Automatic HARDI White Matter Tract Labeling with Multiple Atlas Fusion

Abstract No:

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Authors:

Yan Jin[1], Yonggang Shi[1], Liang Zhan[1], Jesse Brown[1], Susan Bookheimer[1], Arthur Toga[1], Greig de Zubicaray[2], Katie McMahon[2], Nicholas Martin[3], Margaret Wright[3], Paul Thompson[1]

Institutions:

[1]University of California, Los Angeles, Los Angeles, CA, [2]University of Queensland, Brisbane St. Lucia, Queensland, [3]Queensland Institute of Medical Research, Herston, Queensland

Introduction:

High angular resolution diffusion imaging (HARDI [1]) recovers the local profile of water diffusion in tissues, yielding information on white matter (WM) integrity and connectivity that is not available from standard anatomical MRI. Grouping fibers into coherent bundles ("clustering") enables large population studies of disease and genetic effects on tract shapes, or tract integrity. However, a simple ROI method for defining tracts [2] needs manual intervention or depends on the accuracy of a registration to a previously labeled atlas. Typical clustering frameworks [3] are more automated, but they do not use any anatomical information to guide the process. To overcome these shortcomings, we introduce a multi-atlas label fusion framework to automatically extract anatomically meaningful WM tracts from diffusion images of the brain.

Methods:

Our 20 subjects were selected from a larger database of ~700 healthy young adult twins in their twenties from Australia. HARDI images were acquired with a 4T Bruker Medspec MRI scanner. 105 image volumes were acquired per subject: 11 with no diffusion sensitization, i.e., T2-weighted b0 images, and 94 diffusion-weighted volumes (b=1159 s/mm2).
We performed whole-brain streamline tractography to reconstruct fiber paths with the Diffusion Toolkit [4]. Based on convergence analysis in our prior multi-atlas work [5], we created five WM tract atlases, each representing particular tracts in a different subject. Linear registration with FSL [6] and then non-linear registration [7] were performed to align the fractional anisotropy (FA) images of the atlases to a single-subject template in the ICBM-152 space called the "Type II Eve Atlas" [8]. The fibers in the atlases were correspondingly warped to the template space. Then the labeled ROIs of the template were re-assigned to these registered atlases. Fibers that traversed the ROIs were extracted according to the lookup table in [9]. Fig. 1 shows two example WM tract atlases that we created.
For each test subject (i.e., each new image to be labelled), whole brain tractography was extracted with the Diffusion Toolkit as well. The same registration methods were used to align the subject's FA image to each of the five WM tract atlases' FA images. Each subject's fibers were then warped to each of the atlases' spaces. For each fiber that belonged to a particular tract in an atlas, we computed the Hausdorff distance and the average closest distance [10] between this fiber and each fiber in that subject's tractography. An empirical distance threshold was applied to decide which of the subject's fibers should be included in this particular tract for that atlas.
Finally, majority voting was used to decide which fibers belonged to a particular tract in the test subject to be labeled.

Results:

In Fig. 2, the first row shows the five atlas versions of the left cingulum tract. The second row shows the five different candidates for this tract in the same test subject, based on using each atlas to decide what fibers it contains. The final result for this tract was obtained by taking all fibers appearing in 4 out of 5 candidate results. Clearly, label fusion helps to eliminate outliers in each candidate (caused by imperfect tract representations of individual atlases and, possibly, by registration error).
Fig. 3 illustrates the label fusion results for the corpus callosum subdivisions and the right cortico-spinal tract in four different subjects.
Fig. 4 shows automatic WM fiber clustering results for four representative test subjects.

Conclusions:

We presented a new method for labeling tracts automatically in diffusion images of the human brain. The method first constructed a set of WM fiber tract atlases to provide prior anatomical information. We implemented fiber clustering based on two distance metrics with label fusion to fine-tune the results. The method generates anatomically plausible major tracts, at least in 20 subjects, and shows promise for population studies.

Imaging Methods:

Diffusion MRI

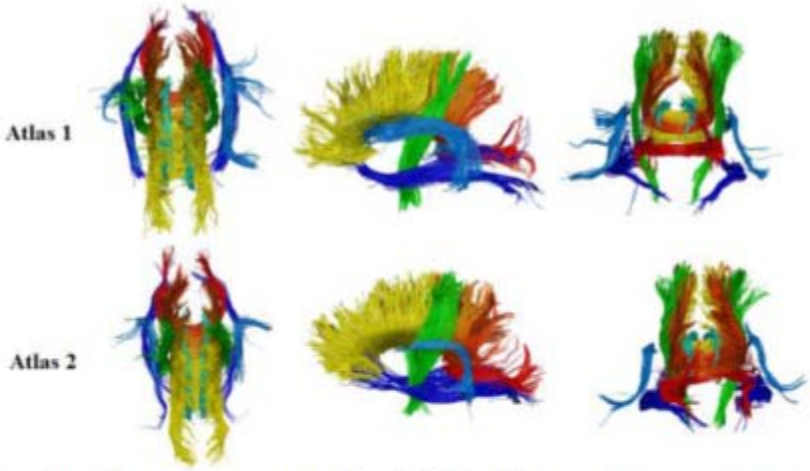

Fig. 1. Two representative WM fiber atlases computed, and manually edited, from 4-Tesla 105-gradient HARDI data, showing major tracts. *Top*, *left side*, and *back* views are shown. Major tracts, distinguished in color, include the corticospinal tracts (*green*), cingulums (*cyan*), superior longitudinal fasciculi (*deep sky blue*), inferior fronto-occipital fasciculi (*blue*), and multiple subdivisions of the corpus callosum (warm colors from *yellow* to *red*).

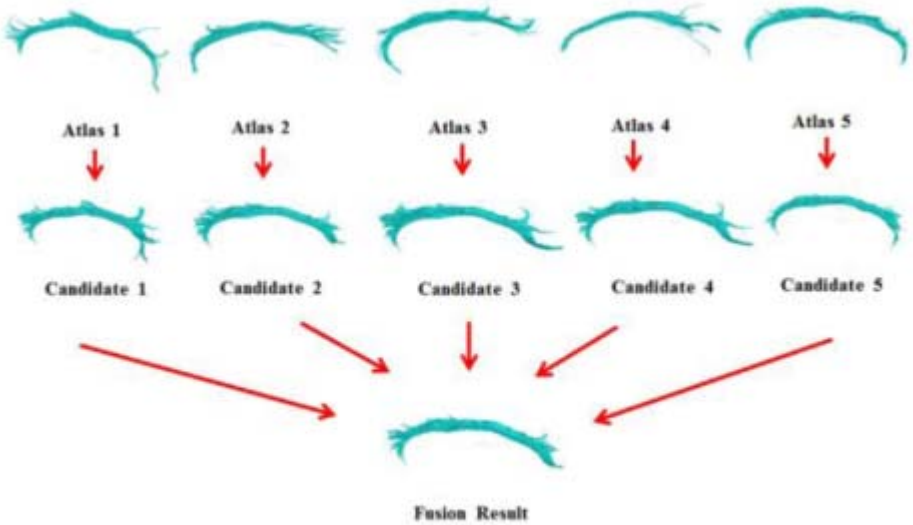

Fig. 2. Label fusion result for the left cingulum tract (in *cyan*) in a test subject (viewed from the *left*).

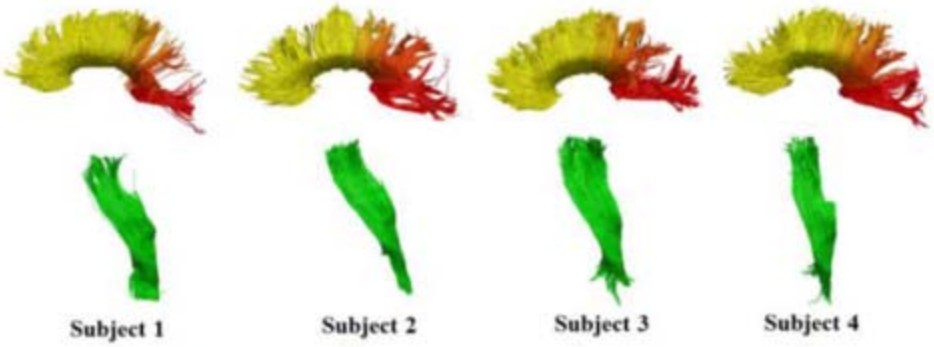

Fig. 3. Label fusion result for corpus callosum subdivisions (in *warm colors*) and the right cortico-spinal tract (in *green*) in four *different* subjects (viewed from the *right*). For the corpus callosum subdivisions, five different segments are shown; they project to both frontal lobes, precentral gyri, postcentral gyri, superior parietal lobes, and occipital lobes. Colors change from *yellow* to *red* while as segments move from anterior to posterior (viewed from the *left*).

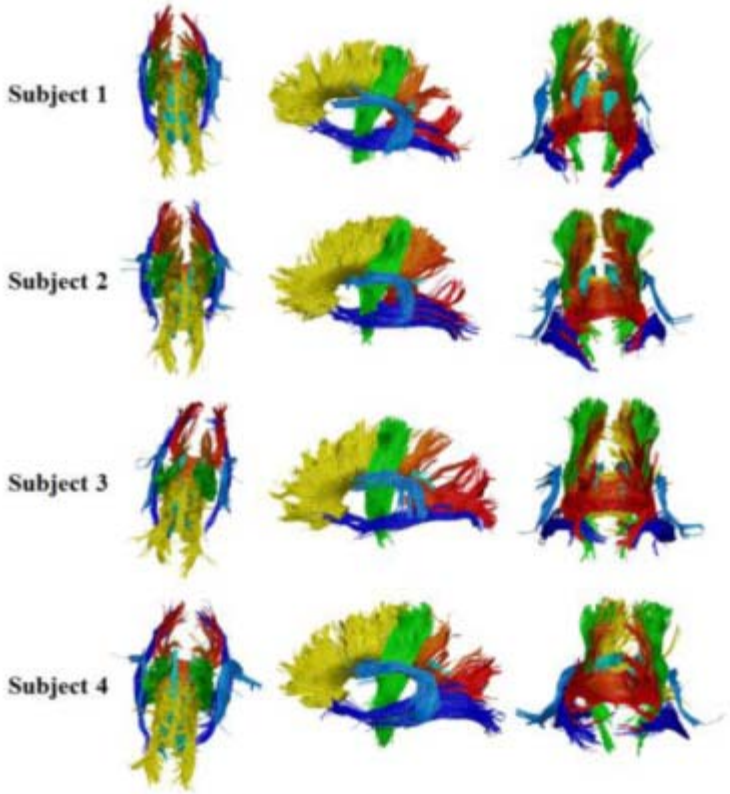

Fig. 4. Results of automatic fiber clustering in four subjects. For the tract names and colors used to distinguish them, please see **Fig. 1** (view from *top*, *left side*, and *back*, respectively).

Abstract Information

References

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