Line propagation based on FDT probabilistic tracking (LP-FPT)

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Introduction:

Diffusion tensor imaging (DTI), a modality of MRI that measures water diffusion properties noninvasively, is highly sensitive to subtle structural changes of white matter [1]. Methods for fiber reconstruction from DTI data are mostly based on a single-tensor modal, such as the Fiber Assignment by Continuous Tracking (FACT) [2], which may be disturbed by the presence of crossing fibers and drop important fiber paths in such areas (e.g., corpus callosum (CC) and cerebellar peduncle (CP)) [3]. The probabilistic method [4] integrated in FMRIB Diffusion Toolbox (FDT) can deal with multi-fiber tractography, but it focuses on the estimation of probability of global connectivity instead of reconstruction of specific fiber tracts. Here, we proposed a line propagation method based on FDT probabilistic tracking (LP-FPT) for reproducible reconstruction of fiber tracts in areas with crossing fiber.

Methods:

DTI dataset from a 25-years old adult was acquired on a Philips 3T Achieva MR system with image resolution of 2 mm isotropic voxels, 30 independent gradient directions and b value of 1000 s/mm2. DTI dataset was preprocessed in FSL. The workflow of our LP-FPT method is shown in Fig. 1. The probability distribution of local directions of preprocessed DTI dataset (Fig. 1a) was obtained with FDT and multiple samples of the directions (Fig. 1b) were generated. With a seed region of interest (ROI) drawn for the reconstruction of particular fiber tracts (Fig. 1d), a voxel-wise map indicating the connectivity probability between every voxel and the seed ROI was gained by FDT probabilistic tracking process (Fig. 1e). Voxels with probability higher than a threshold in the probability map composed a mask (Fig. 1f). We performed a brute force tracking procedure for each sample (Fig. 1c), then selected and merged fiber paths that pass through the seed ROI and lie within the probability mask (Fig. 1g). The tracking process used similar streamlining strategy with FACT with several alterations for multi-fiber case referring to FDT [4] and our previous work [5]. During the selection and merging process, we also removed redundant fiber paths passing through overlap regions with existed ones to reduce the size of final results. The probability mask helps remove some noisy fiber tracts, and may improve the reproducibility. Here, we used Dice ratio to evaluate the reproducibility [6].
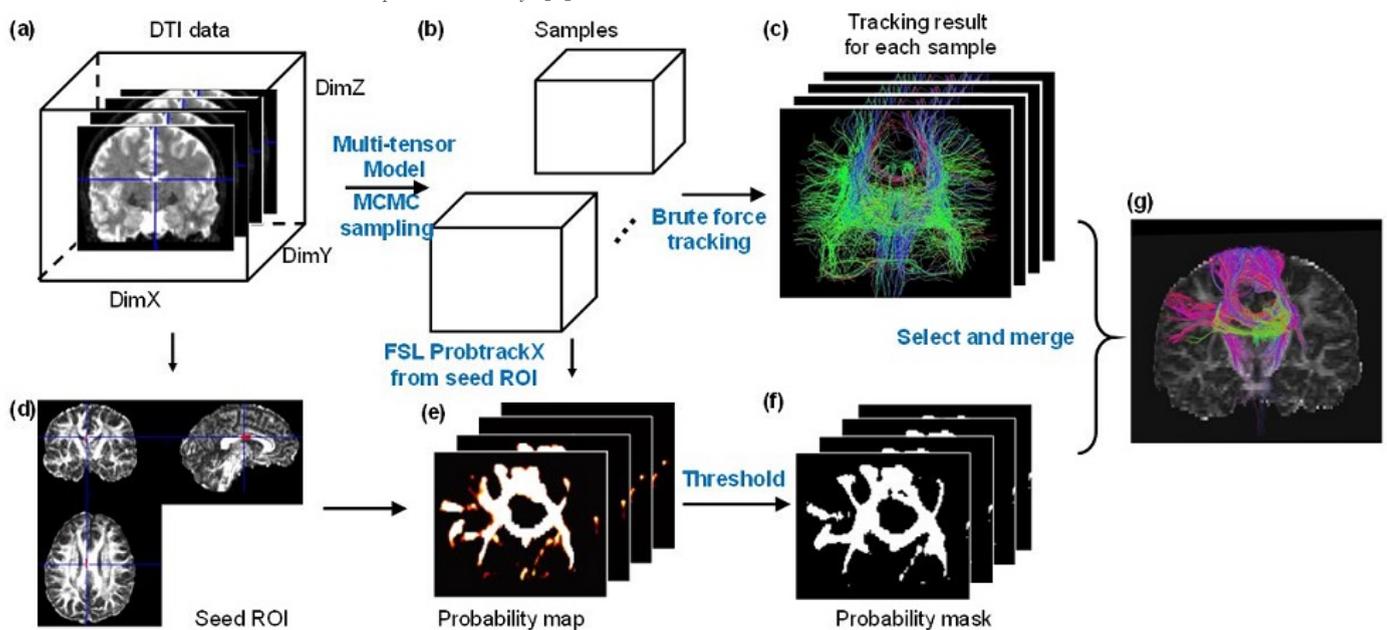

Fig. 1: The schematic pipeline of line propagation based on FDT probabilistic tracking in FSL (LP-FPT). (a) Original DTI data. (b) MCMC sampling by FSL. (c) Brute Force tracking result. (d) seed ROI selection. (e) Voxel-wise probability map connecting to seed ROI. (f) Given a threshold, we generate a binary mask. (g) Select and merge the tracking results within the mask

Results:

As a comparison, FACT was performed using Diffusion Toolkit. Fiber tracking results based on LP-FPT and FACT in two ROIs (middle of CC and CP) are shown in Fig.2. We can see several improved areas with radiation structures of both fiber bundles traced from middle of CC and CP using LP-FPT. In addition, we tested the reproducibility of LP-FPT results. We performed FDT probabilistic tracking 3 times for the test subject data and generated probability masks each time with different thresholds (5, 10, 50, and 100). The number of samples is set to be 5,000 for generating the probability map in FDT as default. Dice ratio was calculated to evaluate the spatial overlap between line propagation results with these masks of each time. A high Dice ratio indicates good reproducibility. From Table 1, we can see that the dice ratio is higher than 0.9 when the threshold for generating probability masks is above 20. LP-FPT results shown in Fig. 2 were obtained with the threshold at 20.
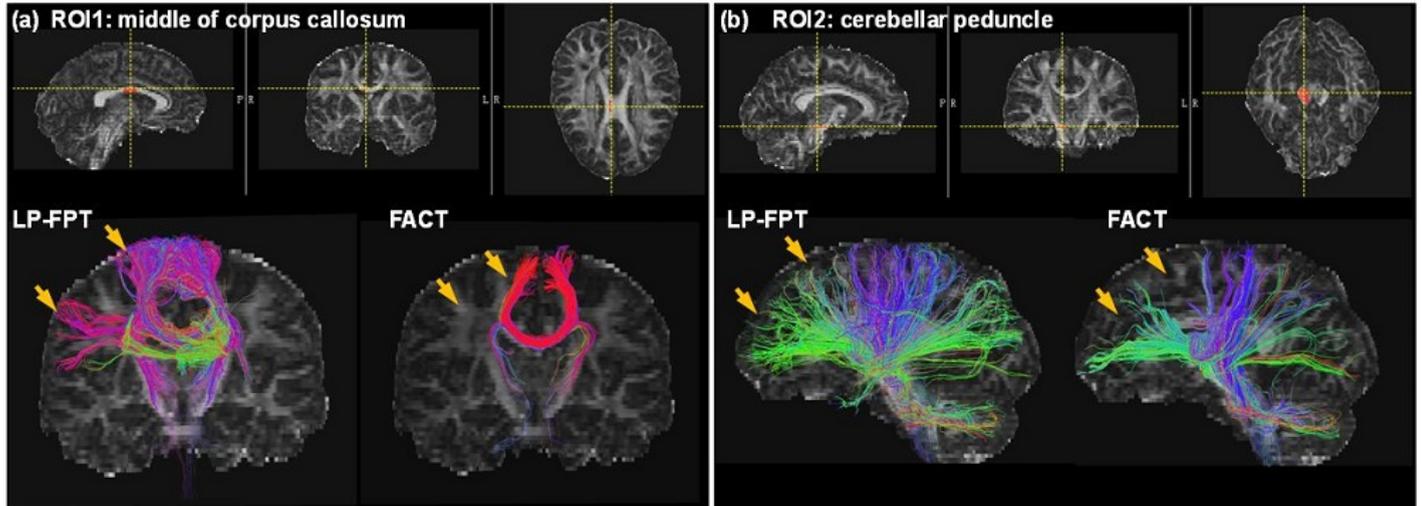

Fig. 2: Comparison of line propagation based on FDT probabilistic tracking (LP-FPT) and FACT in two representative region of interests (ROIs): middle of corpus callosum (a) and cerebellar peduncle (b). In each panel, top view shows the location of ROI, bottom right shows the fiber traced from corresponding ROI using FACT algorithm and bottom left shows the fibers traced from the same ROI using LP-FPT algorithm. Yellow arrows indicate the improved areas using LP-FPT.

Probability Map Threshold	10	20	30	40	50
Dice Ratio (the middle of Corpus Callosum)					
1 vs. 2	0.891	0.923	0.935	0.945	0.951
1 vs. 3	0.891	0.919	0.933	0.943	0.949
2 vs. 3	0.890	0.924	0.936	0.946	0.951
Dice Ratio (Cerebellar Peduncle)					
1 vs. 2	0.905	0.930	0.939	0.946	0.950
1 vs. 3	0.904	0.928	0.939	0.946	0.951
2 vs. 3	0.902	0.926	0.938	0.945	0.949

Fig. 3: Reproducibility of fiber tracking results evaluated by Dice ratio

Conclusions:

Our proposed LP-FDT obtained reproducible and improved tracking results in crossing fiber regions compared with FACT algorithm. Besides, the LP-FPT is also a better simulation of axons than the probabilistic map. This line propagation method can be useful in the study of brain structural connectivity, clinical diagnosis and pre-surgical planning.

Imaging Methods:

Diffusion MRI [2]

Modeling and Analysis Methods:

Diffusion MRI Modeling and Analysis

Neuroanatomy:

White Matter Anatomy, Fiber Pathways and Connectivity [1]

Keywords:

WHITE MATTER IMAGING - DTI, HARDI, DSI, ETC

[1|2]Indicates the priority used for review

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For human MRI, what field strength scanner do you use?

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Which processing packages did you use for your study?

    FSL

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[1] Basser, P.J. (1994), 'MR diffusion tensor spectroscopy and imaging', Biophys J, vol. 66, no. 1, pp. 259-67 1994.
[2] Mori, S. (1999), 'Three-dimensional tracking of axonal projections in the brain by magnetic resonance imaging', Ann Neurol, vol. 45, no. 2, pp. 265-9
[3] Alexander, D.C. (2005), 'Multiple-fiber reconstruction algorithms for diffusion MRI', Ann N Y Acad Sci, vol. 1064, pp. 113-33
[4] Behrens, T. (2007), 'Probabilistic diffusion tractography with multiple fibre orientations: What can we gain?', Neuroimage, vol. 34, no. 1, pp. 144 - 155
[5] Xu, M. (2012), 'Probabilistic Brain Fiber Tractography on GPUs', 2012 Ieee 26th International Parallel and Distributed Processing Symposium Workshops & Phd Forum (Ipdpsw), pp. 742-751
[6] Zou, K.H. (2004), 'Statistical validation of image segmentation quality based on a spatial overlap index', Acad Radiol, vol. 11, no. 2, pp. 178-89