CS 5635/6635 Spring Semester 2022 Assignment 5

Date: Monday, March 28, 2022

Due Date: Monday, April 11, 2022

Multi-Field and Tensor-Field Visualization

For **Part 1** of the assignment, we are going to use data that was created by the National Center for Atmospheric Research's Weather Research and Forecasting Model. The Weather Research and Forecasting (WRF) Model is a next-generation mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting applications:

https://www.mmm.ucar.edu/weather-research-and-forecasting-model

We are going to visualize scalar and vector fields of WRF forecast simulations of Hurricane Katrina's path:

ftp://ftp.ucar.edu/vapor/data/Katrina/

We are going to use one time step in the forecast simulation, which you can download from the class website:

https://my.eng.utah.edu/~cs6635/hurricanekatrina.vts.gz

This has been converted from WRF format to a format ParaView can read. After loading the Hurricane Katrina data set and clicking Apply, you will see four data fields (T, QCLOUD, QVAPOR, and wind). T is the Temperature, QCLOUD is the cloud water mixing ratio, QVAPOR is the Column Water Vapor Content, and wind is Wind Speed.

For **Parts 3 and 4** of the assignment, we are going to use the following data:

https://my.eng.utah.edu/~cs6635/Assignment5-Data.zip

Part 1: Multi-Field Visualization [20 pts]

Now we will put together multiple fields in the same view. Create a single visualization that includes an isosurface of QCLOUD, plus a volume rendering of QCLOUD, plus streamlines of the wind flow, plus arrow glyphs of the wind flow. You will need to make the isosurface semi-transparent and create a transfer function so that you can see the fields. You will want to show a few streamlines and a moderate number of arrow glyphs so you can get a good understanding of the flow, but not occlude the scalar field visualizations.

Please include the figure in your report (5/20) and explain your solution step by step (5/20). Please explain what you can understand of the simulation data via your multi-field visualization (10/20).

Part 2: Reading Questions (The visualization handbook) [20 pts]

Please answer in your own words. Do not write the same thing as in the source material but with only slight changes in phrasing. Do not simply rewrite the same sentences as in the source material. You should be aiming to summarize, maybe with a little bit of paraphrasing, and you can also use some quotations. But even if you are paraphrasing, it cannot be too similar to the source material. You should be able to write your answer without simultaneously looking at the original text. E.g. see this guide on appropriate paraphrasing/summarizing: https://owl.purdue.edu/owl/research_and_citation/using_research/quoting_paraphrasing_and_summarizing/paraphrasing.html

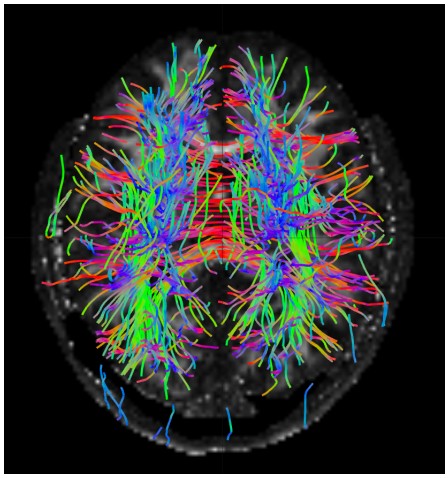
1) What is diffusion tensor MRI imaging? State three types of diffusivities and describe each briefly. How a diffusion tensor can be represented mathematically? [Cchapters 15,16]
2) Briefly describe box, ellipsoid, and superquadric glyphs for visualization of tensors field. Compare and contrast the benefits and disadvantages for these glyphs. [Chapter 16]

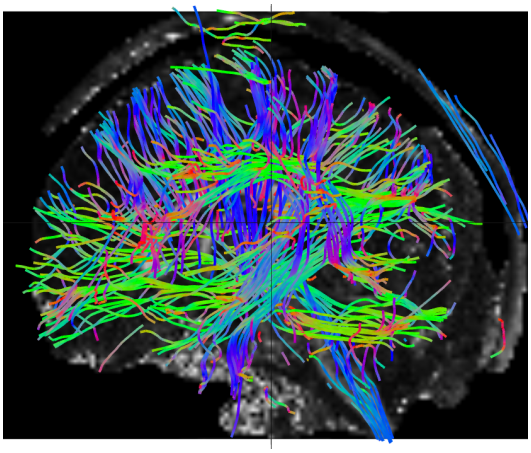
Part 3: Brain DTI Tractography Visualization [20 pts]

In this part, we will use DSI Studio, an open-source diffusion MRI analysis tool. You can download and install it from http://dsi-studio.labsolver.org/Home. I had difficulty getting this application to work on Linux. However, DSI Studio has been tested and is known to work over remote access machines provided by the College of Engineering's CADE lab: https://www.cade.utah.edu/remote-desktop-access/

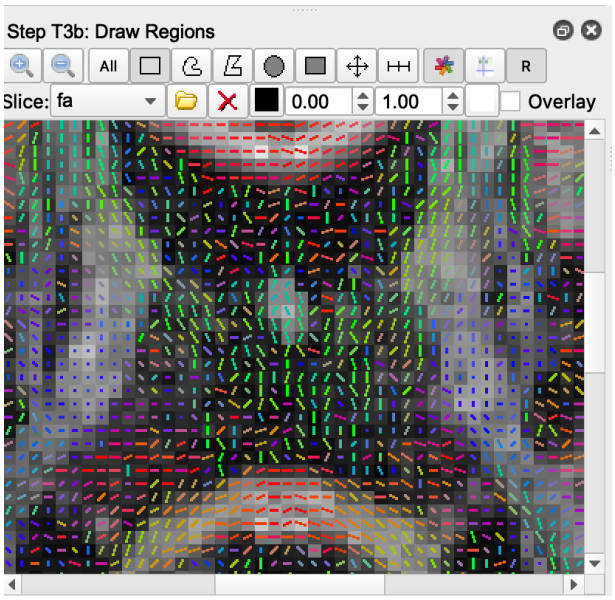
Load the data 'brain_dti' located in the directory data_assignment5 of Assignment5-Data.zip (link near the beginning of this document). It contains diff_5k.nii, a brain DTI scan; bvals_5k.txt, the b-values for each voxel; and bvecs_5k.txt, the b-vectors for each voxel.
1) Perform fiber tracking and visualize tractography for the whole brain. The documentation for DSI Studio can be found here: http://dsi-studio.labsolver.org/Manual The links under "Conventional Tractography" are the most relevant, though you may also want to look under

"General Topics" and "Visualization". Attach your results as images in your report. They should look similar to the images below:





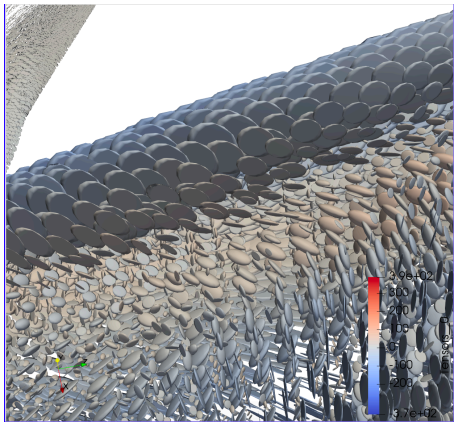
2) Create a tensor field visualization similar to the following for any choice of MRI slice. Describe the diffusivity patterns for a few subregions of the image. Include an image in your report.



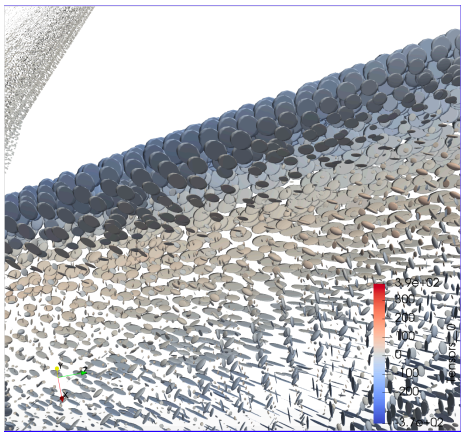
Part 4: Tensor Glyph Visualization in ParaView [20 pts]

1) Load the dataset data_assignment5/tensorFields/3-triangulation/output.vtu
2) Visualize tensor field using box, sphere, cylindrical, and superquadric glyphs. Create images that have a pleasing appearance by playing with the glyph parameters, such as

glyph size, shading etc. and include them in your report. Sample images for sphere glyphs are shown below for different radii.



Radius = 0.18



Radius = 0.08

3) Which glyphs did you find the most informative for gaining insight into the tensor field data? Why?

Part 5: Reading Question on Multi-field Data Visualization (only for CS6635 students) [20 pts]

Choose one of the following papers of your choice and write a review of it:

1. J. Kniss, S. Premoze, M. Ikits, A. Lefohn, C. Hansen, and E. Praun; Gaussian Transfer Functions for Multi-Field Volume Visualization; In Proceedings of the 14th IEEE Visualization 2003, 2003. (https://dl.acm.org/doi/10.1109/VISUAL.2003.1250412)
2. R. Fuchs and H. Hauser; Visualization of Multi-Variate Scientific Data; Computer Graphics Forum, 2009. (https://onlinelibrary.wiley.com/doi/full/10.1111/j.1467-8659.2009.01429.x)
3. S. Nagaraj, V. Natarajan, and R. S. Nanjundiah; A Gradient-Based Comparison Measure for Visual Analysis of Multifield Data, In Proceedings of the 13th Eurographics / IEEE - VGTC conference, 2011. (https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1467-8659.2011.01959.x)

You may need to use the Utah Library Proxy (https://www.lib.utah.edu/help/off-campus.php) in order to access "paywalled" articles. E.g. for #2, and #3, I needed the proxy in order to download the full text PDF, otherwise the web page only lets you see the abstract.

Please answer the following questions when writing your review:

- What is the new innovation described in the paper?
- What did you learn by reading the paper?
- What are the weaknesses in the paper? E.g. What claims are not convincing, and why? Are there claims made without adequate evidence? Are there weaknesses in how the authors evaluate the performance/effectiveness of their proposed technique?
- Is what the paper presents useful, or is it just a curiosity?
- What did you want to know more details about?
- Does the paper provide enough detail to allow you to implement the proposed technique yourself? If not, which part is not detailed enough?

When summarizing, please do it in your own words. Do not write the same thing as in the source material but with only slight changes in phrasing. Do not simply rewrite the same sentences as in the source material. If you are paraphrasing, it cannot be too similar to the source material. You should be able to write your answer without simultaneously looking at the original text. E.g. see this guide on appropriate paraphrasing/summarizing: https://owl.purdue.edu/owl/research_and_citation/using_research/quoting_paraphrasing_and_summarizing/paraphrasing.html

What to turn in

Write a short report explaining and documenting your results. Here are few specifics regarding the report. Create figures, add captions and explain figures for each part above. Figures and

caption should be large enough to be readable. Explanation of a figure should be close to the actual figure. In the Discussion section, compare and contrast results and note any interesting observations when exploring data. You can also elaborate on challenges faced when implementing the project. The Discussion section doesn't have to be close to actual figures. Finally, add a conclusion section in the report to tell us what you learned from this assignment and add references, if any.