Enhancing subcortical image segmentation based on age dependent intensity normalization

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Introduction

Automatic segmentation of MR brain images is being utilized in many clinic applications and research with an increasing trend. Unfortunately, most of these methods have significantly poorer performance within the subcortical area. Intersubject volumetric ratio differences between tissue classes (WM, GM and CSF) is one of the major reasons for this fact, especially in histogram based approaches. It is also known that age is the most prominent factor in the volumetric values of the tissue classes. In a recent approach [5], the segmentation of the subcortical region is improved by registration of the given image to an atlas image and normalization of the intensity differences between both images. In this study, a method that improves the performance of subcortical segmentation using a subject age dependent intensity standardization procedure unified with a Maximum Likelihood approach for voxel classification is developed.

Method

In a previous study[1], subcortical segmentation is performed using Bayesian approach using the prior information extracted from a T1 weighted single subject atlas brain[2]. The iterative approach of the algorithm[1] tries to compensate the intersubject volumetric tissue differences. If the difference of volumetric ratios between the atlas and the subject is very significant (For example, when age related tissue loss is present), the performance degrades dramatically and convergence is problematic. In this new algorithm, this problem is handled by the incorporation of age dependent volumetric values to the intensity standardization step. In order to use the histogram extracted from the atlas subcortical region as the reference histogram, the age dependent volumetric ratios together with the tissue intensity probability density functions (pdf) are used to construct the reference histogram used in intensity normalization. With this improvement, intensity standardization between the atlas and the given image becomes much more reliable and convergence can be achieved easier and faster. The necessary volumetric ratios which is dependent on age is modeled with regression equations (using quadratic as well as linear components) based on the results presented in [3]. In addition, the voxel classification approach of [1] is changed to Maximum Likelihood (ML) because the subject based tissue priors can behave as an excessive damping effect for tissues with lower volume ratio or vice versa.

Results

The method is operated on two T1 weighted images which were taken with a 1.5 Tesla Siemens scanner using slightly different mprage pulse sequence. The subjects are 80 and 40 years old. The results of the proposed method are compared with the output of FSL FAST [4]. The segmentation results for 2 axial slices and the volumetric tissue ratios are presented in Figure 1.

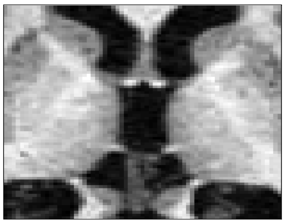
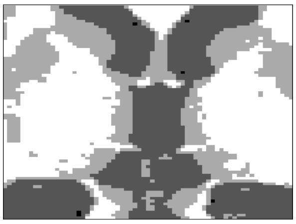
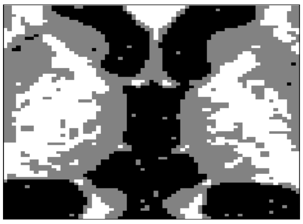
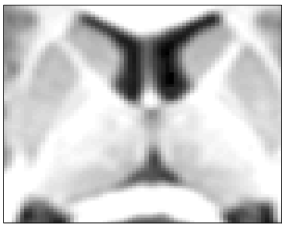
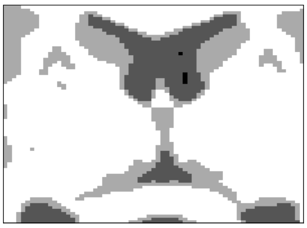
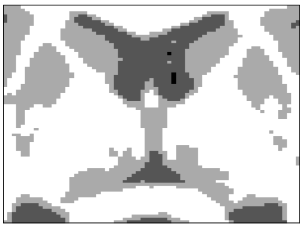
Original Image	FAST[4] Segmentation	New method
 Expected % = 24.2-18.7-57.1	 Calculated % = 34.2-20.7-45.1	 Calculated % = 20.8-31.4-47.8
 Expected % = 47.0-45.5-8.5	 Calculated % = 63.0-23.3-13.7	 Calculated % = 52.9-30.2-16.9

Figure 1 Segmentation results. The above and below rows belong to 80 and 40 year old subjects respectively. The expected and the calculated volumetric percentages (representing whole subcortical region) after segmentation are stated below the images. The order of the percentages: WM-GM -CSF order.

Conclusion

Using the age information in the intensity normalization step, images with different volumetric characteristics can be segmented with improved quality. When compared with the FAST[4] method, improvement in the detection of GM structures such as putamen and thalamus is evident. The running time of the algorithm is short(in the order of minutes) and convergence is achieved in at most 4-5 iterations. This method can easily be embedded into other automatic segmentation algorithms operating in whole brain.

References

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