Visualizing Neural Tissue from MR data

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1 Abstract

MR measurements of water diffusion in organs and tissues having an orderly, oriented structure, such as skeletal, cardiac, and uterine muscle, portions of the kidney, the lens, and white matter, exhibit anisotropy(i.e., a dependence of the diffusivity on direction). We try to develop techniques to visualize white matter or other kinds of neural tissues using this property. Previous work have been done on visualizing anisotropy and its direction in slices. But how to render ellucidating pictures which accurately represent volumetric information remains a challenge. The goal is to visualize not only the shape of the tissue, but also the structure of the tissue. In this proposal, I'll bring up several possible approaches, discuss the pros and cons of each, and give a timeline to implement one or two of them.

2 Related Work

Within biological systems water molecules undergo continuous stochastic Brownian motion. In different tissues the rate of this diffusive motion can vary by several orders of magnitude - faster in liquids like cerebro-spinal fluid, slower in tissues like muscle. In some tissues the rate is anisotropic, or faster in some directions compared to others. Magnetic resonance imaging(MRI) can acquire images with intensity values sensitive to the diffusion rate of water. A quantitative image of the diffusion rate can be calculated from a set of such MR images. From a 2D slice or 3D volume image of this directionally dependent diffusion rate we can infer underlying tissue structure and better understand the anatomy of the nervous system, neuro-degenerative diseases, and neural development. Diffusion-rate images calculated from MRI measurements are second-order tensor fields. There are several kinds of methods for visualizing second-order tensor fields.

- Using ellipsoids to present the tensor value at any spatial location(figure 1). The ellipsoid is a natural icon, since its shape echoes the structure of the diffusion process.

- Using concepts from painting to convey information. This method has been applied to visualize 2D slices of 3D tensor fields(figure 2). If we want to extended this method to 3D, we should carefully distribute the strokes to convey useful information and reduce visual clutter.

- Using hyperstreamlines(figure 3). This method is intended to present volumetric tensor data. However, it's designed for displaying tensor

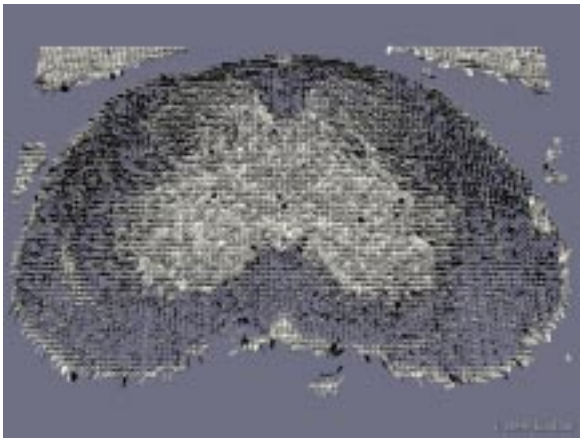

Figure 1: Visualizing slice of mouse spinal cord using ellipsoids

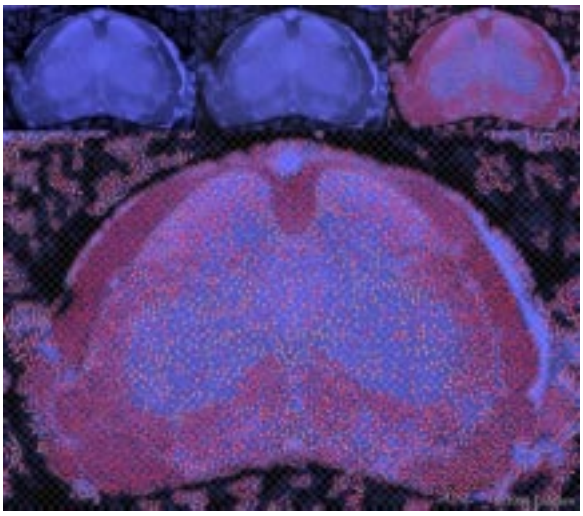

Figure 2: Visualizing slice of mouse spinal cord using painting metaphor

Figure 3: Hyperstreamline

fields with a different physical structure and interpretation than the diffusion tensor.

3 Possible Methods

3.1 Painting Metaphor

Concept borrowed from painting: Using different layers of paint to represent different elements of a scene, and varying the many characteristics of brush strokes. Use brushes, or ellipses as strokes.

Problem: How to design the mapping from data to visual features? How to distribute the strokes? How to remove visual clutter?

3.2 Using cellular texture(hairy texture)

Inspired by "Cellular Texture Generation"(figure 4). Vary the thickness and color of the hair to convey more information.

Using fiber-like long thin hairs to present anisotropy and its direction.

Problem: If we use it as texture on surface, what's the surface? Is there a clear surface? How to find it? How to define the parameters of the cells?

3.3 Using hyperstreamlines

Represent the surface of the neural tissue with hyperstreamlines,

Figure 4: Hairy bear using cellular texture

Problem: What's the color scheme of the hyperstreamline? What's the shape of the cross section? Where does it begin? Where to end? Will it be continuous all the way? Will it run only on the surface? If so, how to keep it on the surface?

3.4 Using ploygon mesh to represent white matter surfaces

Detect the surface and represent it with polygon mesh. Its primary goal is to detect surface. In order to visualize the structure of the neural tissue, we should use other method in combination with this one.

3.5 Computational diffusion(staining)

Theoretically stain the tissues with dye, and simulate the diffusion process. Then find out the structure information from the distribution of the dye.

4 Validation

In order to be able to verify the accuracy of our image, we need to construct phantom models. Imaging phantoms with our methods and compared them to the model image.

5 User surveys and conclusion

User surveys will be included in the research process. We will ask people from biological departments to evaluate the pictures, and we will use the feedback to modify our methods.

6 Timeline

- 4/15-5/15 Reading and thinking

  Milestone: Writing related work section of the paper. Choose one of two methods for implementation. Work out a detailed schedule.

- 5/15-6/15 Integrate available codes. Play with MR data

  Milestone: Get(or write) code whose input is raw MR data and performs certain operations on it. Output should include anisotropy, direction on a certain voxel.This code will be used with all of our methods

- 6/15-8/15 Implement one method(possibly painting metaphor).

  Iterate through the steps of

  - Visualization design
  - Coding the algorithm
  - Generating picture
  - Evaluate picture(user survey)
  - Milestone: Get high quality pictures generated with this method

- 8/15-12/15 Implement another method.

  - Iterate through the same steps as method 1.
  - Milestone: Get high quality pictures generated with this method

- 12/15-2/1 Write the thesis.

  Milestone: Draft thesis.

- 2/1-4/15 Finish thesis and prepare the presentation.