Direct Volume Rendering

Transfer Function Design

Courtesy of Prof. Han-Wei Shen
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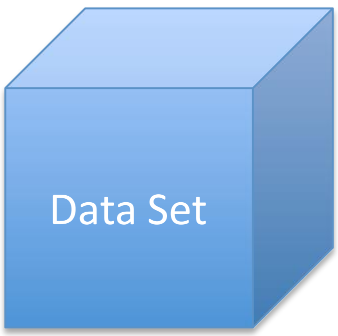
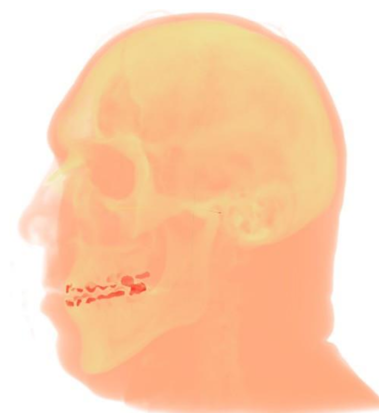
Transfer Function

- 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

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

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

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

Opacity

Color in (R,G,B)

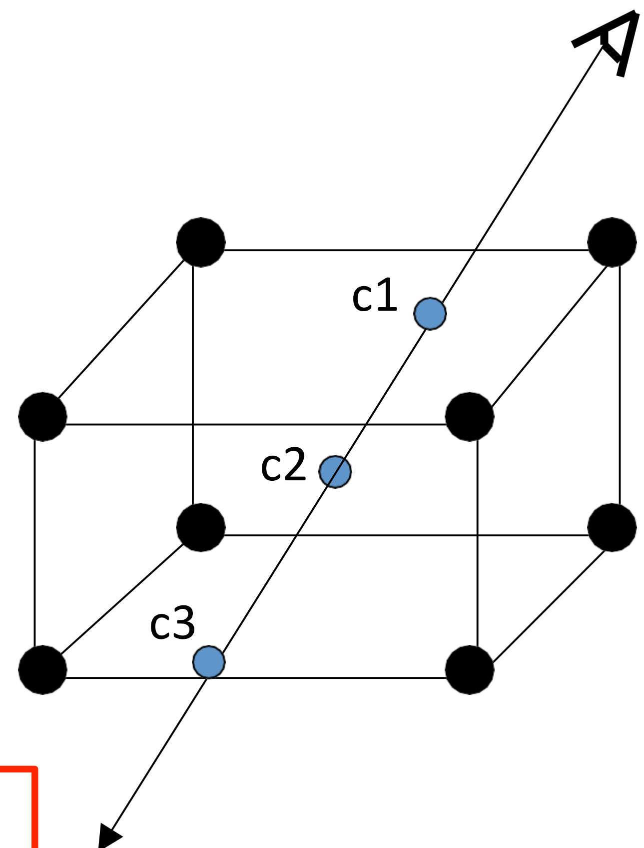
Transfer Function in Back-to-Front Compositing

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)

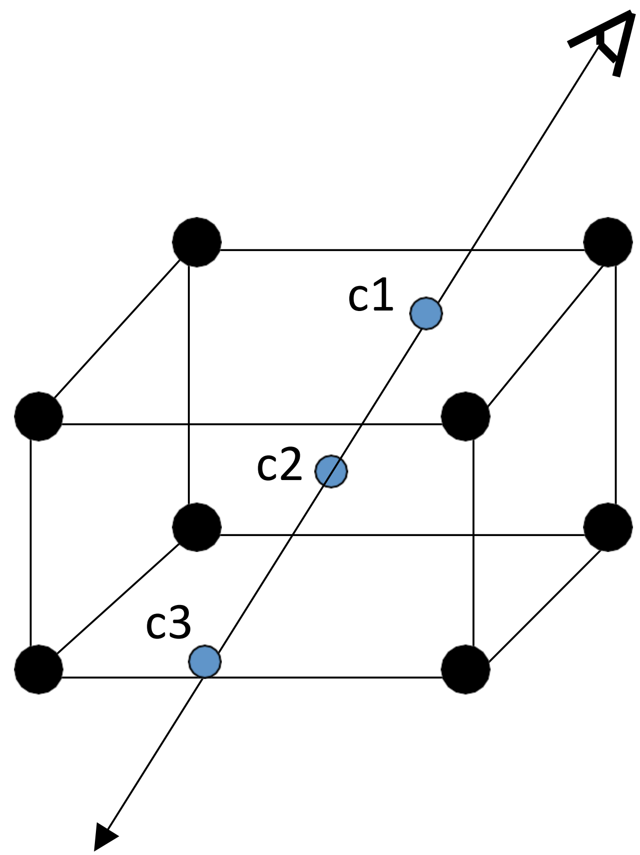


Transfer Function in Front-to-Back Compositing

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

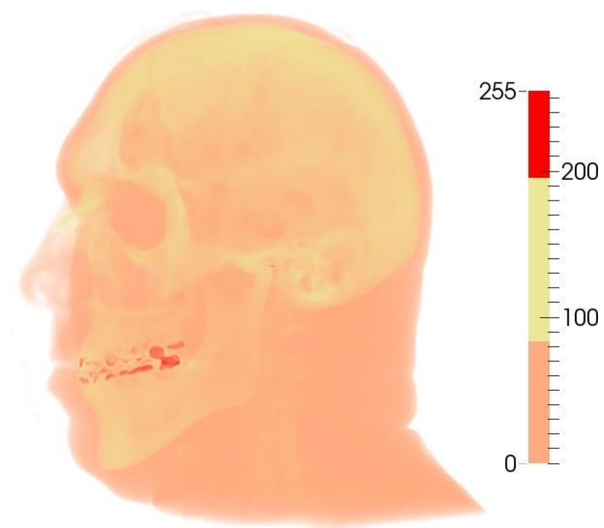
C = background ‘over’ C1
C = C ‘over’ C2
C = C ‘over’ C3
...

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



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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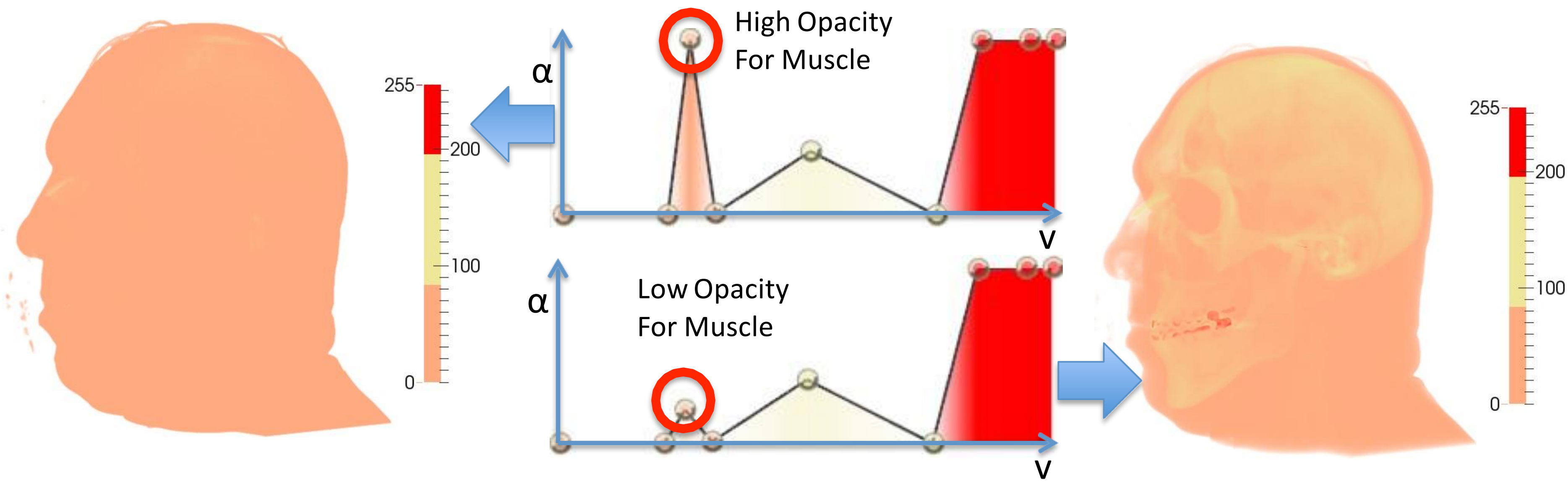
Opacity in Transfer Function

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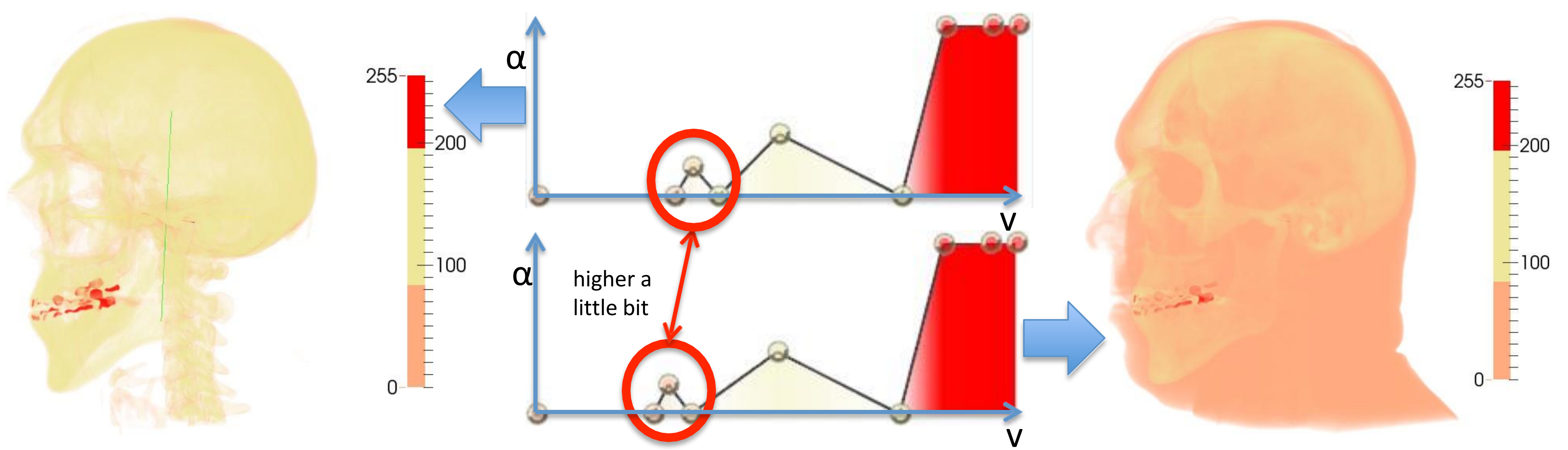
Need algorithms and strategies to assist users to find the desired transfer function in a huge transfer function search space

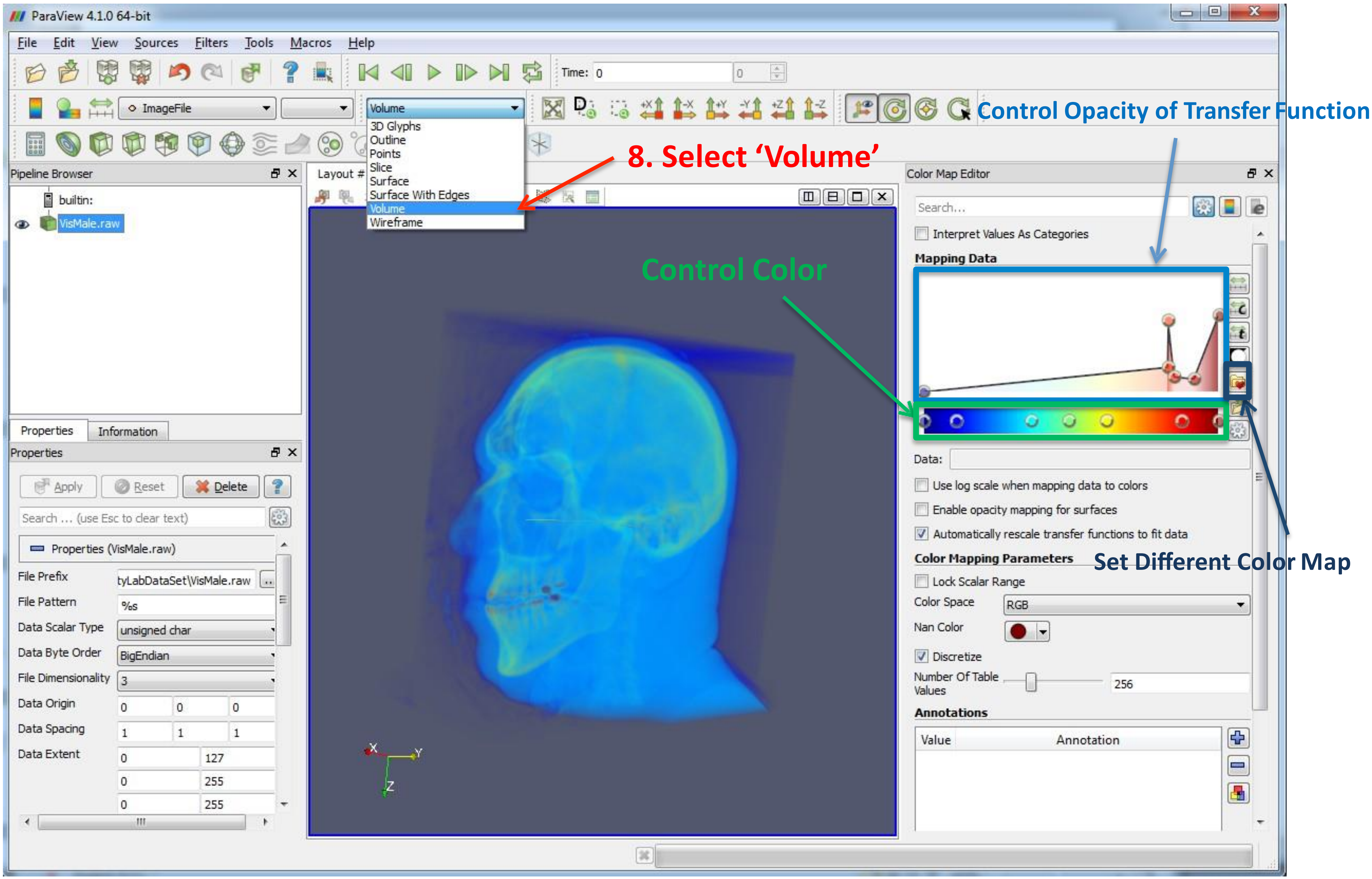
Trial and Error

- 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

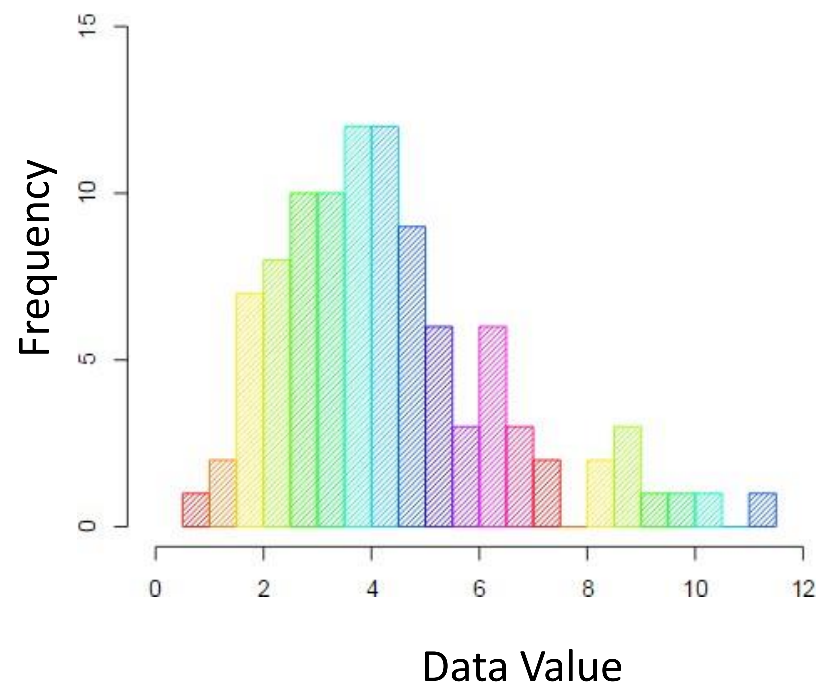


Paraview


Control Opacity of Transfer Function
8. Select 'Volume'
Control Color
Set Different Color Map

Histogram Assisted Transfer Function Design

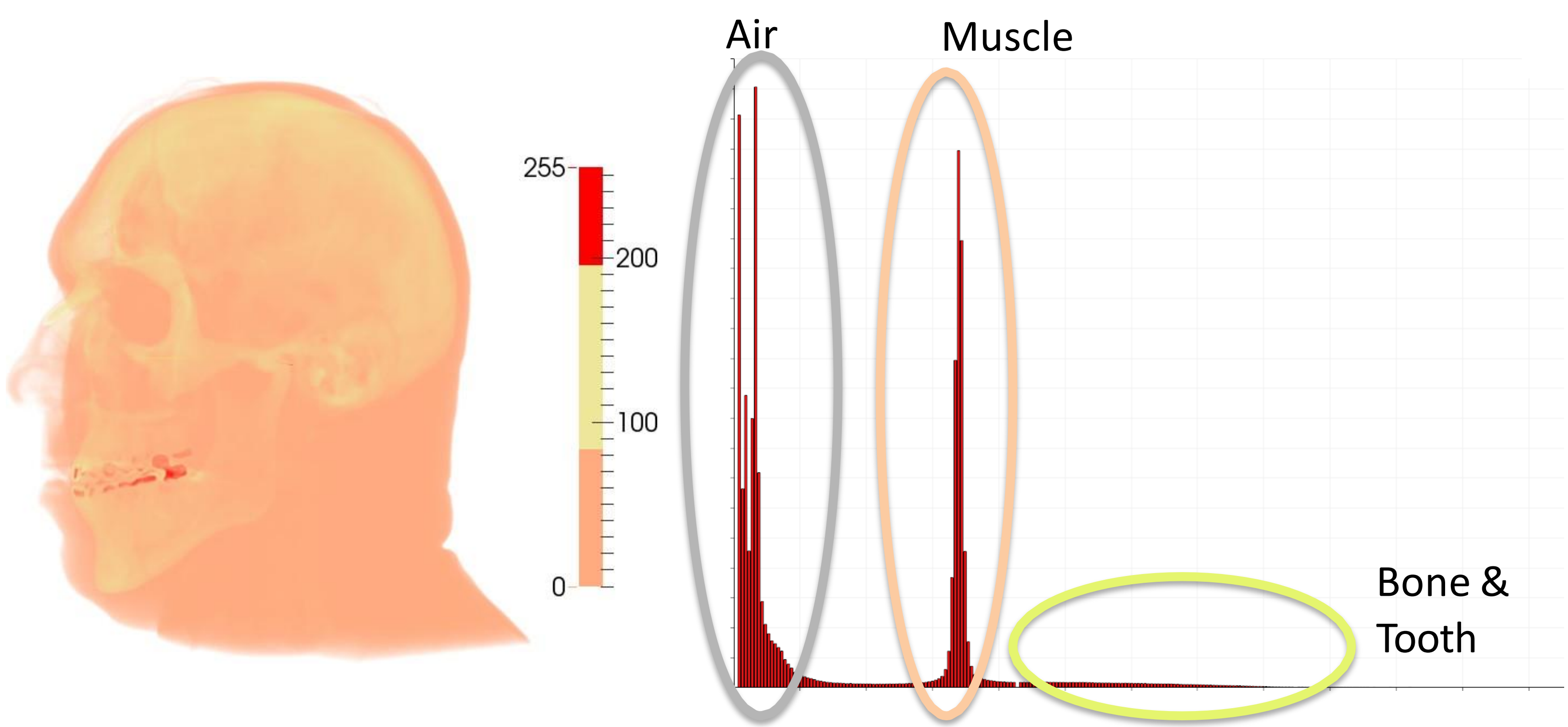
- Histogram
  - Divide the data range into finite intervals(bins)
  - Frequency of a bin is the number of samples whose values are in the interval



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

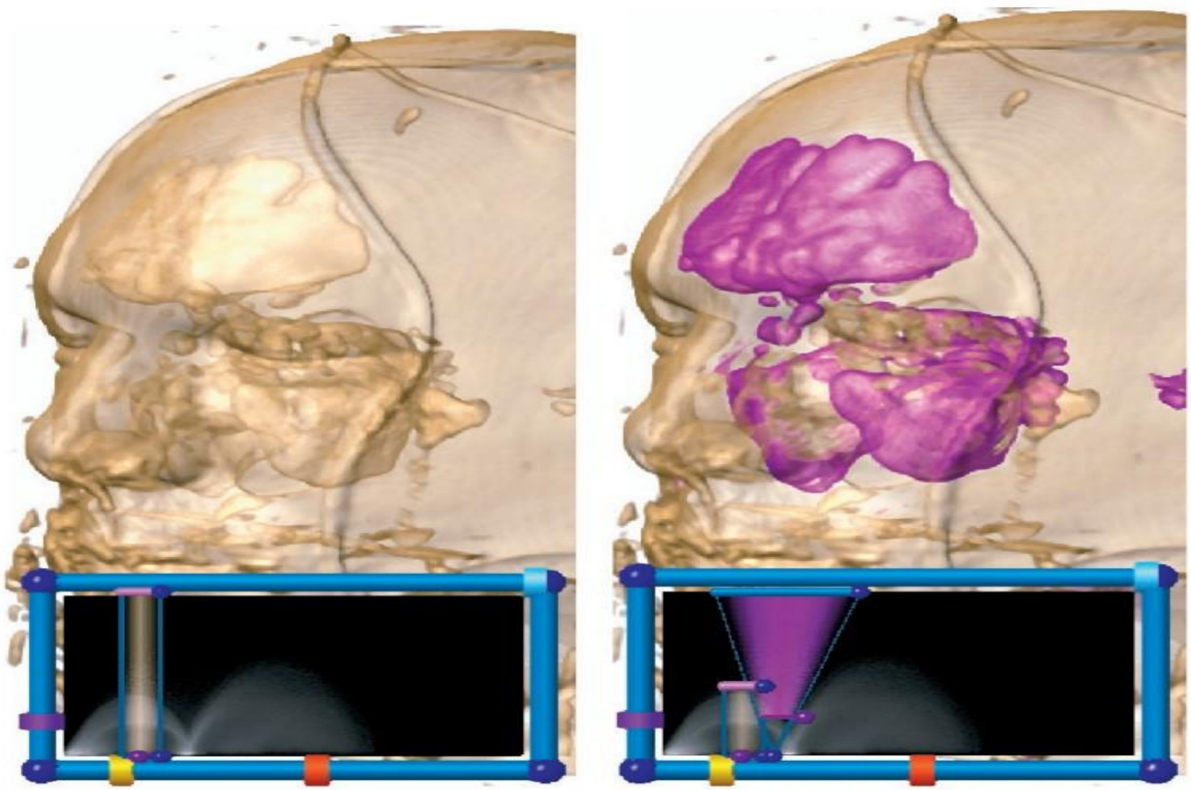
Histogram Assisted Transfer Function Design

- 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

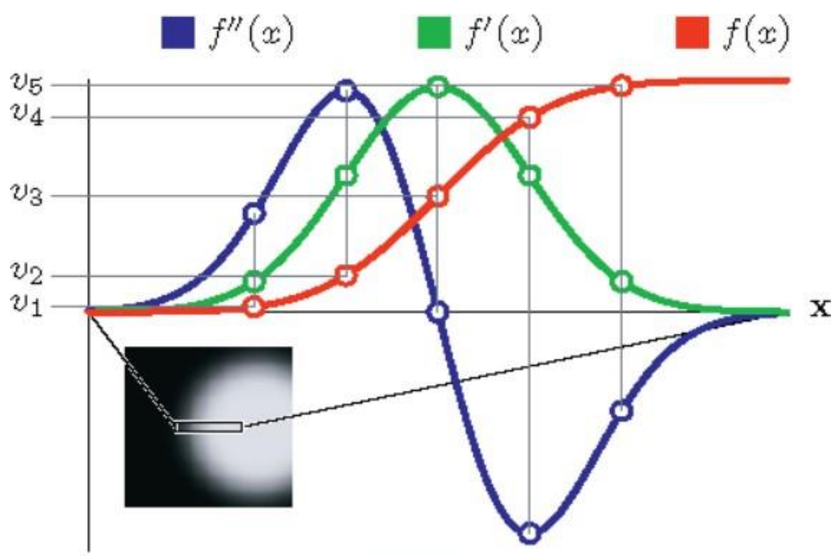
- Certain features cannot be captured by 1D histograms
  - boundary between two materials
    - Ex: emphasize the boundary between sinuses and tissue



***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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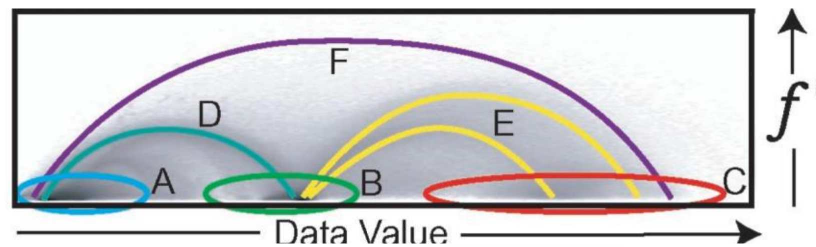
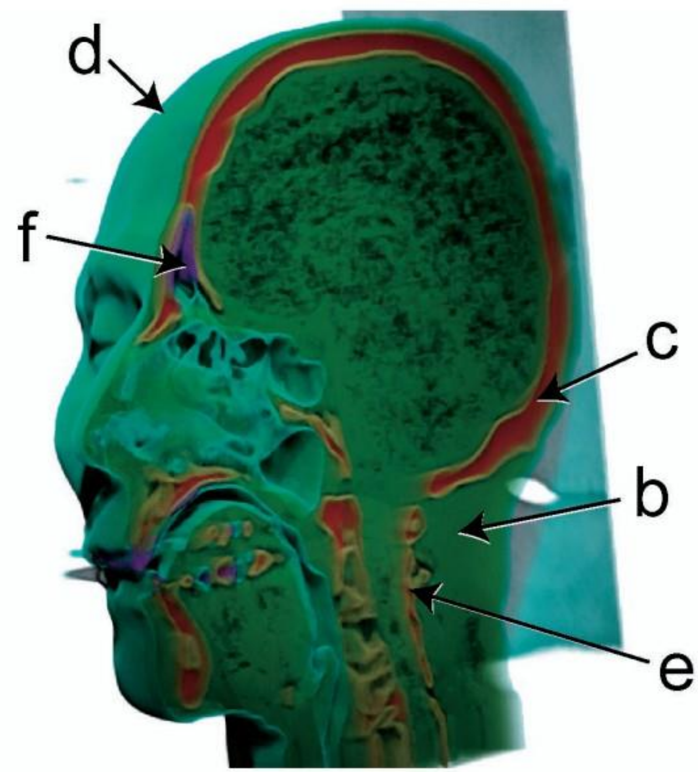
Multi-Dimensional Transfer Functions

- 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