Pyramidal Tract Tracking based on Presegmentation of Superior Longitudinal Fasciculus and Tensor Field Interpolation

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INTRODUCTION AND PURPOSE

The fiber tracking technique [1] based on MR diffusion tensor image (DTI) is one of the standard tools for clinical neuroradiology. However, the fiber crossing problems are remaining as a limitation of the technique. Several countermeasures have been reported intensively and extensively based on imaging techniques based on higher resolution of information, including HARDI, QBI, and so on. Statistical methods with high computational costs were also proposed based on numerical simulation of diffusion, including simpler level-set implementations. However, those studies are not practical in clinical situations because of long image acquisition time and post-processing cost. In this abstract, we propose a practical approach for reconstruction of the pyramidal tracts (PT), including the corticospinal tract (CST) and the corticobulbar tract (CBT), which are important in clinical problems including neurosurgical navigation. The approach is based on pre-segmentation of the superior longitudinal fasciculus (SLF) that is a major crossing structure on the pyramidal tracts, and also based on tensor field interpolation for estimating diffusion tensors at the SLF location assuming the SLF tracts are virtually removed. By using clinical data set, we show the feasibility of our method, and numerical experiments for tensor field interpolation are also presented.

METHODS

Our technique of tracking the PTs, presegmentation of SLF, consists of 3 procedures; (1) pre-segmentation of SLF based on conventional fiber tracking algorithms or voxel-based region-growing by using tensor properties, i.e. FA value and principal direction vector, etc., (2) tensor field interpolation at the voxels classified as SLF in the previous step, and (3) fiber tracking based on conventional algorithm.

(1) ***SLF segmentation***. For pre-segmentation of the SLF, conventional fiber tracking, that is tracing principal direction of diffusion tensors, are employed. The SLF is a major structure laying in AP orientation, and therefore it can be easily extracted. Voxelization of the trajectory is also performed.

(2) ***Tensor field interpolation at SLF location***. We examined three types of tensor field interpolation metrics; diffusion tensor component-wise, Riemannian metric (Log-Euclidean [2]), and DWI signal ratio (*S/So*; *S* and *So* are DWI signals while *So* denotes signal at b=0). It has been reported that tensor field interpolation is not simple and so-called swelling effect is often observed. For interpolation, we employed radial basis function (RBF). The regions in 3 voxels thickness adjacent to the pre-segmented SLF volume are selected first, and then only voxels with high FA values (>0.4) are finally determined for control tensors for RBF interpolation.

(3) ***Fiber tracking in reformed tensor field***. Based on above procedures, we obtain a new tensor field reformed, in which SLF are virtually removed. Fiber tracking are finally performed in the reformed tensor field to extract PTs by using ROIs interactively set. The ROIs for limiting displayed trajectories are two; at white matter boundary close to brain surface, and adjacent to the central sulcus, and at the posterior limb of internal capsule.

In addition to feasibility study based on clinical data set, we performed experiments for tensor field interpolation by using 3 metrics describe above. In the experiments, we checked the swelling effect quantitatively, interns of FA value degradation.

RESULTS

Feasibility study. Fig.1 shows a result based on our proposed method with clinical DTI data of 6 MPG directions obtained with 1.5 MRI scanner. It is obvious that the whole PT structures are clearly depicted, especially the CBTs, which are very hard to obtain with the conventional methods. The difference of final results among tensor interpolation metrics are not clear while tracking termination criteria are slightly changed. It is related to the degree of the swelling effect, which are clarified through the experiment shown below.

Tensor field interpolation experiments. To clarify the difference among interpolation metrics; component-wise (CW), Log-Euclidian (LE), and signal ratio (SR), simple experiments with synthetic data sets were performed. Two tensors of identical eigenvalues and high FA value (=0.7698) are placed at the locations of x=0 and x=32 in the 3D space. One tensor at x=0 is oriented perpendicular to the plane;x=0, while the other is tilted of the angle θ. Tensors at $0<x<32$ are interpolated and two type of studies are performed. First, we observed the mean FA value change averaged on the path (x=0~32) when the angle θ is changed between 0 to $\pi/3$ (Fig.2 left). Then, at the angle of $\theta=\pi/6$, we observed the FA value at each x coordinate so that spatial change of FA degradation is clarified (Fig.2 right). As shown in Fig.2, LE shows slightly better characteristics in terms of FA degradation than other 2 metrics while $\theta<\pi/4$. However, it is also implied that performance at the higher tilt angles may ought to be improved.

SUMMARY

We have shown that the proposed method is feasible for clinical DT-MRI data set, and useful in depicting PTs. The tensor field interpolation study quantitatively shows the degree of the swelling effect, and implied that it leaves room for tensor field interpolation method with less anisotropy degradation.

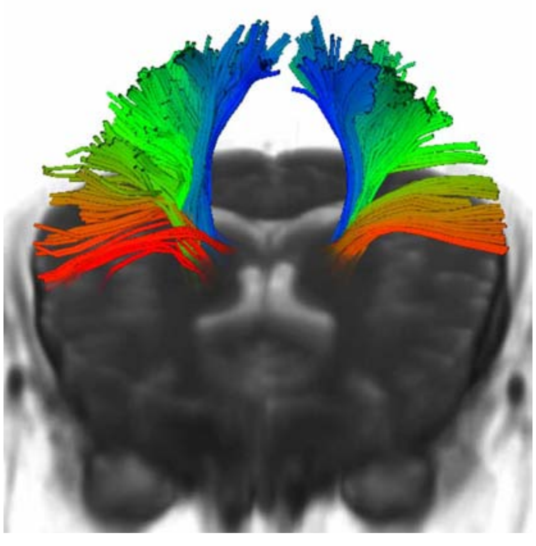

Fig.1 Tracking result by using proposed method
Trajectories are colored based on Z coordinates of seed points.

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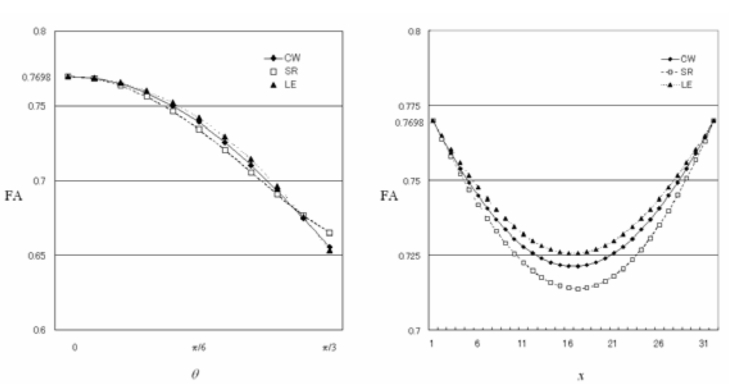

Fig.2 Comparison of swelling effect in terms of FA value
Left: FA value change due to angle between 2 tensors
Right: Spatial change of FA values
CW: component-wise, LE: Log-Euclidean, and SR: signal ratio