ORIENTATION-DEPENDENT RENDERING OF DIFFUSION FIBER TRACTOGRAPHY STREAMLINES FOR IMPROVED VISUALIZATION OF COMPLEX TISSUE ORGANIZATION

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Purpose The complex nature of diffusion MRI data has triggered the development of new approaches to visualize microstructural diffusion properties. With emerging human connectome studies and the growing interest of applying diffusion MRI tractography in surgical planning and other clinical applications, visualizing the architectural organization of diffusion MRI trajectories is becoming increasingly important [1]. However, the great overlap of pathways and the ability to resolve 'crossing fibers' at a voxel level often makes such visualizations cluttered and obscure [1]. We propose a visualization approach that interactively and selectively visualizes these tracts based on their local orientation, by applying an orientation-dependent transparency rendering to the fiber pathways, to achieve a more surveyable and clear picture of the 3D architectural organization of these fiber trajectories. This greatly improves the visualization and exploration of underlying tissue configurations that otherwise would be largely covered by other pathways in conventional visualization approaches.

Methods Orientation-dependent rendering: The local tract orientation is defined as the normalized vector connecting two subsequent points in a tract. Opacity was defined in terms of the inner product between the tract orientation and a predefined 'opacity axis'. Two different opacity functions were defined, see Eq. (1) and (2) in Table 1. The constant t can be used to tune the opacity. Eq. (1) shows decreasing opacity (increasing transparency) with increasing alignment of tract orientation and opacity axis, which is for example useful when setting the opacity axis equal to the 'viewing axis' (the axis normal to the screen). In Eq. (2), opacity increases with alignment, which can be used to look at tracts that are oriented along a particular axis. Data acquisition and processing: Two diffusion weighted (DW) data sets were acquired on a 3T MR scanner: One healthy subject ($2\ mm$ isotropic voxels, one non-DW image and 60 DW images ($b = 2500\ s/mm^2$) with the gradient directions uniformly distributed over the sphere [2]), and a patient with a tumor interrupting the corpus callosum (CC) ($1.75 \times 1.75 \times 2\ mm$ voxels, one non-DW image and 31 $b = 800\ s/mm^2$ images). After correction for subject motion and eddy current induced geometric distortions [3], whole brain CSD ($l_{max} = 8$) tractography (healthy subject) and DTI tractography (patient) were performed with *ExploreDTI* [4].

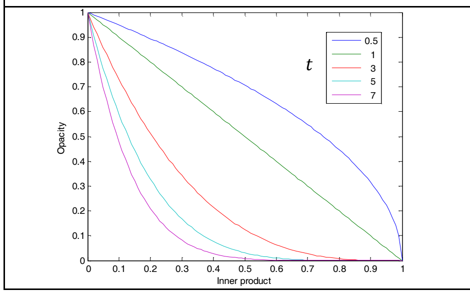
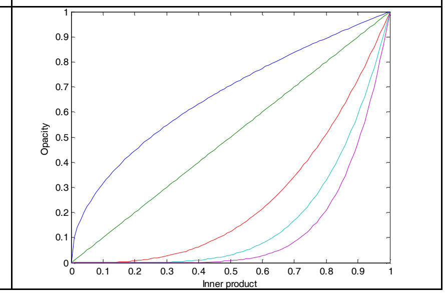
$opacity = (1 - \lvert \textbf{tract orientation} \cdot \textbf{opacity axis} \rvert)^t$ (1)	$opacity = \lvert \textbf{tract orientation} \cdot \textbf{opacity axis} \rvert^t$ (2)
	

Table 1: Two different functions used for opacity with their corresponding graphs for different tuning constants t.

Results Fig. 1 compares conventional tract rendering (a) with orientation-dependent transparency rendering (b) where the opacity axis is set equal to the 'viewing axis' and Eq. (1) is used as opacity function. Pathway segments that are more aligned along the viewing axis are more transparent, improving the visualization of the underlying tissue configuration perpendicular to the viewing axis. Fig. 2 shows a sagittal view in which the opacity axis is defined along the inferosuperior (a) and anteroposterior (b) axis using Eq. (2), thus rendering tract segments aligned with the opacity axis more opaque, virtually eliminating tracts in all the other directions. Transparency rendering in the patient shows that also the left cingulum bundle is (partially) interrupted (Fig. 3 (b), white arrow), which can hardly be seen in the conventional visualization (Fig. 3 (a)).

Discussion and Conclusion The orientation-dependent transparency rendering of tracts presented in this work provides a way to explore the (underlying) tract architecture by *interactively* looking at the brain from different perspectives, avoiding cluttered and obscure visualizations. More explicitly, tracts that are oriented along the viewing axis can be made more transparent, so that they do not obscure underlying pathways. Alternatively, one can exclusively look at tracts that are oriented along a particular axis, virtually eliminating all other tracts. In future work, we will also look at *global* transparency rendering of tracts, e.g. by using the mean tract direction.

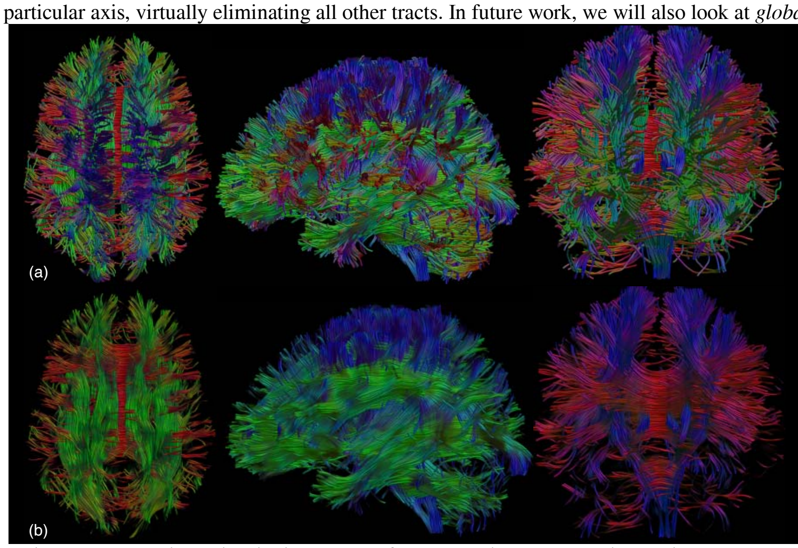


Fig. 1: (a) Conventional visualization approach for whole brain tractography in an axial, coronal and sagittal view, respectively. (b) Orientation-dependent transparency rendering in the direction of the viewing axis, using opacity function (1) ($t = 5$).

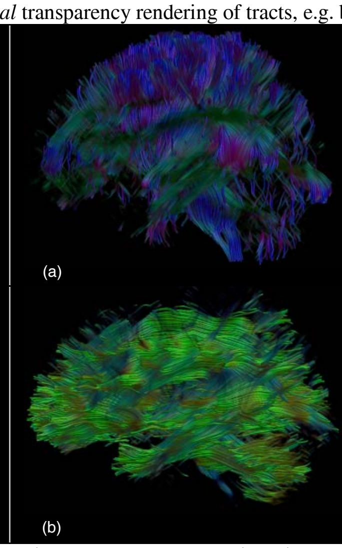


Fig. 2: Transparency rendering with the opacity axis in inferosuperior- (a) and anteroposterior direction (b), using opacity function (2) ($t = 5$).

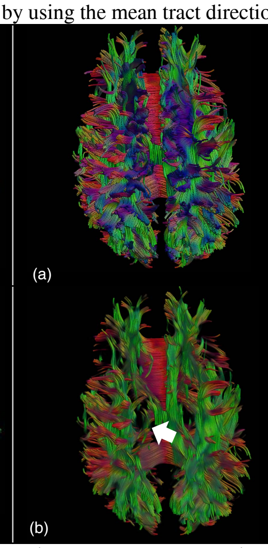


Fig. 3: Transparency rendering in the direction of the viewing axis (Eq. (1), $t = 5$), reveals interruption of the cingulum (b) (white arrow).

References

1. Margulies et al, NeuroImage 80:445-461, 2013; 2. Jones et al, MRM 42:515-525, 1999; 3. Leemans et al, MRM 61:1336-1349, 2009; 4. www.ExploreDTI.com;