Incorporating directional information in diffusion tractography derived maps: angular track imaging (ATI)

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Introduction: A number of diffusion tractography derived scalar maps have been introduced, including track density imaging (TDI, [1]) and average pathlength map (APM, [2]). More recently, information of underlying white matter structural integrity (such as FA) was incorporated in these maps ([3],[4]). In [3], additional directional information was incorporated by separating the streamlines according to peaks of the local fibre orientation distribution (FOD). We extend this technique by using the directional information contained within the streamlines themselves to build an angular track image (ATI) independent of the FOD. ATIs can be displayed and statistically analyzed in the same manner as FODs [5]. In this paper, we describe ATI using streamline number (angular equivalent to TDI), however other metrics, such as streamline length, FA or the apparent fibre density (AFD) [5] can be mapped in the same way.

Methods: MRI data were acquired for one healthy adult participant (female, age 18 years) using a 3T scanner. Diffusion-weighted images were acquired along 64 non-collinear directions at b = 3000 s/mm^2 with an isotropic resolution of 2.5 mm. Image preprocessing included correction for head movement, susceptibility distortions and intensity inhomogeneities. FODs were estimated by constrained spherical deconvolution [6] using MRtrix. One million probabilistic streamlines were generated by seeding randomly throughout the entire brain volume. A colour-coded TDI was generated as described previously [1] at 1 mm isotropic resolution for comparison.

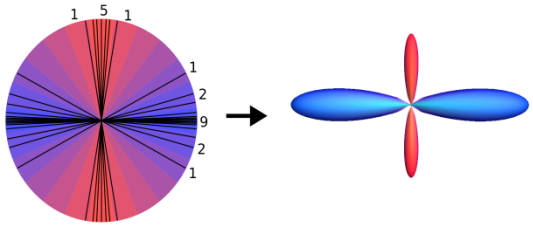

Figure 1: Left: Every streamline (black lines) is assigned to a sampling direction (indicated by coloured segments of the circle), and the number of streamlines within every segment is counted. This information is then visualised using a weighted SH point spread function [5] per sampling vector.

The ATI was calculated along 300 equally distributed sampling vectors using a "binning" approach. This involved assigning each streamline within each voxel to the closest sampling vector (based on the tract tangent), and increasing the streamline count of this particular sampling vector. For visualization, this information was subsequently encoded into "FOD-like" lobes by computing a spherical harmonic point spread function (PSF) along each sampling vector (maximum harmonic degree 8) [5].

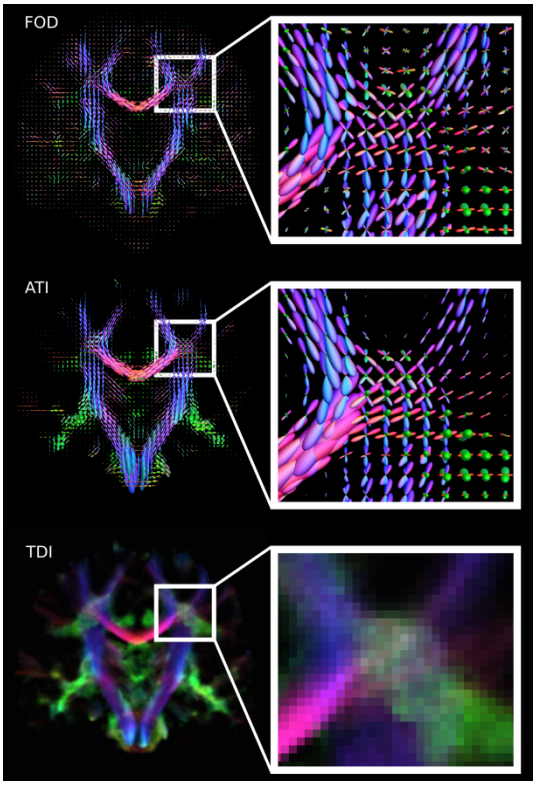

Figure 2: FOD (top), ATI (centre) and colour TDI (bottom) of a coronal brain slice.

Each PSF was then scaled with a weight relative to the number of streamlines that were assigned to the corresponding sampling vector. All weighted PSFs were then summed within each voxel. A schematic diagram of this process is given in Figure 1.

Results and Discussion: An example coronal image slice of the ATI is shown in Figure 2 in direct comparison to FOD and colour-coded TDI. While the FOD contains information about intra-axonal volume of axons thought to be aligned with a given orientation [5], the ATI reveals information about angular tractography streamline distribution. The directions of the lobes of the ATI are overall similar compared to those of the FOD, while they differ significantly in size (Figure 2). In this example the ATI was calculated in native resolution (2.5 mm isotropic), however they possess the same super-resolution property as TDI [1] and other tractography derived maps.

Information other than streamline number, such as streamline length, or mean streamline FA, etc can also be incorporated in the calculation of the ATI. Importantly, the information contained within *weighted* ATI is quantitative (e.g. mean streamline FA, independent of streamline count). Therefore, these maps can be easily compared across participants. ATIs provide more detailed information than scalar tractography maps by incorporating a directional component (Figure 2). Furthermore, they provide a more complete picture than the directional maps described previously [3] because the directional component is not restricted to the main peaks of the FOD. We note that like AFD voxel-based analysis [5] statistical analysis of ATI can be performed using cluster-based permutation testing on population differences extended through space and orientation.

References:

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