Line Propagation Based On FDT Probabilistic Tracking(LP-FPT)

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Introduction

Diffusion MRI (dMRI) measures water diffusion properties noninvasively. Water molecules tend to diffuse along the white matter fibers instead of perpendicular to them. The information obtained from dMRI can then be used to reconstruct brain white matter fibers. A streamline method, Fiber Assignment by Continuous Tracking (FACT) [1], has been widely used for noninvasively tracing white matter fibers with diffusion tensor model [2]. Multiple regions-of-interests (ROI) approach [3] greatly enhanced accuracy of FACT-based streamline approach [e.g. 4]. However, FACT-based streamline tractography yields false-negative results with its known shortcoming of not being able to trace through the regions with crossing-fibers [5]. The probabilistic method [6] integrated in FMRIB Diffusion Toolbox (FDT) can deal with multi-fiber tractography, but it estimates probability of global connectivity and does not render streamlines critical for reconstructing white matter tract pathways. In this study, we proposed a line propagation method based on probabilistic tracking for reproducibly tracing the streamlines of fiber tracts in areas with crossing fiber.

Methods

Example Data.

- 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/mm^2. DTI dataset was preprocessed in FSL.

LP-FPT method.

- 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 [6] and our previous work [7]. 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 [8].

Results

Comparison with FACT.

- Fiber tracking results based on LP-FPT and FACT (using *DiffusionToolkit*) in two ROIs (middle of CC and CP) are shown in Fig.2.
- several improved areas with radiation structures of both fiber bundles traced from middle of CC and CP using LP-FPT.

reproducibility of LP-FPT.

- We performed FDT probabilistic tracking 3 times for the test DTI data and generated probability masks each time with different thresholds (10, 20, 30, 40, and 50). The number of samples is 5,000.
- Dice ratio measures the spatial overlap between line propagation results with these masks of each time. A high Dice ratio indicates good reproducibility. From Table 1, the dice ratio is higher than 0.9 when the threshold is above 20. LP-FPT results in Fig. 2 were under the threshold of 20.

Table 1. Reproducibility of fiber tracking results evaluated by Dice ratio

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

Fig1. The schematic pipeline of line propagation based on FDT probabilistic tracking in FSL (LP-FPT)

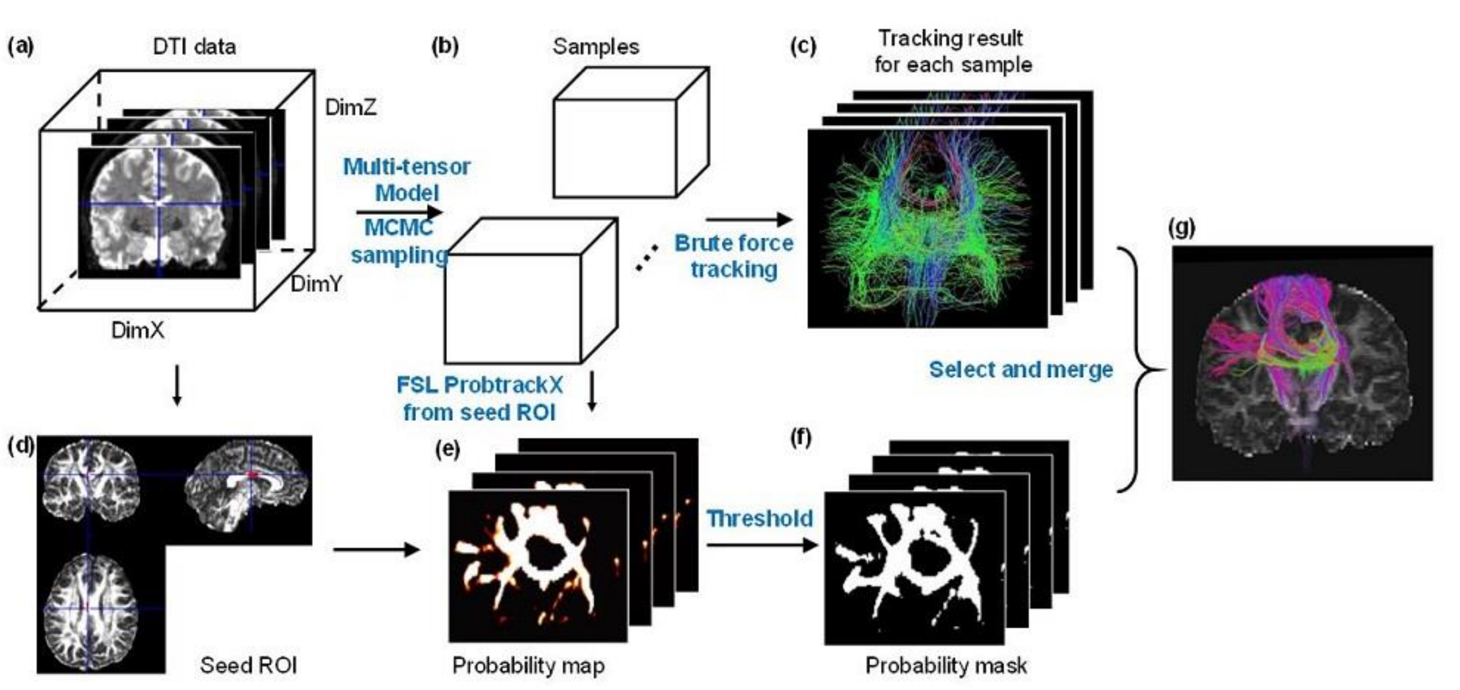
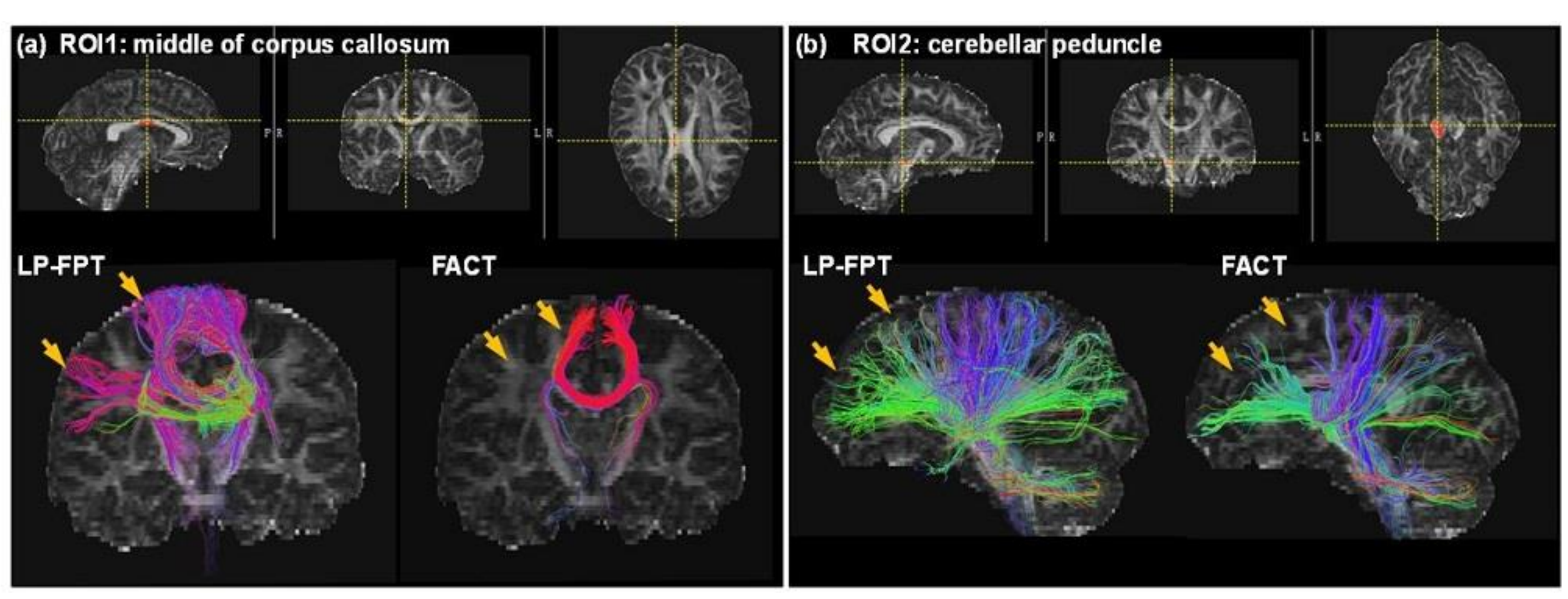


Fig2. Comparison of LP-FPT and FACT in middle of corpus callosum (a) and cerebellar peduncle (b).



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.

References

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