A comparison of seeding strategies for group tractography

J. D. Clayden[1], A. J. Storkey[2], and M. E. Bastin[3]
[1]Institute of Child Health, University College London, London, United Kingdom, [2]School of Informatics, University of Edinburgh, Edinburgh, United Kingdom,
[3]Medical and Radiological Sciences (Medical Physics), University of Edinburgh, Edinburgh, United Kingdom

Introduction

For clinical studies into the effects of pathology on white matter, it is desirable to robustly segment specific tracts from magnetic resonance images. Fiber tracking, or tractography, algorithms are increasingly widely used for this kind of segmentation, but they are sensitive to initialization, which in most cases takes the form of a seed voxel. There are now a number of strategies extant in the literature for choosing seed voxels, and in this study we aim to compare and discuss the issues associated with each approach.

Methods

The data used for this study were acquired from a single 30 year old male volunteer, using a spin-echo echo-planar diffusion MRI protocol consisting of 51 noncollinear diffusion sensitizing gradient directions at 1.5 T, using a *b*-value of 1000 s mm^{-2}. Three T2-weighted volumes were also acquired. In-plane resolution was 1.72×1.72 mm, and slice thickness was 2.8 mm. The data were processed to correct for eddy current induced distortions and extract the brain, using FSL tools (FMRIB, Oxford, UK). The former step involves registering each volume to one of the T2-weighted volumes.

A single starting seed voxel was placed in the MNI standard space brain template within the corpus callosum splenium, at coordinates (-6,-40,14). The reference T2-weighted volume from the subject was then registered to the standard brain using the FLIRT algorithm [1], and the seed voxel was transferred back into native space using the inverse transformation. Tractography was run using this voxel as a seed. A 7×7×7 voxel neighborhood centered at this starting voxel was then used as a seeding region of interest (ROI), and tractography was run using each voxel within the ROI as a seed voxel in turn. The neighborhood tractography method [2] was used to select the single seed voxel in the neighborhood which best matched a reference tract which was created in advance from independent data (see Fig. 1). In addition, the sum of the outputs from tractography in all the voxels in the seed ROI, subject to a conservative anisotropy threshold, was used as the third seeding strategy. Finally, two additional 7×7×7 voxel ROIs were defined either side of the midplane in regions where the tract was expected to pass through, and only those results from the seed ROI which also passed through these two "waypoint" ROIs were retained. All of the above-described seeding strategies have been used previously in the literature. The BEDPOST/ProbTrack algorithm [3] was used for tractography in each case.

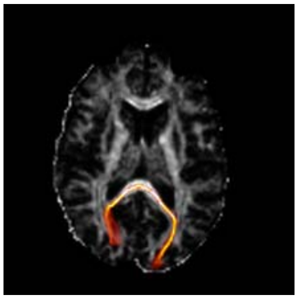

Fig. 1: *The reference tract used for neighborhood tractography.*

Results

Fig. 2 shows the results of applying the four different seeding strategies to segmentation of the splenium. The result in each case is shown with voxelwise likelihoods of connection to the seed voxel thresholded at the 1% level, and unthresholded. In order to make the results as comparable as possible, the waypoint ROIs were centered at the voxels where the neighborhood tractography result crossed the plane shown in green in Fig. 2(b).

Discussion

It is has been shown before (e.g. in [2]) that the strategy of transforming a single seed voxel from standard space is too susceptible to registration error and anatomical variability to yield reliable results. While the results in Figs 2(a,e) are possibly plausible segmentations of the splenium, they compare poorly with our *a priori* expectations, which are represented by the reference tract. They also appear to cross between hemispheres twice, which is nonphysical. By contrast, the segmentation selected by neighborhood tractography matches the reference well—even though it was taken from a different individual—and crosses between hemispheres only once. Full seeding in the seed ROI without constraints produces an incoherent result (g) which is strongly affected by the threshold: only 5.2% of nonzero voxels from (g) survive the threshold, compared to 21.5% from (f). Moreover, this proportion shows an undesirably strong sensitivity to the size of the neighborhood (see Fig. 3). The multiple ROI approach yields Figs 2(d,h), which again suggest multiple crossings between hemispheres and are quite dissimilar to (b) despite being directly informed by it.

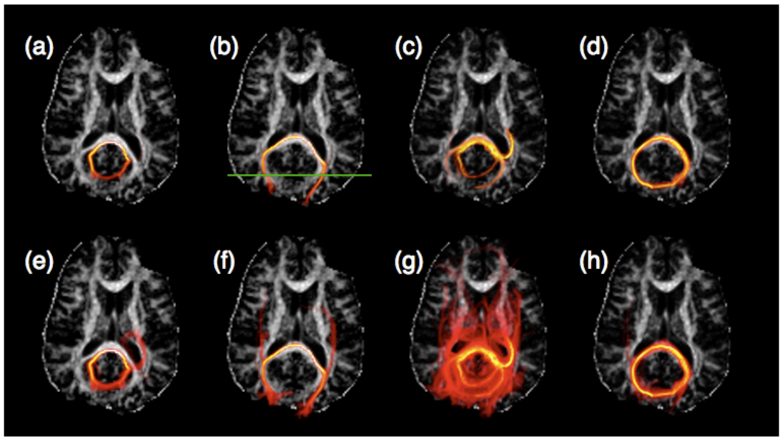

Fig. 2: *Results of each seeding strategy, shown in axial maximum intensity projections. The strategies are:* ***(a,e)*** *single "starting" seed voxel transferred from standard space;* ***(b,f)*** *single seed voxel chosen with neighborhood tractography;* ***(c,g)*** *full seeding in the seed ROI;* ***(d,h)*** *full seeding, subject to two waypoint ROI constraints.* ***(a–d)*** *are thresholded at the 1% level, while* ***(e–h)*** *are unthresholded. Red indicates low likelihood of connection; yellow indicates high likelihood.*

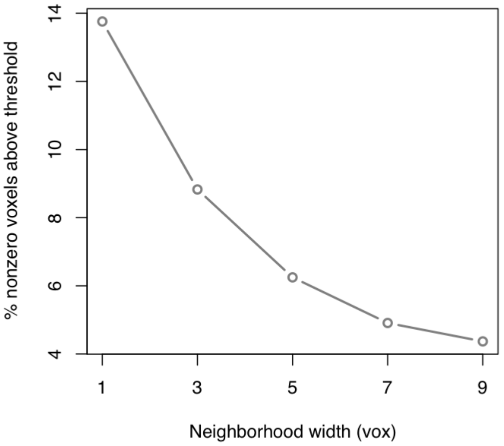

Fig. 3: *The effect of thresholding on connection likelihood when using a single ROI strategy. The impact of the threshold, expressed as a fixed proportion of the total number of streamlines initiated in each case, is more significant as the seeding ROI increases in size.*

We conclude that, while naïve single seed strategies are likely to produce very limited reliability, a single seed carefully chosen using a method like neighborhood tractography can produce good results (see also [2]). Multiple ROI methods are useful but not infallible, and their constraints appear to be insufficient to ensure a reliable and predictable segmentation. A reference tract is also the more intuitive way to represent prior knowledge.

References: **[1]** Jenkinson & Smith, *Med Image Anal* **5**:143; **[2]** Clayden et al., *NeuroImage* **33**:482; **[3]** Behrens et al., *Magn Reson Med* **50**:1077.