Validation Of A Thalamus Segmentation Based On Local Difusion Information

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Introduction: Fast and accurate segmentation of thalamic nuclei is important for clinical applications such as treatment of Parkinson's disease or chronic pain syndrome for example. The intrinsic contrast in standard anatomical MR images in the thalamus is very low, therefore direct segmentation of thalamic nuclei is not possible. Since thalamic nuclei have a distinct and well-ordered fiber structure, DTI promises better contrast within the thalamus. Several methods for the segmentation of thalamic nuclei on DTI data have been proposed (see for example [1-2]). Even though these methods show impressive results they require manual segmentation of the whole thalamus or other brain regions, fine-tuned segmentation parameters and their computation time is in some cases [2] very high. We therefore refine a segmentation method based on local Dominant Diffusion Orientation (DDO) classification that is fast and independent of manual segmentation [3]. Using a group of 63 healthy subjects, we show the anatomical relevance of our DDO-based segmentation method. To prove that the segmented nuclei in individual subject data correspond well to each other we evaluate the spread of the center-of-mass (COM) coordinates for the individual subjects and clusters.

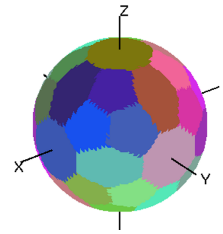

Figure 1: *Color-sphere with unique color coding used in the segmentation. The centroids of the color patches correspond to the RDs.*

Methods: Data: DTI data and T1 weighted images were acquired for 63 healthy right-handed volunteers (32 male and 31 female) between 20 and 40 years old (mean 26.29 years +/- 4.48; females: mean 25.52 years +/- 4.35) on a 1.5T MR-Scanner (Sonata, Siemens, Erlangen, Germany) after written informed consent. Each DTI data set consisted of an un-weighted image and twelve diffusion weighted images with a b-value of 800s/mm^2. The resolution of the DTI data was 2x2mm in plane with a slice thickness of 2.5mm. The data sets were normalized to MNI space using FNIRT [4] and the diffusion direction was corrected accordingly [5].

Segmentation: We classified the DDO using a set of 21 reference directions (RD), so that each voxel is assigned the class whose RD has the least angular difference to the local DDO (see Fig.1). The individual classes are assigned unique colors corresponding to their RDs as defined by Demiralp et al [6]. The segmentation takes only few seconds in our Matlab reference implementation.

Validation: We evaluated the correspond-dence of our segmentation with anatomy from the stereotactic atlas by Morel et al. [7] through visual inspection. We summarized the results of our analysis of 63 subjects in a single segmentation map. Each voxel in this map is assigned the class that was assigned most often to voxels in the same position in the individual subject evaluations. We also investigated the COM coordinates of the distinct clusters in the individual subjects to show their correspondence.

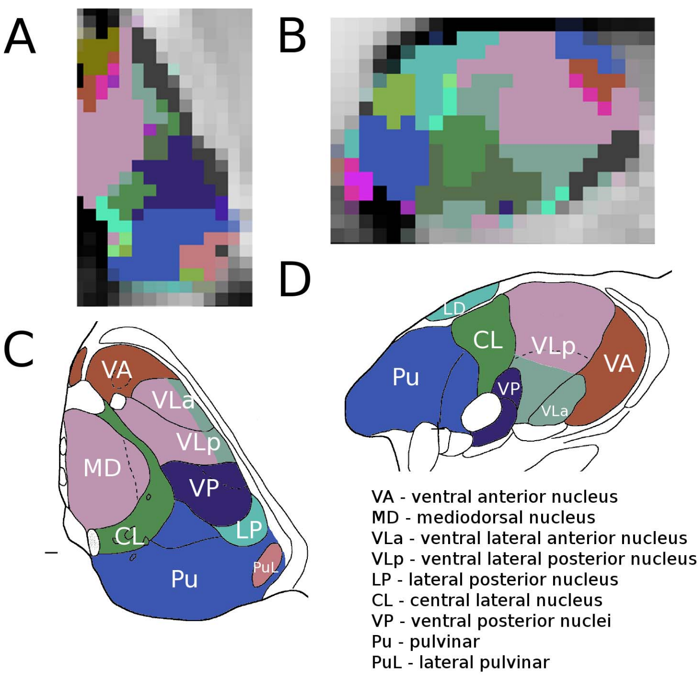

Figure 2: *Segmentation results: The comparison of our combined segmentation results (A - horizontal and B – saggital) with plates from the stereotactic atlas by Morel et al. [7] (C - horizontal (plate D 4.5) and D – saggital (plate L 11.7)).*

Results: The comparison between our segmentation results and the thalamus atlas proposed by Morel at al [7] are shown in Fig.2. We could identify major thalamic nuclei in our segmentation results. The COM coordinates for clusters that were found to be of anatomical relevance did form tight groups (see Fig.3). This indicates a strong consistency of the COMs for the individual clusters over all subjects.

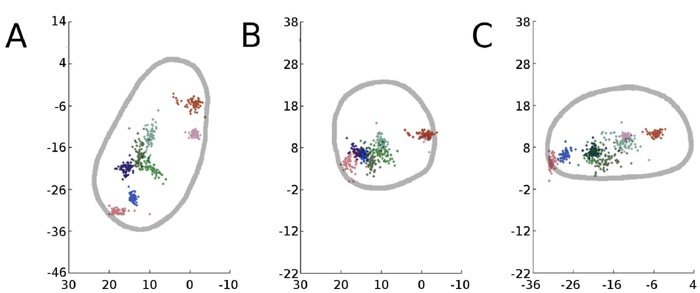

Figure 3: *The COMs (dots) for the most dominant segmented nuclei (colored as defined in Fig.1) in the individual subjects form tight groups. Scatter-plots of all individual COMs for each of the major DOCs are shown in the Horizontal (A), Coronal (B) and Sagittal (C) planes. The outline of the thalamus is indicated for orientation. The axes give the MNI coordinates in mm.*

Discussion and Conclusion: We find that the clusters that were segmented with our method correlate well with thalamic nuclei from the stereotactic atlas by Morel et al. [7]. The segmentation results from individual subjects correspond well to each other in the COM evaluation. This indicates that the individual segmentation results also correspond well to the atlas data. These results, the speed of the method, and the independence from any manual segmentation make our refined segmentation method promising for clinical applications.

References: [1] M. R. Wiegell, D. S. Tuch, H. B. W. Larsson, and V. J. Wedeen. Neuroimage, 19:391–401, 2003. [2] T. E. J. Behrens, M. W. Woolrich, M. Jenkinson, H. Johansen-Berg, R. G. Nunes, S. Clare, P. M. Matthews, J. M. Brandy, and S. M. Smith. Magn Reson Med, 50(5):1077–1088, 2003. [3] A. Unrath, U. Klose, W. Grodd, A. C. Ludolph, and J. Kassubek. Neurosci Lett, 434(3):322–327, 2008. [4] FMRIB Analysis Group. FSL. Oxford University, UK, 2007. [5] D. C. Alexander, C. Pierpaoli, P. J. Basser and J. C. Gee. IEEE Trans. Med Imag, 20(11):1131-1139, 2001. [6] C. Demiralp, J. F Huges, and D. H. Laidlaw. in proceedings of IEEE TVCG, 2009. [7] A. Morel, M. Magnin, and D. Jeanmonod. J. Comp. Neurol. 387:588-630, 1997.