Combining Spherical Deconvolution and Streamline Tractography : Preliminary Results

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Introduction

Diffusion-based tractography methods allow the reconstruction of large scale white matter pathways in the living human brain. However, due to the well known inability of the Diffusion Tensor Imaging to differentiate crossing fibers within a voxel, standard tractography methods fail to correctly reconstruct white matter pathways in complex brain areas with several fiber orientations. One way to attempt to solve this problem is offered by spherical deconvolution methods [1][2][3][4]. In this work, we have combined a simple streamline tractography algorithm with a modified damped Richardson-Lucy spherical deconvolution algorithm [4]. Performances of this approach were tested in regions with several fibre crossings. Preliminary results on in-vivo data are shown.

Methods

Acquisition: A normal brain was acquired on a 3T Philips Intera scanner (Philips Medical System, Best, The Netherlands) with: FOV=240x240 mm, matrix=128x128, slices=40, slice thickness=2.5 mm, NEX=1, SENSE factor=2, TE=74ms, bvalue=3000 s/mm^2, # DW-directions=60. Cardiac gating was applied with an effective TR of 14 R-R intervals. Total scan time was approximately 16 min.

Processing: Deconvolution was performed using a damped version of the Richardson Lucy spherical deconvolution algorithm as described in [4]. We applied as fibre response a tensor equal to [1.5 0.3 0.3] 10^{-3} mm^2/s and 200 algorithm iterations.

Tracking algorithm: The tracking procedure was performed applying a streamline approach. ROIs were placed as shown in fig. 1 (yellow marks). Tracks were propagated using a 4th order Runge-Kutta method, following the fiber direction of least curvature. Tracking was stopped when curvature was > 40° or when the convergence speed index of the deconvolution algorithm was < 0.15 [5].

Results

In fig 2, the unnormalized fiber orientations obtained with the spherical deconvolution algorithm are shown. To better visualize fiber crossing regions, the amplitude of fiber orientations was exaggerated in high anisotropic tissues. White matter organization and distinct pathways are clearly visible. In fig. 3 the pathways passing through the ROI are reconstructed in different colours. The streamlines of the corpus callosum (white) crossed the streamlines of the subcallosal fasciculus (yellow), the internal capsule (red) and the superior longitudinal fasciculus (not shown) to reach the lateral frontal cortex. Similarly the internal capsule streamlines crossed the other two populations of streamlines to reach dorsal frontal cortex.

Discussion and conclusion

This method was able to propagate successfully streamlines in regions with high fiber crossing density and revealed the presence of streamlines of the subcallosal tract, a poorly myelinated bundle connecting the dorsolateral prefrontal cortex to the head of the caudate. The method, however, performed poorly in regions with high fibre kissing or spreading density leading to a partial reconstruction of the lateral projections of the internal capsule. Further optimizations of this method are necessary and are currently being developed.

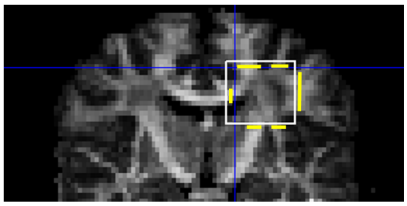

Fig.1

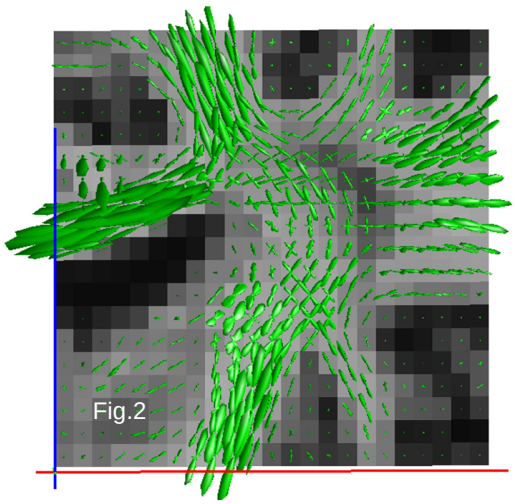

Fig.2

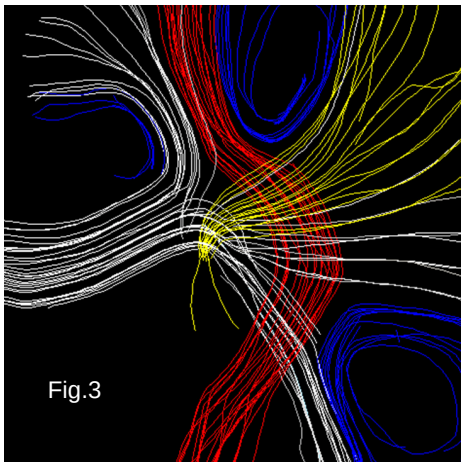

Fig.3

References: [1] Tournier JD et al, NeuroImage, 23:1176-1185 (2004) ; [2] Anderson AW, MRM 54:1194-1206, (2005) [3] Alexander DC Proc. IPMI (2005); [4] Dell'Acqua et al proc. 16th ISMRM (2008-submitted); [5] Dell'Acqua et al. NeuroImage 31, S1, s953 / Proc. 12th OHBM (2006).