ECS 277 - Homework # 1

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We employed webGL to develop a dashboard for studying common techniques used in volume rendering on two neighboring graphics side by side. This tool allows users to manipulate lighting, control interpolation schemes, select from multiple datasets, and much more. Figure 1 Shows the dashboard with two volume renderings of the same bonsai tree. Each visualization has seperate controls, but both share an interactable transfer function and Phong lighting control.

Running the Application

If running in a Chrome or Safari browser, cross-origin requests need to be enabled. The simplest way to do this is to run

```
python -m SimpleHTTPServer
```

while inside the directory containing `Index.html`. Then the app will be at `http://0.0.0.0:8000/`.

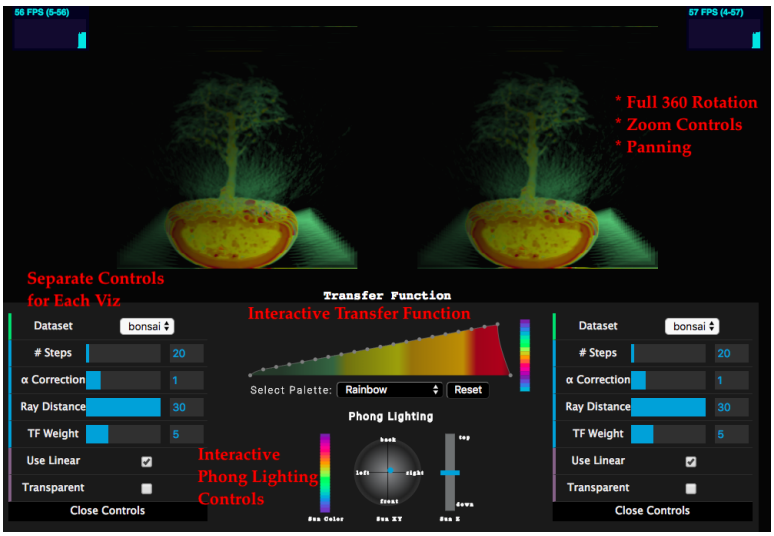

Figure 1: The dashboard for the Volume Rendering Comparison Tool. Here the user can select from a multitude of different controls for each visualization. Moreover, they have control over a shared transfer function or Phong lighting direction and intensity.

Controls

For each visualization there is a set of user-driven values that can be interacted with. These values allow the user to explore different techniques in volume rendering, and the two sets of controls allow for comparisons between two visualizations. Table 1 explains each control in detail.

Name	Range	Description
Dataset	Allows the user to choose from 3 datasets. These include a Bonsai Tree, a Scan of a Human Foot, and an X-Ray of a Teapot.	Bonsai, Foot, Teapot
# Steps	Controls the granularity of the volume rendering by including more points in each ray for ray casting.	[0,512]
Ray Distance	Sets a hard limit to how many points will be included in each ray.	[0,1.5 * # Steps]
TF Weight	Sets a hard limit on the opacity and colors from the transfer function. In practice, this controls where the transfer function begins.	[2,12]
Use Linear	Should Tri-Linear interpolation be used? If not, Tri-Cubic interpolation should be used. Both choices are shown in Figure 2.	True / False
Transparent	Controls the transparency of the visualization. If True, then low opacities will be completely transparent.	True / False

Table 1. A table depicting the main controls available in the Volume rendering dashboard. Each visualization has its own set of the above controls so the user can compare different values of each.

Interpolation

We offer the user two different interpolation schemes to use with the ray casting. These methods are Tri-Linear and Tri-Cubic interpolation which estimate the voxel values between two points in space. Tri-Linear interpolation assumes a linear plane change between both points, and Tri-Cubic fits a cubic polynomial using the two points and their derivatives to satisfy the constraints. Since Tri-Cubic interpolation uses more information to estimate the voxel intensity, this provides a smoother curve as seen in Figure 2. The linear method fits a linear trend between both points. This approximates the value of some $f(x)$, between two points f_0 and f_1, as

$$f(x) = f_0(1-x) + f_1 x$$

For the cubic interpolation, we first approximate the derivatives at f_0 and f_1, then use a Bezier curve to fit three points b_0, b_1, b_2, and b_3. These b_i values are obtained as

$$b_0 = f_0 \quad b_1 = f_0 + \frac{1}{3}f_0' \quad b_2 = f_1 - \frac{1}{3}f_1' \quad b_3 = f_3$$

Then, the estimated $f(x)$ is given as

$$f(x) = \sum_{i=0}^{3} \binom{3}{i} b_i (1-x)^{3-i} x^i$$

Phong Lighting

The Phong lighting controls allow the user to control the direction and intensity of an external light source assumed to be 'very far' away. This lighting affects the rendering following a reduced Phong's lighting model

given by

$$I(p) = I_a + \left(\hat{L} \cdot \hat{N}\right) I_{Sun}$$

where I_a is the intensity of the ambient color, I_{Sun} is the color of the external light source, N a normal vector from the target point p, and $\hat{L}$ is the light direction. With the Phong Lighting controls, the user can control the sun direction $\hat{L}$ and the sun color I_{Sun}. To select a different direction for the Sun, the user control's its x and y coordinates using the circular dial. By selecting a specific point on the dial, this translates into a circle surrounding the rendered volume. Moreover, the user selects different z values using the bar to the right. The color legend allows the user to choose the color of the light, and different palettes can be selected using the palette selector directly above the Phong lighting controls. Different choices for this are shown in Figure 2.

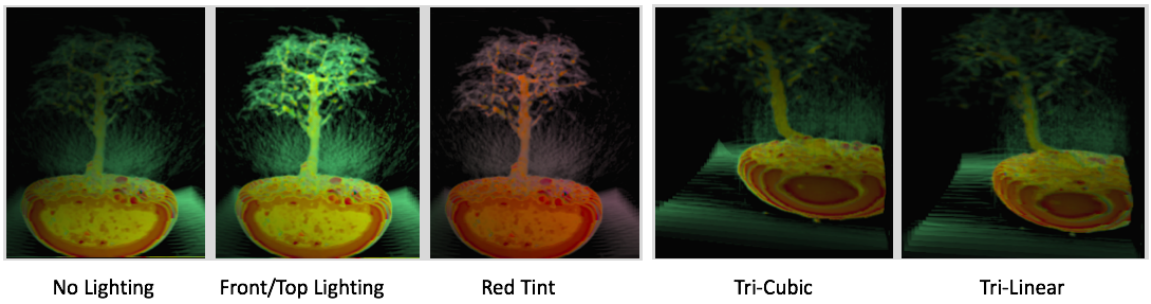

Figure 2: Selected screenschots of the Bonsai tree under different conditions. The different lighting choices (Left) depict the tree under no changes to the lighting, a user's point-of-view light source, and a red-tinted light source. The images to the Right depict both interpolation schemes: Tri-Linear and Tri-Cubic.

Transfer Function

The transfer function tool allows for controlling the opacity values and color for associated voxel intensities of the rendered volume. Starting with a standard linear scale, the user can specifically increase the opacity of each voxel intensity by dragging the associated transfer function's value to a larger y value (or decrease it by dragging it down). Moreover, The legend to the right of the plot allows the user to select a specific color and then brush it onto different areas of the transfer function by dragging across different x values. The choices of colors that can be painted onto the transfer function can be altered using the "Select Palette" drop-down. Here a choice of palettes, default to D_3, are available. Figure 3 shows a customized transfer function and the associated bonsai rendering.

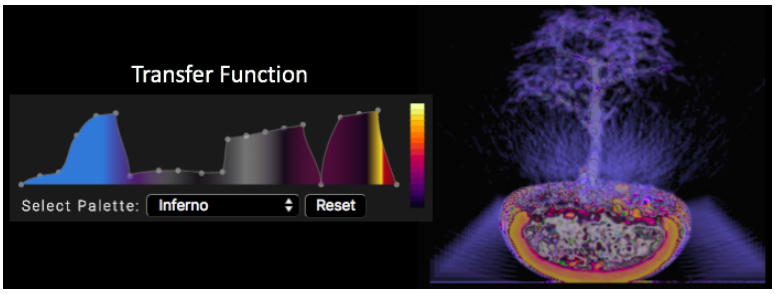

Figure 3: An example of using the Transfer Function controller to change the colors and opacities obtained from the different voxel intensities. Here we are able to paint the colors onto the transfer function and scale the y values to obtain different opacities.