Automated extraction of fiber bundles for population studies

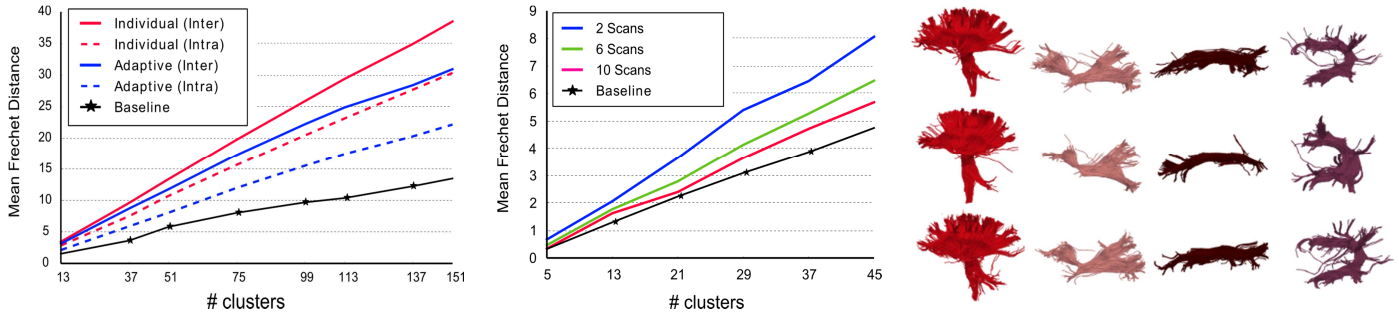
Birkan Tunc[1], William A. Parker[1], and Ragini Verma[1]
[1]*Department of Radiology, University of Pennsylvania, Philadelphia, PA, United States*

Target audience The proposed automated fiber tract extraction framework is intended to be used as a tool for tract of interest (TOI) based analyses. Specifically, we believe, it will have an effective use in studies that need the unsupervised automated extraction of tracts, to study brain connectivity changes in a population or for applications like surgical planning.

Purpose The superior characterization of complex WM structure by advanced diffusion imaging protocols[1], has improved the reliability of the tractography leading to an increasing interest in tract based analyses. The main challenge with the tract-based studies is the automated extraction of tracts of interest (TOIs) from the whole brain, in a group-wise consistent manner, such that they can be compared across subjects. In this study, we develop a framework for automatically extracting any TOI while minimizing the need for manual intervention to draw regions for extracting these tracts.

Methods The proposed TOI extraction technique is based on fiber clustering[2,3] , leading to a fully automated unsupervised technique. A multinomial connectivity based representation will be used to describe fibers[2]. To guarantee the consistency among clustering results of different scans, an atlas based clustering technique is used. The atlas is prepared by combining the connectivity representations of several representative subjects. Our connectivity based representation enables such combinations inherently owing to its coordinate free specification. Once a fiber clustering atlas is prepared, the fibers of a new subject is clustered adaptively using the atlas as a prior model so that the automatic correspondence will be guaranteed for all scans in our dataset. Then, any specific TOI can be extracted automatically. *Dataset:* Experiments were performed on HARDI[1] scans of 6 male healthy subjects (Age 31.25 ± 4.2 years) at three time points, separated by two weeks. Images were acquired using a Siemens 3T VerioTM scanner using a monopolar Stejskal-Tanner diffusion weighted spin-echo, echo-planar imaging sequence (TR/TE=14.8s/111ms, 2mm isotropic voxels, b = 3000 s/mm^2 , number of diffusion directions=64, 2 b0 images, scan time 18 minutes).

Results The applicability, reliability, and consistency of the proposed framework were validated on the specified dataset. To assess the consistency of the adaptive clustering technique, the average intra- and inter-subject distances are compared to those distances that are calculated when the fibers of subjects are clustered individually, as shown in Figure 1(a). The repeatability and reliability of the framework is tested by fixing a randomly selected test scan and changing the scans used for atlas generation, repeatedly. Results are given in Figure 1(b). Finally, Figure 1(c) shows a successful application of the framework with group-wise consistent TOI extraction.



(a) (b) (c)

Figure 1: (a) Intra- and inter-subject distances with and without using the framework. Baseline distance shows the lowest possible distance caused by random initialization in clustering. (b) Distances between the clustering results of a fixed test subject when the scans in the atlas are changed. Test was repeated for different numbers of scans in the atlas. Baseline distance is same as (a). (c) Four tracts (internal capsule, ifof, ilf, arcuate) of three subjects that are extracted automatically.

Discussion The main contribution of the framework is the automation of the TOI extraction for large groups of scans. For any study dealing with group differences or longitudinal analyses over fiber tracts, this achievement is critical. The unsupervised nature of the fiber clustering eliminates the need for manually drawing any inclusion or exclusion ROI to define the TOI after the tractography. Also correspondences between subjects is automatically set up facilitating group-wise statistics.

Conclusion A framework for automatic group-wise consistent extraction of any TOI is developed. The framework is extensively examined by using HARDI scans of healthy individuals acquired repeatedly. Experiments have established the use of the proposed framework in group and longitudinal studies to create TOIs that could be used for subsequent statistical analyses.

References

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