Towards a Unique Segmentation Map of Seed Points for Generation of White Matter Pathways

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Introduction

Generation of fibre pathways by diffusion tensor imaging requires an investment of time and anatomical expertise that may limit its widespread clinical application. Current fibre tracking techniques (1) involve placement of regions of interest (ROIs) that are vulnerable to inter and intra-rater variability. Here we present a method for creating a whole-brain map of seed points (voxel centres) that generate segmented fibre pathways based on user-defined anatomical labels. This technique removes the need for ROI placement. It involves repeated application of a region growing algorithm (RGA) that segments white matter pathways from single user-defined voxels until all voxels are assigned. This labelling process exhaustively identifies all voxels that generate fibre tracks throughout the entire brain and provides a map of seed points from which pathways are reconstructed. Seed points are mapped rather than the tracks they produce because an image voxel does not always belong exclusively to a single track. For example in Figure 1 the central voxel belongs to three separate tracks and consequently three maps would be required to display the track morphology, but only one map is required to display the track seed points.

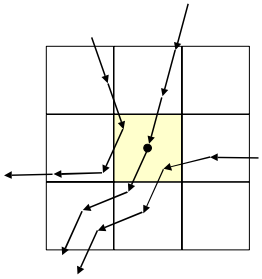

Figure 1

Methods

MRI Data Acquisition: Ten healthy subjects were scanned on a 1.5T General Electric Signa MRI system with maximum field gradient strength of 22mTm^{-1}. Diffusion tensor imaging (DTI) was achieved using a single shot echo planar sequence with 12 diffusion sensitised directions (2). Whole brain coverage was achieved with two interleaved acquisitions comprising 25 slices each. In plane resolution was 2.5mm and through plane resolution was 2.8mm. Each subject's DTI was normalised by affine transformation using the method of Alexander et al., (3), thus preserving the orientation of the tensor field. A normalised mean DTI was then computed (4).

Anatomical Labelling: The co-ordinates of regions anywhere in the brain where a track could potentially terminate were labelled (fig.2). Figure 2 displays a sagittal projection of labelled co-ordinates in the left half of the brain coloured according to the anatomical structure in which the tracks end. For example, frontal lobe structures are coloured red, parietal lobe structures dark blue and temporal lobe structures light blue.

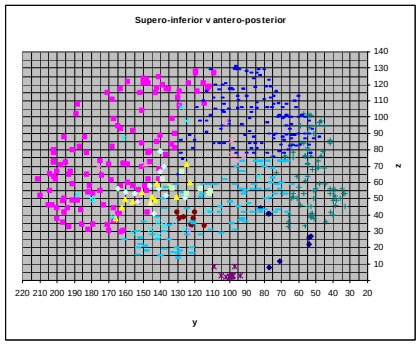

Figure 2

Fibre Tracking: Subvoxel principal direction tracking was performed by interpolation of the tensor field (5). Tracking was initiated from the centre of every voxel in the normalised mean DTI for an FA above 0.08, with vector step length 0.8mm and no angular threshold.

Pathway Segmentation: Each putative pathway in a given brain region was grown from a single user-defined seed point by application of the RGA (flowchart in 6). This found the co-ordinates of the origin and termination of each putative pathway. Pathway termination co-ordinates were then labelled by an automatic algorithm that found the nearest anatomical location using the map of labelled points (fig.2). Valid pathways with the same anatomical label at their origin and termination were merged to form a single pathway. The seed points generating this pathway were assigned an anatomical label based on the pathway's termination co-ordinates. Once all pathways from a region of the brain were identified, a segmentation map consisting of seed points for these pathways was constructed (e.g. fig.3, a, b). Seed points generating different pathways were displayed as different colours and a cursor moving over this coloured map revealed the corresponding anatomical label for the pathway termination points. Pathways were then reconstructed by initiating fibre tracking from the centre of seed points bearing the same anatomical label.

Results

The segmented seed map of the supramarginal gyrus and its associated pathways are presented as an illustration of the method in fig.3. A parasagittal and an axial plane through the segmented seed map are shown overlaid on slices of the mean FA image in the central part of the upper and lower sections of the figure. The pathways emerging from the supramarginal gyrus are displayed to each side (a-f), and are coloured according to orientation. Vertical components are coloured blue, antero-posterior components green and medio-lateral components red. The pathways terminate in the inferior part of the precentral gyrus (a and d), the inferior part of the postcentral gyrus (b and e) and the posterior part of the temporal lobe at the confluence of the middle and inferior gyri (c and f). The anatomical label for these pathway termination points is represented by coloured voxels in the centre of the figure (inferior part of the precentral gyrus: yellow; inferior part of the postcentral gyrus: green; the confluence of the middle and inferior temporal gyri: brown).

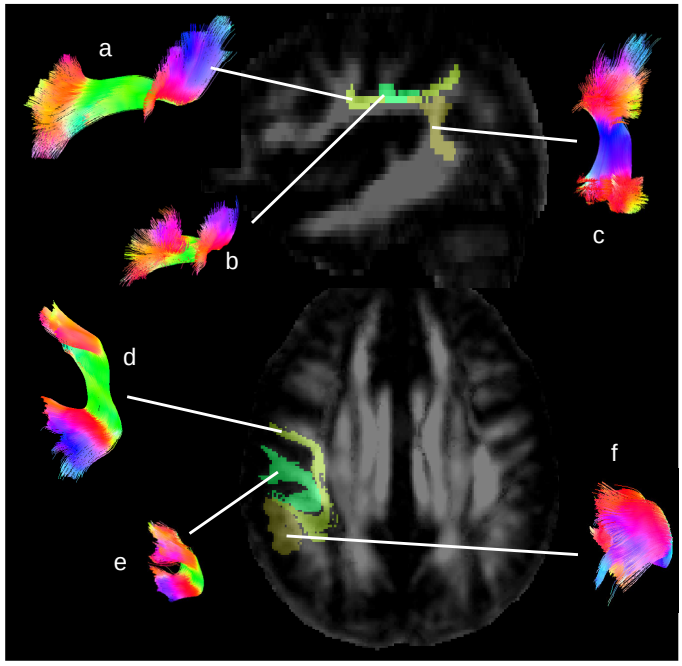

Figure 3

Discussion

A comprehensive map of the destinations of pathways seeded from labelled voxels has several advantages over current ROI based pathway reconstruction techniques. Firstly, it is possible to check that all of a region has given rise to a pathway, allowing missed voxels to be included and erroneous voxels excluded. Secondly, because the same voxels are identified each time, inter and intra-rater variation is minimised. Finally, pathway seed points can be automatically extracted from the segmented map, providing a compact method of data storage. Potentially, the stored map can be compared to fMRI and other data placed in register with the nearest contiguous seed points.

References

[1] Conturo TE et al., 1999 *Proc Nat Acad Sci*, **96**: 10422-10427
[2] Clark CA, Barrick TR, et al., *Neuroimage*, in press.
[3] Alexander DC et al., *IEEE Trans Med Imaging*, 2001; **20(11):** 1131-1139.
[4] Jones DK et al., *Neuroimage*, 2002; **17:** 592-617.
[5] Barrick TR and Clark CA, 2003, ISMRM, Toronto, #2159
[6] Barrick TR, Lawes INC & Clark CA, submitted to ISMRM, 2004