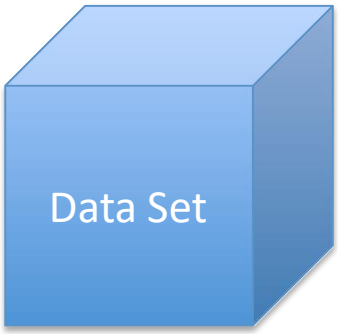
Direct Volume Rendering

Transfer Function Design

Courtesy of Prof. Han-Wei Shen
(CSE 5544, The Ohio State University)

Transfer Function

- Map a data sample to color and opacity



$$f_{color}(s) = (r, g, b)$$

$$f_{opacity}(s) = \alpha$$

- The sample could be
  - A single value (scalar)
  - Multiple values (scalar, gradient magnitude, etc)

Transfer Function in Rendering Equation

$$I(D) = I_0 \times e^{-\int_0^D \tau(t)dt} + \int_0^D g(s) e^{-\int_s^D \tau(t)dt} ds$$

$$I_0 \prod_{i=1}^{i=n} (1 - \alpha_i)$$

$$\sum_{i=1}^{i=n} (g_i \times \prod_{j=i+1}^{n} (1 - \alpha_i))$$

Opacity

Color in (R,G,B)

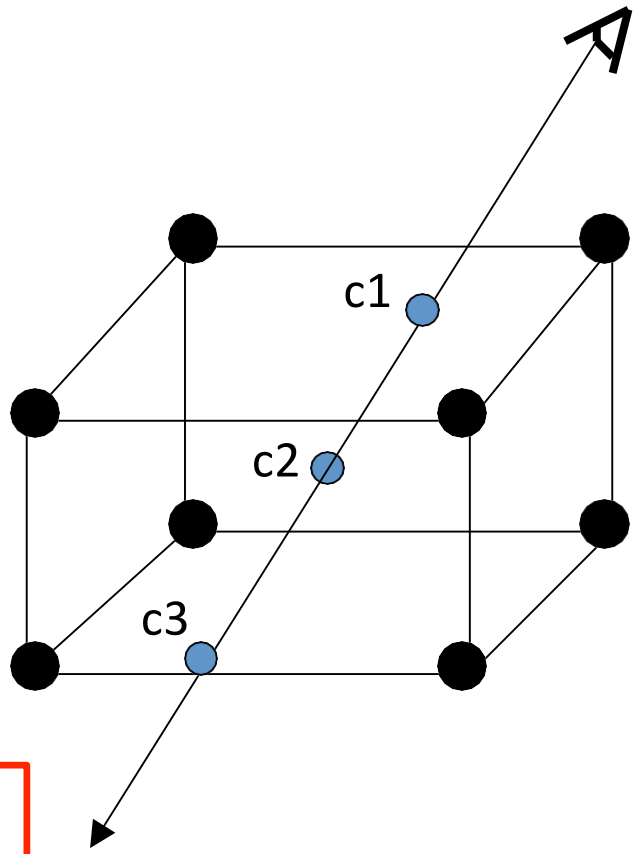
Transfer Function in Back-to-Front Compositing

The initial pixel color = Black

Back-to-Front compositing:
use ‘under’ operator

C = C1 ‘under’ background
C = C2 ‘under C
C = C3 ‘under C
…

$C_{out} = C_{in} * (1-\alpha(x)) + C(x)*\alpha(x)$
(this is the alpha blending formula)

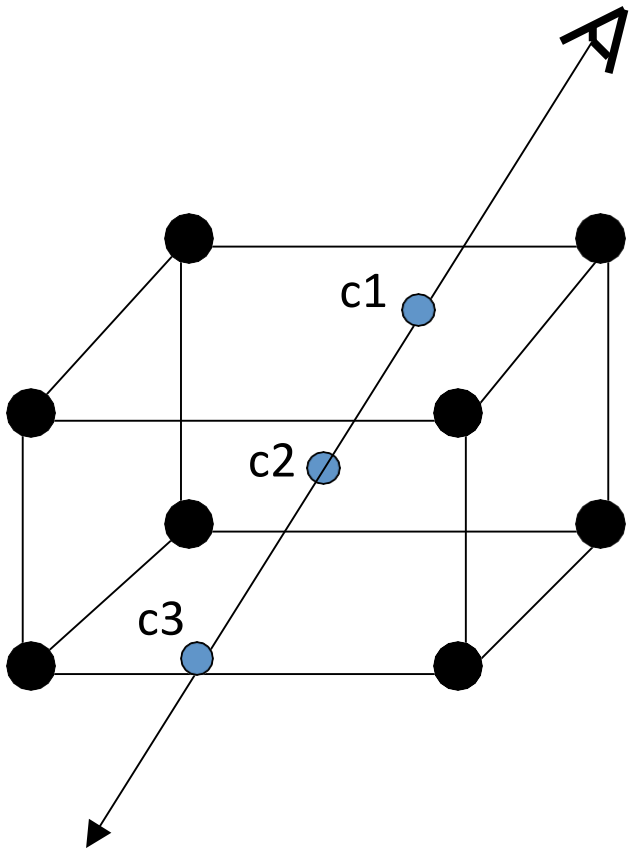


Transfer Function in Front-to-Back Compositing

Front-to-Back compositing:
use ‘over’ operator

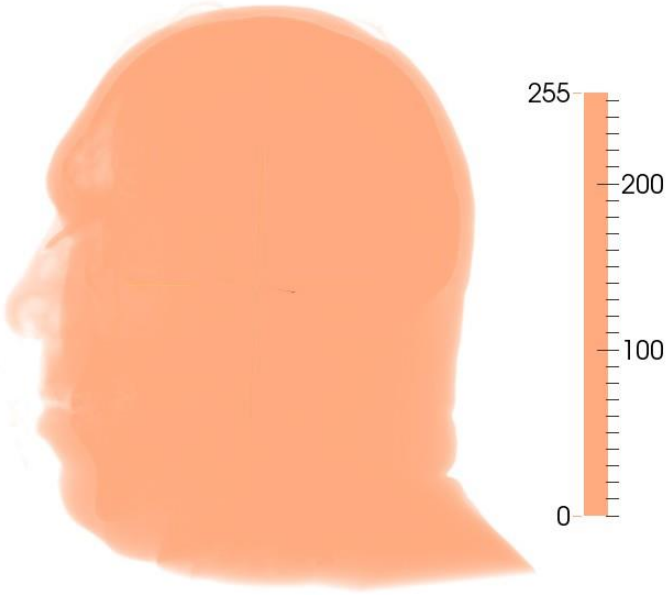
C = background ‘over’ C1
C = C ‘over’ C2
C = C ‘over’ C3
…

$$C_{out} = C_{in} + C(x)*(1-\alpha_{in});$$
$$\alpha_{out} = \alpha_{in} + \alpha(x) *(1-\alpha_{in})$$

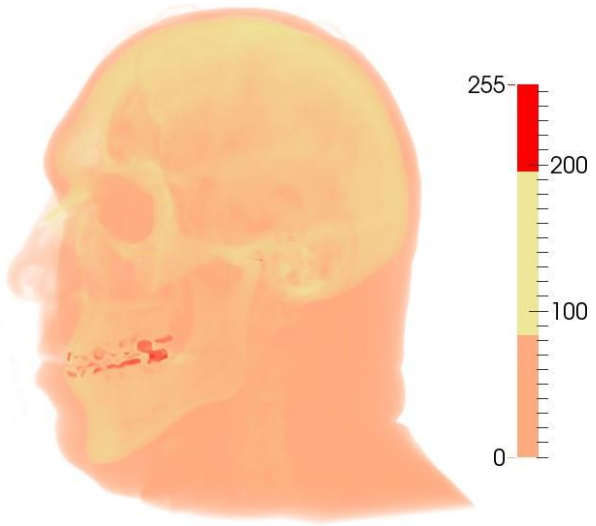


Color in Transfer Function

- Color
  - Distinguish different materials



- All Materials uses same color
- See no features



- Muscle: orange
- Bone: yellow
- Tooth: red

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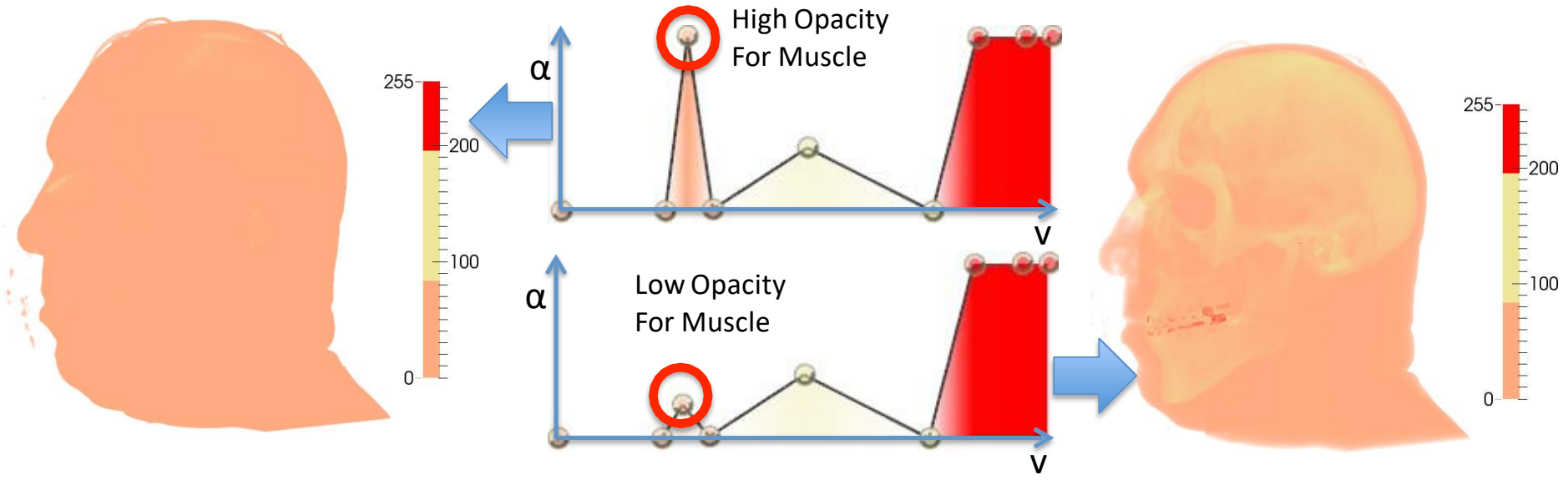
Opacity in Transfer Function

- Opacity
  - Opacity (transparency) of each sample
  - That multiple materials is shown in the rendered image provides more context



- Material inside the muscle is occlude
- See no features

- Make the muscle transparent
- See the bone and tooth

Transfer Function Design

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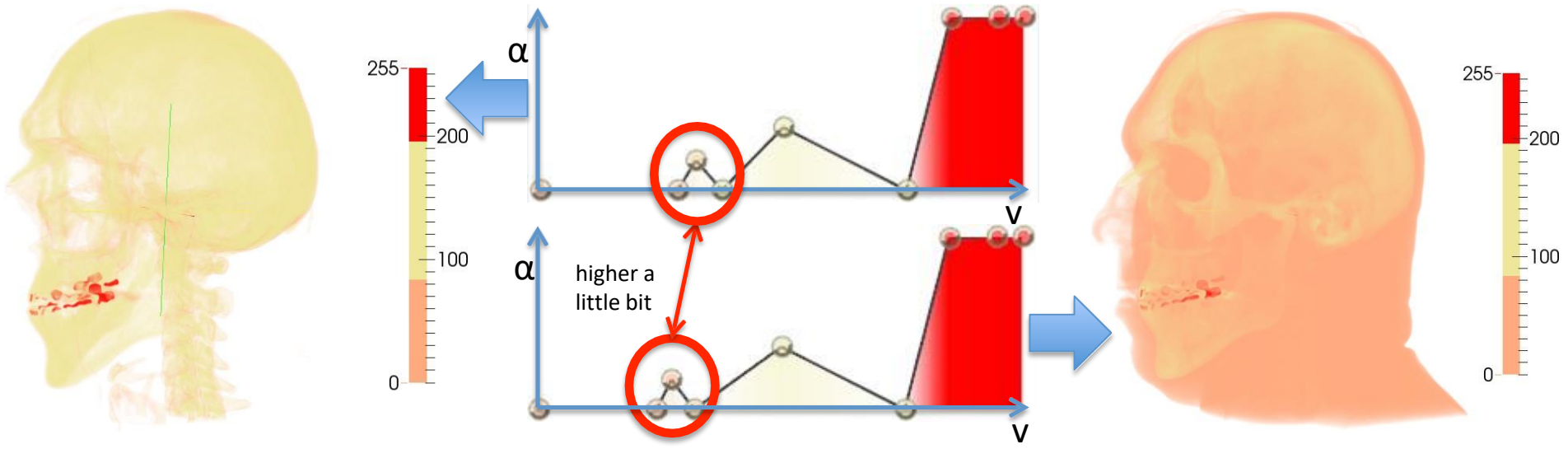
Need algorithms and strategies to assist users to find the desired transfer function in a huge transfer function search space

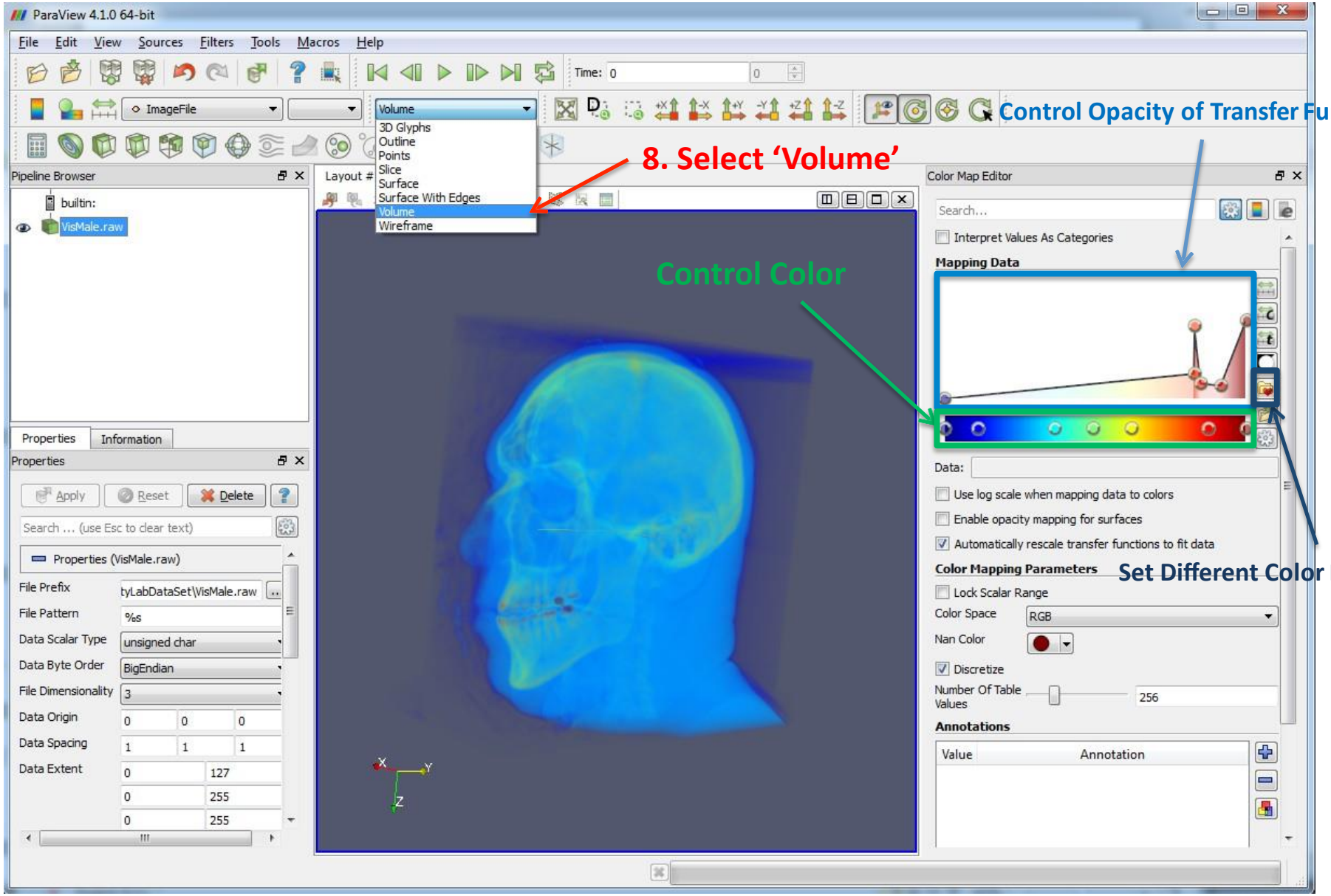
Trial and Error

- Manually control the color and opacity of each scalar value using graphical user interface (GUI)
  - Very tedious work and inefficient
  - Small transfer function change can produce very different images

It could be difficult to get a good image without enough prior knowledge

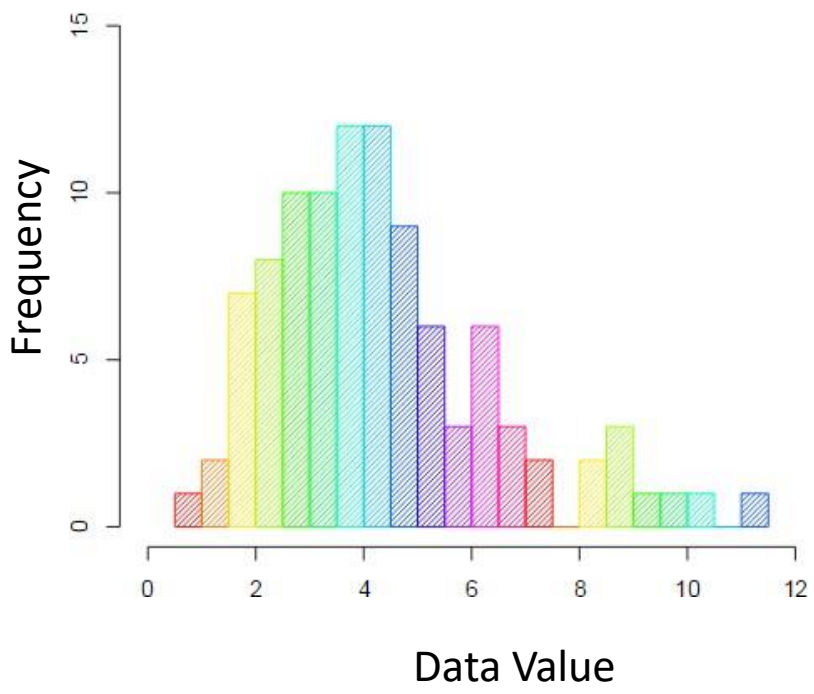


Paraview


ParaView 4.1.0 64-bit
File Edit View Sources Filters Tools Macros Help
Time: 0
ImageFile
Volume
3D Glyphs
Outline
Points
Slice
Surface
Surface With Edges
Volume
Wireframe
8. Select 'Volume'
Control Opacity of Transfer Function
Control Color
Pipeline Browser
builtin:
VisMale.raw
Properties
Information
Properties
Apply
Reset
Delete
Search ... (use Esc to clear text)
Properties (VisMale.raw)
File Prefix
tyLabDataSet\VisMale.raw
File Pattern
%s
Data Scalar Type
unsigned char
Data Byte Order
BigEndian
File Dimensionality
3
Data Origin
Data Spacing
Data Extent
Color Map Editor
Search...
Interpret Values As Categories
Mapping Data
Data:
Use log scale when mapping data to colors
Enable opacity mapping for surfaces
Automatically rescale transfer functions to fit data
Color Mapping Parameters
Set Different Color Map
Lock Scalar Range
Color Space
RGB
Nan Color
Discretize
Number Of Table Values
256
Annotations
Value
Annotation

Histogram Assisted Transfer Function Design

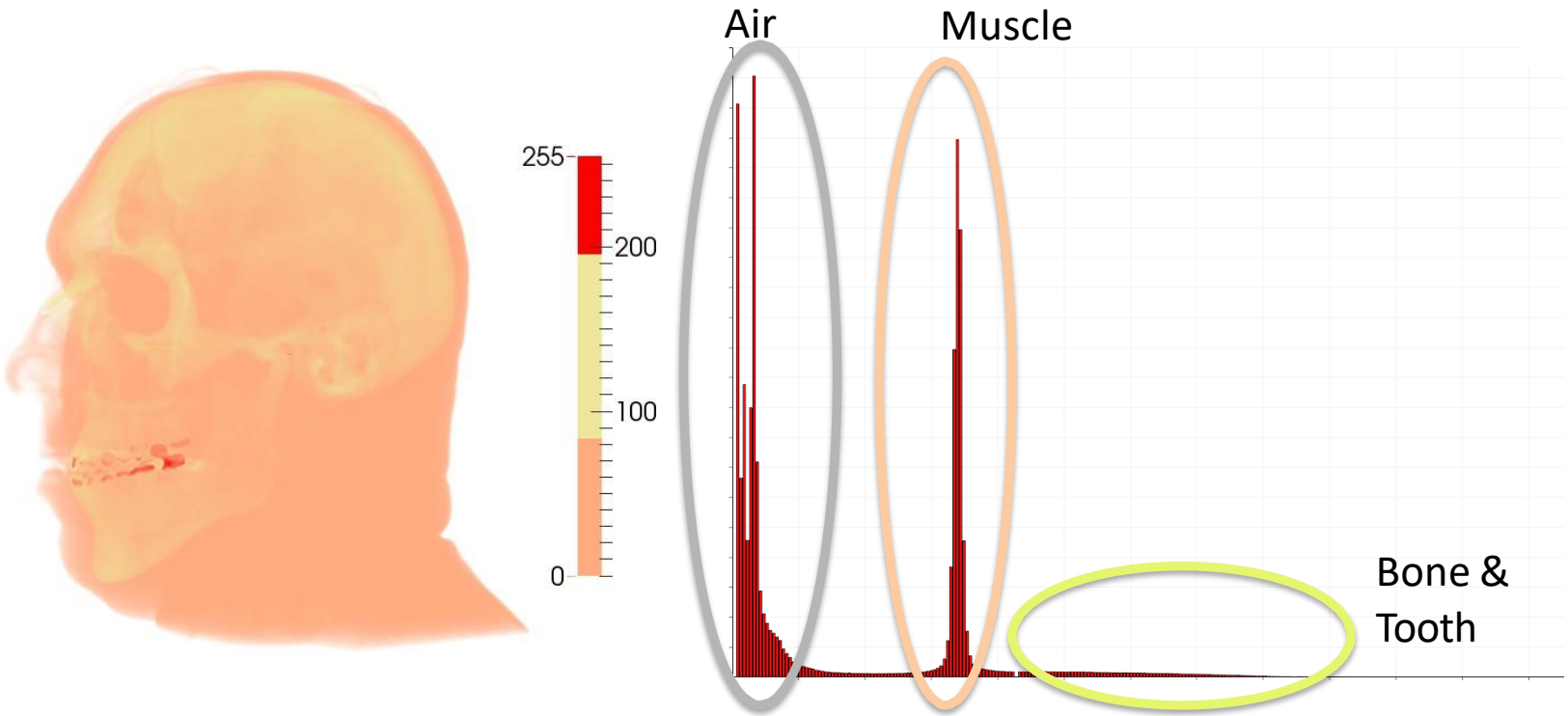
- Histogram
  - Divide the data range into finite intervals(bins)
  - Frequency of a bin is the number of samples whose values are in the interval



*hAp://en.wikipedia.org/wiki/Histogram

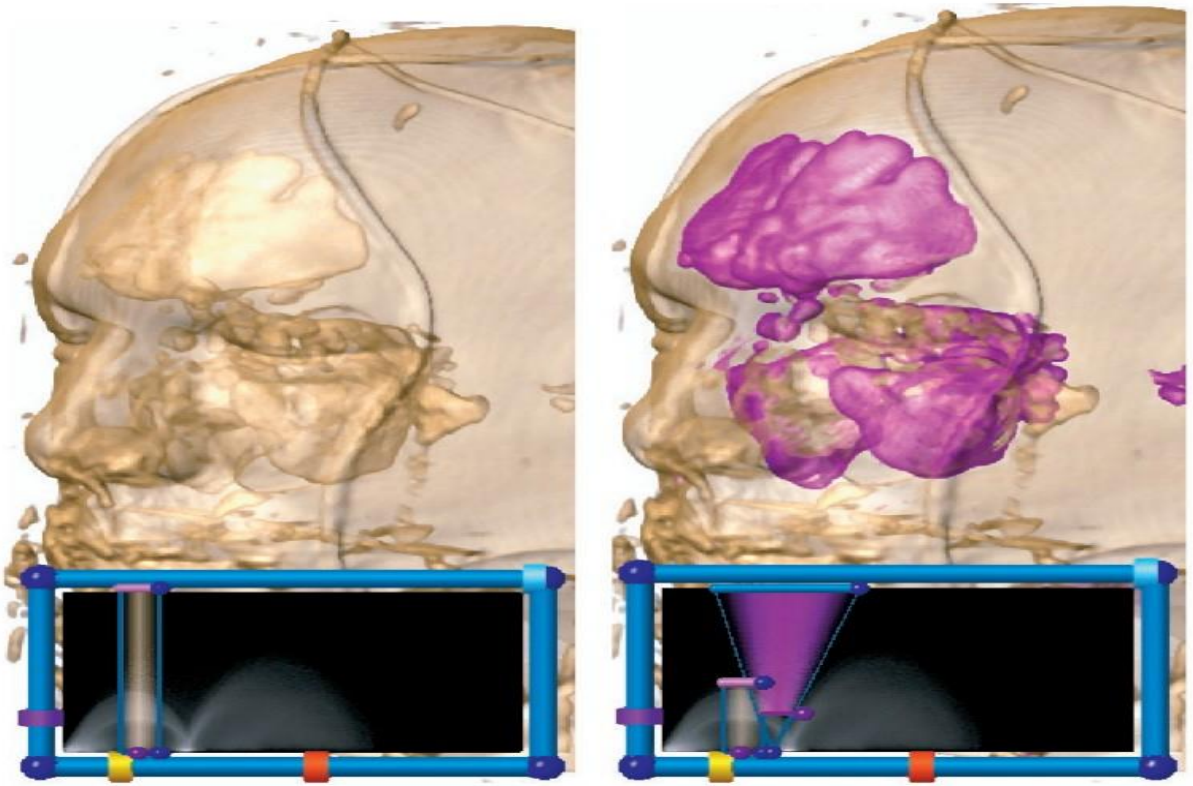
Histogram Assisted Transfer Function Design

- Different features in the data set sometimes have values in different scalar ranges
- If this is the case, value clusters can be seen from the histogram
- Different value clusters can be assigned with different colors and opacities



Multi-Dimensional Transfer Functions

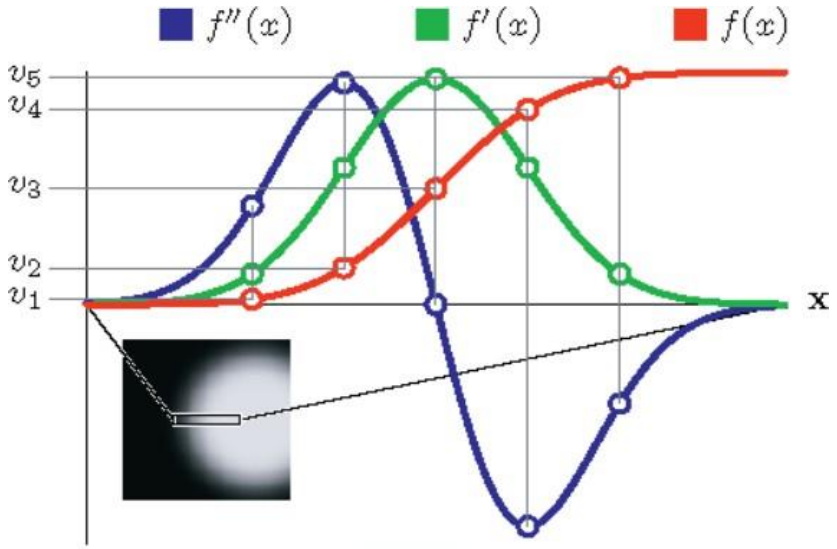
- Certain features cannot be captured by 1D histograms
  - boundary between two materials
    - Ex: emphasize the boundary between sinuses and tissue



***Interactive Volume Rendering Using Multi-Dimensional Transfer. Functions and Direct Manipulation Widgets. Joe Kniss. Gordon Kindlmann. Charles Hansen. 2001**

Multi-Dimensional Transfer Functions

- How to detect/capture the boundaries
  - Values: step function
  - Gradients: local maximum
  - 2nd derivatives: zero crossing
    - 1st derivative of the raw data at a point



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Multi-Dimension Transfer Function Design

- 2D Histogram
  - X-axis – data value
  - Y-axis – gradient
  - Color intensity – frequency of the histogram (darker means more here)

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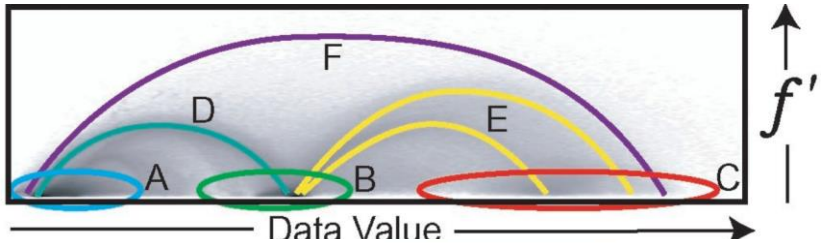
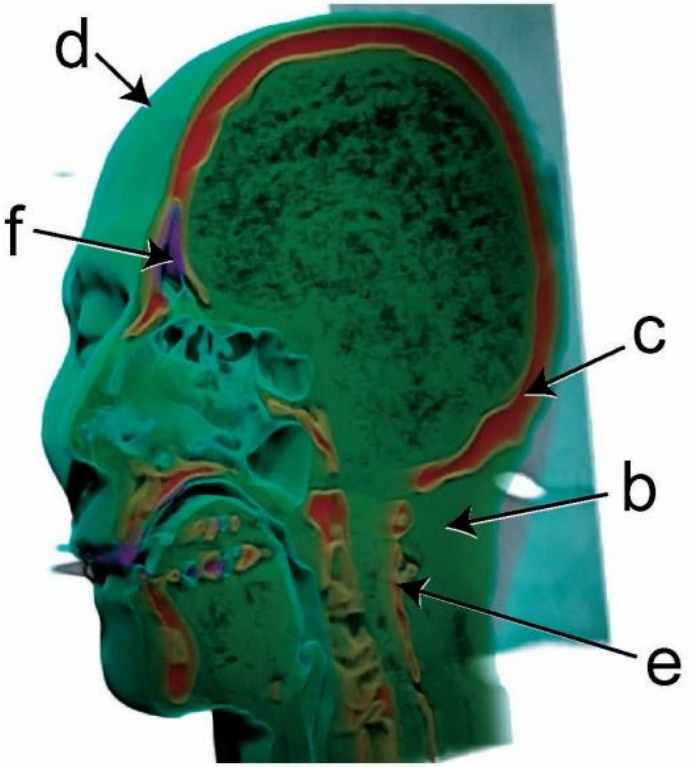
Multi-Dimensional Transfer Functions

- 1D histogram can capture homogeneous region only
  - A : air
  - B : tissue
  - C : bone
- 2D histogram can capture
  - D : air and tissue boundary
  - E : tissue and bone boundary
  - F : air and bone boundary





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References

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- G. Kindlemann and J.W. Durkin, Semi-automatic Generation of Transfer Functions for Direct Volume Rendering, Proc. of IEEE Symposium on Volume Visualization, pp. 79-86, 1998
- J. Kinss, G. Kindlemann, C. Hansen, Multidimensional Transfer Function for Interactive Volume Rendering, IEEE Transactions on Visualization and Computer Graphics, Vol. 8, No. 3, pp. 270-285, 2002