The Effects of Seeding Resolution on DTI Streamtube Visualization Comprehension

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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 density display
- Preliminary analysis of the differences made by various densities in terms of user task performance and fiber integrity
- Results that set boundaries for future optimization of DTI visualization in the context of sensor processing parameters during the 3D visualization 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).

Fiber Integrity Measurements

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Width (μm)</th>
<th>Density (mm³)</th>
<th># of Tubes</th>
<th>Total Length</th>
<th>Total Weighted Length by Linear Anisotropy</th>
<th>Average Total Length</th>
<th>Average FA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1x1x1</td>
<td>0.5x0.5x0.5</td>
<td>133,000</td>
<td>6935</td>
<td>274036</td>
<td>56780</td>
<td>123800</td>
<td>0.48</td>
</tr>
<tr>
<td>2x2x2</td>
<td>1.0x1.0x1.0</td>
<td>56,000</td>
<td>6250</td>
<td>45213</td>
<td>49575</td>
<td>10175</td>
<td>0.49</td>
</tr>
<tr>
<td>3x3x3</td>
<td>1.5x1.5x1.5</td>
<td>35,900</td>
<td>3952</td>
<td>29855</td>
<td>29855</td>
<td>7925</td>
<td>0.50</td>
</tr>
<tr>
<td>4x4x4</td>
<td>2.0x2.0x2.0</td>
<td>25,800</td>
<td>2842</td>
<td>22222</td>
<td>22222</td>
<td>5555</td>
<td>0.50</td>
</tr>
<tr>
<td>5x5x5</td>
<td>2.5x2.5x2.5</td>
<td>16,700</td>
<td>2365</td>
<td>16725</td>
<td>16725</td>
<td>4185</td>
<td>0.50</td>
</tr>
</tbody>
</table>

While white matter integrity of the normal subject’s whole brain DTI tractography 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.

Five Seeding Resolutions Studied

Five seeding resolutions were studied for the DTI tractography: (1) 1x1x1, (2) 2x2x2, (3) 3x3x3, (4) 4x4x4, and (5) 5x5x5.

Six Tasks Designed for the experiment

1. Which box, 1 or 2, has higher average FA value?
2. The tubes originating in the yellow spheres end in box 1, 2 or 3?
3. To which bundle does the yellow fibers belong?
4. Where is the lesion in the bundle?
5. Do the yellow fibers belong to the same bundle?
6. Do the two bundles have the same size or not?

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

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 are 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.

Conclusions
- Lower data densities can present the brain structures clearly but may risk losing MRI data integrity at least at the lowest resolution of 5x5x5.

- Seeding resolutions between 2x2x2 and 4x4x4 were optimal for the tasks measured.

- Fiber density resulting from fiber in the lowest one reasonable in terms of task completion time.

- Incrementally higher density will be used in the tool design for different analytical stages.

References