



Big Data Visual Analytics (CS 661)

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Acknowledgements

- Some of the following slides are adapted from the excellent course materials and tutorials made available by:
 - Prof. Han-Wei Shen (The Ohio State University)
 - Prof. Klaus Mueller (State University of New York at Stony Brook)
 - Engel, Hadwiger, Salama; Real time volume graphics tutorial, EuroGraphics 2006
 - Prof. Tino Weinkauff (KTH Stockholm)

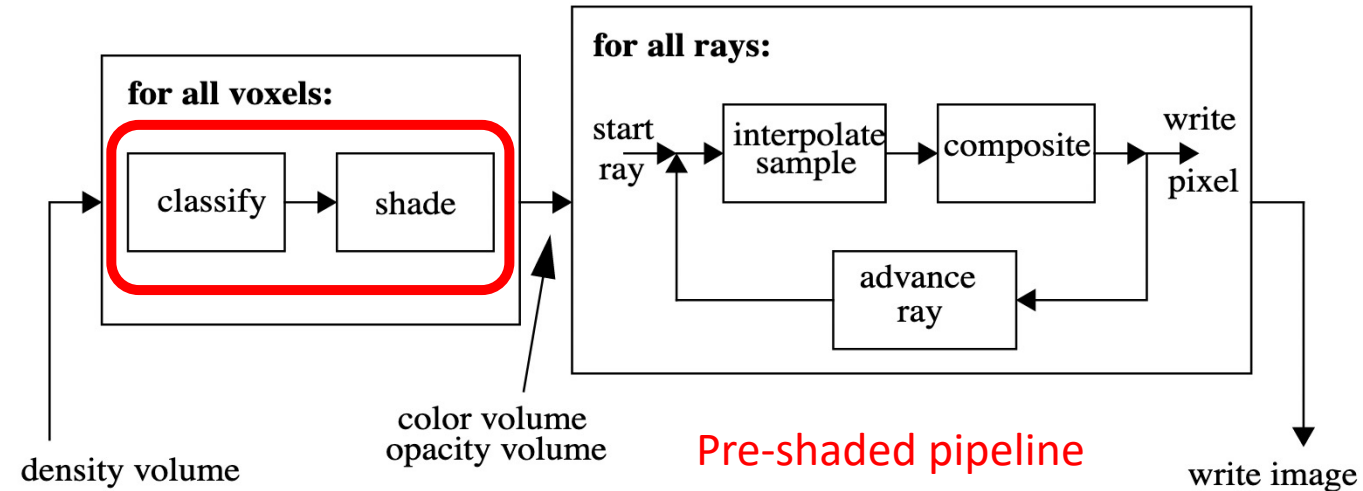
Study Materials for Lecture 7

- The Visualization Toolkit by Will Schroeder, Ken Martin, Bill Lorensen
 - Chapter 7 (Volume Rendering section)
- Transfer function:
 - State of the Art in Transfer Functions for Direct Volume Rendering, Ljung et al., EuroVis 2016
 - Multidimensional Transfer Functions for Interactive Volume Rendering, TVCG 2002
 - Visibility-Driven Transfer Functions, IEEE PacificVis

Types of Volume Rendering Pipelines

- Pre-shaded pipeline

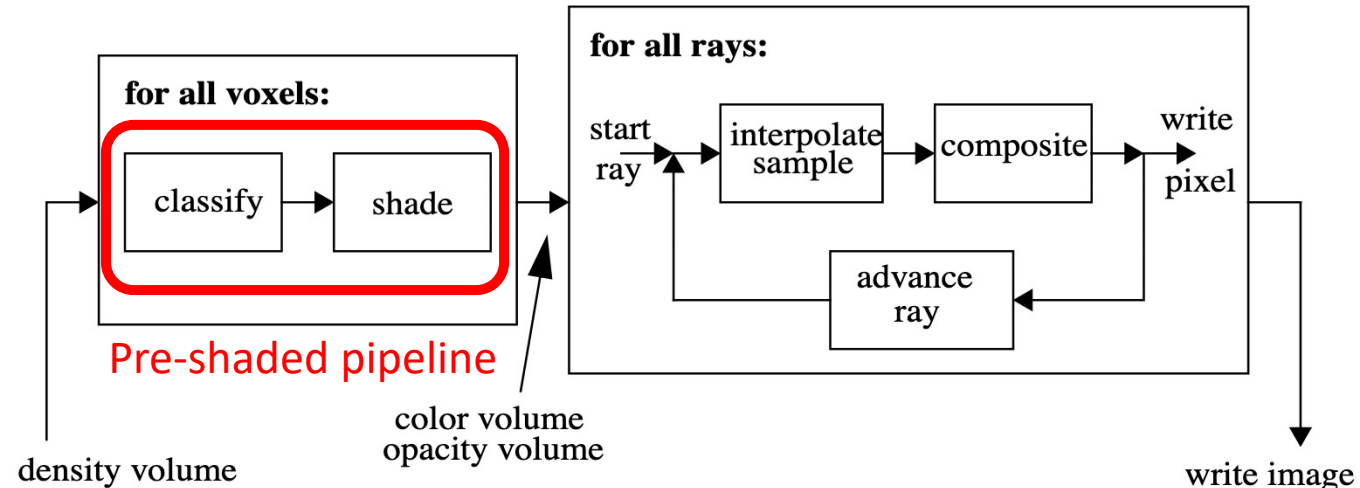
- Classify and shade the data first and then perform ray casting and compositing
- Color and opacity values are interpolated



Types of Volume Rendering Pipelines

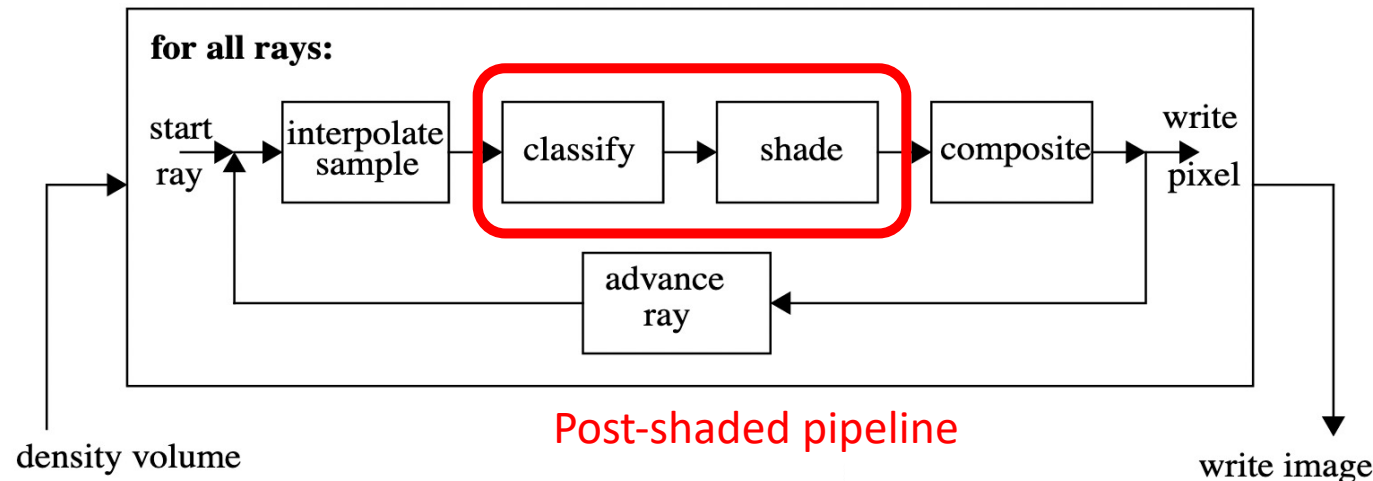
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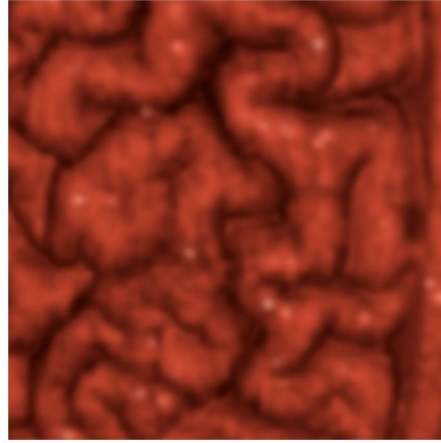
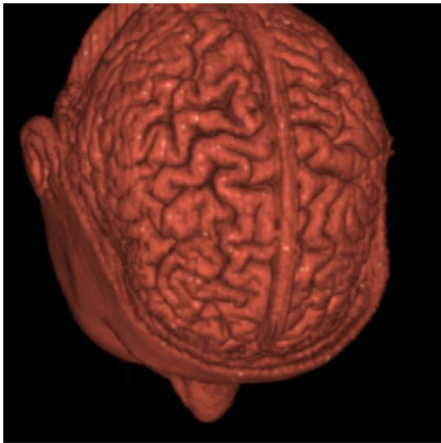


- Post-shaded pipeline

- Directly ray cast into the data, get data values at query location and use transfer function to shade and then composite
- Data value are interpolated



Pre-shaded vs Post-shaded Volume Rendering



Blurry edge

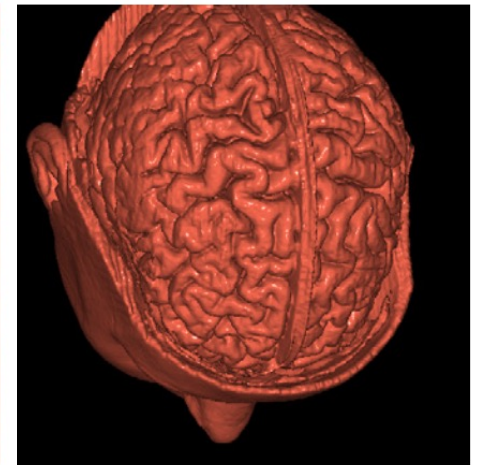
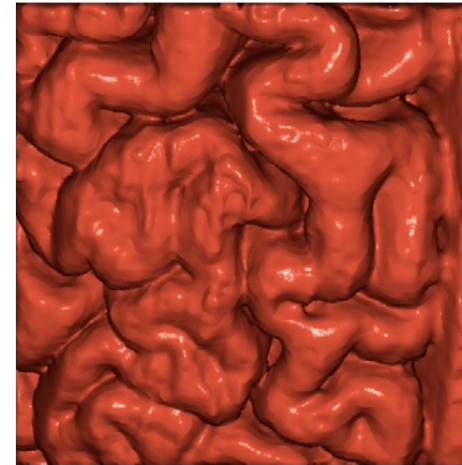
Pre-shaded pipeline



classify and shade first



interpolate shaded edge



Sharp edge

Post-shaded pipeline



interpolate first

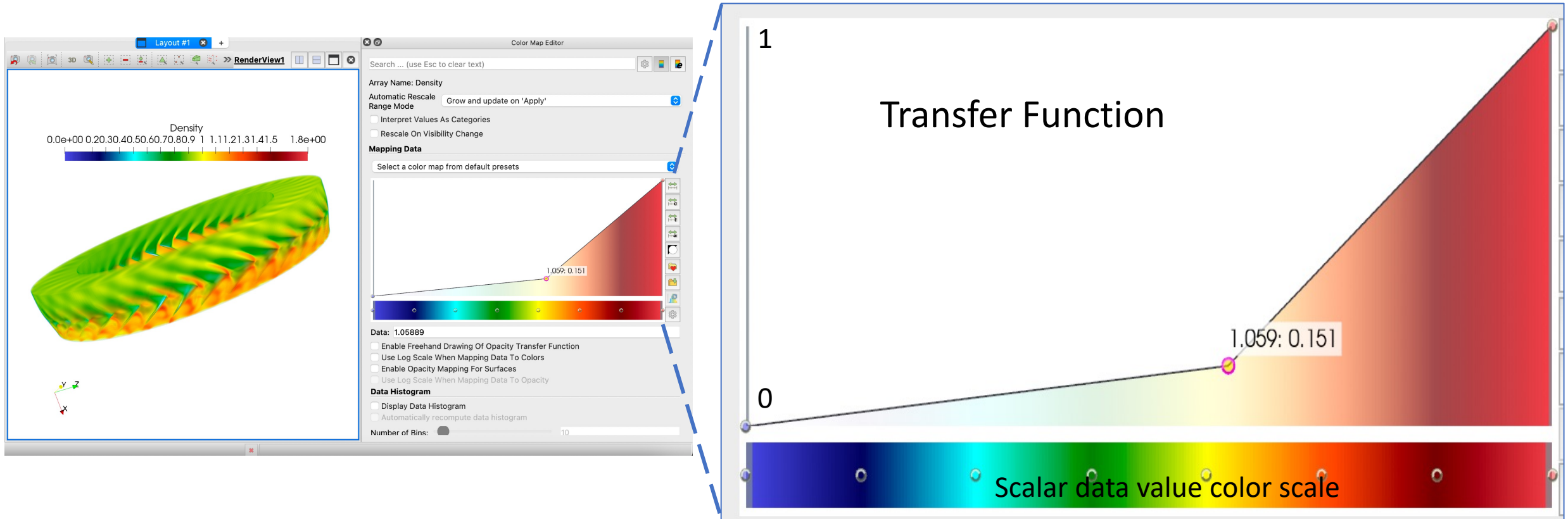


classify and shade



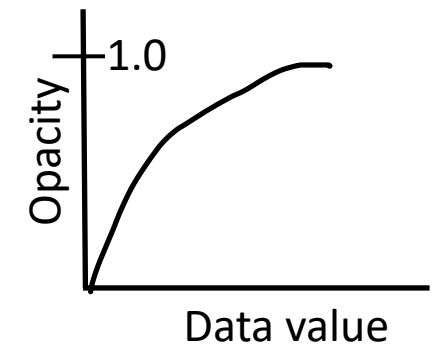
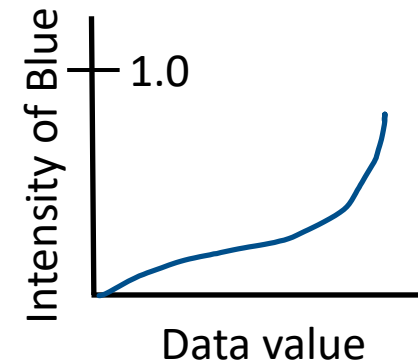
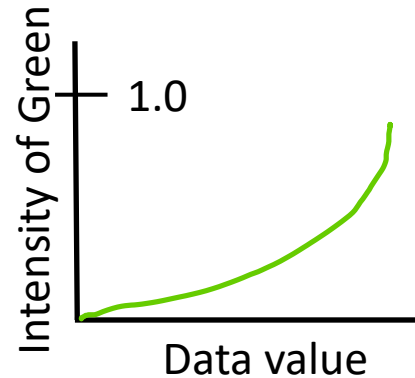
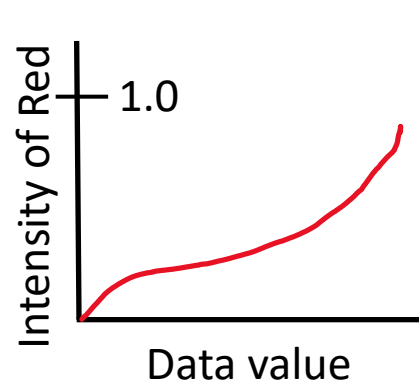
Transfer Function

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



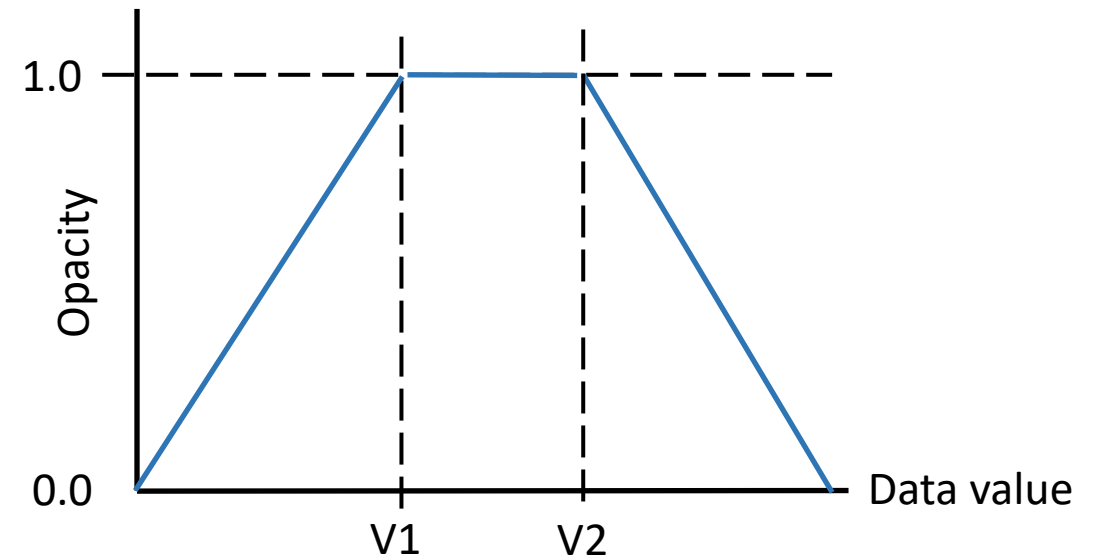
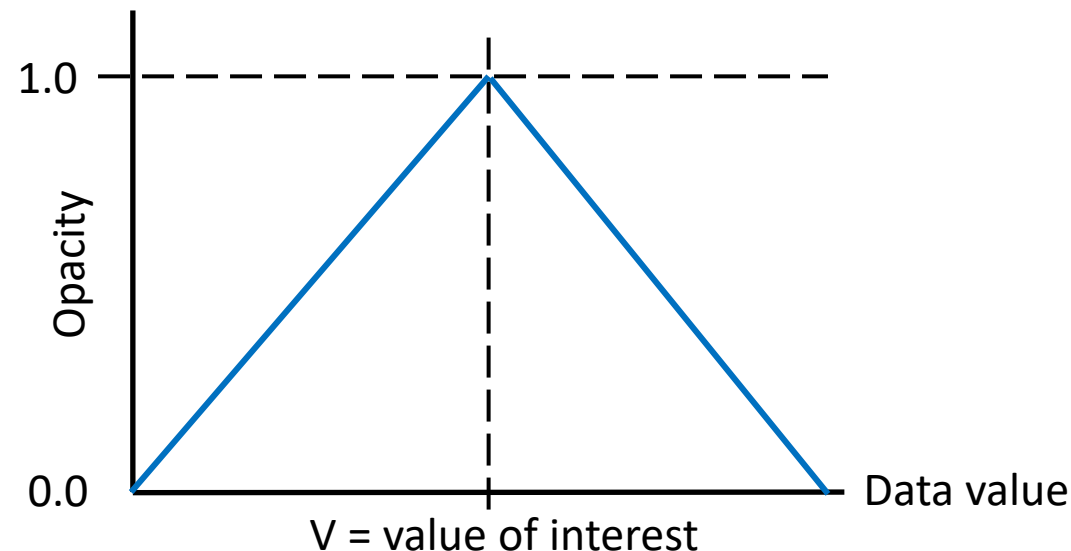
Transfer Function

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



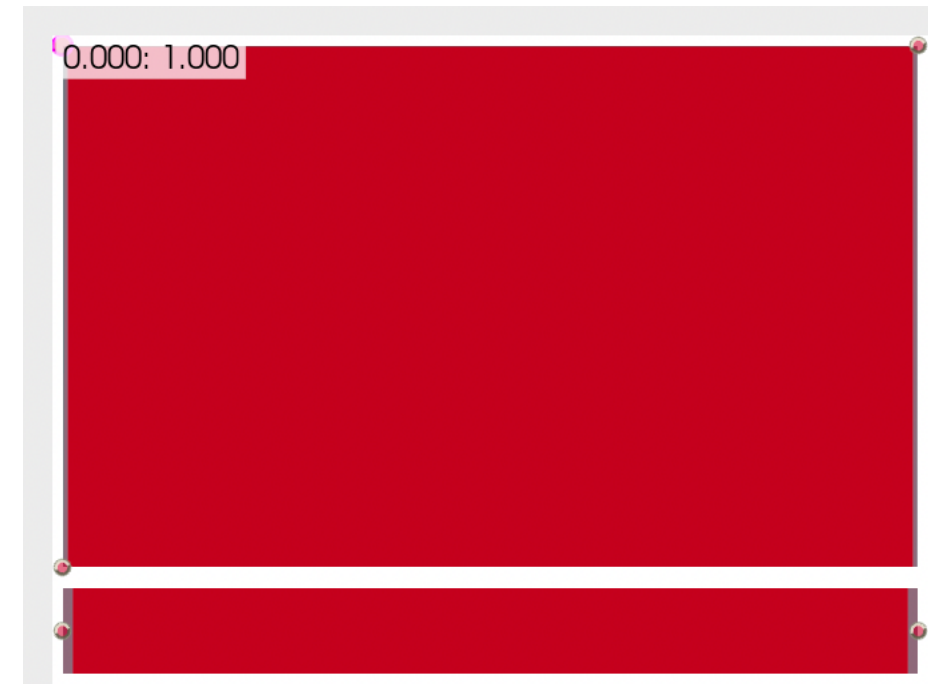
Classification and Shading

- We have already seen that 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 \rightarrow High Opacity so that clearly seen
 - Unimportant regions \rightarrow Full or semi transparent



Classification: Color + Opacity Transfer Function

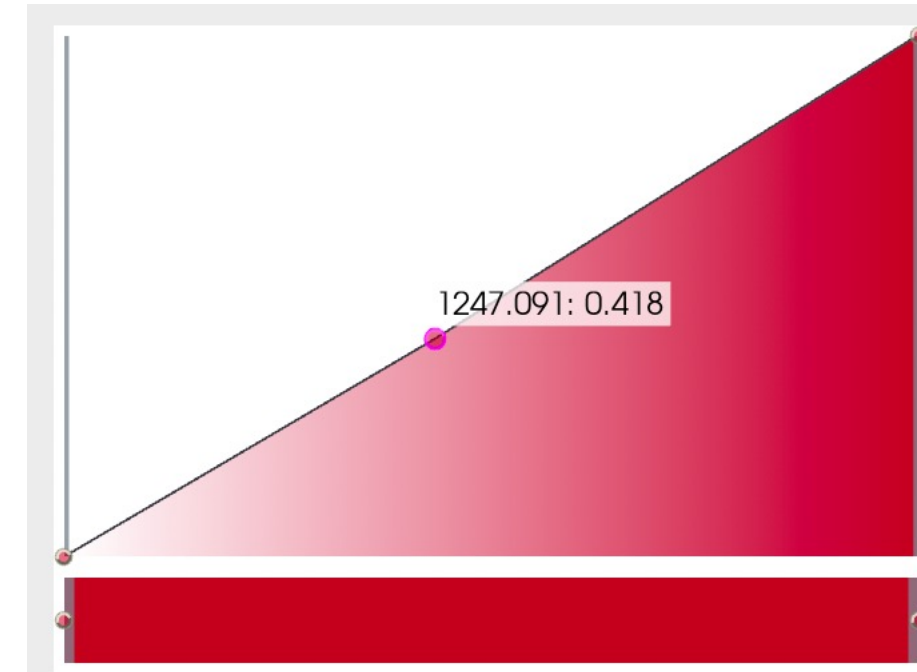
- Distinguish between different materials or features in the data



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

Classification: Color + Opacity Transfer Function

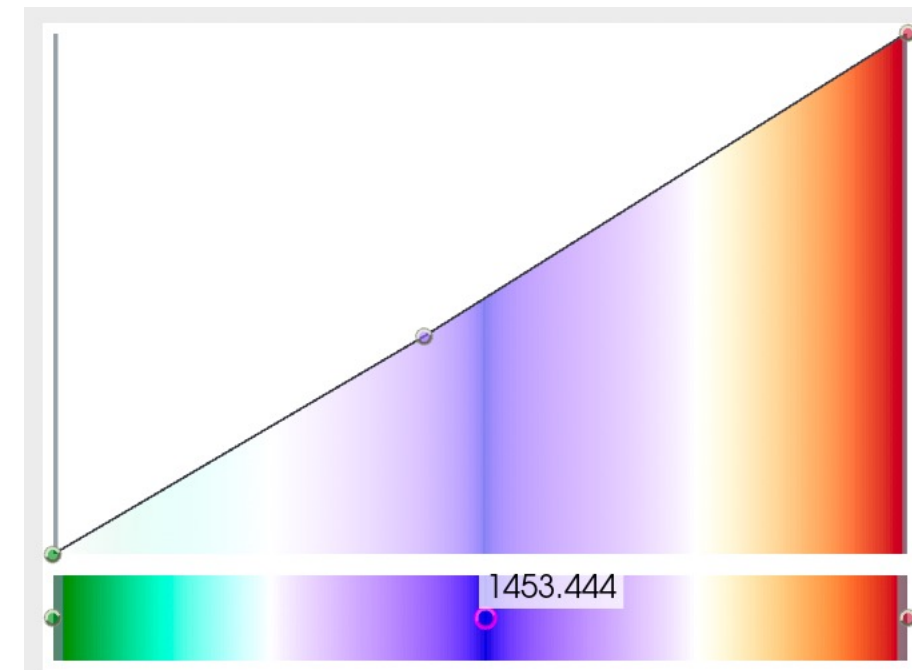
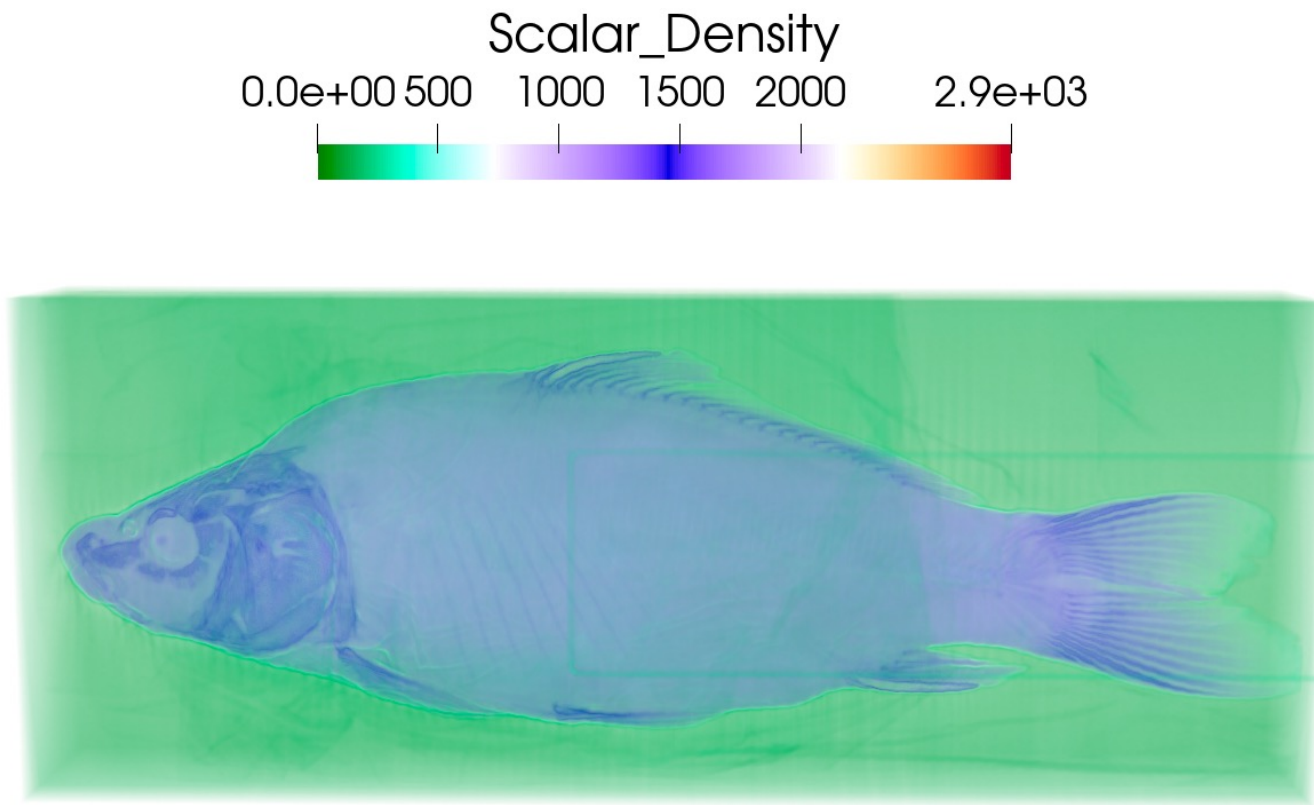
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Set opacity function as a ramp function, shows some structure inside

Classification: Color + Opacity Transfer Function

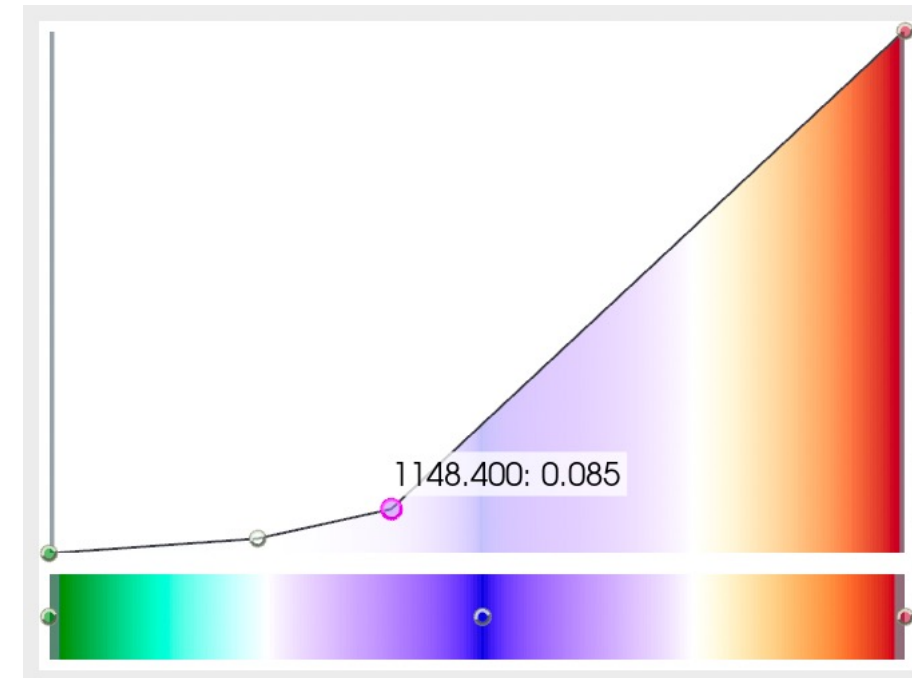
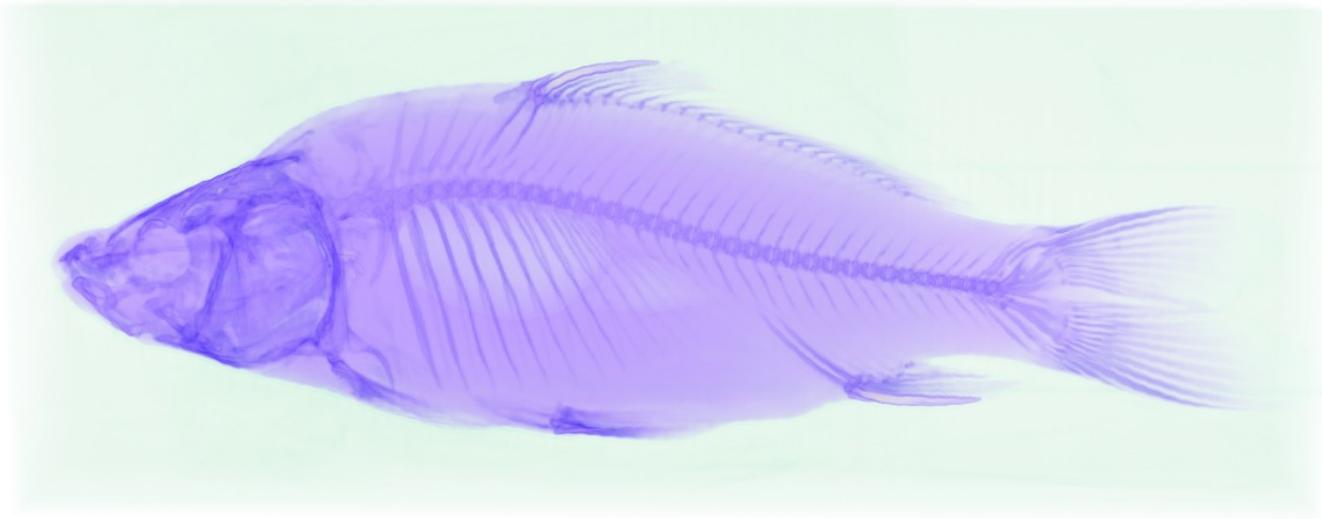
- Distinguish between different materials or features in the data



Add two more colors in the color transfer function, fish is blue, background is green

Classification: Color + Opacity Transfer Function

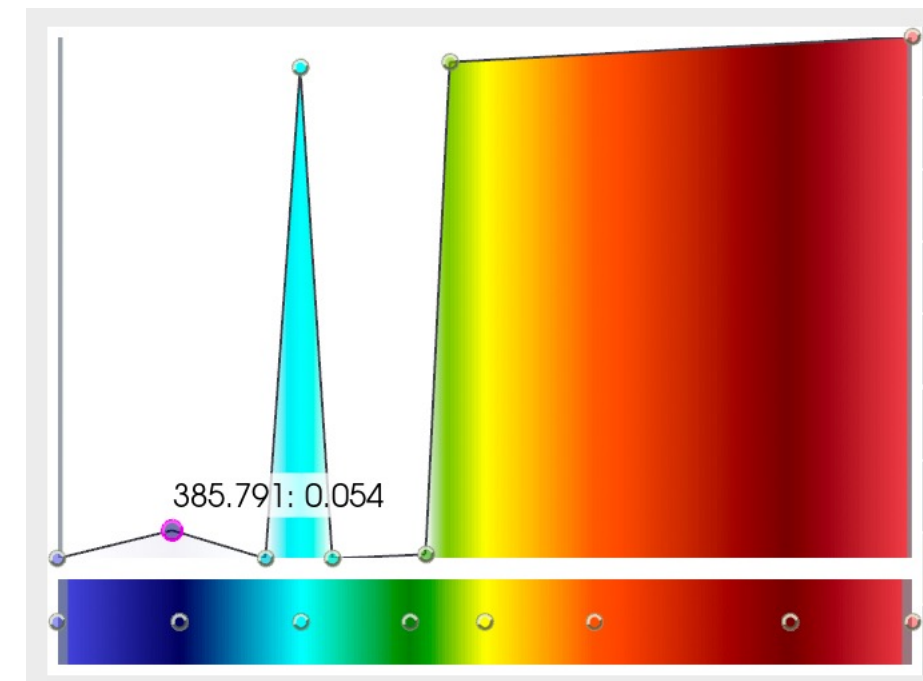
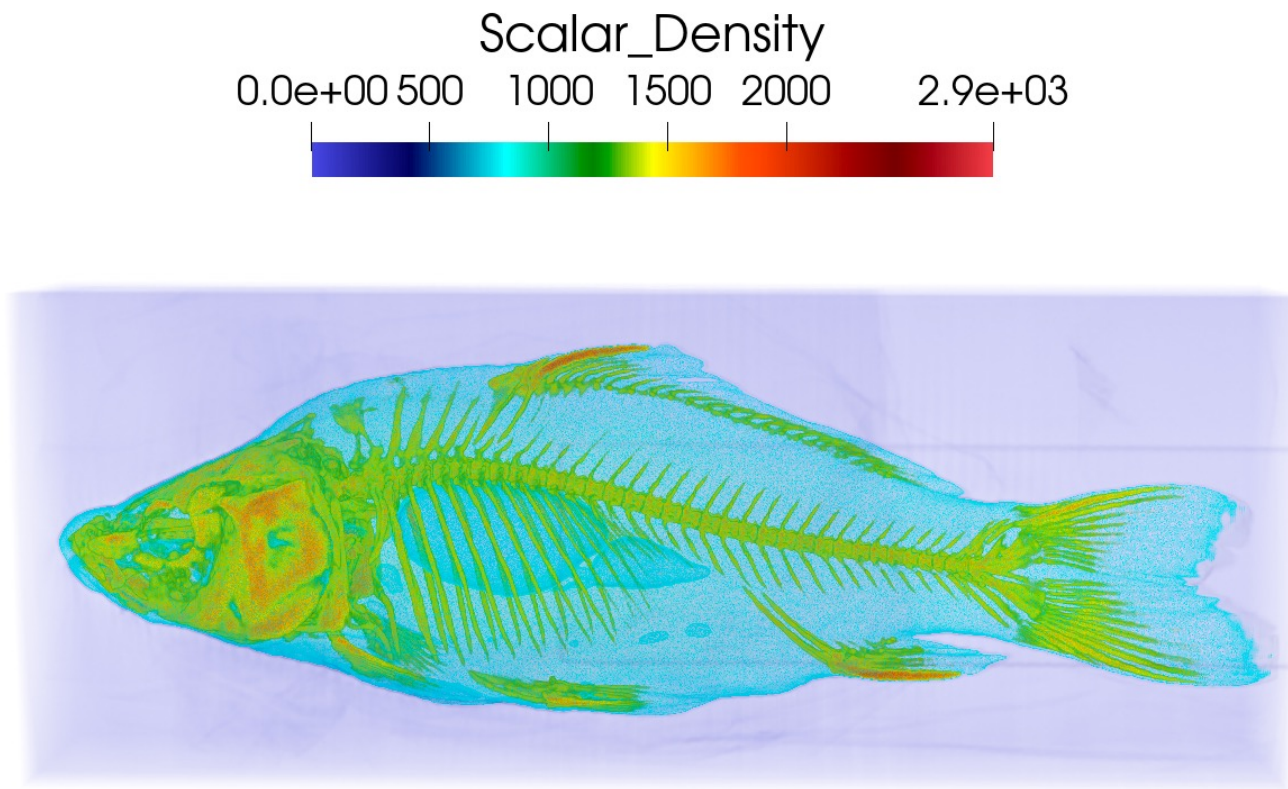
- Distinguish between different materials or features in the data



Modified opacity transfer function to remove some of the background

Classification: Color + Opacity Transfer Function

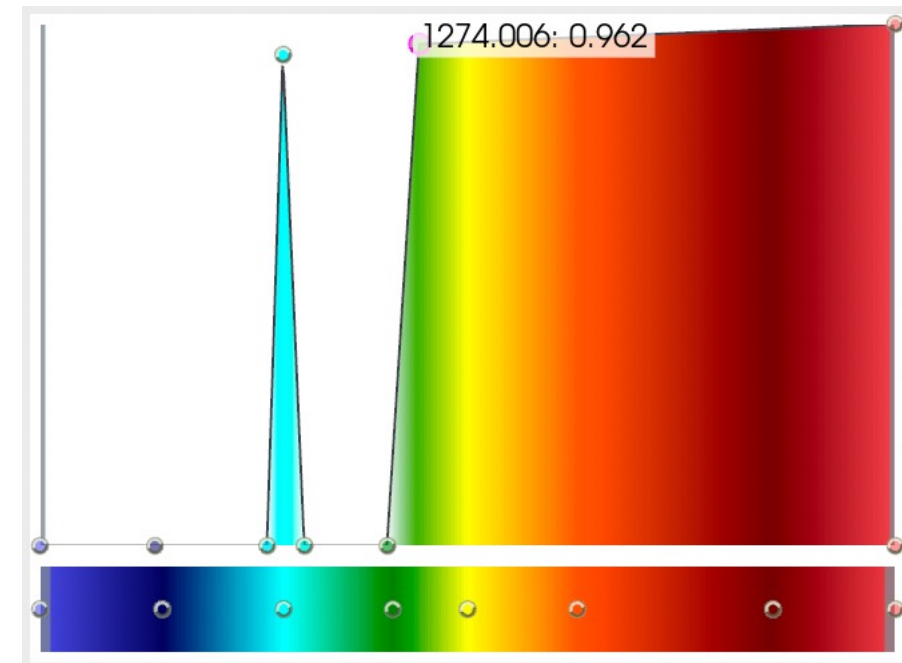
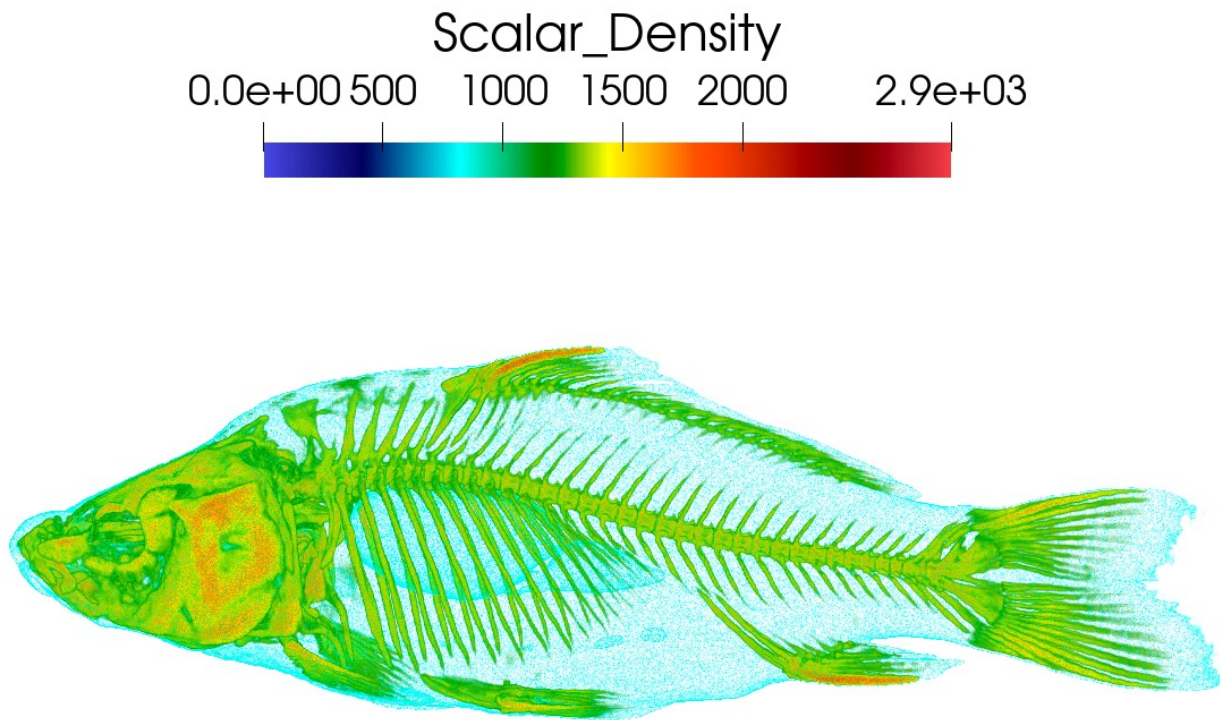
- Distinguish between different materials or features in the data



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



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

Transfer Function Design

- Goal:
 - Use transfer functions to show salient features from the data set and deemphasize the unimportant data

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 - A small difference in transfer function can change the visualization drastically
 - Lots of manual tweaking might be required!

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 - Lots of manual tweaking might be required!
- Need algorithms and strategies that can automatically analyze data design an effective transfer function given all possible transfer functions in the search space

Trail and Error + Domain Knowledge

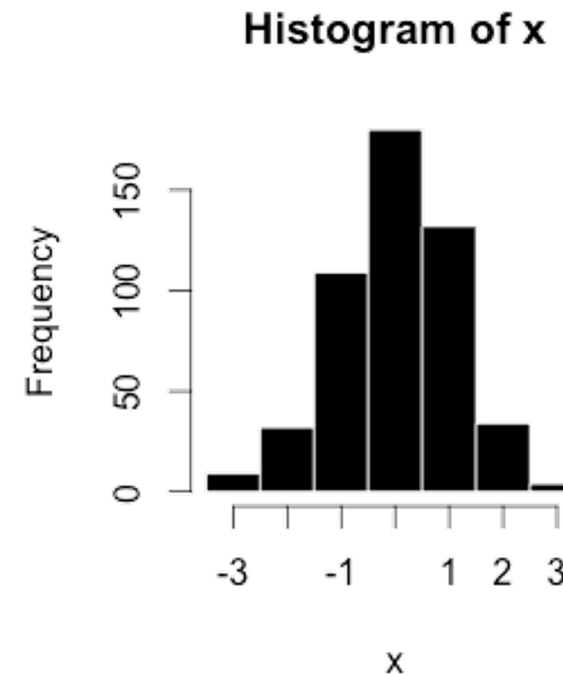
- Manually control colors for scalar values and try different opacity functions to find an optimal one
- Use domain knowledge about the data set to guide the design process
 - E.g.: what range of values correspond to bone and skin?
- Can take significant amount of time!

Histogram

- Histogram: A histogram is an approximate representation of a statistical distribution. The area under a histogram can be normalized and used as a probability distribution function

$$H(s) = \sum_i \delta(x - x_i)$$

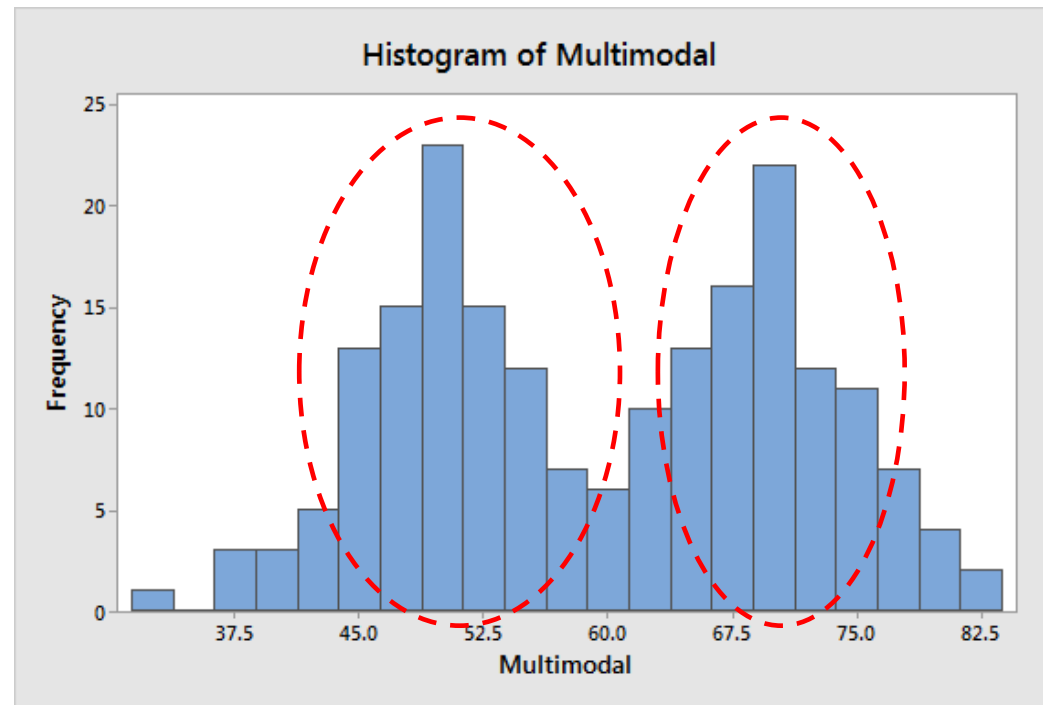
$$\delta(x) = \begin{cases} 1, & \text{if } x = 0 \\ 0, & \text{otherwise} \end{cases}$$



Source: Wikipedia

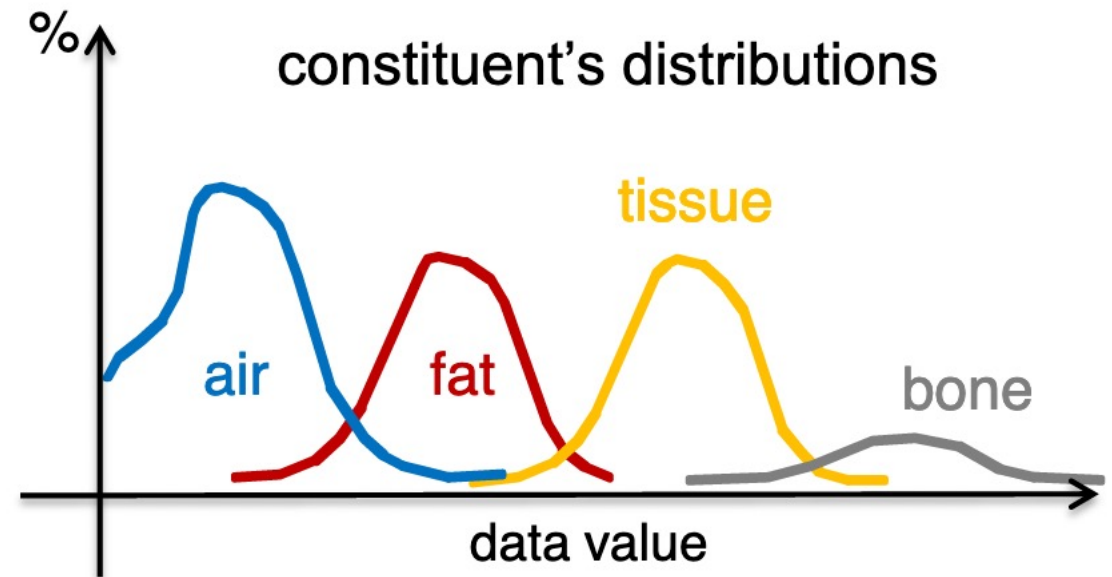
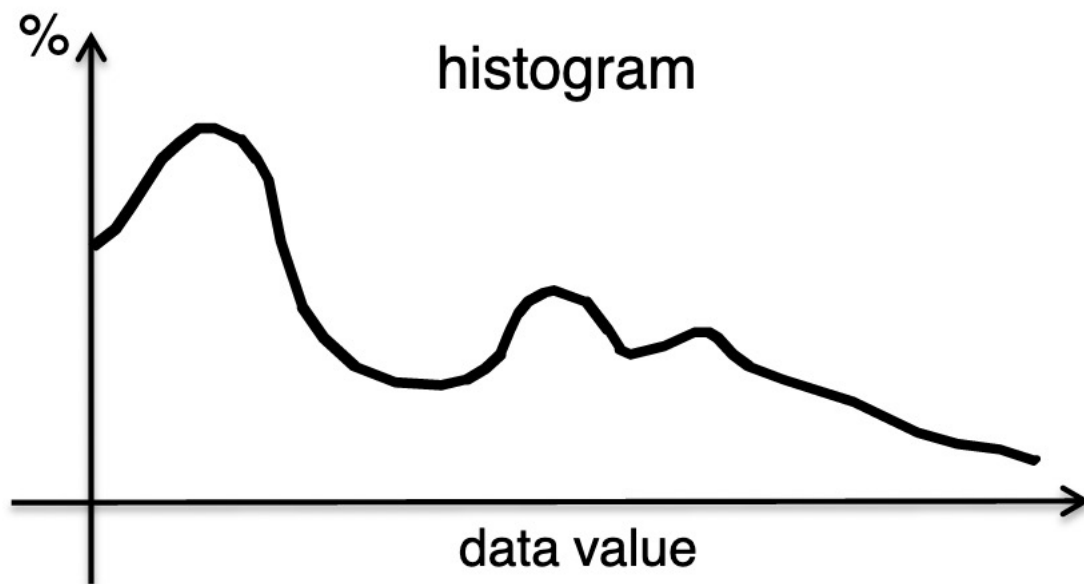
1D Histogram Assisted Transfer Function Design

- Different features in data set can have different value ranges
- Value clusters can be seen from histogram plots
- Assign different colors for different clusters/histogram regions



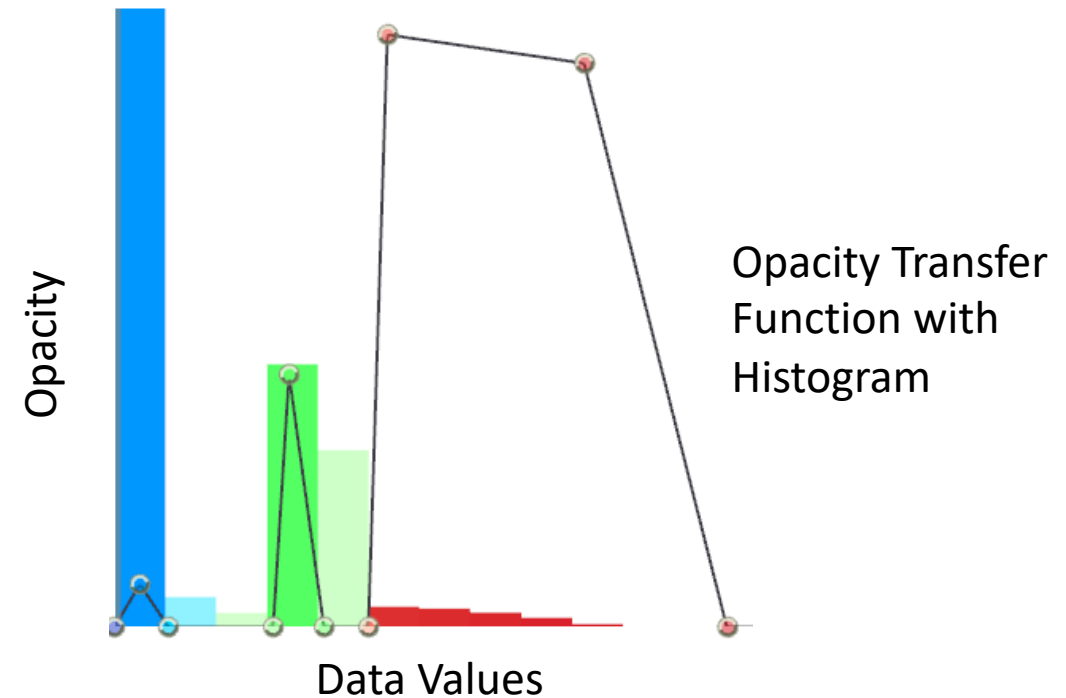
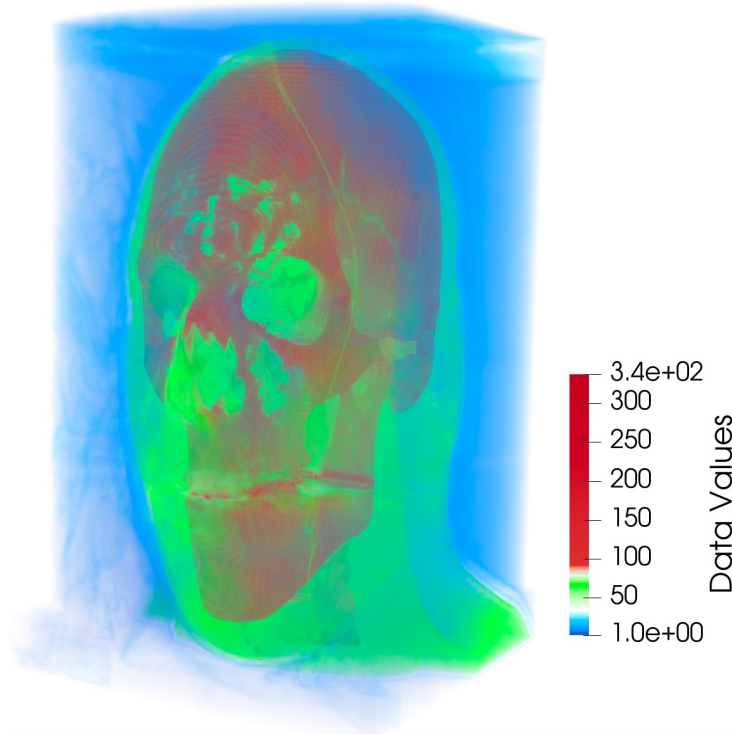
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Multi-dimensional Transfer Function

- Use the gradient information of the data to design a better transfer function that can highlight boundaries clearly
 - Distinct features/materials have roughly constant data value
 - Data values transition smoothly from one material to the next

$$\text{Gradient of } f: \nabla f(p) = \begin{bmatrix} \frac{\partial f}{\partial x_1}(p) \\ \vdots \\ \frac{\partial f}{\partial x_n}(p) \end{bmatrix}$$

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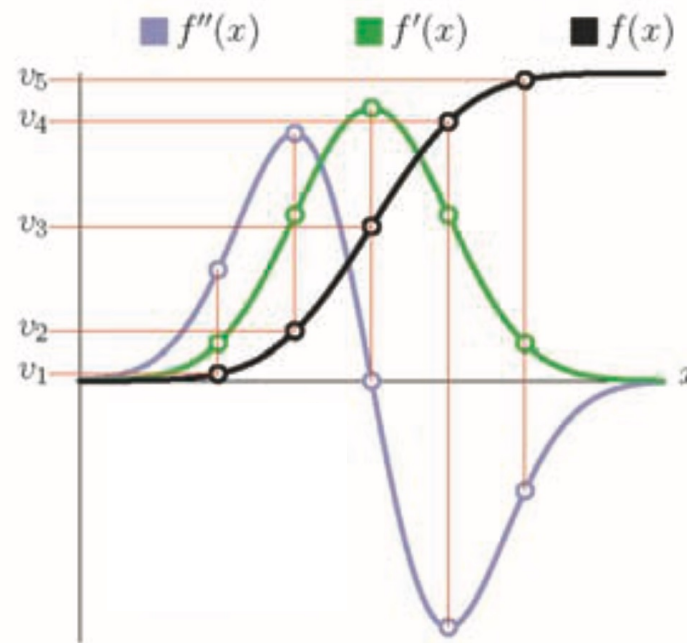
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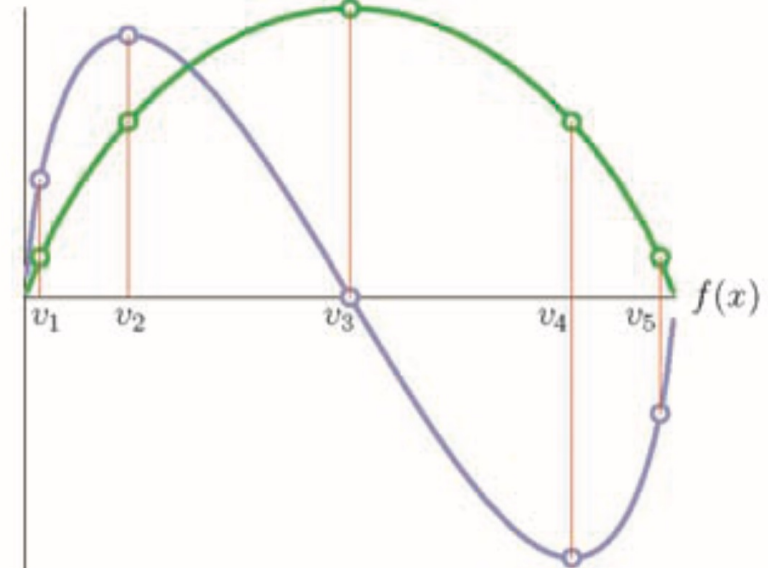
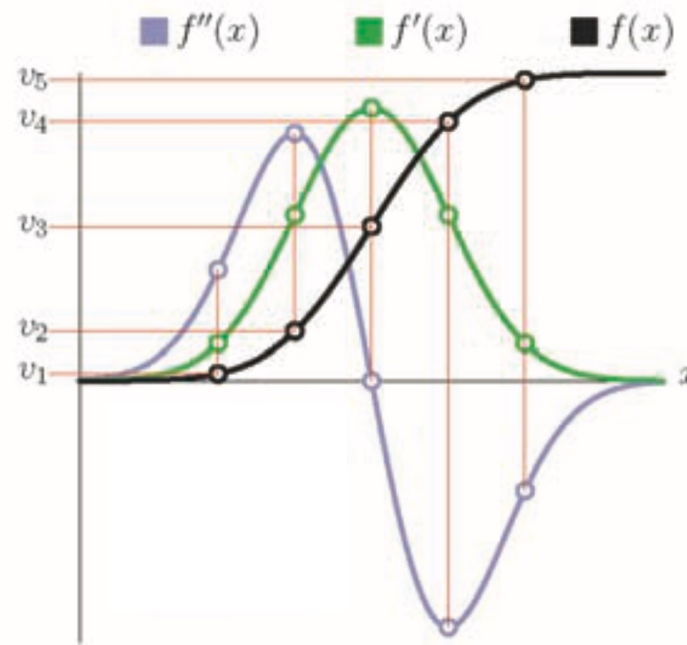


Relationships between f , f' , f'' in an ideal boundary

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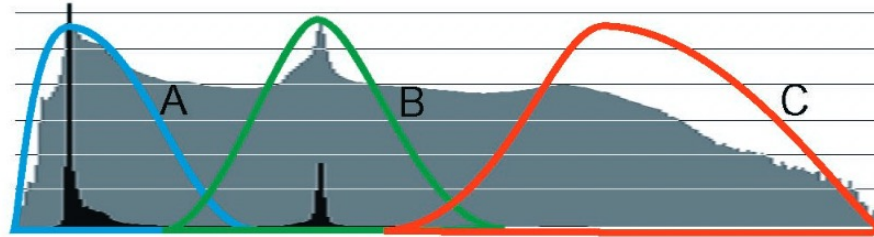
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Relationships between f , f' , f'' in an ideal boundary

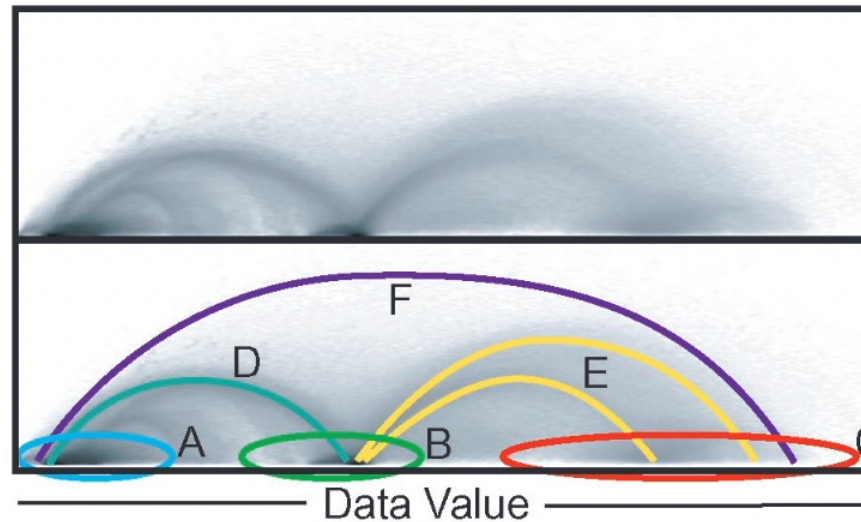
Multi-dimensional Transfer Function

A: Air
B: Tissue
C: Bone



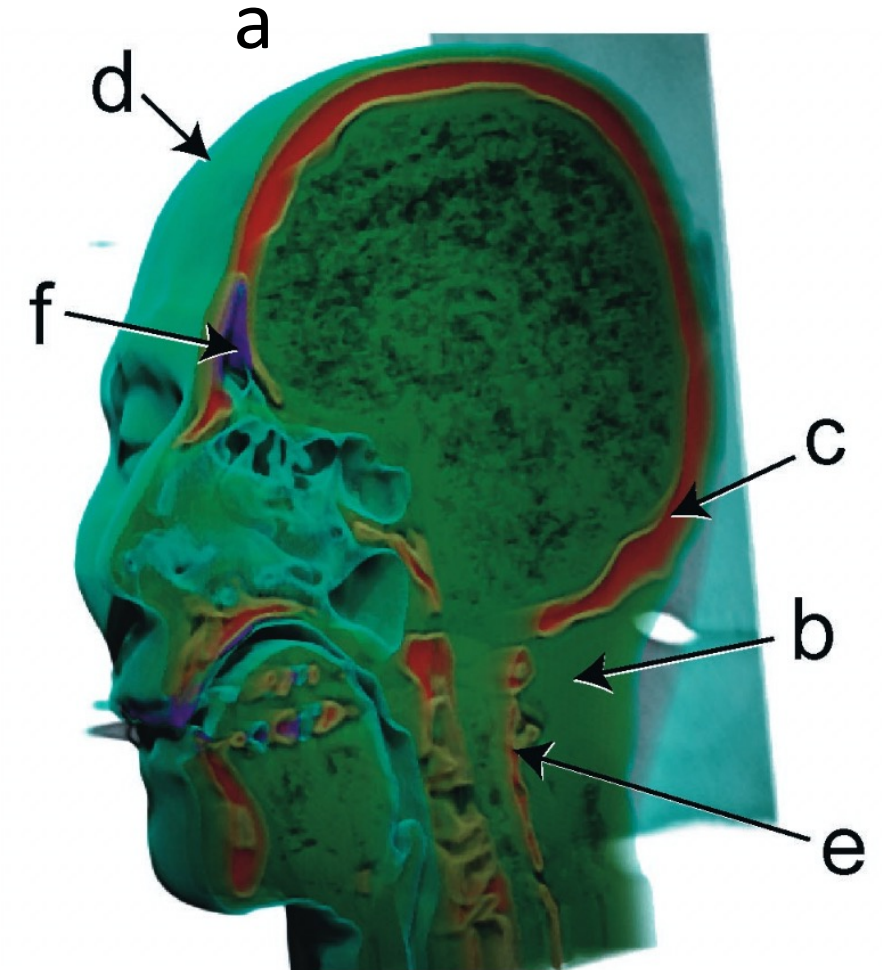
1D Transfer Function

D: Air and tissue boundary
E: Tissue and bone boundary
F: Air and bone boundary



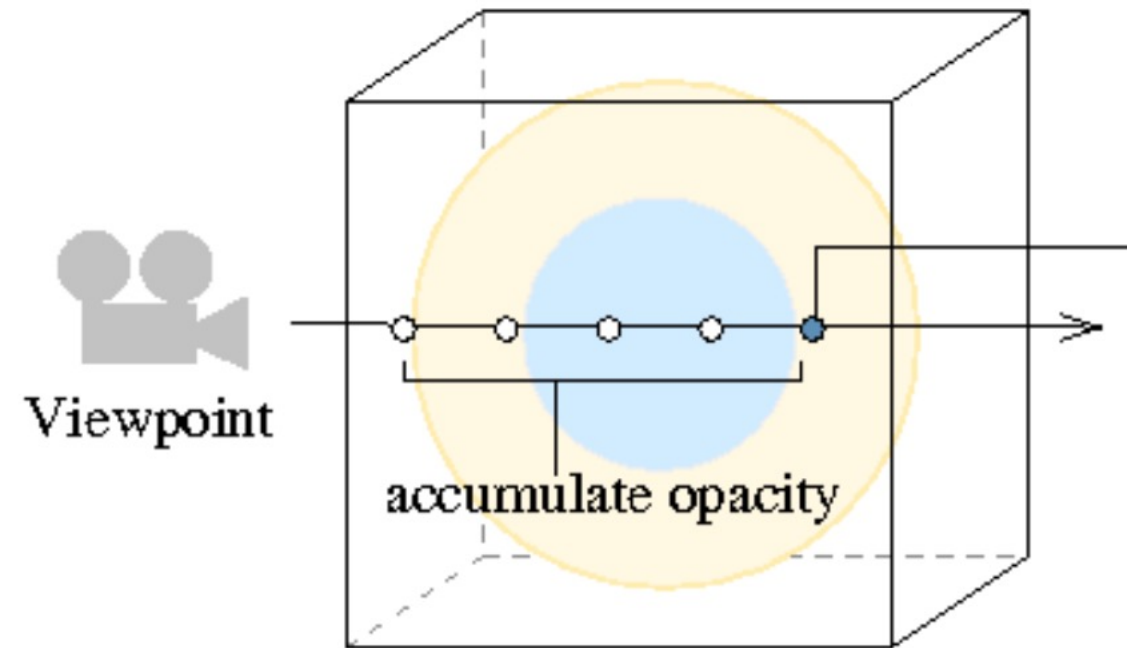
2D Transfer Function

X-axis: Data Value, Y-axis: Gradient



Visibility Histogram Guided Transfer Functions

- A semi-automatic approach for generating opacity transfer function
- The visibility of a sample refers to the contribution of a sample to the final image, in terms of opacity
- Visibility depends on
 - Opacity of the sample
 - The viewpoint which affects the accumulated opacity in front of the sample



Visibility Histogram Guided Transfer Functions

- Visibility Histogram: Distribution of the visibility function in relation to the domain values of the volume

$$VH(x) = O(x) \int_{s \in \Omega} \delta(s, x) (1 - \alpha(s)) ds$$

$$\delta(s, x) = \begin{cases} 1 & V(s) = x \\ 0 & otherwise \end{cases}$$

x = data value at sample s

$VH()$ = Visibility Histogram

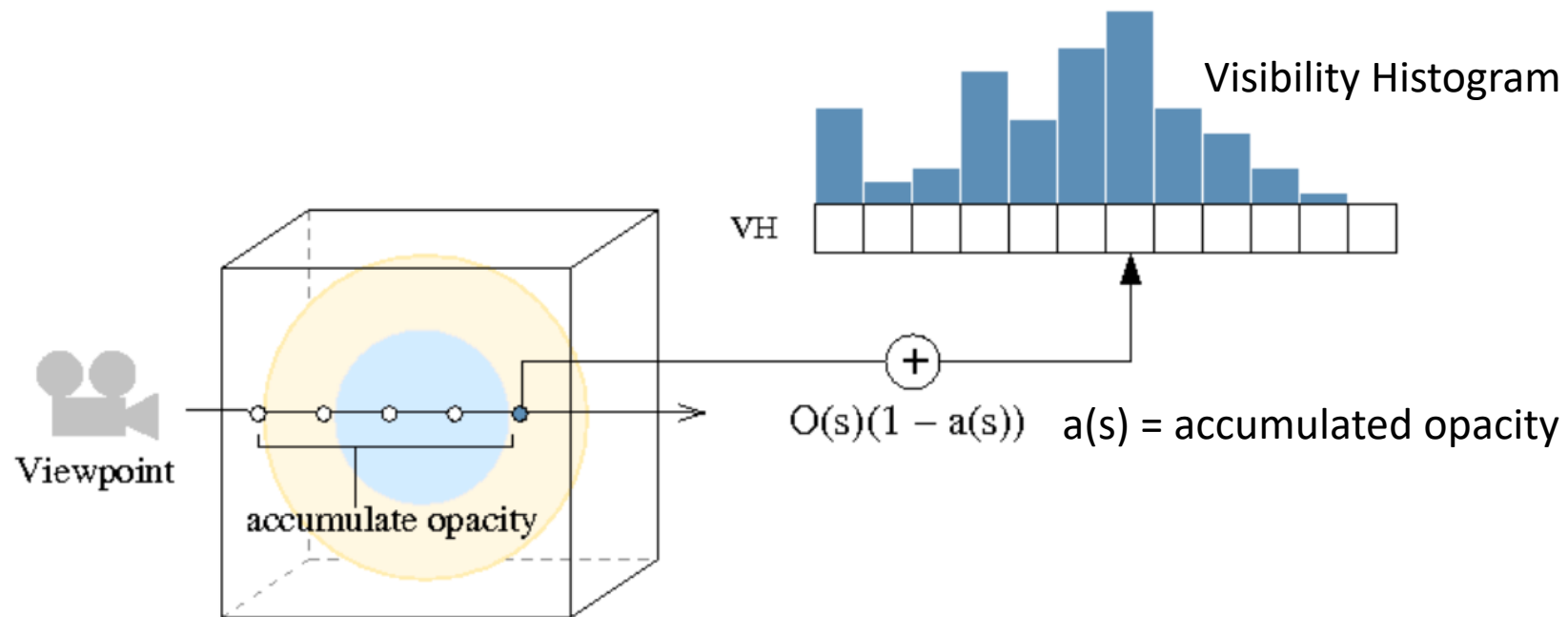
$O()$ = Opacity transfer function

V = Volume

$\alpha(s)$ = accumulated opacity in front of the sample s

Visibility Histogram Guided Transfer Functions

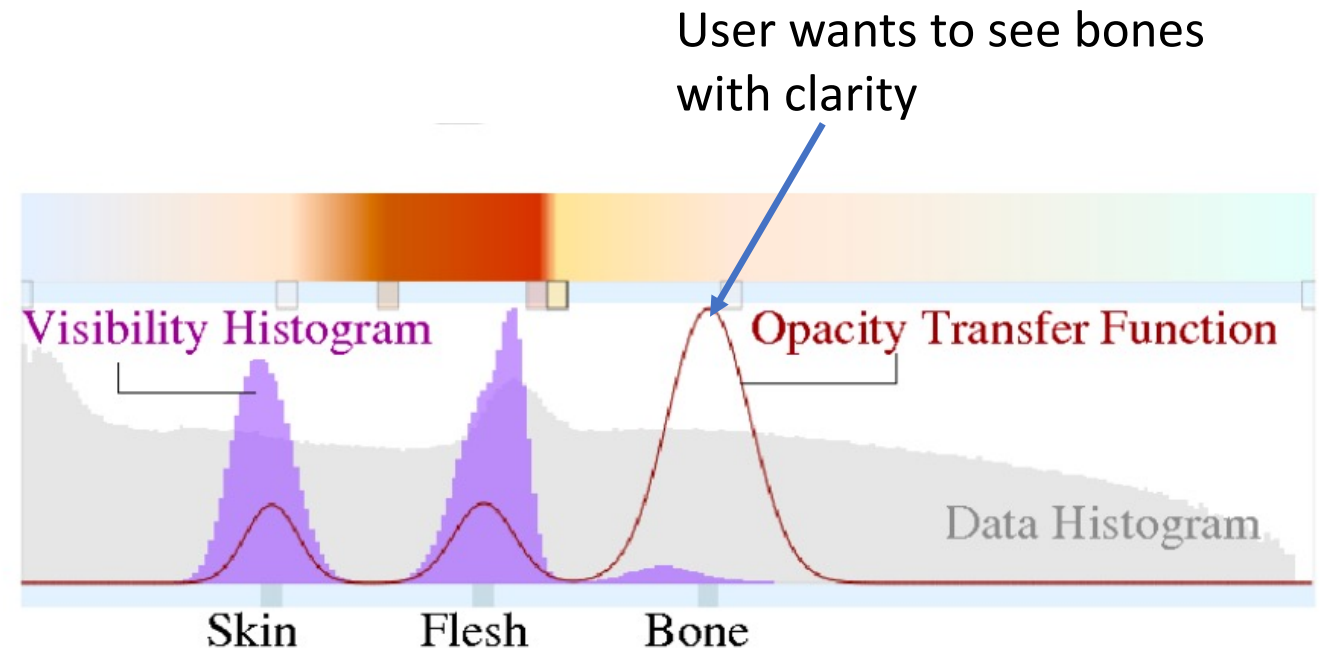
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Visibility Histogram Guided Transfer Functions

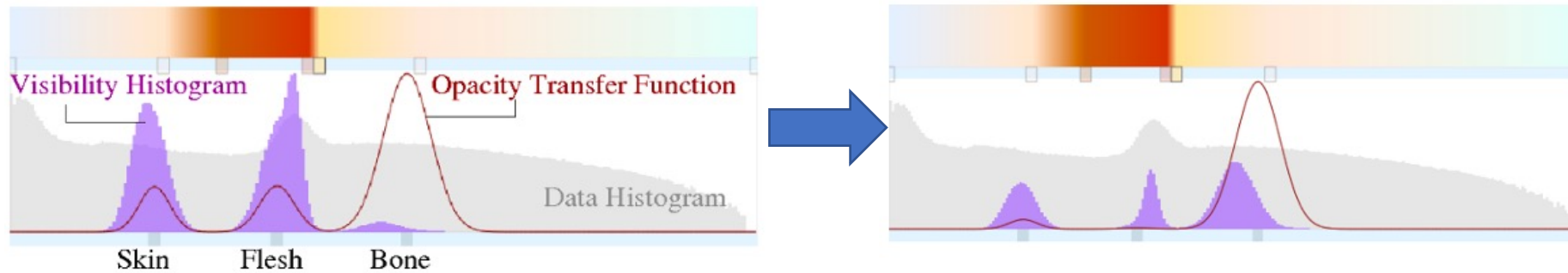
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But we can't see bones as flesh and skin is blocking it

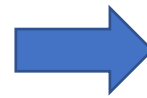
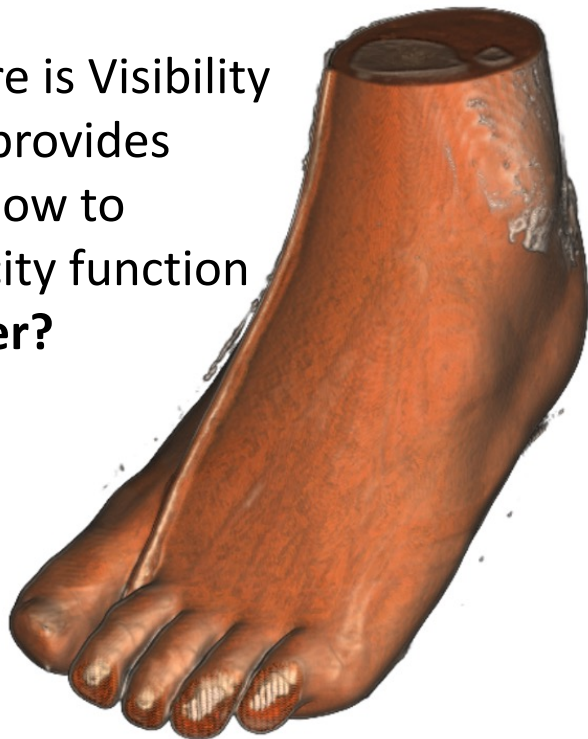


Visibility Histogram can provide the guidance

Visibility Histogram Guided Transfer Functions



Manual but there is Visibility Histogram that provides guidance as to how to modify the opacity function
Can we do better?



Now, bones are clearly seen

Visibility Histogram Guided Transfer Functions

- Semi-automatic transfer function design using Visibility Histogram
- Use Optimization technique
 - selection of the best solution, with regard to some criterion, from some set of available alternatives by minimizing(maximizing) an energy function
- Energy function considers characteristics of a good opacity transfer function
 - User satisfaction: minimize mismatch between user provided initial and computer transfer function
 - Visibility: maximize visibility of samples
 - Constraints: Constraints for opacity transfer function parameters

Visibility Histogram Guided Transfer Functions

