Track Ribbons - Visualising Structural Information in Diffusion Tensor Axial Asymmetry

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Introduction

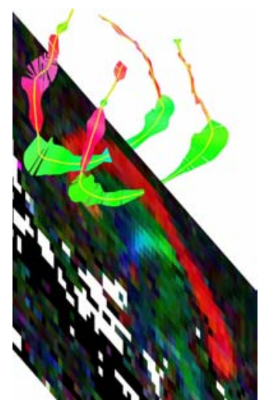
Diffusion tensor tractography uses only the principal eigenvector to determine a track direction. Information about the orientation of the 2nd and 3rd eigenvectors is typically ignored and the corresponding eigenvalues used only for calculating fractional anisotropy (FA). There is evidence across subjects of consistent anatomical structure in the minor eigenvector directions [1,2]. These studies presented image slices color-coded by the directions of the 2nd or 3rd eigenvectors from which it is difficult to infer information about their variation along the length of a 3D track. Jones et al [3] used a streamtube approach to display tensor-derived quantities along a fibre path but did not visualise the eigenvector directions. Here we devise a new visualisation that plots a ribbon along the track. The ribbon width is proportional to the tensor axial asymmetry and the ribbon normal and color are given by the 3rd eigenvector direction. The plane of the ribbon is the same as if the diffusion ellipsoid were squashed flat along its shortest axis. In regions where the tensor is axially symmetric, the 2nd and 3rd eigenvectors are degenerate but here our ribbon has no width. Axial asymmetry may result from asymmetries in the way axons are organised in cross section, it may be related to fibre packing or to the crossing of axonal pathways. We present results from the mid-body of the corpus callosum where fibre crossing is not expected.

Methods

Data from 10 volunteers ranging in age from 21 to 74 was taken from the IXI database [4]. Scan parameters were: Philips 3T Intera, b=1000 s/mm^2, 15 diffusion gradient directions and reconstructed image 128x128x64. Tracks were seeded manually in the body of the corpus callosum as this is easily identifiable, is not expected to contain crossing or dispersing fibres and has less chance of partial voluming effects. At each point along a track, a colored patch was added with width proportional to (v2 – v3) / (v1 + v2 + v3) where vj is the jth eigenvalue. The direction of the 3rd eigenvector determines the patch normal and local color. The conventional scheme is used with red left-right, green anterior-posterior and blue head-foot.

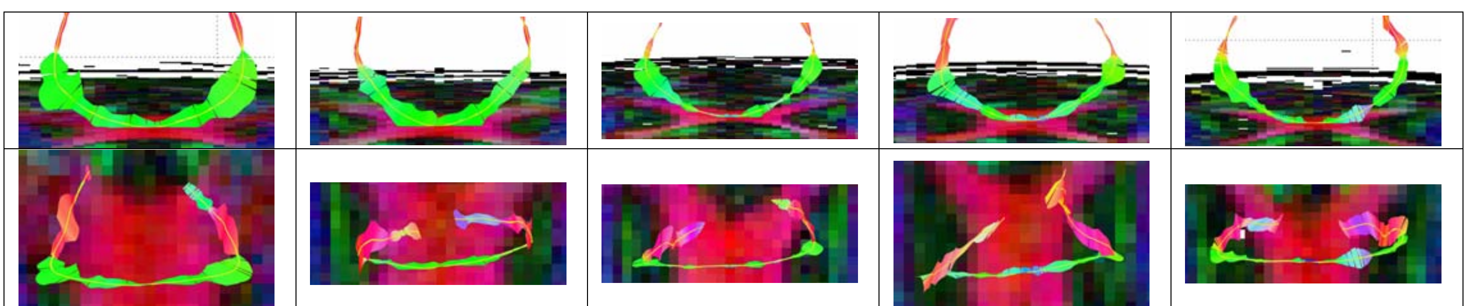
Results

Figure 1 shows an example of two fibres seeded near the mid-body of the corpus callosum. The underlying image is a sagittal FA map with conventional color coding determined by the principal eigenvector direction. The ribbons appear green in the body of the corpus callosum and as the fibres ascend, the ribbons turn red in the region of the corona radiata. Figure 2 shows track ribbons from 5 volunteers each seeded in the mid-body viewed from the posterior direction (upper row) and the top of the head (lower row). The underlying images are axial FA maps. Visually similar results were obtained on another 5 volunteers with a similar age and gender spread. Across age and sex we consistently observe a predominantly green ribbon in the centre of the body of the corpus callosum i.e. axially asymmetric tensors with the shortest axis being in the anterior-posterior direction.



Discussion and Conclusion

We speculate that our observations of consistent axial asymmetry in the mid-body of corpus callosum are related to fibre organisation and note an apparent directional structure visible in an electron micrograph of a sagittal cross section of tissue [5]. We have presented a method that can visualise potentially new information concerning the organisation and arrangement of white matter architecture in the human brain. The method may also provide new contrast for investigating white matter tract damage following pathology.



Female 21	Male 41	Male 55	Female 63	Female 74

[1] Lazar et al. *Axial Asymmetry of Water Diffusion in Brain White Matter*. Magn Reson Med 2005;54:860-867.
[2] Zhang et al. *Image Contrast Using the Secondary and Tertiary Eigenvectors in Diffusion Tensor Imaging*. Magn Reson Med 2006; 55:439-449.
[3] Jones et al. PASTA: *Pointwise Assessment of Streamline Tractography Attributes*. Magn Reson Med 2005;53:1462-1467.
[4] IXI Information eXtraction from Images http://www.ixi.org.uk , a UK e-science core-funded project.
[5] Aboitz F et al. *Fiber composition of the human corpus callosum*. Brain Research 1992;598:143-153.