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The Effects of Seeding Resolution on DTI Streamtube Visualization Comprehension

Jian Chen Haipeng Cai David H. Laidlaw and Alexander P. Auchus
University of Maryland Baltimore County, University of Southern Mississippi, Brown University, University of Mississippi Medical Center

Motivation

This project is motivated by the desire to study the relationships between data density and streamtube visualization of DTI brain model that could lead to optimal seeding resolution choice in DTI tractography.

Theoretical Foundation

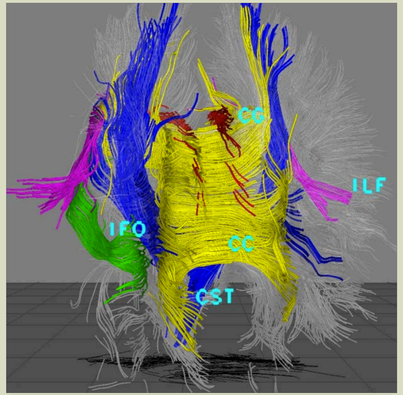
This work is based on the needs for exploring legible graphics in DTI visualization using streamtubes. According to Bertin [1], general data legibility rules can be characterized by rules of:

- graphical density
- angular separation
- retinal separation

Contributions

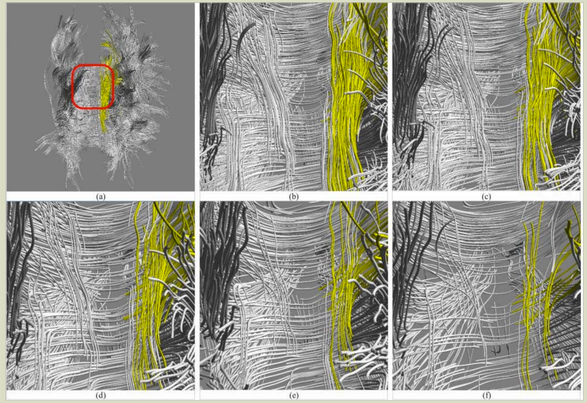
- Investigation of different seeding resolutions in DTI tractography for optimal visual density display
- Preliminary analysis of the differences made by various densities in terms of user task performance and fiber integrity
- Results that can broaden the purview of DTI visualization in the choice of tensor processing parameters during the 3D tractography of DTI datasets

Five Brain Structures in the Study



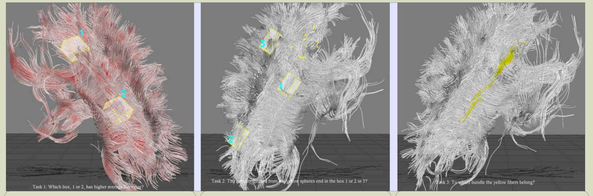
Five brain structures as task data foci are corpus callosum (CC), cingulum (CG), corticospinal tracts (CST), inferior longitudinal fasciculus (ILF) and inferior frontal-occipital fasciculus (IFO)

Five Seeding Resolutions Studied



A partial brain tractography (a) and 5 closeups into the cingulum region (red block) is the region of interest in (a) and magnified views in all other views in tractography produced from 5 seeding resolutions: (b) 1x1x1, (c) 2x2x2, (d) 3x3x3, (e) 4x4x4, and (f) 5x5x5.

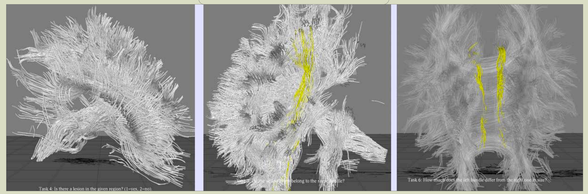
Six Tasks Designed for the Experiment



Task 1: which box, 1 or 2, has higher average FA value?

Task 2: The tubes originating in the yellow spheres end in box 1 or 2 or 3?

Task 3: To which bundle does the yellow fibers belong?



Task 4: Where is the lesion in the bundle?

Task 5: Do the yellow fibers belong to the same bundle?

Task 6: Do the two bundles have the same size or not?

Fiber Integrity Measurements

Resolution	Voxel size (mmxmmxmm)	# of Tubes	Total Length	Total Weighted length by Linear Anisotropy	Total Weighted Length by Average FA	Average Total Length	Average FA
1x1x1 (# of images: 13x30)	0.94x0.94x4.52	9635	279438	64788	125851	29	0.45
2x2x2	1.88x1.88x9.04	6416	44563	44563	85974	29	0.45
3x3x3	2.81x2.81x13.56	4059	29855	29855	57261	30	0.46
4x4x4	3.75x3.75x18.08	2492	20119	20119	38246	32	0.47
5x5x5	4.69x4.69x22.59	1572	12900	12900	24412	33	0.47

White matter integrity metrics of the normal subject's whole brain DTI streamtube model, calculated according to the quantitative measurement proposed in [2]. We use these metrics to measure the fiber integrity in the DTI tractography produced by different seeding resolutions in fiber tracking.

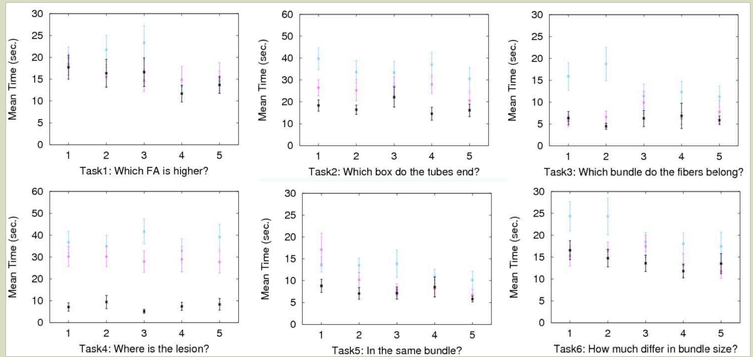
Observations

- Lower resolutions bring about higher task correctness over all tasks consistently.
- Task completion time fluctuated with changing resolutions and the pattern of change varies from task to task.
- Though there is no obvious visual differences between adjacent densities, task completion time can largely differ from one to the other across all six tasks.
- Higher data density conveys more completion information of the original MRI data but brings about more visual clutter impeding effective examination.
- Lower data densities can present the brain structures clearly but may risk losing MRI data integrity at least at the lowest resolution of 5x5x5.

Conclusions

- Seeding resolutions between 2x2x2 and 4x4x4 were optimal for the tasks measured.
- Fiber density resulting from 4x4x4 is the lowest one reasonable in terms of task completion time.
- Interactivity changing density will be useful in the tool design for different analytical stages.

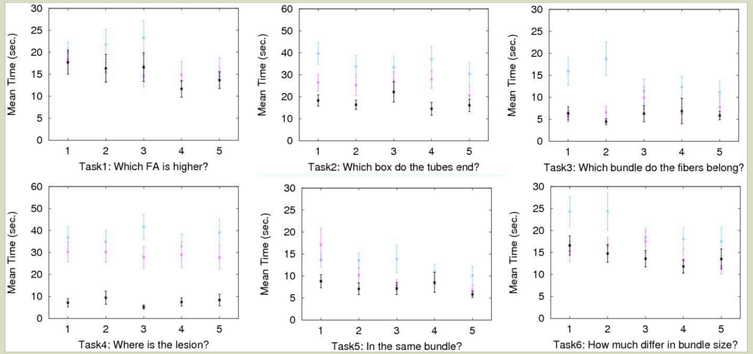
Task Completion Time



Results from 10 participants: whole dataset (cyan), partial brain volume (pink), and regions of interest only (black)

- Fiber tracing task (which box do the tubes end?) is the most challenging one as most participants reported in the post-study interview
- Pattern of changes in time by resolution differs from task to task

Task Correctness



Results from 10 participants: whole dataset (cyan), partial brain volume (pink), and Regions of interest only (black); 1: correct, 0: wrong

- Participants achieved significant higher average accuracy with the ROI volume category that the other two categories.
- Correctness was high except for task 6. Participants mostly guessed the answers for this task.

References

[1] Bertin, J., Semiology of Graphics: Diagrams, Networks, Maps, University of Wisconsin Press, 1983.

[2] Correia, S, et al., Quantitative Tractography Metrics of White Matter Integrity in Diffusion-Tensor MRI, Neuroimage, 42(2): 568-581, 2008.