ATLAS-BASED FIBER CLUSTERING FOR MULTI-SUBJECT ANALYSIS OF HIGH ANGULAR RESOLUTION DIFFUSION IMAGING TRACTOGRAPHY

Gautam Prasad [1], Neda Jahanshad [1], Iman Aganj [2], Christophe Lenglet [2,3], Guillermo Sapiro [2], Arthur W. Toga [1], and Paul M. Thompson [1]

[1]Laboratory of Neuro Imaging, Department of Neurology, UCLA School of Medicine, Los Angeles, CA, USA
[2] Department of Electrical and Computer Engineering, University of Minnesota, Minneapolis, MN, USA
[3]Department of Radiology - CMRR, University of Minnesota Medical School, Minneapolis, MN, USA

Abstract

Purpose: Analyze white matter tract fiber integrity and connectivity in high angular resolution diffusion images (HARDI), compute population-based statistics from the tracts

Method: We scanned 20 young adults with HARDI at 4 T and performed whole brain tractography using streamlines and a novel Hough transform method, used measures of agreement between the extracted fibers and a co-registered probabilistic DTI atlas to select key pathways, applied a threshold and median filtering to refine the cluster, and used shortest path graph search to create maximum density path (MDP) representations of the tracts

Results: MDPs compactly represent each tract in our subject data. We found significant differences in FA along the MDPs from the two tractography methods and significant hemispheric asymmetry in FA from MDPs generated from streamline fibers

Introduction

- Fiber integrity and connectivity measured from high angular resolution diffusion images (HARDI)
- Tractography recovers geometry and connectivity of major white matter fiber pathways
- Finds hemispheric asymmetries and functional lateralization [2], identifies genetic effects and sex differences in neural networks organization [3]
- Fibers clustered into bundles for white matter tract analysis
- Existing methods: projecting into high-dimensional space to cluster, *k*-means, fuzzy clustering, regression Dirichlet processes mixture model [4]
- Current methods may split or combine tracts and don't incorporate prior anatomical knowledge

Methods

1. Generate representative curves for tract based analysis of HARDI
2. Derive them guided by regions of interest to represent anatomy
3. Make tract analysis robust to differences in the atlas and subject

1. Image Data

- 105-gradient HARDIs acquired from 20 healthy young adults [6]
- FSL (www.fmrib.ox.ac.uk/fsl/) corrected images for motion and eddy current distortions

Method Overview

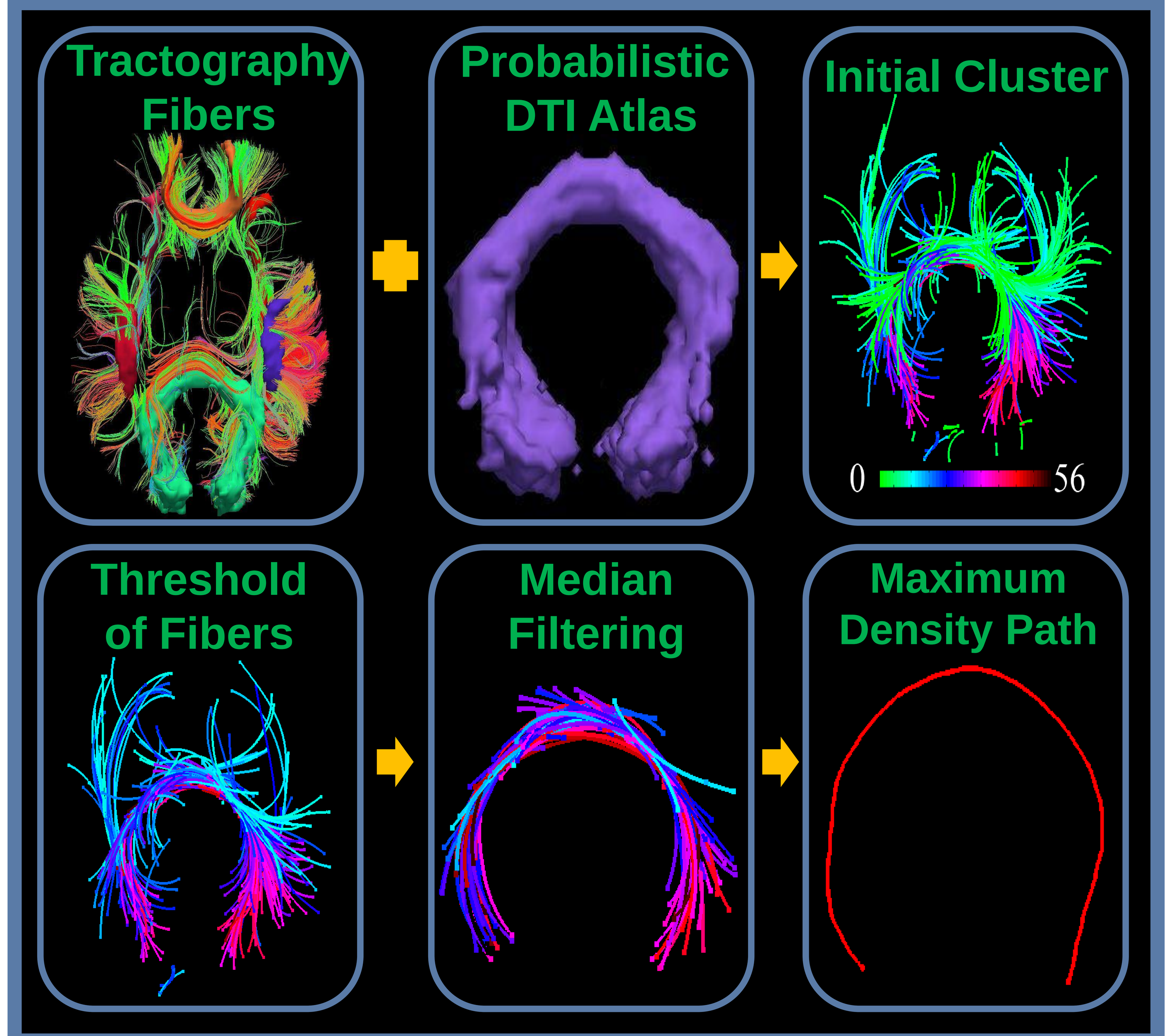

Figure 1. Overview of our tractography fiber clustering pipeline that creates maximum density path (MDP) representations of white matter tracts

2. Tractography Methods

1. Novel Hough transform method using constant solid angle orientation distribution functions (CSA-ODFs) derived from HARDI data [7]
2. Streamline method based on diffusion tensor [8]

3. Probabilistic Atlas Clustering

Clustered fibers by selecting those intersecting white matter tract regions in JHU white matter tractography atlas [9]

4. Median Filter

Median filtering on binary volume representation of the paths to threshold spurious fibers in cluster [10]

5. Maximum Density Paths (MDP)

Density volume image generated from cluster and Dijkstra's shortest path algorithm [5] finds maximum density path through graph derived from volume

Results

Figure 2. Maximum Density Paths (MDPs) from Hough transform (green) and streamline method (blue)

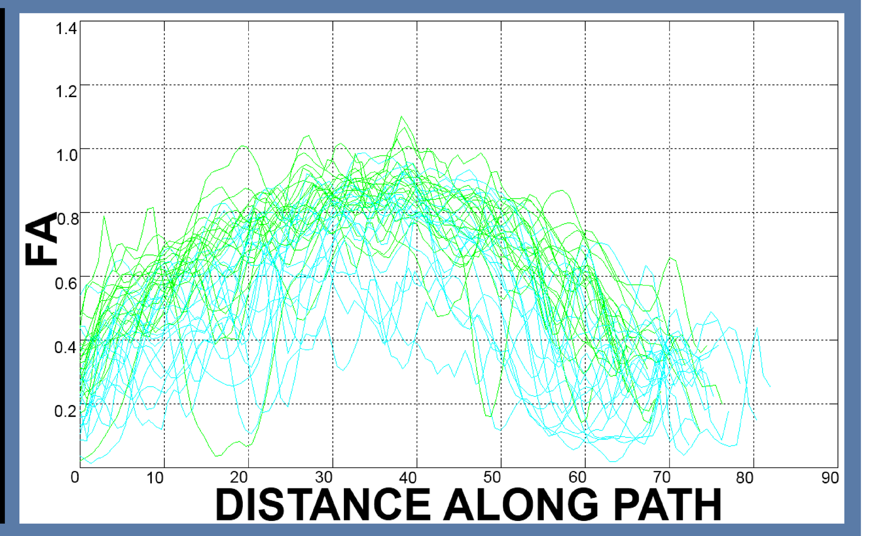

Figure 3. FA along MDPs from Hough transform (green) and streamline method (blue).

Paired sample *t*-test comparing FA along MDPs from the two methods gave *p*-value of 8.8 x 10^{-8}. *t*-test assessing hemispheric asymmetry gave *p*-values of .56 and 9.4 x 10^{-3} for Hough and streamline methods respectively

Discussion

- Maximum density path (MDP) representation may help in population studies
- Recovers homologous anatomical tracts across subjects without requiring manual labeling of tracts
- We are exploring population comparisons using MDPs registered into the same space

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Corresponding Authors:
Paul Thompson (thompson@loni.ucla.edu)
& Gautam Prasad (gprasad@ucla.edu)