Freesurfer-Initialized Large Deformation Diffeomorphic Metric Mapping with application to Parkinson's Disease

Jingyun Chen[1], Samantha J. Palmer[2], Ali R. Khan[1], Martin J. McKeown[2], Mirza Faisal Beg[1]

1. School of Engineering Science, Simon Fraser University, 8888 University Drive, Burnaby BC, V5A 1S6, Canada

2. Pacific Parkinson's Research Centre, Brain Research Centre, University of British Columbia, Vancouver BC, V6T 2B5, Canada

Introduction:

We apply a recently developed automated brain segmentation method, FS+LDDMM[1], to brain Magnetic Resonance (MR) scans from Parkinson's Disease (PD) subjects, and normal age-matched controls, and compare the results to manual segmentation done by trained neuroscientists. The data set consisted of 14 PD subjects and 12 age-matched control subjects without neurologic disease and comparison was done on six subcortical brain structures (the left and right caudate, putamen and thalamus). Comparison between automatic and manual segmentation was based on Dice Similarity Coefficient (DSC), L1 Error, Symmetrized Hausdorff Distance and Symmetrized Mean Surface Distance. Results suggest that FS+LDDMM is well-suited for subcortical structure segmentation and further shape analysis in Parkinson's Disease. The asymmetry of the Dice Similarity Coefficient over shape change is also discussed based on the observation and measurement of FS+LDDMM segmentation results.

Goals:

Parkinson's Disease is a neurodegenerative disorder that affects approximately 1% of the population above the age of 65. It causes movement symptoms such as shaking, stiffness, slowness of movement and difficulty with balance. These symptoms are the result of disrupted transmission through dopaminergic pathways in the Basal ganglia. Therefore, it would be desirable in PD research to segment and analyze the Basal ganglia structures from clinical magnetic resonance brain scans.

Methods:

FS+LDDMM a template-based brain segmentation method that combines the probabilistic-based Freesurfer (FS) subcortical segmentation pipeline[2] with Large Deformation Diffeomorphic Metric Mapping (LDDMM) based label propagation[3]. FS+LDDMM computes the deformation between FS initiated Regions of Interest (ROI) of template and target images, then use the same deformation to propagate automatic labels from manual labels, as shown in Figure 1.

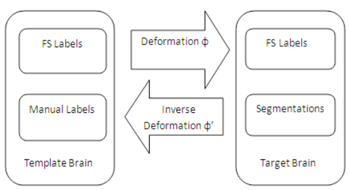

Figure 1 Illustration of FS+LDDMM method.

Results:

One typical set of segmentation are compared in Figure 2. There is a monotonic improvement in the surface smoothness of FS+LDDMM segmentations when comparing manual, FS-only. Qualitative evaluation of overlap percentages and surface distances to manual segmentations is also conducted on FS+LDDMM and FS methods. Under most measurements, FS+LDDMM shows general improvement over FS method alone on segmenting

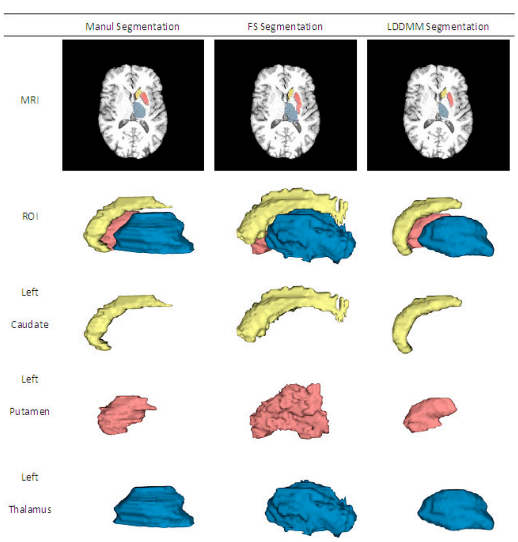

Figure 2 Comparison of segmentations

Varying Bias of DSC Metric:

In the validation study, relatively less DSC improvement for FS+LDDMM segmentation was observed than other similarity measurements. By Rohlfing's argument[4], this the mainly because DSC depends strongly on subject sizes and is smaller for smaller subjects. Figure 3 shows that FS method tends to "over-segments" a given ROI compared to the FS+LDDMM method. Therefore FS+LDDMM segmentations are more heavily penalized by DSC because they tend to have smaller volumes compared to FS-only.

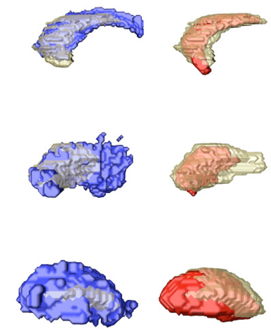

Figure 3 Illustration of FS's over-segmentation and LDDMM's under-segmentation.

The left column is FS segmentations (blue) overlapping on manual segmentations (transparent).

The right column is FS+LDDMM segmentations (red) overlapping on manual segmentations (transparent).

The first row from upside is caudate, the second is putamen, the third is thalamus.

A numerical simulation was conducted to explore this potential bias of the DSC metric. We perform morphological operation on the left caudate template. Dilation and erosion are performed once and twice to generate four different simulated volumes. Let the increase or decrease generated by dilation or erosion be denoted as *e*. The change of DSC over *e* is plotted in Figure 4. From the plot we can see that for the same *e* the DSC is smaller for the

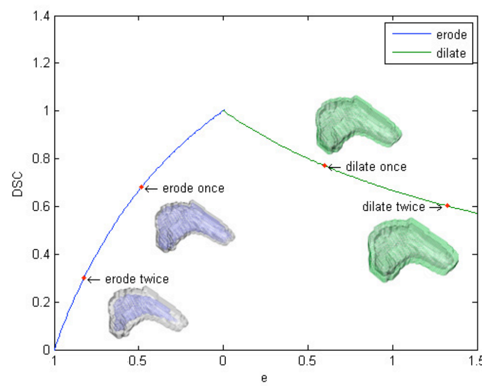

Figure 4 DSC changes over subject erosion and dilation. The left curve (blue) represents the DSC change over erosion. The right curve (green) represents the DSC change over dilation.

Conclusion:

FS+LDDMM method was successful implemented to segment three Basal Ganglia structures in subcortical areas which are highly related to dopaminergic pathways. Validation study was conducted through the examining both overlap percentage and surface distance with manual segmentation. Under most measurements, FS +LDDMM showed general improvement over FS method alone.

References:

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