Overview: This assignment will familiarize you with the Visualization Toolkit (VTK) used for many scientific visualization applications.

Objectives: The theme of this project is color visualization. You will work with 2 datasets from different application domains and in each case your task will be to select an effective color map to represent the data. In your report, you must justify the design decisions you made in picking a particular color map and provide a critical assessment of the strengths and weaknesses of each considered color map. Your argumentation should address perception aspects and take into account the specific properties (qualitative and quantitative) of each dataset.

Ground Rules: This assignment is to be done alone. You may ask others for help with using VTK or for feedback on your visualization choices. However, you should develop the code, write-up, and ideas.

Background

The purpose of a color transfer function is to express numerical values through colors by constructing a mapping (a function) from value space to color space.
Navigating the color space: We saw in class that the RGB and HSV color space has 3 degrees of freedom. For RGB, we have Red, Green, and Blue mixing. For HSV, we have Hue (color), Saturation (colorfulness), and Value (lightness).

A color scale corresponds to a curve through this 3 dimensional space with the associated variations of hue, saturation, and value. The curve is defined by control points, which are used to assign a color to specific values. Hence, choosing control points does two things: we select the geometry of the curve (how does it look?) by indicating consecutive points along it and we fix the parameterization of the curve (how fast are we moving along the curve?) by specifying how changes in value correspond to a motion along the curve.

How to pick control points: To successfully complete the tasks below, you will need to understand the meaning of a given value (or value range) in the considered dataset. Designing a color map amounts to selecting a number of control points that fix the relationship between values and colors at discrete locations and computing the remaining (value, color) pairs through interpolation. Unless you are very familiar with a dataset, finding good control points can be difficult and time-consuming. To make this problem more tractable, you will be provided a small program that allows you to interactively highlight a range of values in a gray scale visualization. You will apply this tool to complete the project.

Exploring the value space: As stated above, getting a good understanding of the value space is a nontrivial task. One way to facilitate this process is to interactively select a range of values and highlight the corresponding portion of the dataset in an otherwise grayscale color representation. The included python program implements this strategy and uses the color map shown in the images below.

As you can see from the illustration on the left, this color map inserts a uniformly red region in a standard grayscale color map. In addition, this color map contains two small windows, one on each side of the red region, in which a linear transition between
grayscale and red takes place. Hence the width of these windows controls the sharpness of the red region's boundary. An alternative way to describe this color map is to describe it in the HSV color space. In this case, the smooth transition from grayscale to red corresponds to an increase in saturation from 0 to 1 that coincides with an increase in value from the current level to 1. The reverse transition takes place at the other end of the region. The corresponding path in HSV space is shown both in the upper diagram of the left image and in the right image.

**Task 1. MRI Data**

Magnetic resonance imaging (MRI) is a powerful noninvasive medical imaging modality. In this task, you are given 3 axial slices extracted from of a MRI dataset of a human head courtesy of NIH NLM’s Visible Human Project. Your first task is to create, with the help of the program discussed in the previous section, an effective color mapping to distinguish the important anatomical structures that can be seen in those slices (among air, skin, bones, muscles, white matter, gray matter, fat, ...) and to then apply your color map to visualize the data.

**Color bar**

A color map visualization must always be accompanied by a corresponding color bar that indicates the meaning of the colors shown. Therefore your visualization must include a color bar that describes your color map. Note that your program must also ensure that the color bar always reflects the choices made through the GUI.

As a practical matter, color bars are created through a [vtkScalarBarActor](https://vtk.org/doc/nightly/html/classvtkScalarBarActor.html) in VTK as demonstrated [here](https://www.vtk.org/).  

**Implementation**

Specifically, you will write a program that allows the user to toggle between a discrete color map and a continuous color map, each corresponding to a different set of color control points provided on the command line. You will apply the same color maps to all three slices. In summary, your program for this task must meet the following requirements.

- Import the text description of the control points associated with the continuous and discrete case from files provided on the command line and create a corresponding color map visualization of the data.
- Provide a GUI with two radio buttons through which the user can choose between the discrete and the continuous color map and update the visualization instantly.
• Include a color bar showing the color map currently in use.

Your program will use **vtkInteractorStyleImage** to control the mouse interaction with the visualization. This interaction style precludes 3D manipulations while the data is 2D. Please refer to the supplied program to see how this class is used in a VTK program.

**API**

Your program will have following API:

```
> colormap[.py] <image> <continuous> <discrete>
```

where `<image>` is the scalar image to visualize and `<continuous>` (resp. `<discrete>`) is a file containing a text description of the control points selected for a continuous (resp. discrete) color visualization of this dataset. The format of your control points information must be as follows.

- Lines starting with '#' should be considered comments and ignored.
- The first non-comment line will indicate the number of control points defined in the file followed by either "RGB" or "HSV" to indicate the color space in which the control points are defined.
- Each following line that is not a comment will indicate the value color pair in the selected color space. It will have the form "<value> <x> <y> <z>" where "<x> <y> <z>" are the 3 coordinates in the chosen color space of the color associated with `<value>`.

**Task 2. Topography Data**

For the second task of this project you will focus on the topography data of the western part of the United States. Like in the previous task, your goal is again to design a suitable color map and create a good visualization for this type of data. You will reuse here the program that you wrote in Task 1 and use the same API to supply both image and control points on the command line.

**Supplied Code and Data**

Provided with this document are a zip file containing source code and data. The program needed to better understand each dataset `valbrowser.py` and `valbrowser_noQt.py`. These programs allow you to browse the range of values present in each dataset and understand their meaning in the context of the data as well as their spatial distribution. The first program requires PyQt4 and a VTK installation that
supports Qt. The second program does not use Qt and will work with any installation including Python support. Both offer similar features.

The data (axial1.vtk, axial2.vtk, and axial3.vtk) needed for Task 1 is comprised of three axial slices from a MRI dataset. The data (westUS.vtk) needed for Task 2 corresponds to a portion of a worldwide bathymetry dataset that covers the western part of the United States.

Report

The report plays a significant role in this project. As indicated above, you are expected to provide a discussion of the approach you used to design your color maps, the criteria you applied in selecting them, and their respective strengths and limitations. Use in your reasoning arguments based on the information that we saw in class about color perception. Also, make sure to take into account the specific properties of the data.

- Include high quality images showing the visualization results achieved by your color map on each slice. Do so for both continuous and discrete versions of your color map.
- Explain how you have selected your color map and motivate this choice. In particular, include pictures created by the value browser program and discuss their connection to the control points you have chosen.
- Include a critique of your visualization and describe the anatomical structures that are revealed by your color map.
- Discuss the results obtained with the discrete and the continuous color maps and comment on their respective suitability for this dataset.
- Include any necessary close-ups.

Submission

Please submit the document and code (no executables or data files) in a zip file on Canvas by the start of class on the due date. Your document can be in pdf format and has no length requirement.

Grading

This work is partially objective and partially subjective. Objective grading will be judged on the required implementation. The subjective grade will be based on the quality of your color maps and document relative to your peers. Submissions will be ranked best to worst and assigned a grade based upon that ranking.