DTI fibre tracking: beyond the main eigenvector

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Target audience: Researchers interested in DTI and fibre tracking based on DTI.

Purpose: DTI is a well-known imaging technique allowing one to visualize neuronal tissue in the human brain. Many fibre tracking algorithms are described in the literature and accessible for the MRI community[1-4]. However, all DTI fibre tracking approaches operate only with the main eigenvector and only a few publications are devoted to the information hidden in the second and third eigenvectors[5,6]. It is known that the three eigenvectors of the diffusion tensor produce an orthonormal basis in the space. The basis could potentially establish a structure between neighbouring voxels, similar to a crystal lattice. This kind of "fibre lattice" can be generated using the tracts reconstructed from the second and third eigenvectors. In order to test the "fibre lattice" hypothesis we performed numerical simulations and applied this approach to an *in vivo* dataset.

Methods: The "fibre lattice" approach was tested on numerical simulations and seven *in vivo* datasets. In the simulations four 3D regions were set up with different diffusion parameters (main eigenvector direction, mean diffusivity, and fractional anisotropy). The regions represent typical tissue property: isotropic (CSF), two regions with high anisotropy (white matter) and one region with low anisotropy (grey matter). In all simulations Rician noise is applied. For the estimation of the diffusion tensor and related eigenvalues the ExploreDTI toolkit was used[2]. In order to produce the fibre tracking for each eigenvector we kept the eigenvalues of the original diffusion tensor and permuted the eigenvectors only. For each eigenvector permutation we used the conventional streamline algorithm with equal parameters (FA threshold 0.2, angle deviation 30°). In order to produce the merged "fibre lattice" a simple convolution approach was realized for the three estimated tracts based on the different eigenvectors.

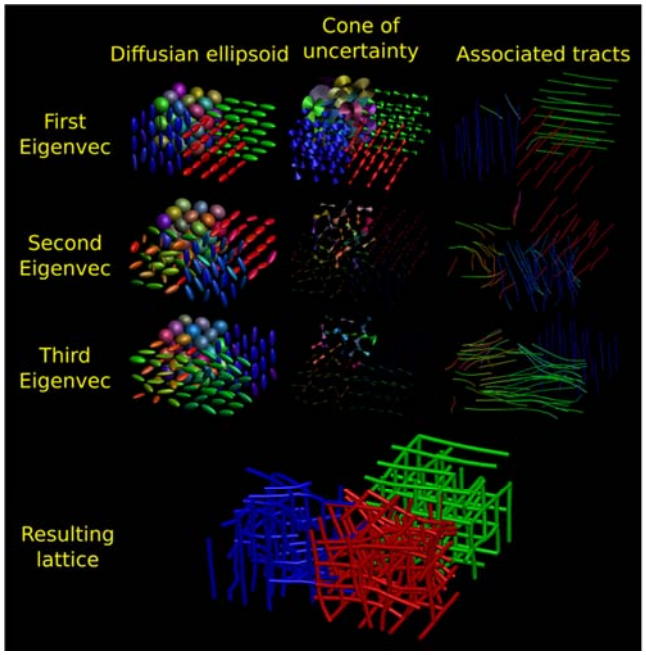

Figure 1. Result of numerical simulations. The first row represents the conventional parameters of the diffusion tensor of four regions.

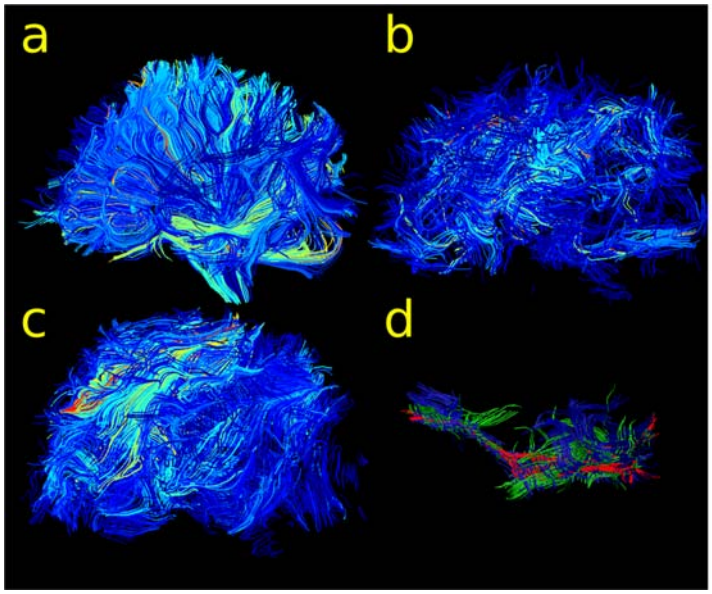

Figure 2. Fibre tracking (a) normal, based on the second eigenvector (b), based on third eigenvector (c), and left fronto-occipital faciculus generated by the merged "crystal lattice". In (a)-(c) the colour corresponds to fibre length, in (d) – to the eigenvectors: red – main, green – second, and blue – third.

Results: In Fig. 1 we present the results from simulations. Each row corresponds to a given eigenvector permutation. The last row shows the resulting "fibre lattice" obtained after merging of all tracts for each region and marked by different colours (green and red colours reflect WM, blue colour is GM, and no lattice corresponds to CSF). A similar approach was applied for the *in vivo* dataset and the results are presented in Fig. 2. Figs. 2a-c present the whole brain fibre tracts based on the main, second and third eigenvectors, respectively. Fig. 2d exhibits the reconstructed "fibre lattice" for the left fronto-occipital fasciculus.

Discussion and conclusion: We hypothesized that in regions with high anisotropy we can extract the so-called "fibre lattice" generated by the tracts based on the three eigenvectors. Such kind of lattice could keep its structure along the conventional fibre tract and allows one to improve the tract estimation/segmentation. Thus, one could build the "fibre lattice" for conventional tracts and introduce numerical parameters from crystal physics, which could be treated as a source of additional biomarkers of fibre tract integrity in the white matter.

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References: 1. Smith et al., NeuroImage 23(S1) (2004) 208. 2. Leemans et al., Proc. ISMRM 17 (2009) 3537. 3. Cook et al., Proc ISMRM 14 (2006) 2759. 4. Toussaint et al., Proc MICCAI 07 (2007). 5. Mamata et al., Proc. ISMRM 10 (2002). 6. Zhang et al., MRM 55 (2006) 439.