

Challenges of Cortical Connectivity Measurements using MR Tractography

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Introduction

The study of anatomical connections often involves tracing fiber bundles to or from the cortex. This poses significant challenges to MR fibertracking, due to low diffusion anisotropy in gray matter, and the high directional uncertainty this causes. This problem is often circumvented by including the border of white matter in seed regions for fiber tracking [1, 2]. In this abstract the risk of such approach is observed by looking into the histological sections of the borders between white matter and gray matter.

Methods

A fixed squirrel monkey brain was scanned on a Varian 9.4T scanner for 60 hours using a multi-slice, pulse gradient spin echo sequence (32 weighting directions, $b = 0$ and 1022 s/mm^2 , $TE = 26.27 \text{ ms}$, $TR = 5170 \text{ ms}$, $128 \times 128 \times 192$ image volume matrix, $0.3 \times 0.3 \times 0.3 \text{ mm}^3$ voxels resolution). After scanning, the brain was sectioned and stained for myelin. Three major data sets (DT-MRI, block face photographs, and high resolution light micrographs) were acquired from this procedure in order to observe DMRI data in high resolution micrograph space, as described previously [3, 4]. A few subcortical regions were observed with light microscopy to reveal the underlying microstructure. Upon ROIs were selected in the subcortical regions and used as seed regions for fiber tracking using dtiStudio [5].

Results

Fiber structure in subcortical regions varies greatly from one region of cortex to another. Figure 1 shows two examples of such structures. Figure 1(a) and (b) show a region where fibers peel off from the main bundle in a coherent fashion. When diffusion fibers tracked from a seed region placed at the white matter border are overlaid, it can be seen that few of those originating at the interface correctly join the bundle. Figure 1(c) and (d) shows a region where fibers in the gray matter cross a large bundle after traveling only a short distance from the border. Figure 1(d) shows overlaid diffusion fibers that fail to track the bundles stemming from gray matter. Figure 1 also reveals the possibility of following fibers that do not originate in the seed volume. The extent to which this happens has been examined using several seed volumes, an example of which is shown in Figure 2. Figure 2 (a) shows fibers that begin from a seed region which was placed in the somatosensory subcortical region. Fiber 2 (b) shows all fibers that begin and passthrough the seed region. Fibers that do not begin in the seed region are color coded according to the distance between their starting points and the center of mass of the seed region. Figure 2 (c) shows that in Figure 2 (b) fibers which begin as far as 16 voxels away from the seed region are being selected.

Conclusion

It was shown that the underlying microstructure of the gray/white matter interface is complex and placing seed regions in the subcortical white matter for the purpose of fiber tracking from cortical regions may result in incorrect connectivity information. It was also shown that choosing fibers that merely pass through the seed region may result in incorrect connectivity results.

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References

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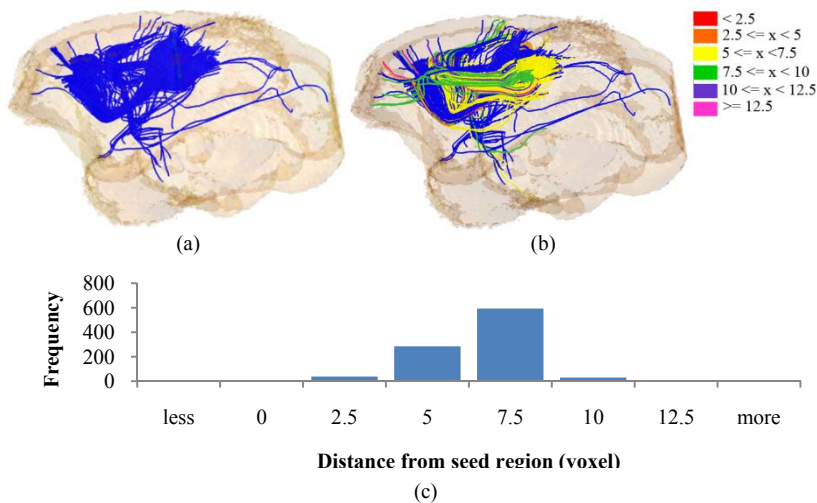
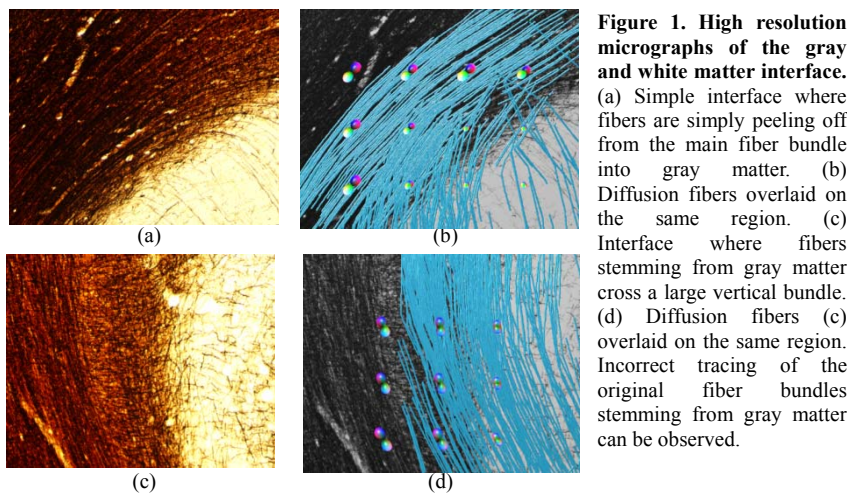


Figure 2. Diffusion fibers tracked from a seed region in somatosensory cortex. (a) Fibers which started from the seed region. Total number of fibers tracked was 1167. (b) Fibers starting from and passing through the seed region. Total number of fibers tracked was 2125. Fibers that pass through the seed region are color coded by the distance between their starting points and the center of mass of the seed region. (red: < 2.5 , orange: $2.5 \leq x < 5$, yellow: $5 \leq x < 7.5$, green: $7.5 \leq x < 10$, purple: $10 \leq x < 12.5$, pink; > 12.5 voxel)