

Cerebellar GM-WM segmentation accuracy in assessing brain atrophy

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Introduction:

Cerebellum plays an important role in motor control, cognitive functions and emotion [1]. Cerebellum is also affected by aging and various neurological disorders leading to atrophy of gray matter (GM) and white matter (WM). Accurate segmentation of cerebellum into GM and WM is important in establishing correlation with clinical measures. Cerebellum is one of the most difficult regions to segment for various reasons, including different intensity profile from cerebrum [2]. We have developed an integrated approach for segmenting brain images. Currently, freely available software packages such as SPM (<http://www.fil.ion.ucl.ac.uk/spm/software/spm8/>), FreeSurfer (<http://surfer.nmr.mgh.harvard.edu/fswiki>), and FSL FAST (<http://www.fmrib.ox.ac.uk/fsl/>) are most commonly used for quantifying GM and WM volumes. The purpose of this study is to evaluate the performance of these techniques against our integrated segmentation approach for classification of cerebellar GM and WM.

Image Acquisition:

Brain MRI on 13 normal volunteers was performed on 3T Philips intera scanner with a dual quasar gradient system with a SENSE factor of 2. Three dimensional Magnetization-prepared rapid gradient echo (MPRAGE) T1-weighted (TR/TE = 8.1 ms/3.7 ms) and 3D fat-saturated (fat-sat) T2-weighted (TR/TE = 2500.0 ms/362.9 ms) images with 1 mm³ isotropic resolution were acquired.

Methods:

We implemented a fully automated technique based on multi-spectral T1-weighted and T2-weighted images to classify GM, WM, and CSF. The pre-processing of images prior to segmentation includes application of rigid body registration algorithm to co-align T1-weighted images to T2-weighted images. The brain was then extracted from T2-weighted images by exploiting the fat-sat technique on T2-weighted images and using automated image histogram-based thresholds identification, region connectivity and region labeling algorithms followed by intensity inhomogeneity correction. Due to different tissue intensity profiles between the cerebellum and cerebrum [2], the whole brain was partitioned into cerebellum and remaining part of the brain by deforming the ICBM template (<http://www.loni.ucla.edu/Atlases/>) to subjects' T1 images using symmetric non-linear registration technique [2, 3]. Following partitioning, tissues were classified using the expectation maximization–hidden Markov random field (EM-HMRF) classifier [4]. The segmented regions (cerebellum and remaining part of the brains) were combined for complete classification of tissues. Finally, deep GM structures were extracted from deformed ICBM template.

Additionally, SPM, FreeSurfer, and FAST (FSL) were applied for GM-WM classification and the results were compared subjectively by experts with an emphasis on the cerebellum. SPM employs a single channel for segmentation and therefore, T1-weighted images served as the input for SPM. Both T1- and T2-weighted were used for segmentation with FreeSurfer multi-spectral and FSL FAST.

Results and Discussion:

Figure 1 shows T1-weighted, T2-weighted, and segmented results obtained with our method, SPM, FreeSurfer, and FAST techniques on four cross-sections, including cerebellum, from same subject. As can be observed from this figure, classification of GM and WM, particularly in the cerebellum, by our technique resembles closest to the T1- and T2-weighted images relative to all the other techniques. Of these three, the classification of GM and WM with FreeSurfer is relatively good in the cerebellum but proved to be inferior in segmenting the deep GM structures. On the other hand, SPM and FAST techniques failed to properly segment GM and WM in the cerebellum and other parts of the brain, particularly the deep GM structures. Relative to SPM, FreeSurfer, and FAST techniques, our method has provided excellent GM-WM segmentation throughout the brain. This was consistently observed in all the 13 subjects included in this study.

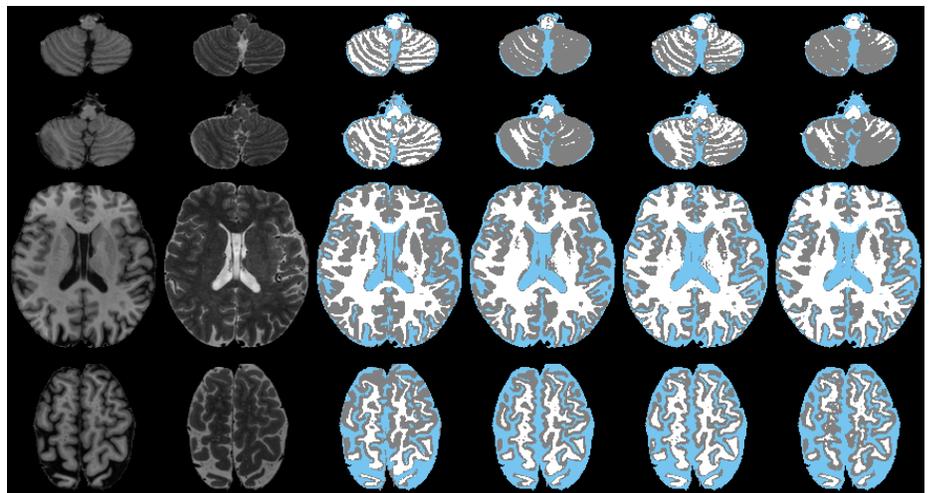


Fig. 1: MPRAGE T1-weighted (first column) T2-weighted (second column) and segmented results from our method (third column), SPM (fourth column), FreeSurfer (fifth column) and FSL FAST techniques (sixth column).

Conclusions:

We have implemented an automated segmentation approach and compared the segmentation results obtained with SPM, FreeSurfer, and FAST techniques. As compared to other techniques, we obtained excellent GM-WM classification in the whole brain including cerebellum. One of the limitations of this study is that the results were evaluated subjectively based on visual inspection.

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References: [1] Schmahmann and Caplan, *Brain* 2006;129:290-292; [2] Datta et al., *JMRI* 2009;29:1035-1042; [3] Tao et al., *JNS* 2009;282:39-46; [4] Zhang et al., *IEEE Trans Med Imaging* 2001;20:45-57.