Assigned: *3-20-2024*
Due Date: ***4-3-2024 by Noon***

CS 6635/5635 Spring Semester 2024

Assignment 5 (Multi-Field and Tensor 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 both scalar and vector fields of WRF forecast simulations of Hurricane Katrina:

https://www.youtube.com/watch?v=dW3pErARlYc

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]

The goal is to effectively visualize 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.

1) What is diffusion tensor MRI imaging? State three types of diffusivities and describe each briefly. How a diffusion tensor can be represented mathematically? [Chapters 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]

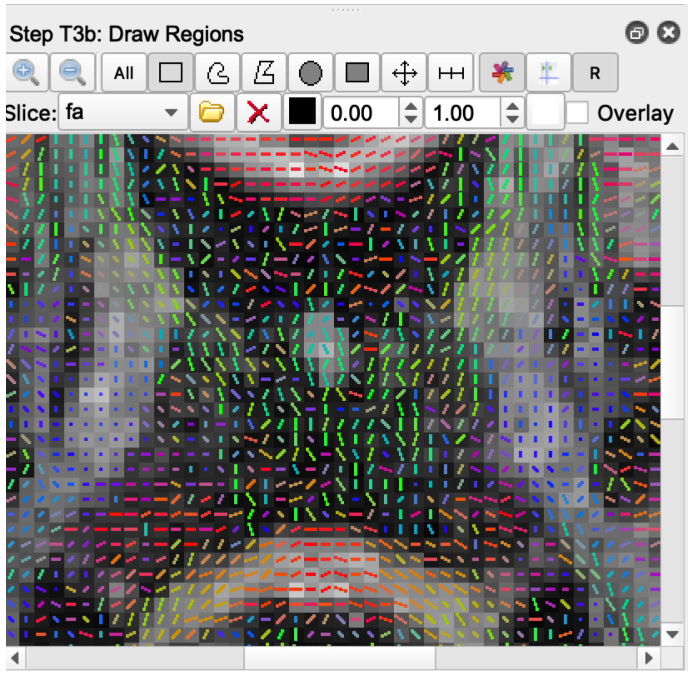
Part 3: Brain DTI Tractography Visualization [30 pts]

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. We 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/

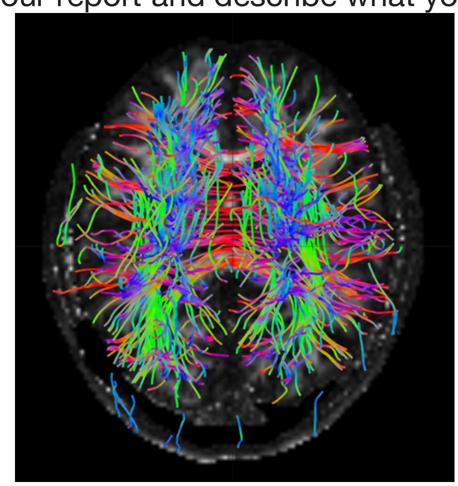
Load the data 'brain_dti' located in the directory data_assignment5 of Assignment5-Data.zip (link near the beginning of this document). It contains diff_5k.nii, a brain DTI scan; bvals_5k.txt, the b-values for each voxel; and bvecs_5k.txt, the b-vectors for each voxel. The documentation for DSI Studio can be found here: http://dsi-studio.labsolver.org/Manual

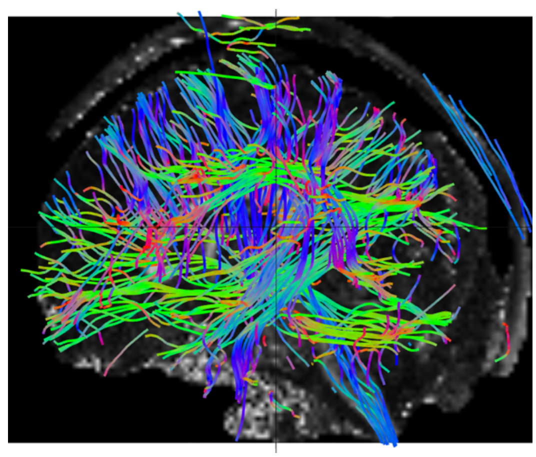
1) Following the DSI Studio Manual, perform steps T1 and T2 to compute fiber tracking data. Note that the diffusion sampling length ratio in T2 will have an effect on step T3. Look at the Reconstruction page in the manual. Try some different values to find a good fit.

2) In step T3, create a tensor field visualization similar to the following for any choice of MRI slice. If you choose a poor diffusion sampling length ratio in the previous step, you will have too many fiber directions per pixel in this image. Describe the diffusivity patterns for a few subregions of the image. Include an image in your report.

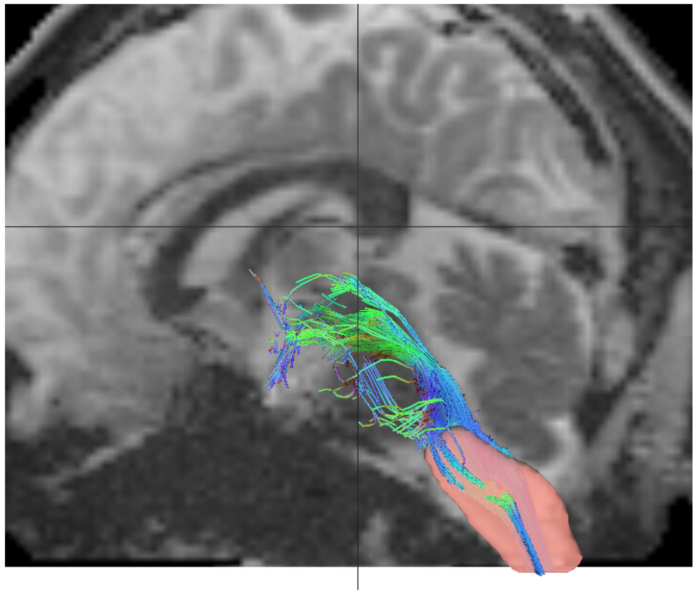


3) Perform fiber tracking and visualize tractography for the whole brain. The links under “Conventional Tractography” are the most relevant, though you may also want to look under “General Topics” and “Visualization”. In the step T3c window, you will find Tracking Parameters, Slice Rendering, and Tract Rendering to be useful. <u>Attach your results as images</u> in your report and describe what you see. They should look similar to the images below:

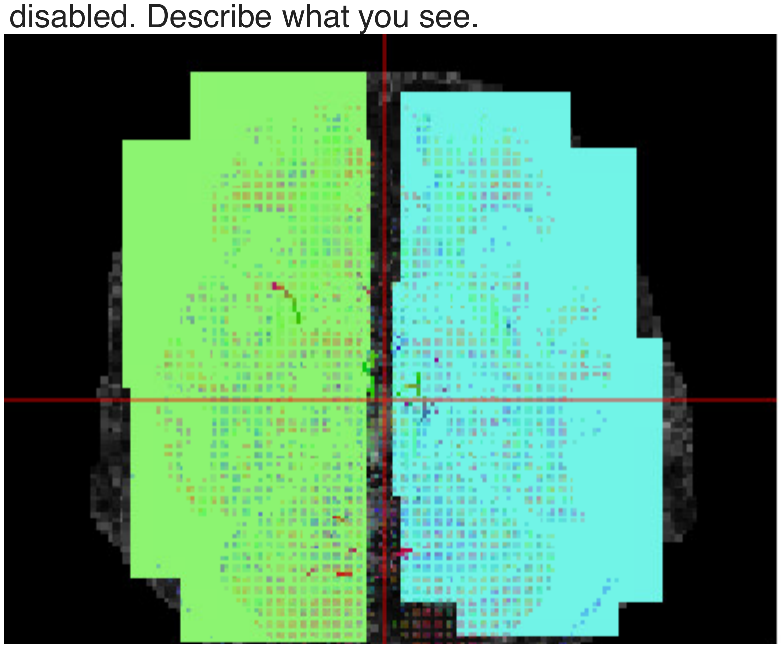




4) Remove or hide the previous tracts. Now draw a region roughly corresponding to the brain stem. You can see this in the middle of the brain in the sagittal view. You can change your slice image to help you find it. Set this region as the Seed and compute tractography again. Show a image of your tractography in the 3D view. Describe what you see. They should look similar to the image below:



5) Remove or hide the previous tracts and regions. Now using the cubic region *(not the rectangular)* selector, make 2 new regions where each roughly cover each brain hemisphere, as shown in the image below. You can add multiple cuboids for each region to achieve this. Set one of the regions as the Seed and set the other as ROI (Region of Interest). This will visualize tracts that start in one region and connect to the other. Remember that you can edit the tracking parameters. Show an image of your tracts in the 3D view with the region rendering and slice rendering disabled. Describe what you see.

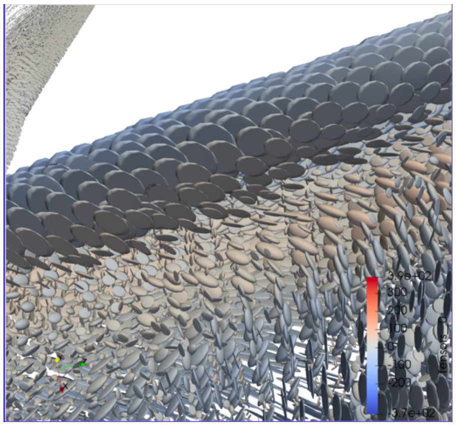


Part 4: Tensor Glyph Visualization in ParaView [20 pts]

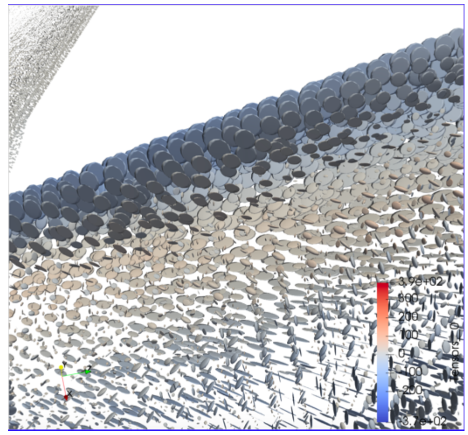
1) Load the dataset data_assignment5/tensorFields/3-triangulation/output.vtu
2) Visualize the tensor field using box, sphere, cylindrical, and superquadric glyphs. Turn off the toroidal shape setting for superquadrics. Create images that have a pleasing appearance

by playing with the glyph parameters, such as glyph size, shading etc. and <u>include them in your report</u>. 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 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, we 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.

Conclusion: [5 pts]

As part of your report, compare and contrast results and note any interesting observations when exploring data from the assignment. You can also elaborate on challenges faced when implementing the project. In addition, tell us what you learned from this assignment and add appropriate references, if any.

What to turn in:

Write a **report documenting your results**, including any necessary plots/figures, and answering any questions asked above. Be sure to explain any figures you submit and to write a **conclusion** at the end of your report. Your homework is primarily graded upon your report. Please submit your report on Canvas in PDF format. Please also submit your code/.pvsm files as compressed zip files.

- Your report should be in PDF format and should stand on its own.
- It should describe the methods used.
- It should explain your results and contain figures.
- It should also answer any questions asked above.
- It should cite any sources used for information, including source code.

Note: Any figures/plots in the report should be captioned appropriately. Also be sure to include axis labels in all plots.

This homework assignment is due on **April 3, 2024 by 11:59 am**. If you don't understand these directions or have questions, please send questions to teach-cs6635@sci.utah.edu or come see one of the TAs or the instructor during office hours **well in advance of the due date.**