown in Fig. 1(b), where so many tiny regions are generated that regions of interest cannot be identified easily.

There are two main methods to restrain the over-segmentation of watershed. One way is to perform pre-processing before segmentation, such as obtaining sparse representation of original images

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1746-8094/

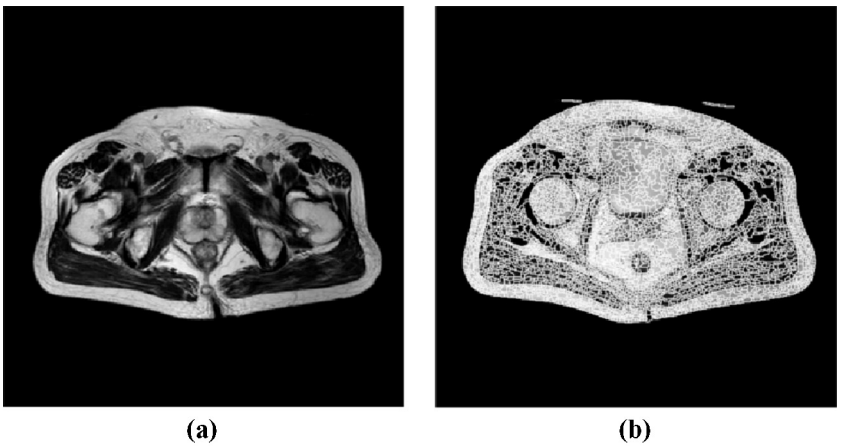

Fig. 1. Over-segmentation caused by watershed. (a) Original image, (b) the segmentation results of watershed only. The original image is over-segmented.

[9], the other is to improve the watershed segmentation, such as marker-controlled watershed-based segmentation [10]. In this paper, two methods are studied. In the process of pre-processing, a new kind of multi-scaled transform, contrast à trous wavelet based contourlet transform, is proposed and constructed to get sparse representation. In the aspect of modifying watershed, the concept of the "texture gradient" and marker-based watershed segmentation are introduced, and the texture gradient is used in marker-based watershed to reduce the number of segmented regions. The main procedures of the proposed method are shown in Fig. 2. First, original images are performed the decomposition of contrast à trous wavelet based contourlet transform, and low-frequency images and high-frequency images are separated. Through the transform, some spurious minimal values widely exists in medical images are removed. Then, the low-frequency images are segmented by the marker-based watershed segmentation using texture gradient. Although images in level 2 in Fig. 2 are not clear in visual aspect, they make contribution to the final segmentation result. The results achieved in this step are low resolution image, which is vaguer than original image. Finally, the inverse contourlet transform is implemented to get high resolution image. The achieved image is the final segmentation results. In order to facilitate reconstructing three-dimensional model and enhance the intuition of the model, the segmentation results are labeled with special numbers and colored by different colors. Based on a series of segmentation results, the three-dimensional model can be reconstructed.

Through these processes mentioned above, the over-segmentation of watershed is efficiently reduced. The segmentation has been evaluated using prostate MR images. The achieved results are more continuous and satisfying as a result of the human organs. According to the experiment results, this method lends itself well to the multi-organ segmentation.

This paper is arranged as follows: Section 2 introduces in detail the contourlet transform and the way implementing image analysis by contrast à trous wavelet based contourlet transform and directional filter bank. In Section 3, "stationary texture gradient" and its combination with watershed algorithm are addressed, the integration of marker watershed segmentation and contrast à trous wavelet based contourlet transform is also proposed. In Section 4, experimental results and related analysis are presented. Finally, the whole paper is concluded.

2. Contrast à trous wavelet based contourlet transform

The watershed segmentation has been widely used in medical image segmentation. Although the method is efficient, the segmentation is often over-segmented. In order to restrain the over-segmentation, contourlet transform [11], which is a new method of two-dimensional image representation, is performed

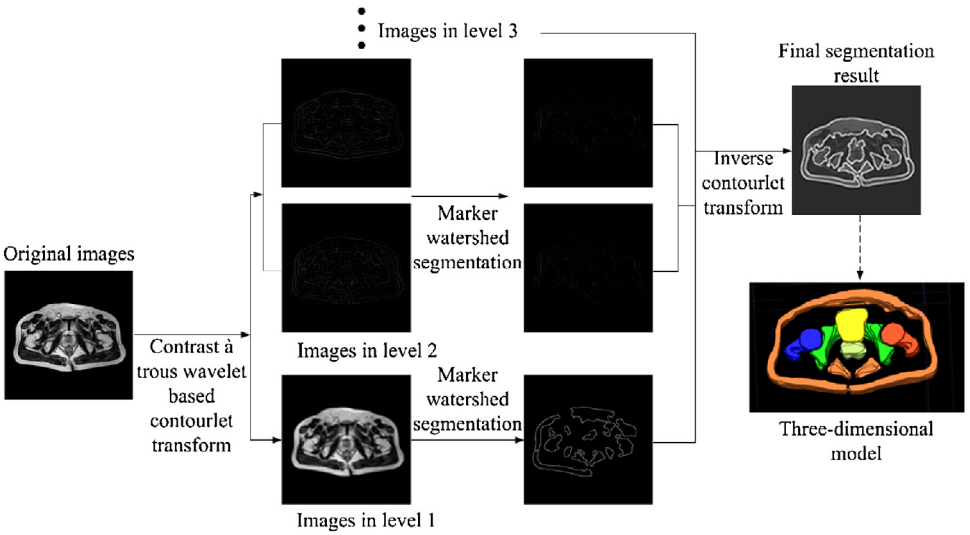

Fig. 2. Flowchart of the proposed segmentation method.