Brain Extraction Algorithm using 3D Level set and Refinement

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Introduction

Brain region extraction is to segment brain region from nonbrain regions in magnetic resonance (MR) images. The segmented brain is usually used for measuring individual cortex thickness and brain volume, monitoring the development of the brain, and surface-based analysis. Brain region extraction is, therefore, an important step for various applications above mentioned. We present a brain region extraction method which consists of two parts - 3D level set method and refinement process. The 3D level set method is used for estimating coarse boundary surfaces, where its result shows artifacts in some regions such as sudden changes between slices and within a slice. In order to improve an accuracy of the segmentation results, a refinement process is applied to correct the artifacts of the 3D level set method. The proposed method is applied to images in the BrainWeb [1] and IBSR (Internet Brain Segmentation Repository) [2], and images obtained from 1.5T MRI system. In addition, three well-known brain extraction algorithms of brain extraction tool (BET) [3], BrainVisa [4], and FreeSurfer [5], were compared to our method.

Methods

1) Coarse segmentation step: We first perform the Otsu thresholding to separate foreground (brain region and skull) and background (residual regions). A normalization process of image intensity is then applied to overall slices. Then, we implement the 3D level set function proposed by Li et al. [6] as follows,

$$\frac{\partial \phi}{\partial t} = \mu\{\Delta\phi - \mathrm{k}\} + \lambda\delta(\phi)\operatorname{div}(g \cdot \mathbf{n}) + vg\delta(\phi) \quad (1)$$

where Δ represents the Laplacian operator, k is a mean curvature of ϕ, g is the edge indicator function, and **n** is an unit normal vector of ϕ. In addition, div means divergence, and μ, λ, and v are constants. Using Eq. (1), we acquire a coarse segmentation results, but, fundamental problem of the level set function is that an abrupt change between slices makes segmentation difficult due to the internal force. Therefore, a refinement step is required after the 3D level set operation.

2) Refinement step: We analyze three orthogonal planes separately - axial, coronal, and sagittal. The normal vector on contour, which is acquired from the coarse segmentation step, is utilized to find a new contour exactly as shown in Fig.1. B and B^* are current and target blocks, respectively. If mean and standard deviation of B and B^* are similar, B^* becomes included in Ω. In a final procedure, we integrate results from the three orthogonal planes to construct a single volume having at least two among three planes by comparing voxel-by-voxel.

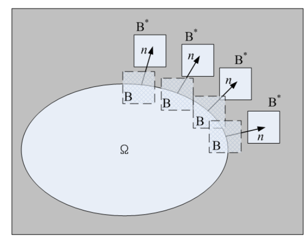

Fig. 1 Schematic diagram of refinement step

Result

We applied the proposed method to the images in the BrainWeb and IBSR data, which provided manual segmentation results. Fig.2 shows the experimental results at three orthogonal planes, whereas Fig.3 shows results of similarity indices for 1.5T MRI data using BET, BrainVisa, FreeSurfer, and the proposed method. In this experiment, we did not set any parameters for fair comparison. The proposed method provided better results, which are 0.895 of SI, 0.903 of sensitivity, 0.999 of specificity, and 0.939 of Dice coefficient [7], than those of others.

Discussion

We presented a novel segmentation algorithm using 3D level set and refinement process, which showed better performance than widely used softwares. Besides, the proposed method could be utilized to normal or abnormal subjects since our algorithm does not need pre-defined brain atlas.

References

[1] BrainWeb, http://www.bic.mni.mcgill.ca/brainweb [2] IBSR, http://www.cma.mgh.harvard.edu/ibsr [3] S. Smith et al., HBM, 2002 [4] BrainVisa/Anatomist, http://www.brainvisa.info [5] http://surfer.nmr.mgh.harvard.edu [6] C. Li et al., IEEE CVPR, 2005 [7] A. Zhuang et al., NeuroImage, 2006

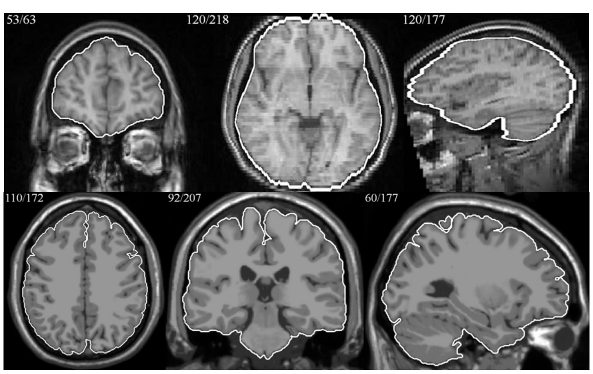

Fig. 2 Experimental results of the proposed method for images in IBSR and BrainWeb.

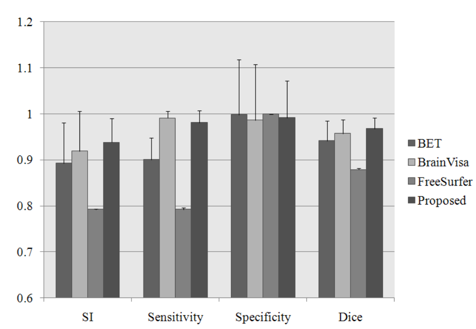

Fig. 3 Evaluation index results of 1.5T data for the previous three algorithms and the proposed method. Overall results of the proposed method are better than three other algorithms.