Knowledge-based Tractography Using Path Finding by Dynamic Programing

Muwei Li[1], J. Tilak Ratnanather[2], Yajing Zhang[1], Hangyi Jiang[1], Kenichi Oishi[1], Michael I. Miller[2], and Susumu Mori[1]
[1]*The Russell H. Morgan Department of Radiology and Radiological Science, Johns Hopkins University School of Medicine, Baltimore, MD, United States,* [2]*Center for Imaging Science, Johns Hopkins University, Baltimore, MD, United States*

Target audience

Tractography can reconstruct macroscopic architecture of major white matter bundles in vivo noninvasively. This study would benefit researchers who are gaining insights into brain white matter structure and help clinicians to have further understanding of pathologies, surgery planning and recovery predictions.

Purpose

Tractography results are known to have false positive and false negative results due to experimental (SNR and partial volume effect) and anatomical (crossing fibers) factors. Knowledge-based ROI-guided tractography could effectively reduce false positive.[1] In this study, we combined the knowledge-based approach with a path-finding algorithm, which finds most probable path and, thus, removing the false negative. If the knowledge-based guidance ensures removal of false positive, we expect a highly useful tool to study white matter architecture.

Methods

Twenty healthy young adults participated in this study. Subjects were scanned twice using a 3T MR scanner. The DTI dataset was acquired with a multi-slice, single-shot, echo-planar imaging (EPI), spin-echo sequence (TR/TE = 6281/67 ms, SENSE factor = 2.5). Sixty-five transverse slices were acquired with no slice gap and 2.2 mm nominal isotropic resolution (FOV = 212 × 212, data matrix = 96 × 96, reconstructed to 256 × 256). Diffusion weighting was applied along 32 directions with a b-value of 700s/mm^2. DTI images of each subject were automatically segmented to 211 structures by using an atlas-warping tool. For each tract of interest, a combination of segmented structures was defined as the knowledge-based ROIs to guide the path-finding algorithm, which was then applied to all subjects. Region-to-region path finding was based on dynamic programming method.[2]

Results

The knowledge-guided path-finding algorithm could reconstruct 16 commissural and 90 projection tracts faithfully to our anatomical knowledge, including the lateral projections, which are difficult to reveal by conventional streamline techniques. Intra-subject (test-retest) reproducibility of the method was within 2.5 mm for 22 out of 36 cortico-pontine fibers in this study. For the along-tract FA analysis, the test-retest error was 0.6% and population-variability was 4.5%. The population-probabilistic maps of these tracts are now incorporated and available in the MNI space.

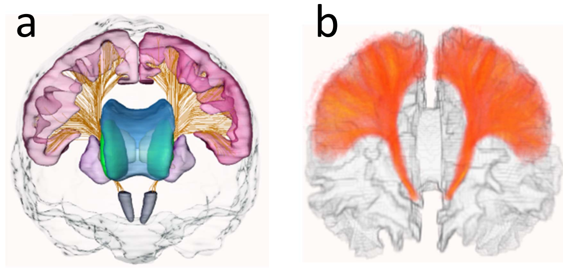

Figure1. Reconstruction of cortico-spinal tract. a) on single subject. b) probabilistic map over 21 subjects.

Discussion

The path-finding by the dynamic programming could effectively remove false negative between two regions that are known to be connected. The trajectory was guided by anatomical knowledge stored in the automatically segmented 211 structures as path-guiding ROIs. Combined with the automated brain segmentation, this approach can automatically generate 106 tracts based on our anatomical knowledge. The test-retest and inter-subject reproducibility were high. This tool can be used to investigate tract-specific white matter anatomical states in various brain disorders.

Conclusion

The path finding approach effectively removed the false positive and avoided the false negative by combining it with path-guiding ROIs, which were automatically generated by atlas warping. Test-retest reproducibility and cross-population probabilistic map of tracts certify the robustness of the approach. It improved the accuracy of tractography and provided a way to enrich our current tract atlas.

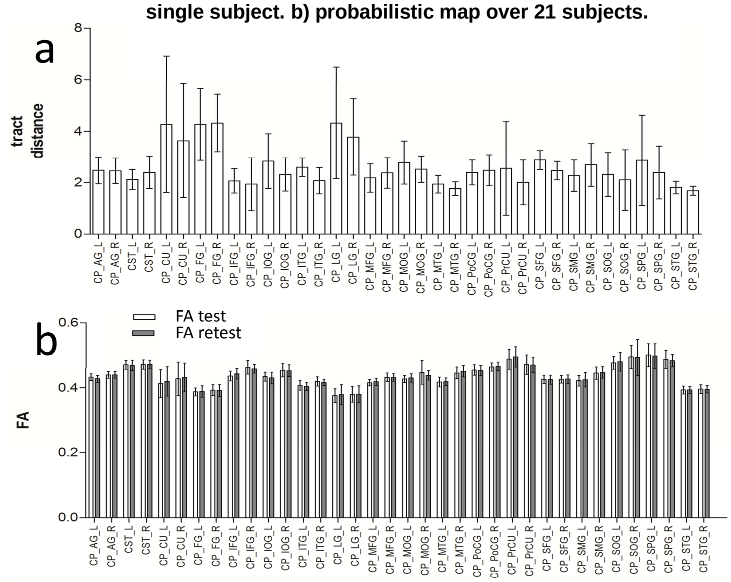

Figure2. Reproducibility validation. a) distance measurements between test and retest cortico-pontine tracts over 21 subjects. b) along-tract FA over 21 test-retest subjects.

References

1. Zhang, Y, et al. Atlas-guided tract reconstruction for automated and comprehensive examination of the white matter anatomy. Neuroimage. 2010;52(4):1289-1301.

2. LAL, R. M. 2001. Tracking in Diffusion Tensor Imaging. MSE thesis, The Johns Hopkins University.