Automated Cerebellum Segmentation Based on Knowledge Guided Active Contour in T1-Weighted MR Images

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Introduction:

Although many reports have been published on automatic brain segmentation in MR images recently, most of them were devoted to small structures, such as ventricle, caudate, thalamus, hippocampus, and putamen. However, cerebellum segmentation also plays an important role in quantitative MR, because not only is it a prerequisite for quantifying cerebral volume, but also aids in studies to understand the functions of cerebellum. In this study, an automatic algorithm for cerebellum segmentation in T1-weighted MR head images was developed and then applied to twenty data sets of medulloblastoma patients for evaluation of reliability and validity.

Methods:

All data sets were preprocessed by first aligning all image sets with a rigid-body registration (1). Then a histogram-base brain segmentation algorithm (HBRS) was applied to separate the brain from head images (2).

The cerebellum was segmented with a series of four steps. First, the average template of cerebellum was generated by manual drawing on the arbitrary selected ten brain images. Second, the contour of the template was superimposed onto brain images of given patients. Thirdly, the contour was adjusted to locate the boundary of the cerebellum using active contour method, which is also known as SNAKE. Finally, a series of morphologic operations were applied to smooth the surfaces of the cerebellum.

The algorithm was applied to another twenty MR data sets of medulloblastoma patients. The automatically rendered images were compared with manually drawn images. The Jaccard similarity and Kappa index were calculated to evaluate the similarities between automatic and manual results. A regression analysis was used to test the differences between the automatic and manual volumetric results.
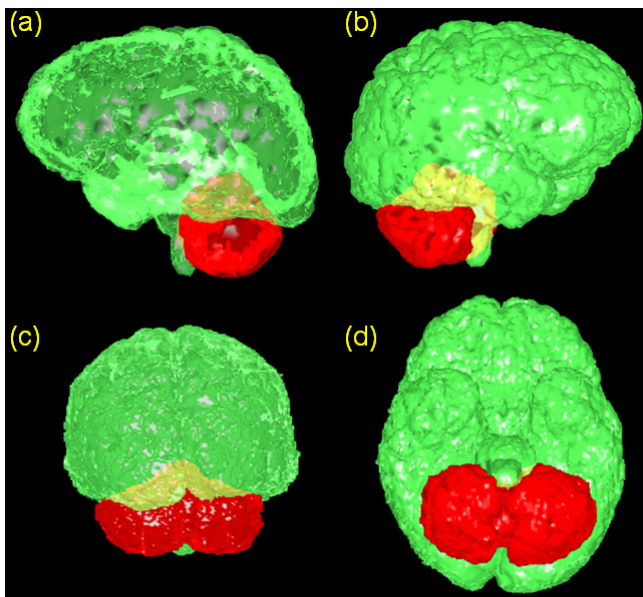

Fig. 1 Semi-transparent 3-D surface rendering of the brain volume, in which the cerebellum was segmented and assigned as red, cerebrum and brain stem were assigned as green. (a) right, (b) left, (c) posterior, and (d) inferior views.

Results:

Fig. 1 illustrated a typical result of the algorithm. The average Jaccard similarities of 20 data sets manually drawn by two observers were 0.89 and 0.88, respectively. The corresponding Kappa indices were 0.94 and 0.93, respectively. There were no significant differences between automatic and manual volumetric results. Strong correlations were found between the automatic and manual results. The correlation coefficient between the automated and two manual results were 0.974 and 0.971, respectively.

Discussion:

Image segmentation methods can be roughly divided into two categories: registration-based and knowledge-based methods. Both of them have inherent advantages and disadvantages. Therefore, a combination of both methods should provide a reasonable improvement in performance. The algorithm presented here uses registration as an initialization to overcome a major shortcoming of knowledge-based methods, which generally require a good initialization. Then the algorithm uses an active contour method to locate the boundaries of cerebellum, overcoming a major shortcoming of registration-based methods, in which a one-to-one match does not always exist, and an exact match is hard to achieve.

Conclusion:

In this study, an automatic algorithm for cerebellum segmentation in T1-weighted MR head images was developed and validated. The method is robust and accurate for cerebellum segmentation, and may be applied to various research and clinical investigations in which cerebellum segmentation and quantitative MR measurement of cerebellum are need.

Reference:

1. Ostuni JL et al. *J Magn Reson Imaging* 1997; **7**: 410-5.   2. Shan ZY et al. *NeuroImage* 2002; **17**: 1587-98.