Neighbourhood tractography: a new approach to seed point placement for group fibre tracking

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Introduction

One area in which diffusion MRI (dMRI) based fibre tracking techniques have strong potential is in the segmentation of individual white matter structures (tracts) from dMRI images. The segmented areas can be used as regions of interest (ROIs) for studying tract specific effects of pathology [1]. This kind of tractography based segmentation is advantageous over more established ROI methods because the regions are calculated algorithmically, removing observer subjectivity; and because the regions can be arbitrarily shaped in three dimensions, matching the anatomy of the underlying fasciculus.

However, fibre tracking algorithms typically require as input a seed point, a location in dMRI space from which the algorithm begins to reconstruct a tract. The resultant segmentation can be very strongly dependent on the exact location of this point. This sensitivity can be problematic when trying to consistently segment a specific tract from several brain volumes. In this work we demonstrate the inconsistency of segmentations derived from registration based seed point placement, and describe an alternative approach that is based on maximising output similarity to a reference tract within a seeding neighbourhood in native image space.

Methods

***Data acquisition*:** Six normal volunteers (2 male, 4 female; mean age 27 ± 3.4 years) were recruited for this study. Each subject underwent a dMRI protocol on a GE Signa LX 1.5 T clinical scanner (GE Medical Systems, Milwaukee, WI, USA). The protocol was a single-shot spin-echo echo-planar imaging sequence with 51 noncollinear diffusion weighting gradient directions, at a *b*-value of 1000 s mm^{-2}, and 3 T2 weighted scans. TR was 17 s per volume and TE was 94.3 ms.

***Registration based seed placement*:** We placed a seed point in the splenium of the corpus callosum in a standard (MNI) brain volume, and transferred it to each subject's native dMRI space using the FLIRT registration tool (FMRIB, Oxford, UK), with the MNI white matter map as a weighting mask [2]. The BEDPOST/ProbTrack fibre tracking algorithm [3] was then seeded at these locations in each brain volume. This algorithm models one fibre direction per voxel.

***Neighbourhood tractography*:** One of the tracts produced by the registration based seeding method described above was chosen as the reference tract for the purposes of this study. For every other brain volume, the BEDPOST/ProbTrack algorithm was then seeded at every voxel location within a 7x7x7 voxel neighbourhood centred at the seed point chosen by registration. The similarity of each of these "candidate" tracts to the reference tract was then calculated using a tract similarity measure that we have developed and previously described [4], and only the tract with the greatest similarity was retained. The associated seed point is thus the best match to the reference tract seed point, based on the evidence of output similarity.

Results

Fig. 1 shows axial projections of the tracts produced by applying registration based seed placement to one brain volume from each subject. The tract output is probabilistic, with red indicating areas of low likelihood of connection to the seed point, and yellow indicating high likelihood. Fig. 2 shows the equivalent projections for the tracts chosen as most similar to the reference tract (a), within the seeding neighbourhood. In both figures, all tract data have been thresholded at the 1% level to ignore areas of very low connection likelihood; and the underlying greyscale images show the slice of the subject's anisotropy map in plane with the seed point.

Discussion

There is a general improvement in consistency, in terms of tract shape, in the neighbourhood tractography results shown here, relative to the results from a purely registration based seeding process. Fig. 2(b) and 2(c) are clearly better matches to 2(a) than their equivalents in Fig. 1, while the remaining tracts at least do not represent worse matches. It should be noted that in any given seeding neighbourhood, there is no guarantee that a good match to the reference tract will be available. In addition, the efficacy of neighbourhood tractography will depend on the capabilities of both the fibre tracking algorithm and the similarity measure being used.

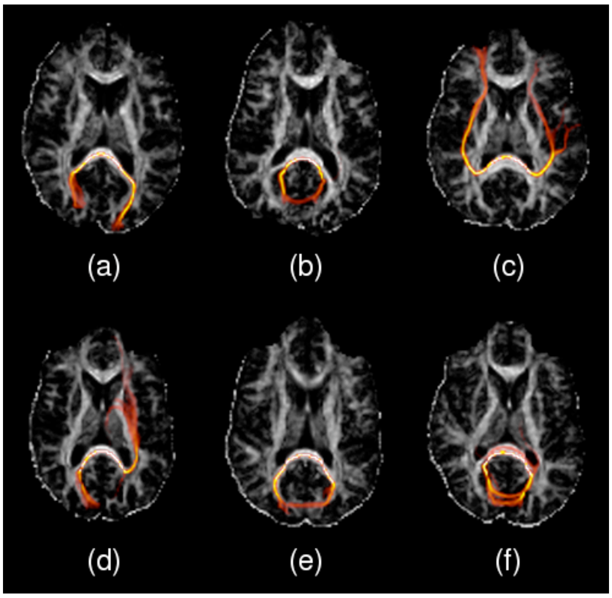

Figure 1: Tract output produced by using registration to place seeds.

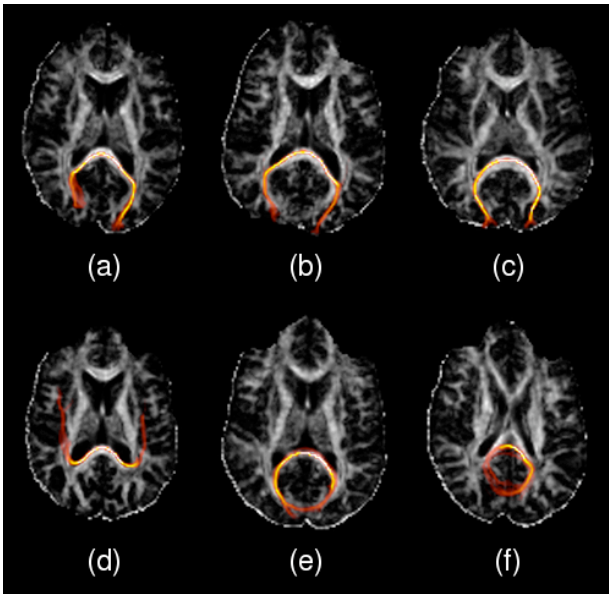

Figure 2: Tract output chosen by the neighbourhood tractography method, using (a) as the reference tract.

Conclusion

Neighbourhood tractography is a novel approach to an important problem in group fibre tracking—that of consistent tract segmentation. It neither manipulates the dMRI data nor constrains the fibre tracking algorithm, instead simply providing a preference for seed points that produce tracts with high shape and length similarity [4] to a reference tract. Whilst for the purposes of this study the reference tract was taken from our dataset, in general it would be preferable to work from a standard set of reference tracts, and we would advocate the creation of such a set. We believe that this technique could have considerable promise, particularly as similarity measures are refined.

References

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