Topics in Large Data Analysis and Visualization (CS677)

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Acknowledgements

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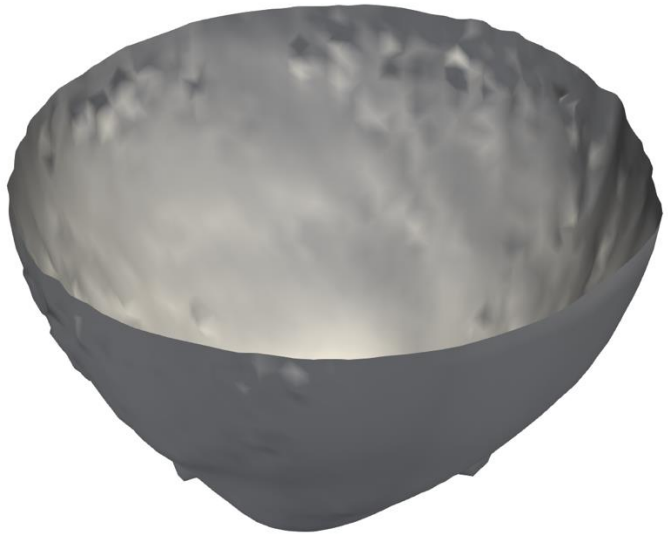
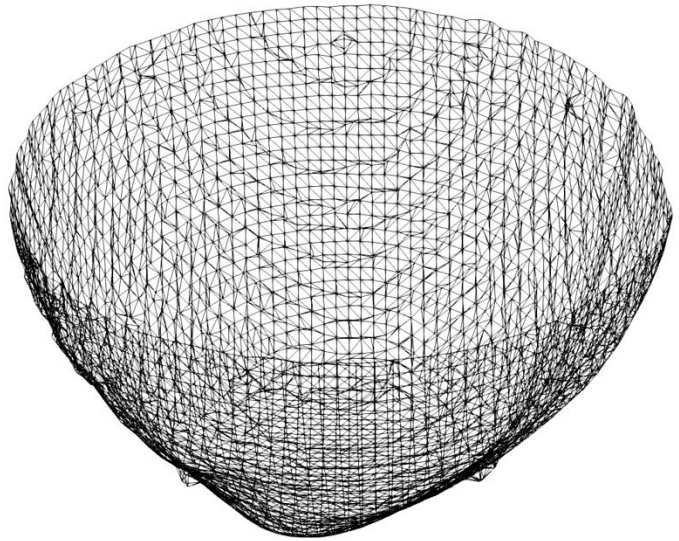
  - Engel, Hadwiger, Salama; Real time volume graphics tutorial, EuroGraphics 2006

Indirect Visualization of Volume Data

- We have seen isosurfaces for 2D/3D data in the last class
  - Example of indirect technique for volume data exploration
  - Using geometric representations
    - Points, meshes, surfaces, etc.



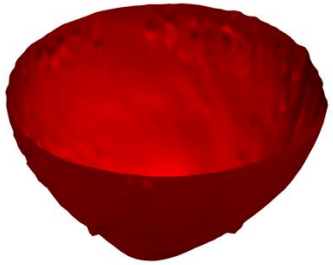
Isosurface



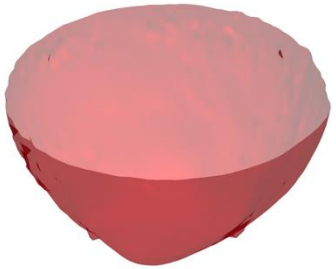
Geometric mesh of the isosurface

Volume Rendering

- Isosurface visualization is a way of showing data features as opaque objects
  - Though you can apply transparency on surfaces
- Many applications demand techniques that allows “see-through” capability
  - Users can make parts of the data (semi)transparent so the data behind can be seen
- Volume Rendering technique is the answer
  - Direct mapping of underlying 3D data into an image space

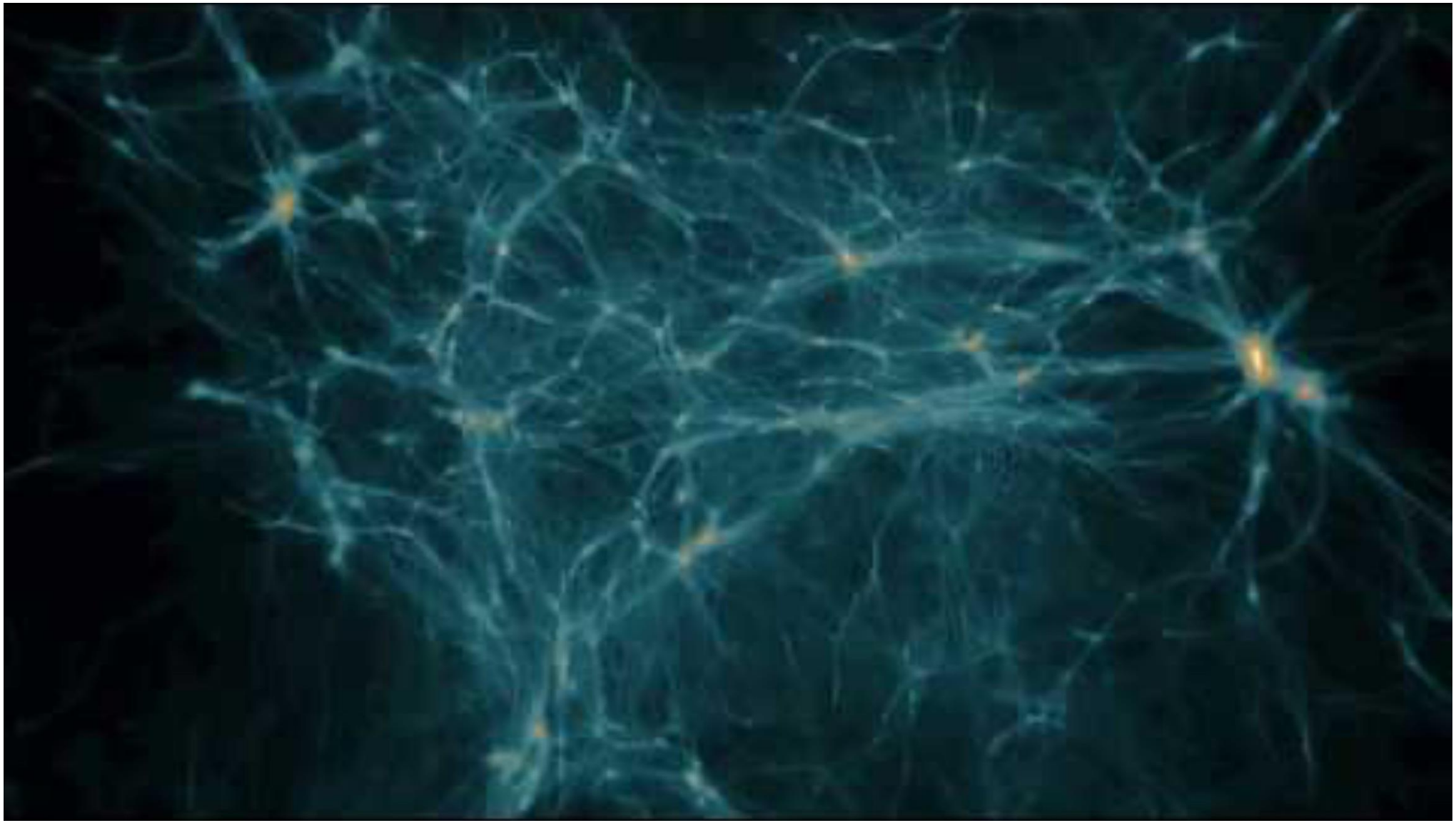


Opaque

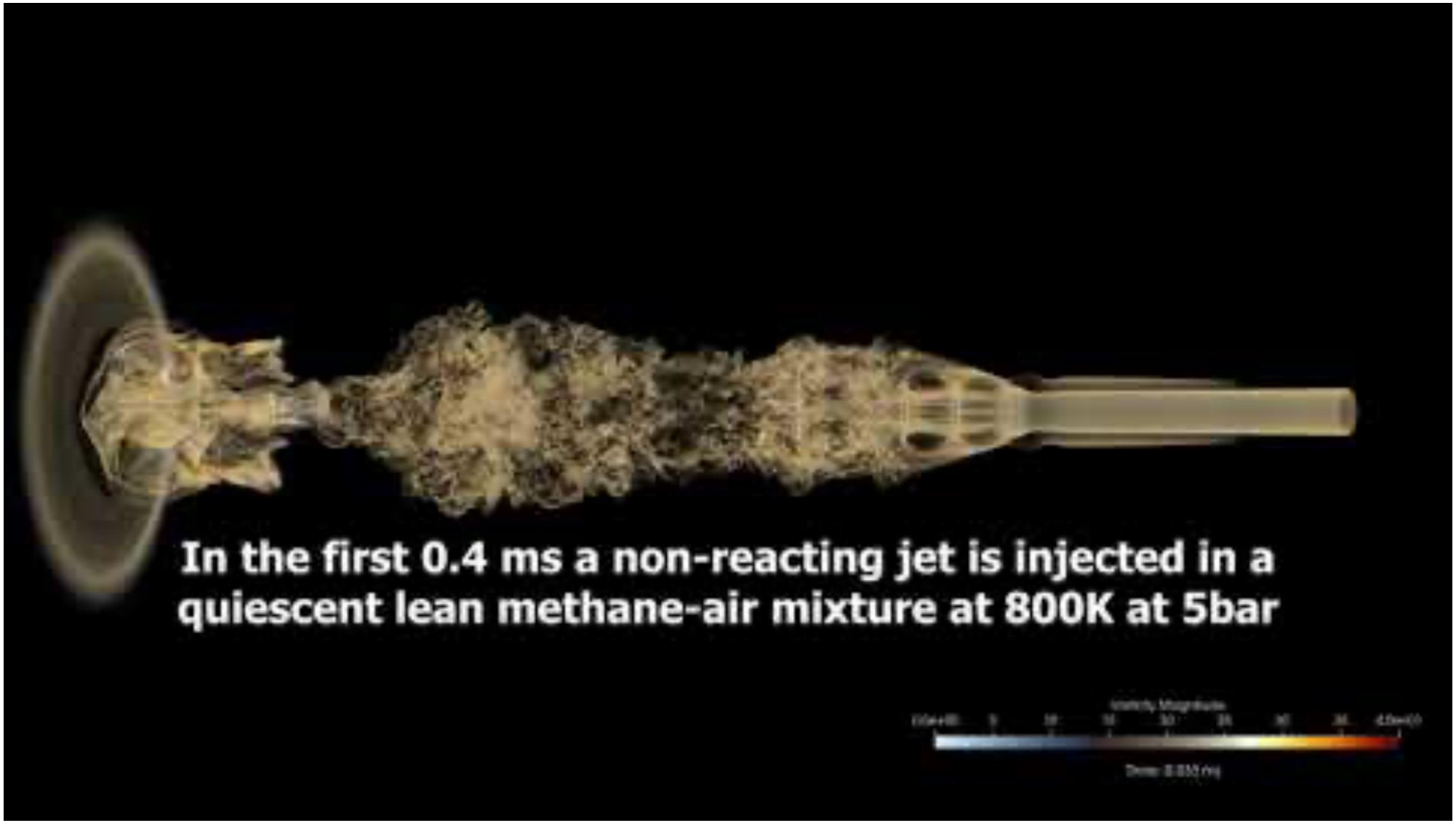


Semi-transparent

Volume Rendering



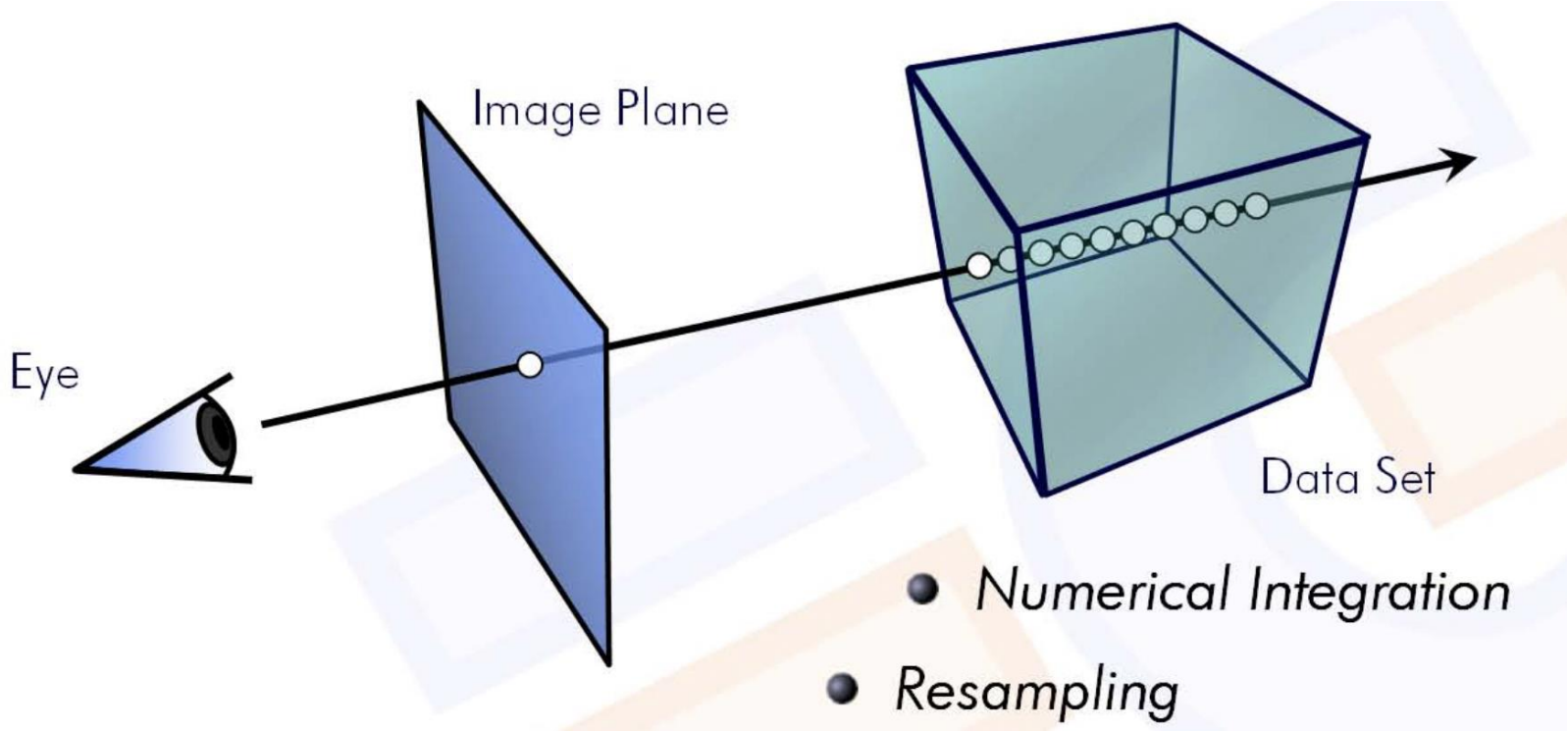
Volume Rendering



Volume Rendering

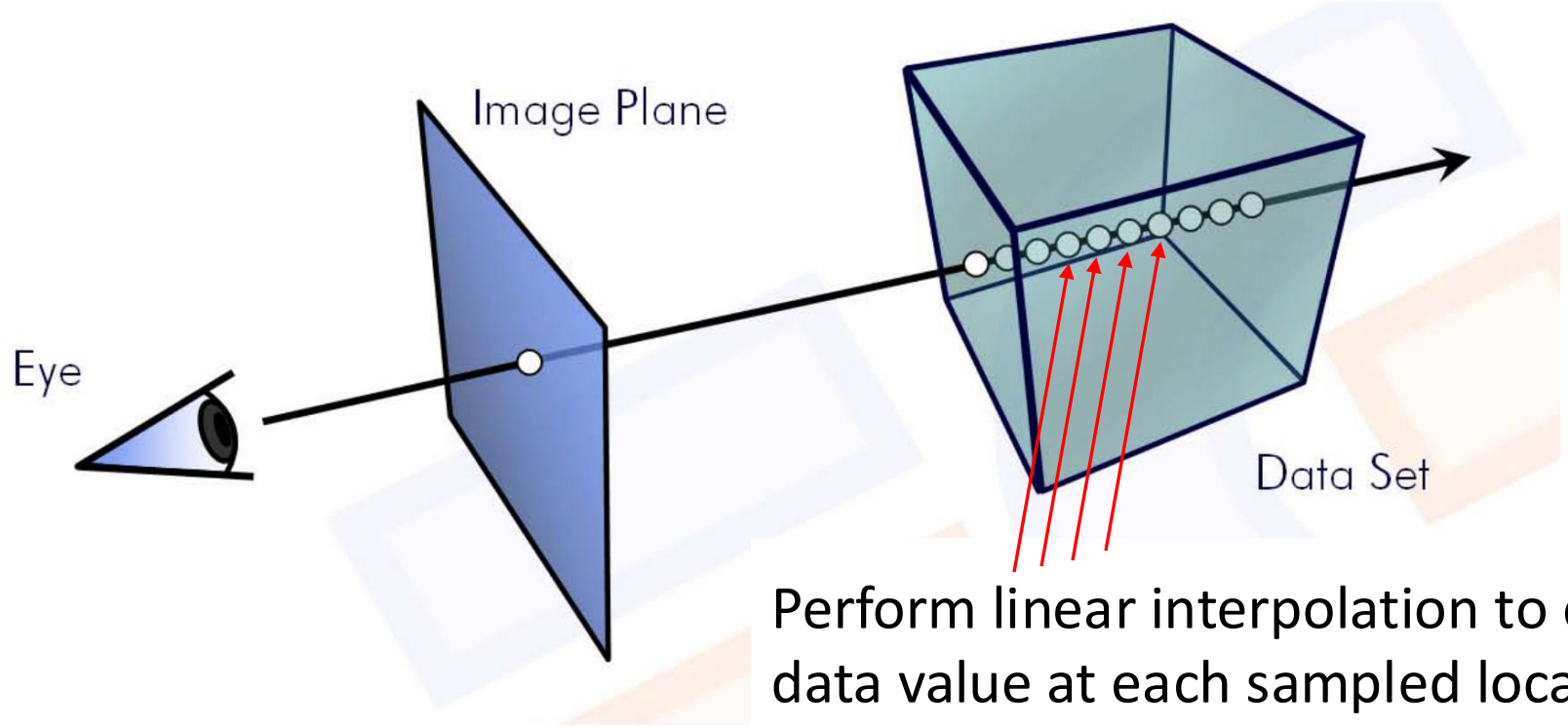
Volume Rendering Key Idea

- Data is considered as a translucent gel
- Rays are cast into the volume data to sample data values
- Rays accumulate color and opacity values along the ray



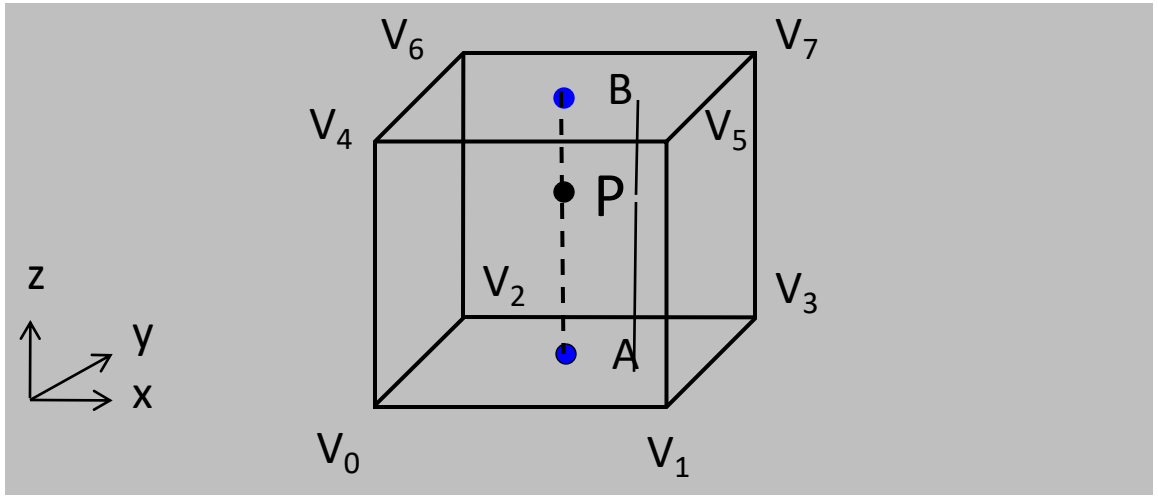
Sample Along the Ray to Collect Data Values

Estimate sample values via interpolation



Perform linear interpolation to compute data value at each sampled location

Sampling via Trilinear Interpolation



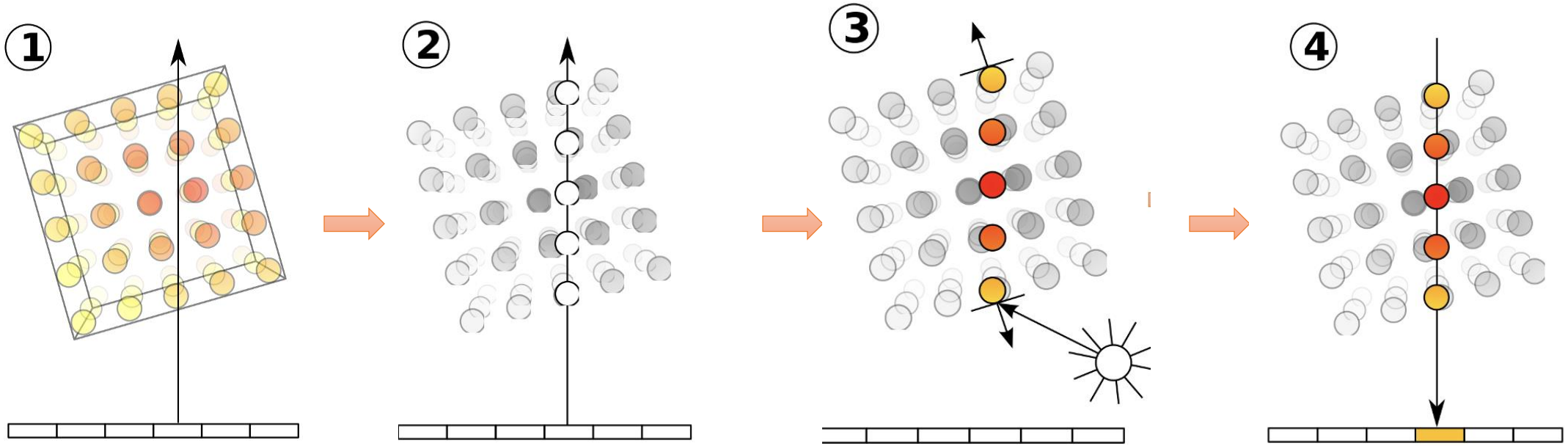
- Value at A = Bi-Lerp(V_0,V_1,V_2,V_3) ;
- Value at B = Bi-Lerp(V_4,V_5,V_6,V_7) ;
- Value at P = Lerp(A,B, PA/AB);

← Tri-linear interpolation

Ray Casting and Compositing

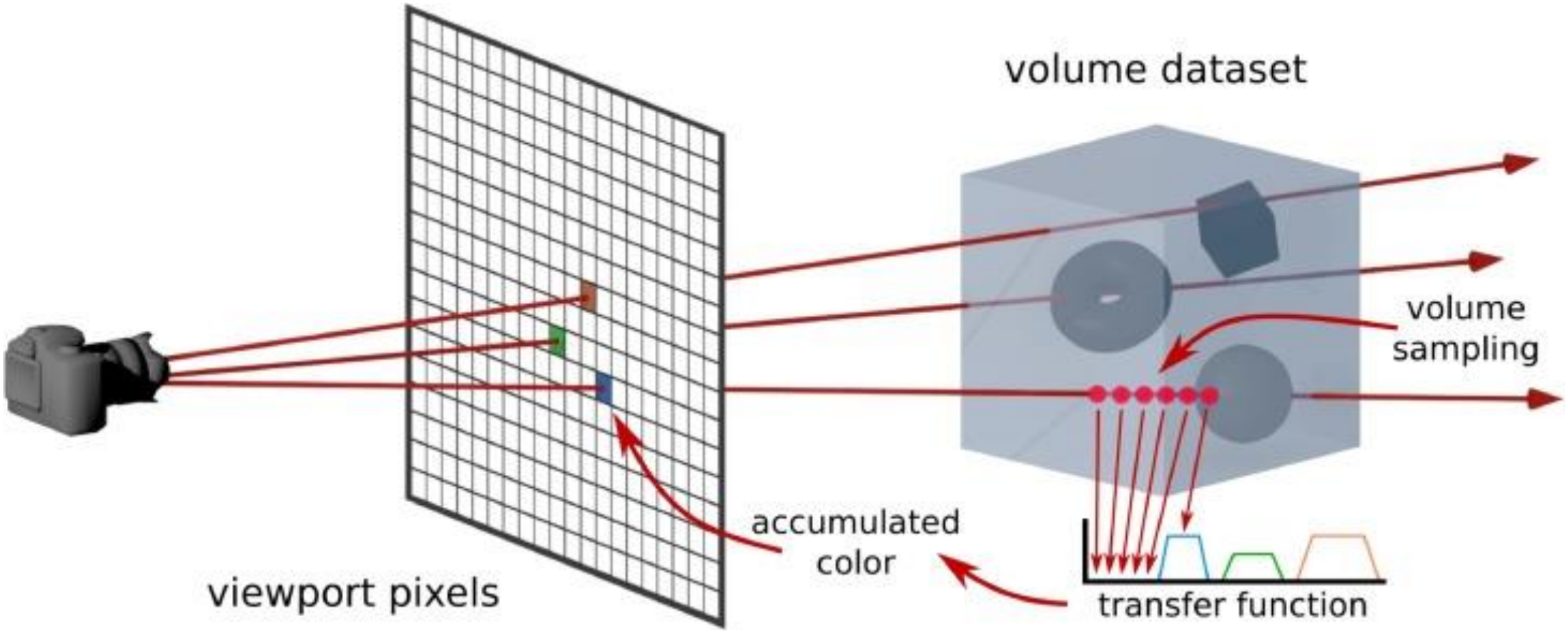
- Direct Volume Rendering Algorithm

1. Ray Casting
2. Sampling
3. Shading
4. Compositing



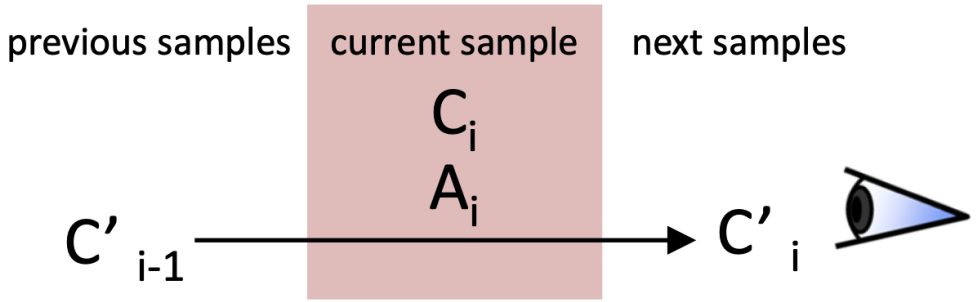
Ray Casting and Compositing

- Direct Volume Rendering Algorithm



Opacity and Color Blending: Compositing

Back-to-front rendering



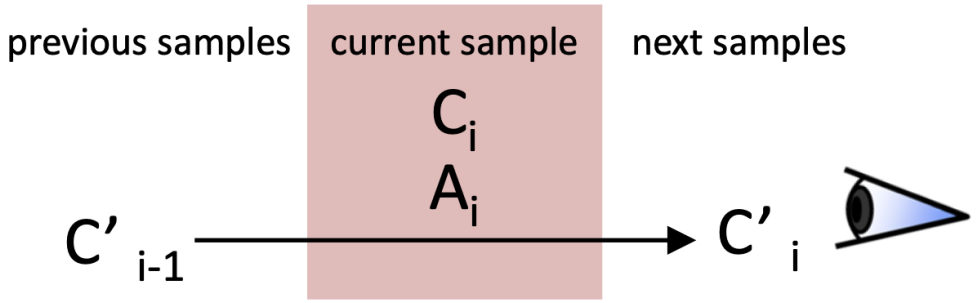
$$C_i^{'} = C_i A_i + (1 - A_i) C_{i-1}^{'}$$

A: Opacity = 1- Transparency = 1 - T

C: Color

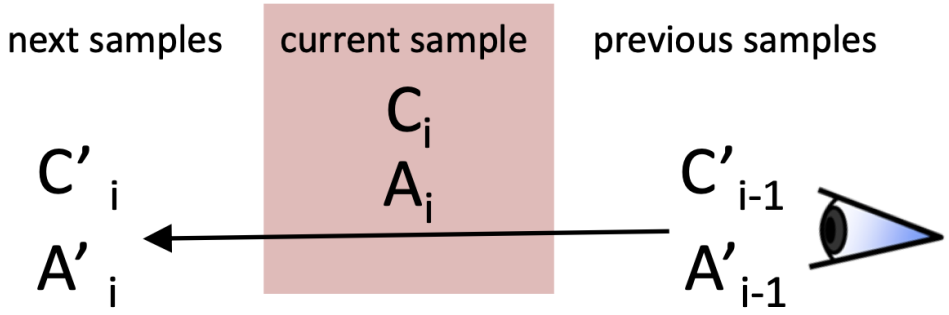
Opacity and Color Blending: Compositing

Back-to-front rendering



$$C_i^{'} = C_i A_i + (1 - A_i) C_{i-1}^{'}$$

Front-to-back rendering



$$C_i' = C_{i-1}' + (1 - A_{i-1}') C_i A_i$$

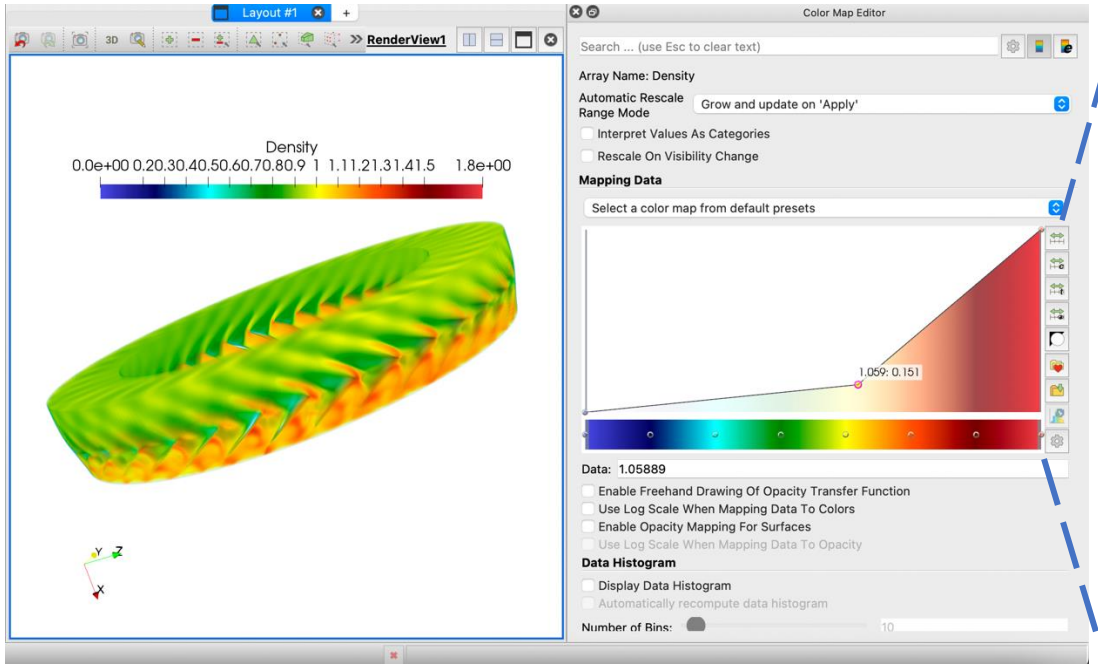
$$A_i' = A_{i-1}' + (1 - A_{i-1}') A_i$$

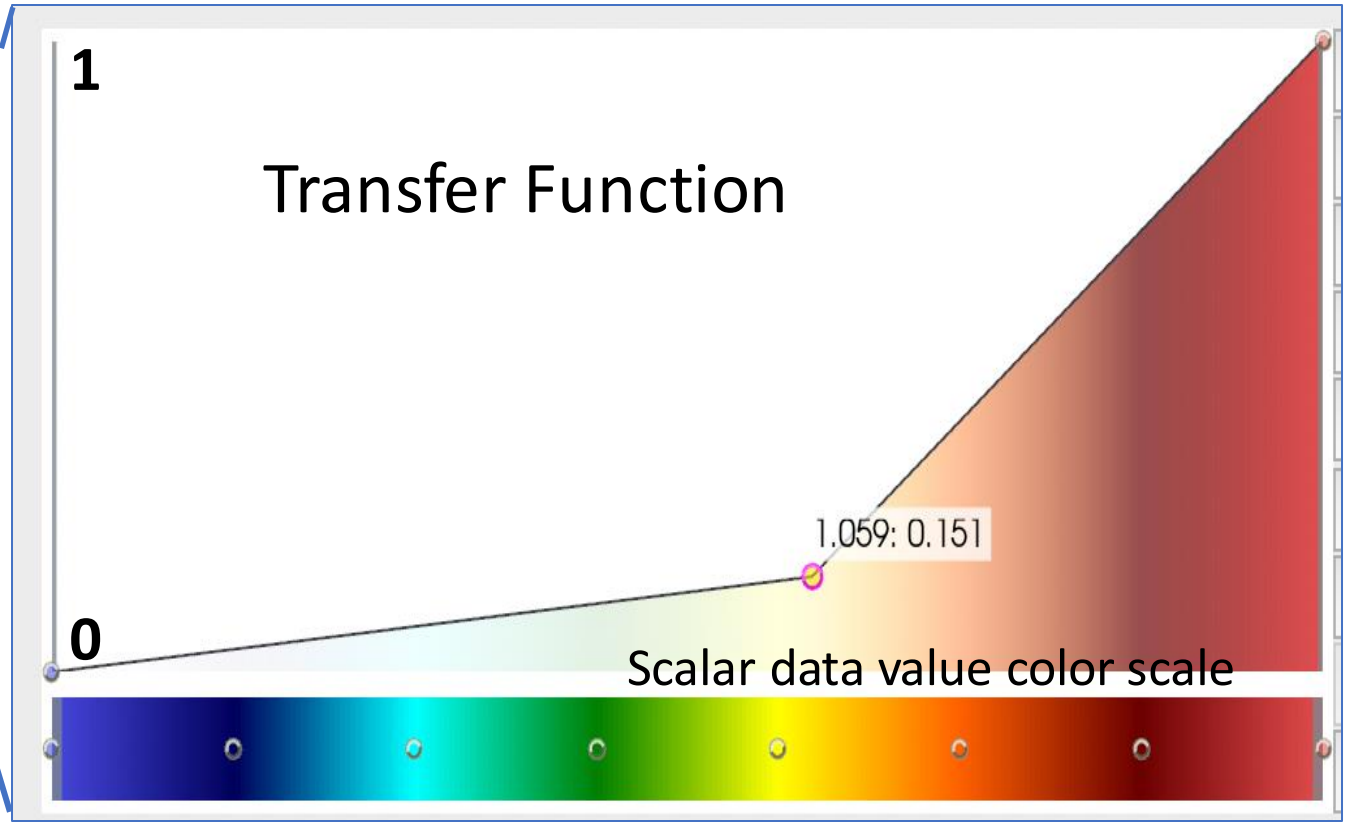
A: Opacity = 1- Transparency = 1 - T

C: Color

Transfer Function

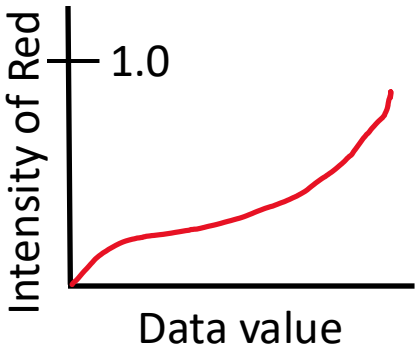
- Determines what color & opacity a sample value should have
  - Input: an interpolated data value
  - Output: a color and opacity (RGBA)

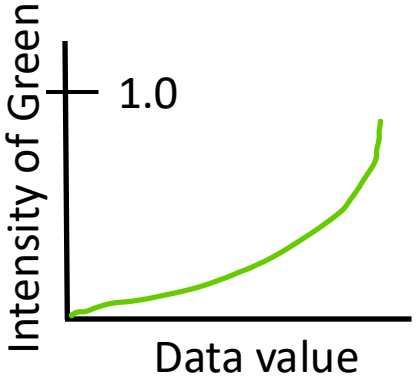


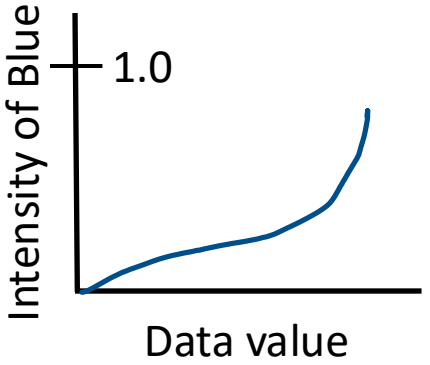


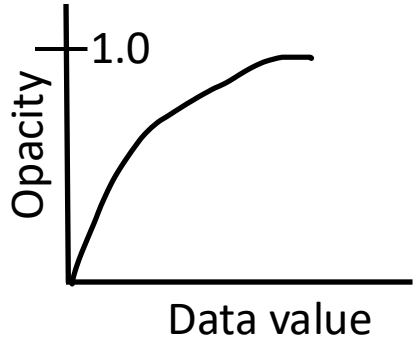
Transfer Function

- At the simplest form, we can think of four 1D transfer functions
  - Red, Green, Blue, Alpha (opacity)



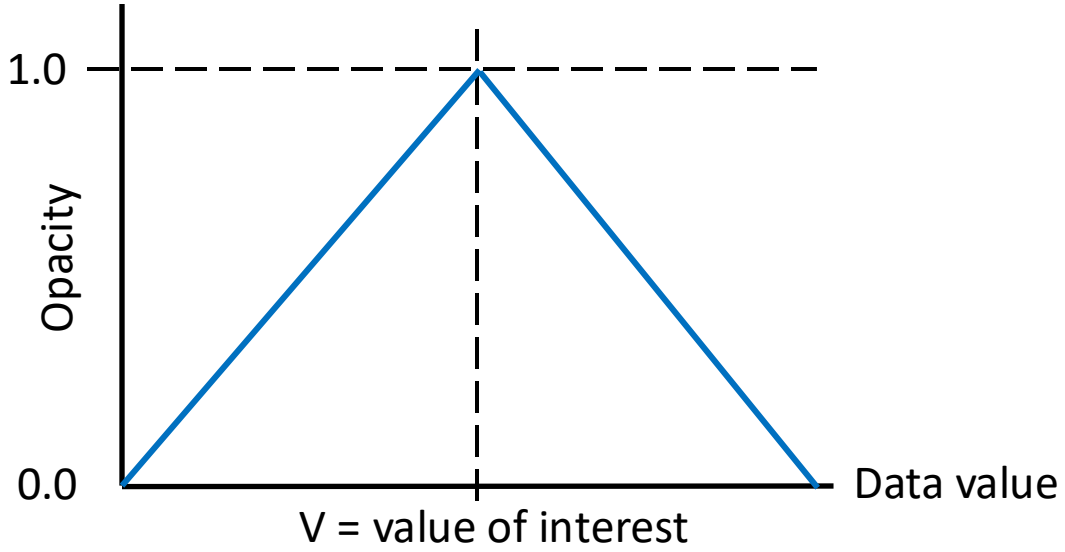


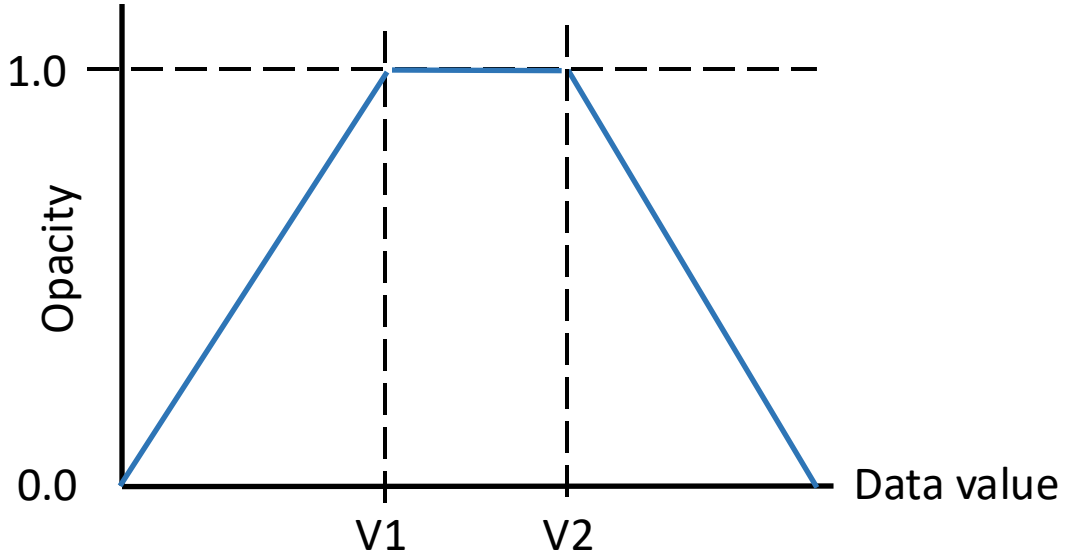




Shading and Classification

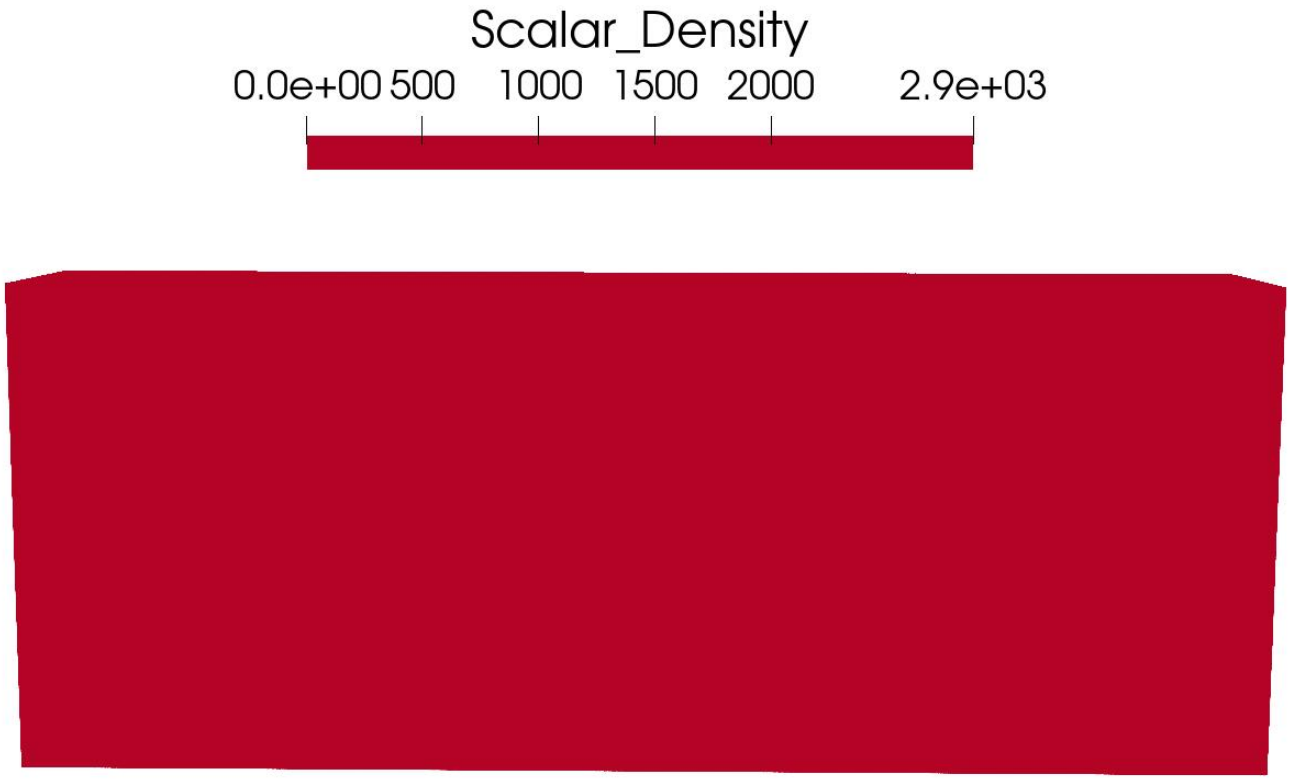
- Shading is the process of assigning color values to data points considering parameters of the rendering system
- Classification: Mapping data values to opacities
  - Region of interest → High Opacity so that clearly seen
  - Unimportant regions → Full or semi transparent



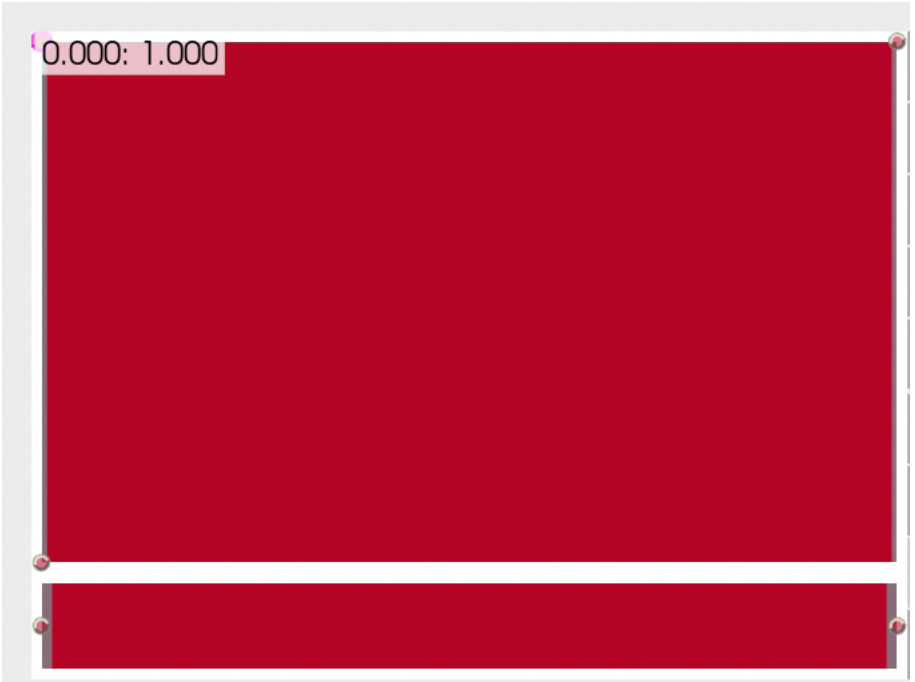


Classification: Color + Opacity Transfer Function

- Distinguish between different materials or features in the data



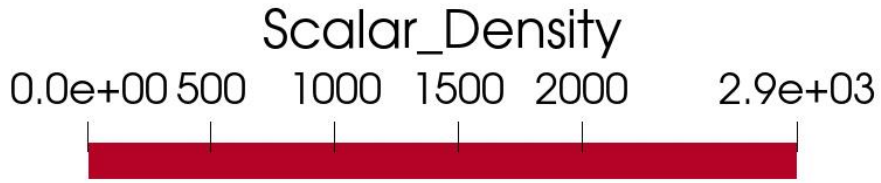
Transfer function editor



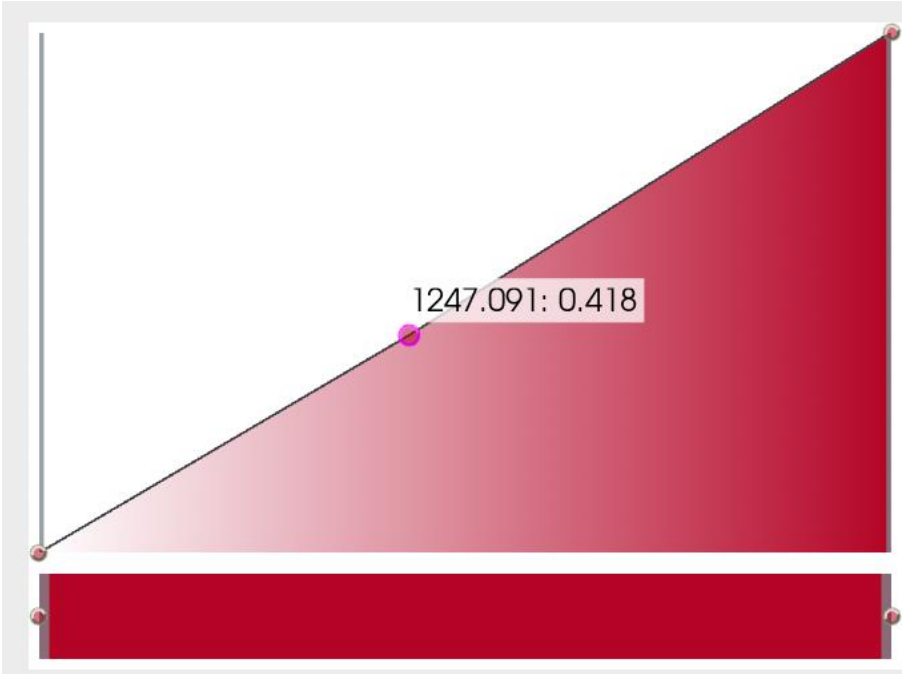
Single color for all data values and all data values have opacity = 1.0

Classification: Color + Opacity Transfer Function

- Distinguish between different materials or features in the data



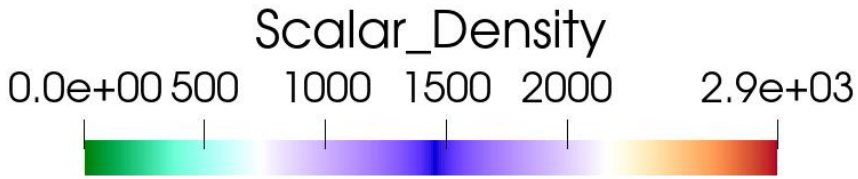
Transfer function editor

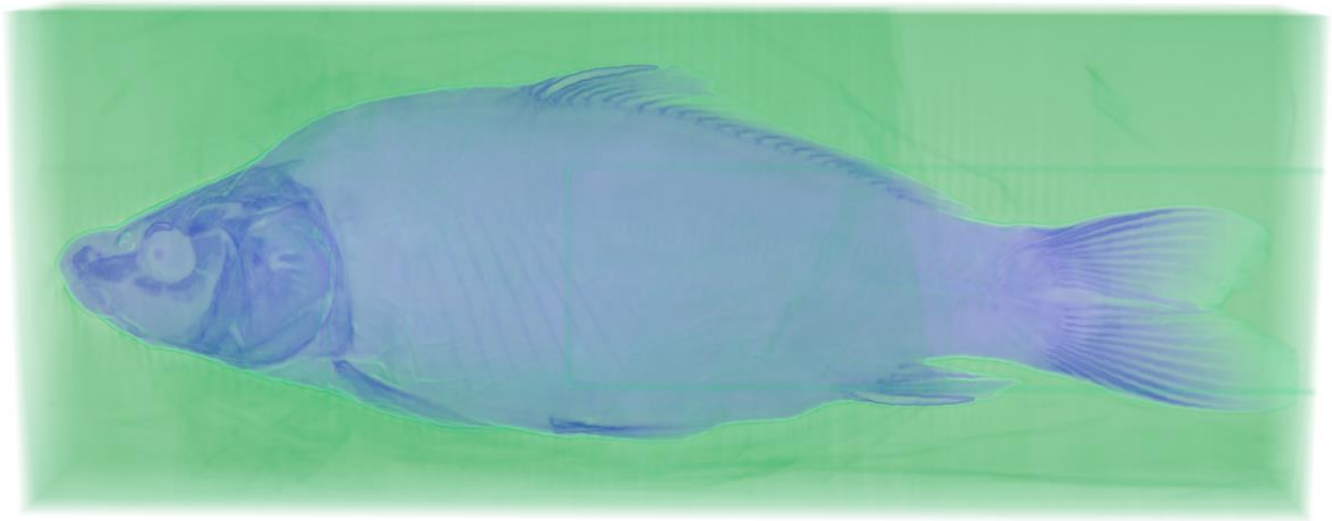


Set opacity function as a ramp function, shows some structure inside

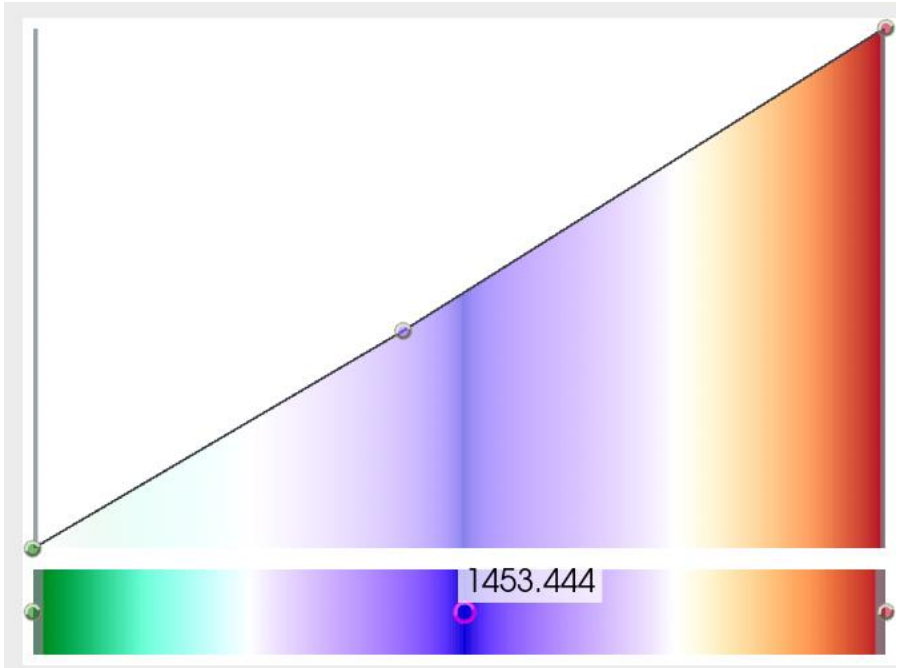
Classification: Color + Opacity Transfer Function

- Distinguish between different materials or features in the data





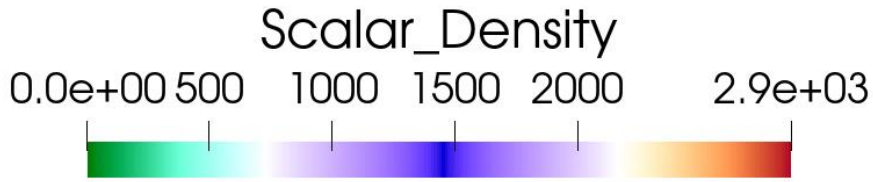
Transfer function editor



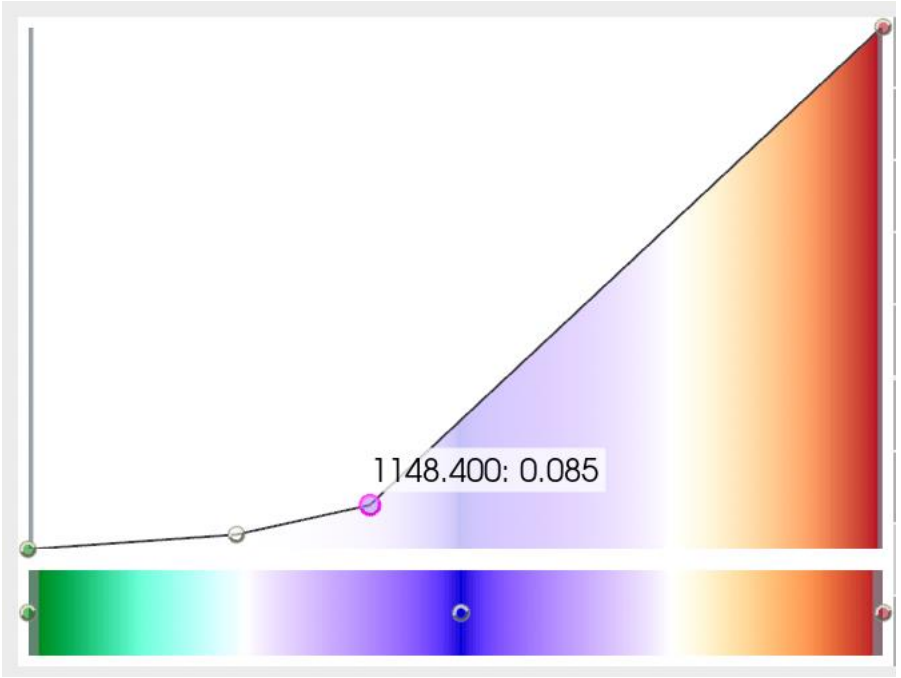
Add more colors in the color transfer function

Classification: Color + Opacity Transfer Function

- Distinguish between different materials or features in the data



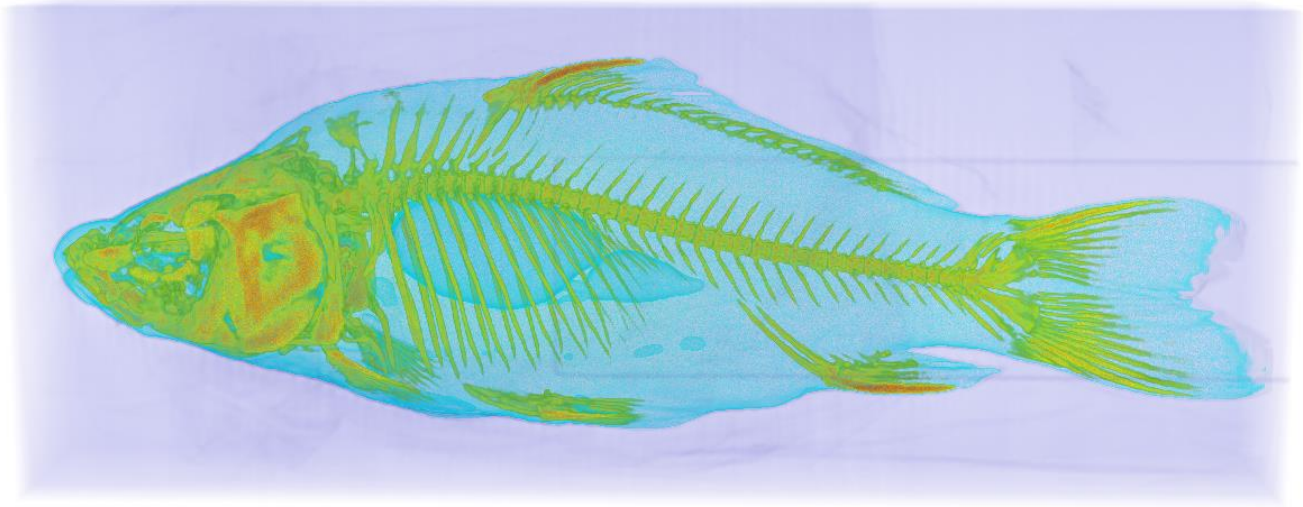
Transfer function editor



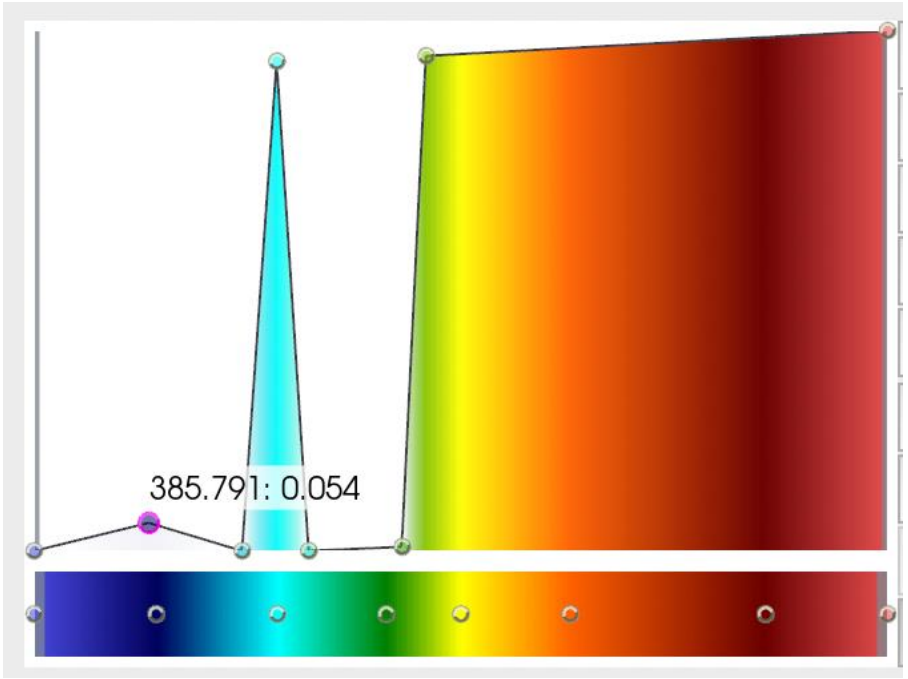
Modified opacity transfer function to remove some of the background

Classification: Color + Opacity Transfer Function

- Distinguish between different materials or features in the data



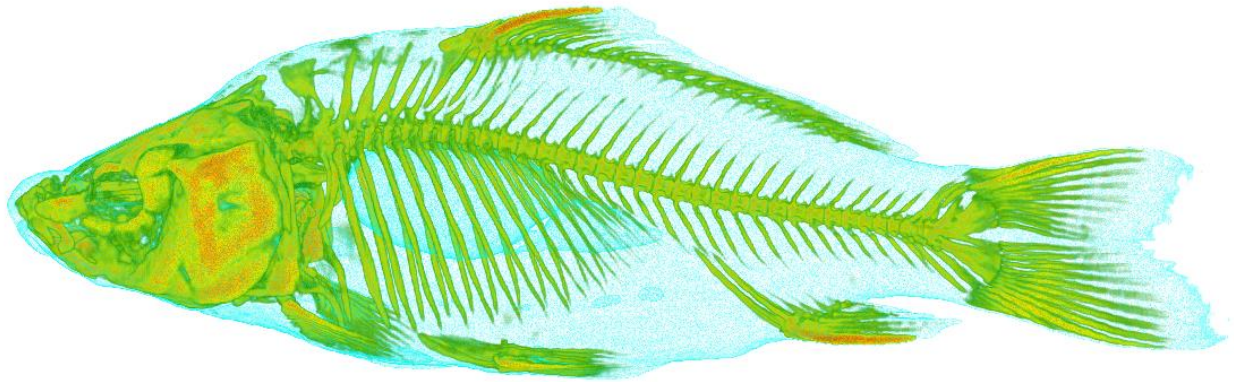
Transfer function editor



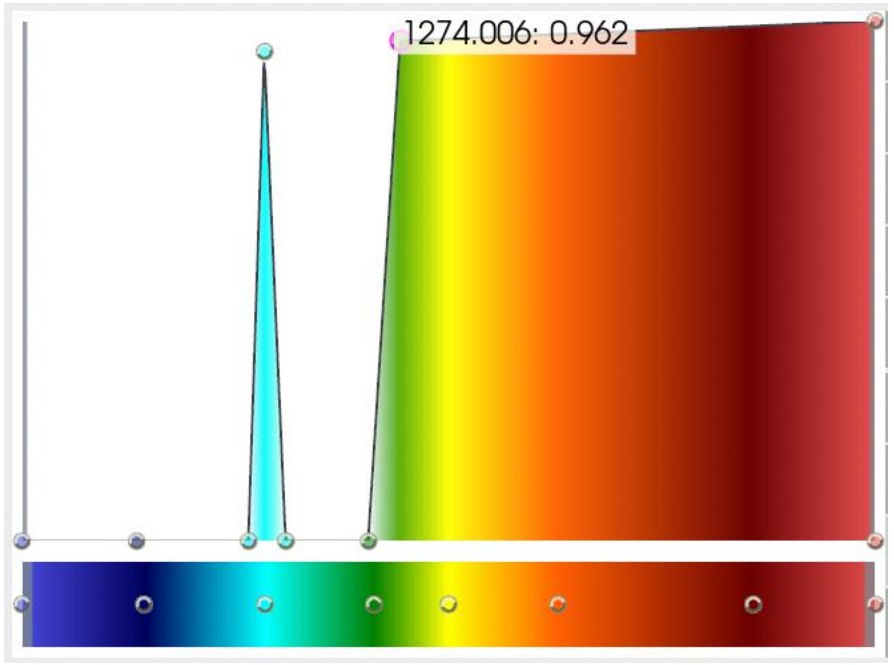
Use a different color transfer function and try to engineer a more effective opacity function

Classification: Color + Opacity Transfer Function

- Distinguish between different materials or features in the data



Transfer function editor



Change the opacity function to remove the background and the fish is seen clearly