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A New Method of Tracking of WM Crossing Fiber Bundles Based on QBI*

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ABSTRACT

Tracking of crossing WM fiber bundles can be resolved using diffusion MRI imaging. DTI can only resolve a single fiber orientation within each voxel due to the constraints of the tensor model. DSI requires large pulsed field gradients and time-intensive sampling. This paper puts forward with a new method based on QBI, which uses a spherical tomographic inversion called Funk-Radon transform to get high angular resolution diffusion imaging signal. From the tracking results, we can get the conclusion that QBI-tracking can resolve crossing fiber time-savingly.

Keywords: Diffusion Tensor Imaging; Diffusion Spectrum Imaging; q-Ball

1. Introduction

White matter is mainly composed of nerve fibers, which are the connected channels of brain different function areas. The tracking of nerve fibers is very important for white matter disease, and is of great significance for cognitive research. Diffusion MRI has been widely used to assess the integrity of axonal fibers because of its unique ability to map fiber orientations *in vivo*.

Diffusion tensor imaging (DTI) provides a powerful tool for mapping neural histoarchitecture *in vivo*. However, DTI can only resolve a single fiber orientation within each imaging voxel due to the constraints of the tensor model. DTI cannot resolve fibers crossing, bending, or twisting within an individual voxel [1-4].

As to diffusion spectrum imaging (DSI), diffusion is described with the probability density function (PDF) which for each voxel specifies the 3D distribution of microscopic displacements of MR-visible spins that it contains. Reconstruction of the diffusion PDF by Fourier transform of the diffusion signal forms the basis of the QSI method. But DSI requires large pulsed field gradients and time-intensive sampling [5-7].

Q-ball imaging can resolve multiple orientations of crossing fiber in one voxel and does not require any assumptions on the diffusion process of water molecules.

2. Method and Material

2.1. Reconstruction of the Diffusion Orientation Distribution Function (ODF)

QBI is reconstructed based on the relationship of the interested ODF vector and its orthogonal plane projected on to the acquired q-space data. The ODF was directly calculated from the attenuated echo signal on a shell in the q-space with a fixed b-value based on the Funk-Radon transform approach.

$$\mathrm{ODF}(\mathbf{u})=\frac{1}{C}\int_{q\perp\mathbf{u}} E(q,\Delta)\mathrm{d}q \tag{1}$$

where **u** is the unit vector for the desired ODF direction, and C is the normalization constant, and E is the attenuated echo signal [8].

The diffusion MRI dataset was provided by Advanced Biomedical MRI Lab of National Taiwan University Hospital. The acquisition equipment was 3 Tesla Trio of the company Siemens of Germany, 1.9 mm × 1.9 mm × 1.9 mm, TR = 11,500 ms, TE = 31 ms, Δ/δ = 80/35 ms, the maximal b value is 4000 s/mm^2. **Figure 1** shows the reconstruction of QBI.

2.2. Tracking of Crossing Fiber Bundles

Firstly all of local maximums of ODF were got, then the parameters of angle threshold and stepping size were set; At last we found the smooth lines among the adjacent voxels. Here the value of angle threshold was set to 60 degrees, and the value of stepping size was set to 1.4 mm. The constraint of fiber bundle length was between 16 mm and 86 mm.

3. Results

Figure 2 is the tracking of whole brain WM. The first low is based on DTI, the second one is based on DSI, and the third one is based on QBI. **Figure 3** is the tracking of

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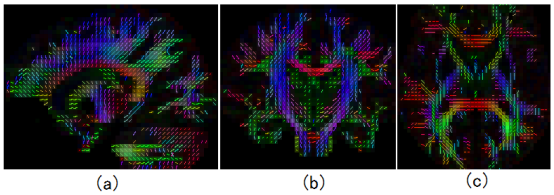

Figure 1. Reconstruction of QBI, (a) Sagittal view; (b) Coronal view; (c) Axial view.

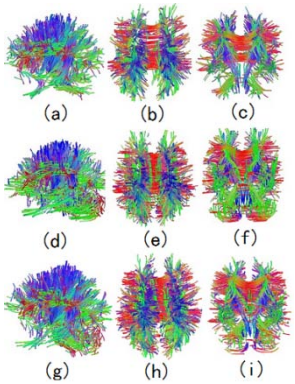

Figure 2. Tracking of whole brain. (a)-(c) DTI; (d)-(f) DSI; (g)-(i) QBI.

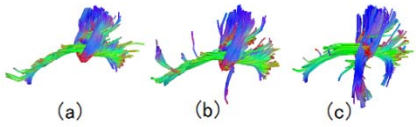

Figure 3. Tracking of corpus callosum. (a) DTI; (b) DSI; (c) QBI.

corpus callosum.

4. Conclusion

The ability of QBI to resolve crossing fibers is of great significance that helps to understand the detailed architecture of the cerebral white matter. Compared to DTI and DSI, the tracking based on QBI is capable of distinguishing crossing fiber bundles within each voxel timesavingly.

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