Transfer Function Issues

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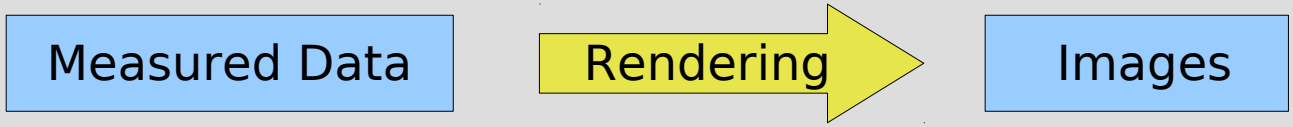
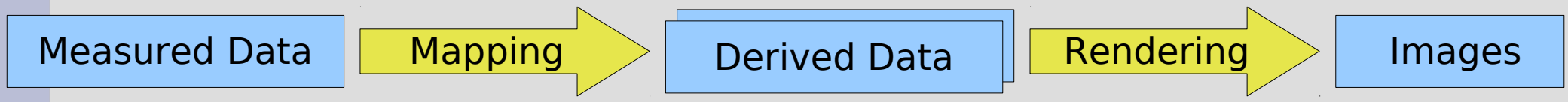
Volume Visualization

Visually perceivable data presentation

- Understanding, not photorealism
- Simple volume viewing
  - Straightforward presentation of measured data

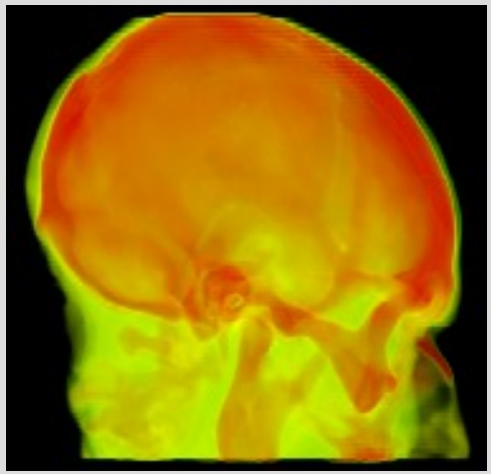


- Mapping techniques
  - Measured densities are mapped to visual attributes (transparency, color)



Assignment of Visual Attributes

- Mapping: Assignment of visual attributes to data:
  - transparency, color, reflectance, surface strength...
- “Area of interest” specification achieved:



Density-based
classification

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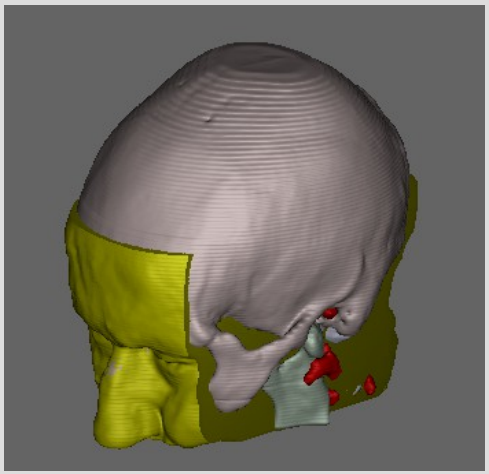
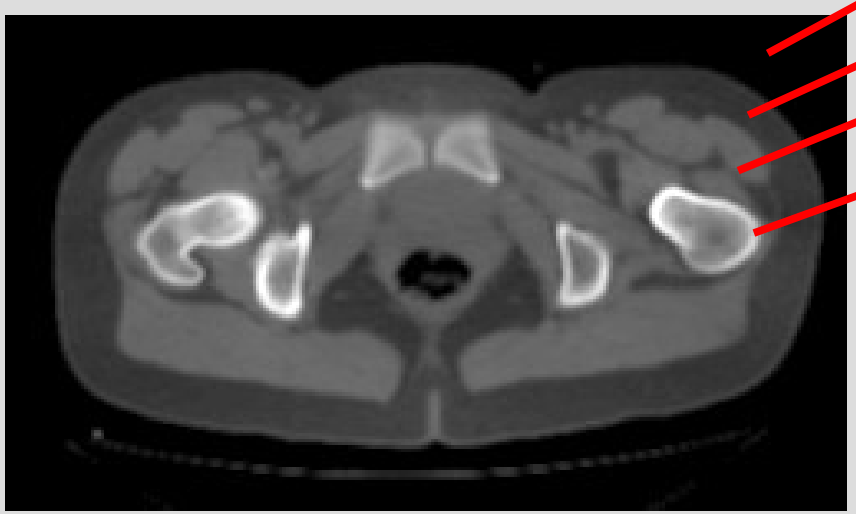


Space-based
segmentation

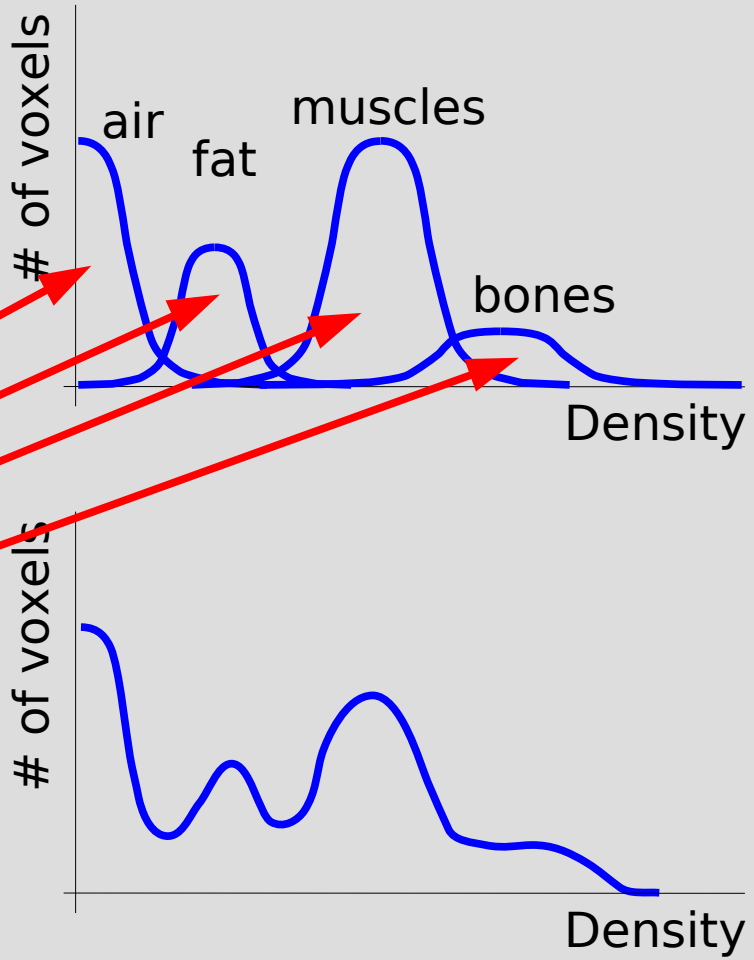
Mapping by Density Classification, Transfer Functions

$$TF:\ \rho(t)=f_{\rho}(d(t)),\ k(t)=f_{k}(d(t))$$

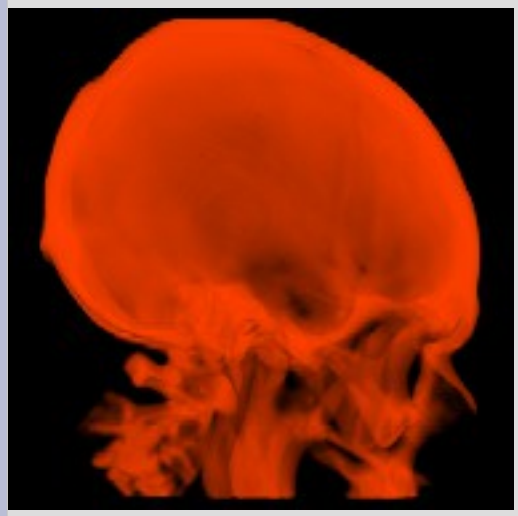
- Prerequisites:
  - Areas of interest identified solely by density value
  - Neighbors in histogram are neighbors in space



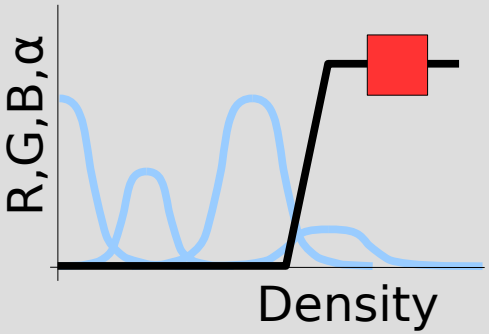
CT scan of a human pelvis



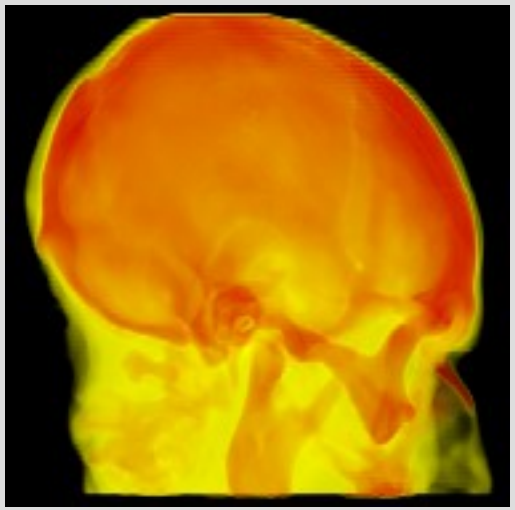
Density Classification by Transfer Functions (1)



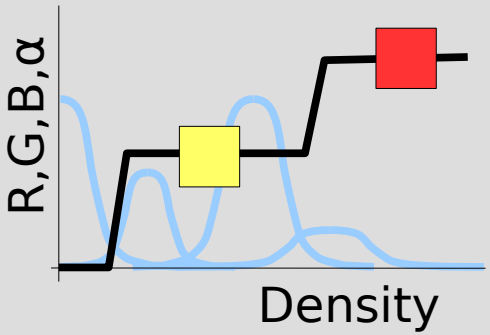
Bone only

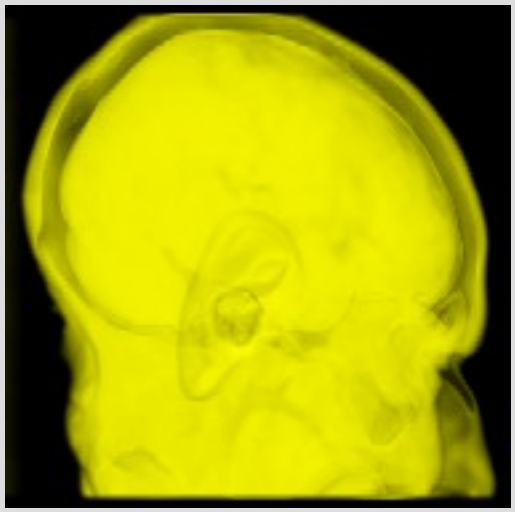


$$R, G, B, \alpha = f(density)$$

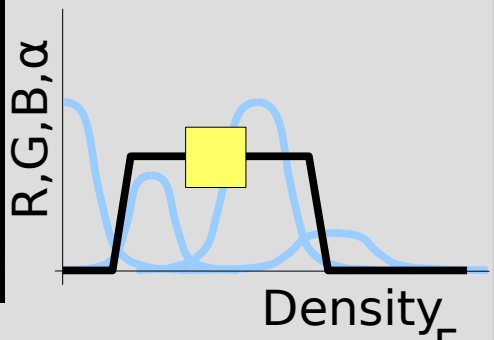


Bone & soft

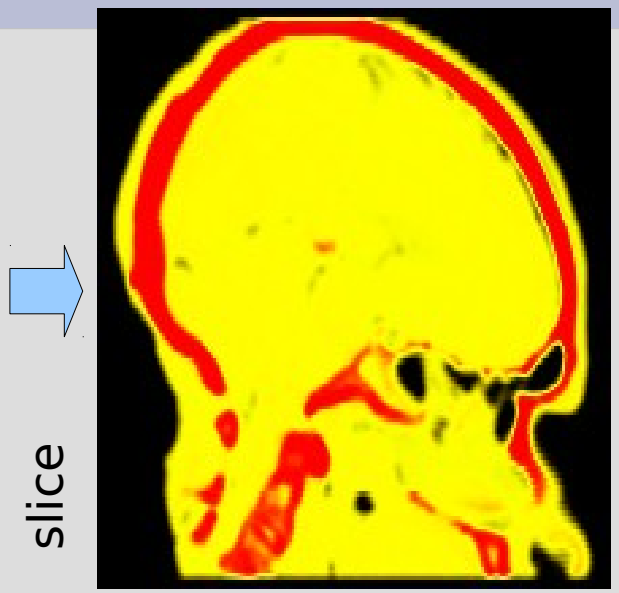


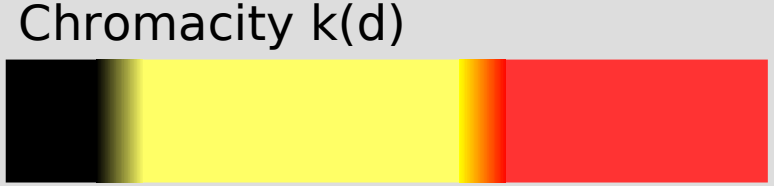


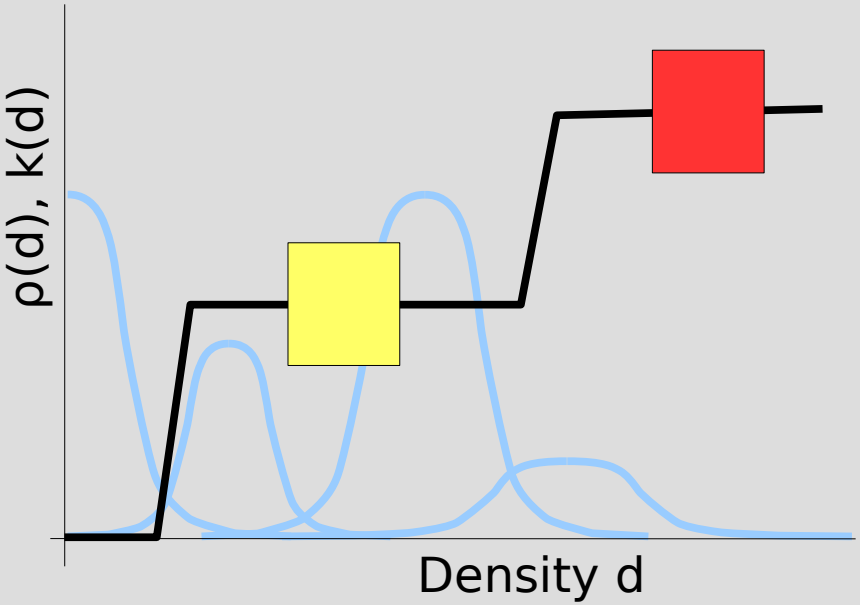
Soft only



Density Classification by Transfer Functions (2)







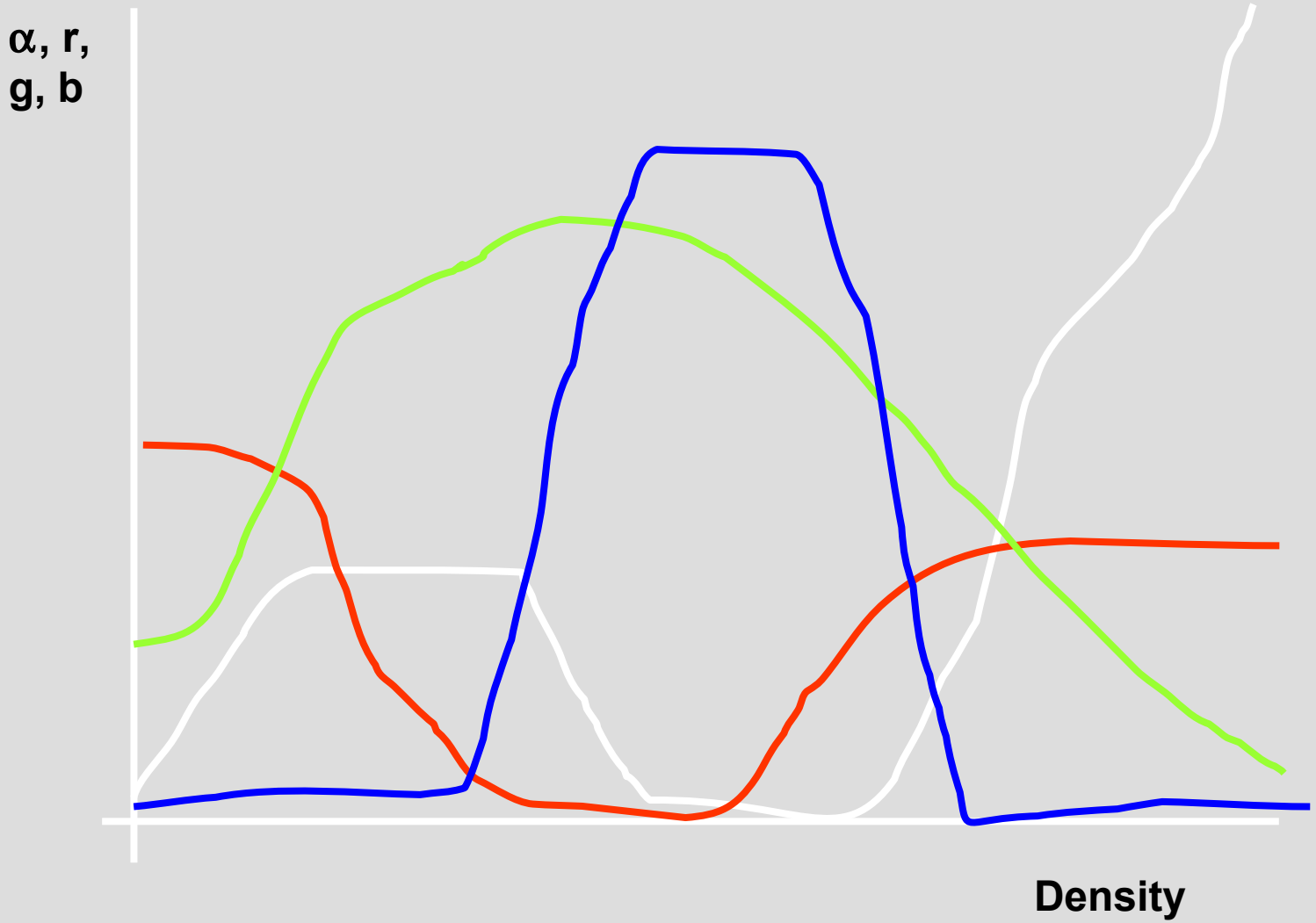
TF Design Questions

- How to set TFs to get desired appearance
  - A typical inverse problem
- How to set TFs for unknown data
  - Meaningful TFs reflect data properties

- Possibilities
  - Hand drawing
  - Inverse design
  - Design galleries
  - Multidimensional Tfs
  - ...

Hand-drawn TF

- A typical result:



Inverse Design

- Optimization according to a criterion (He 1996):

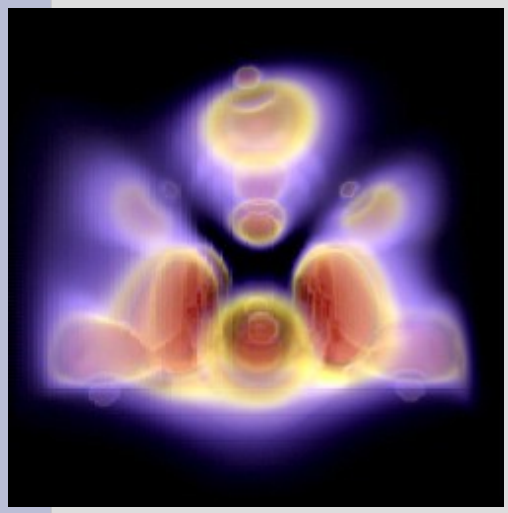


Image entropy

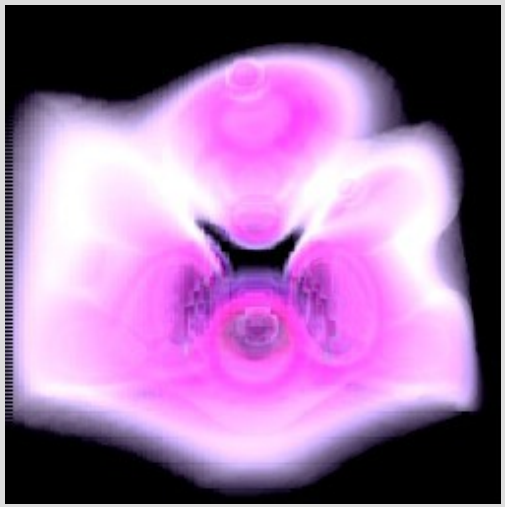
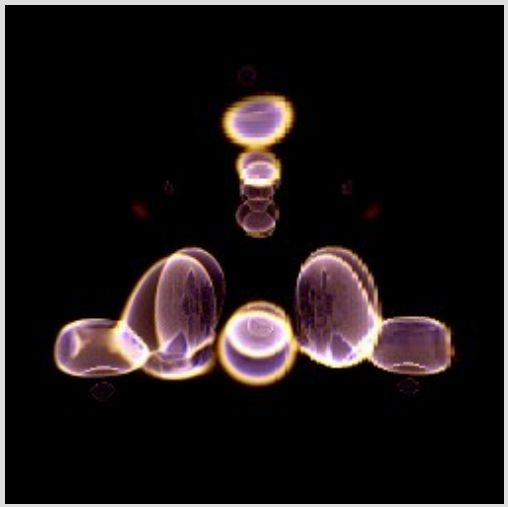
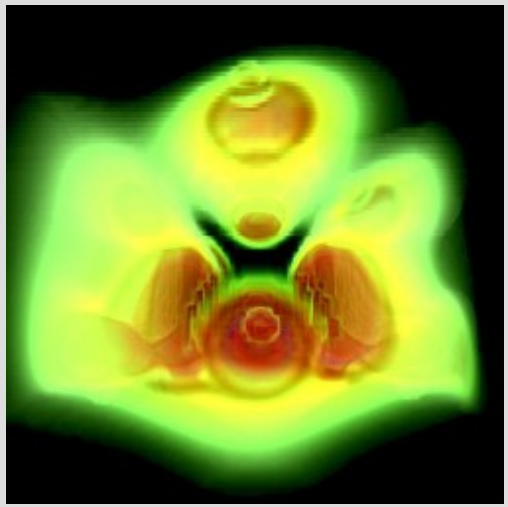


Image variance

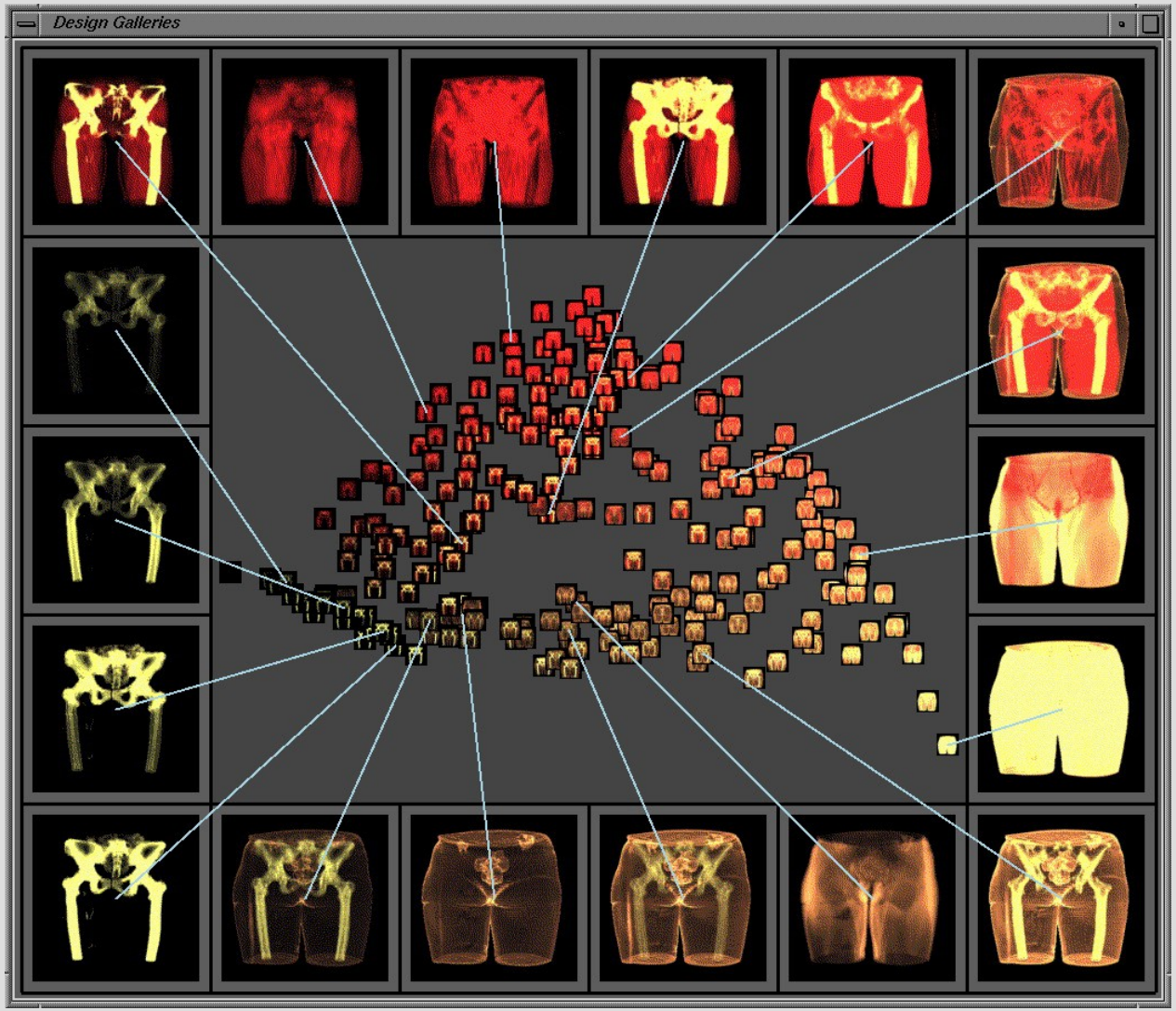


Edge content



Combination

Design Gallery

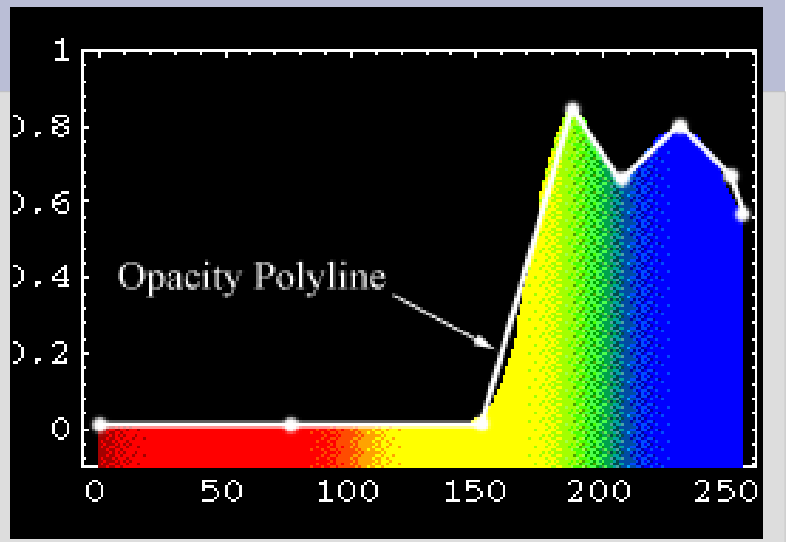


[Marks 1997]

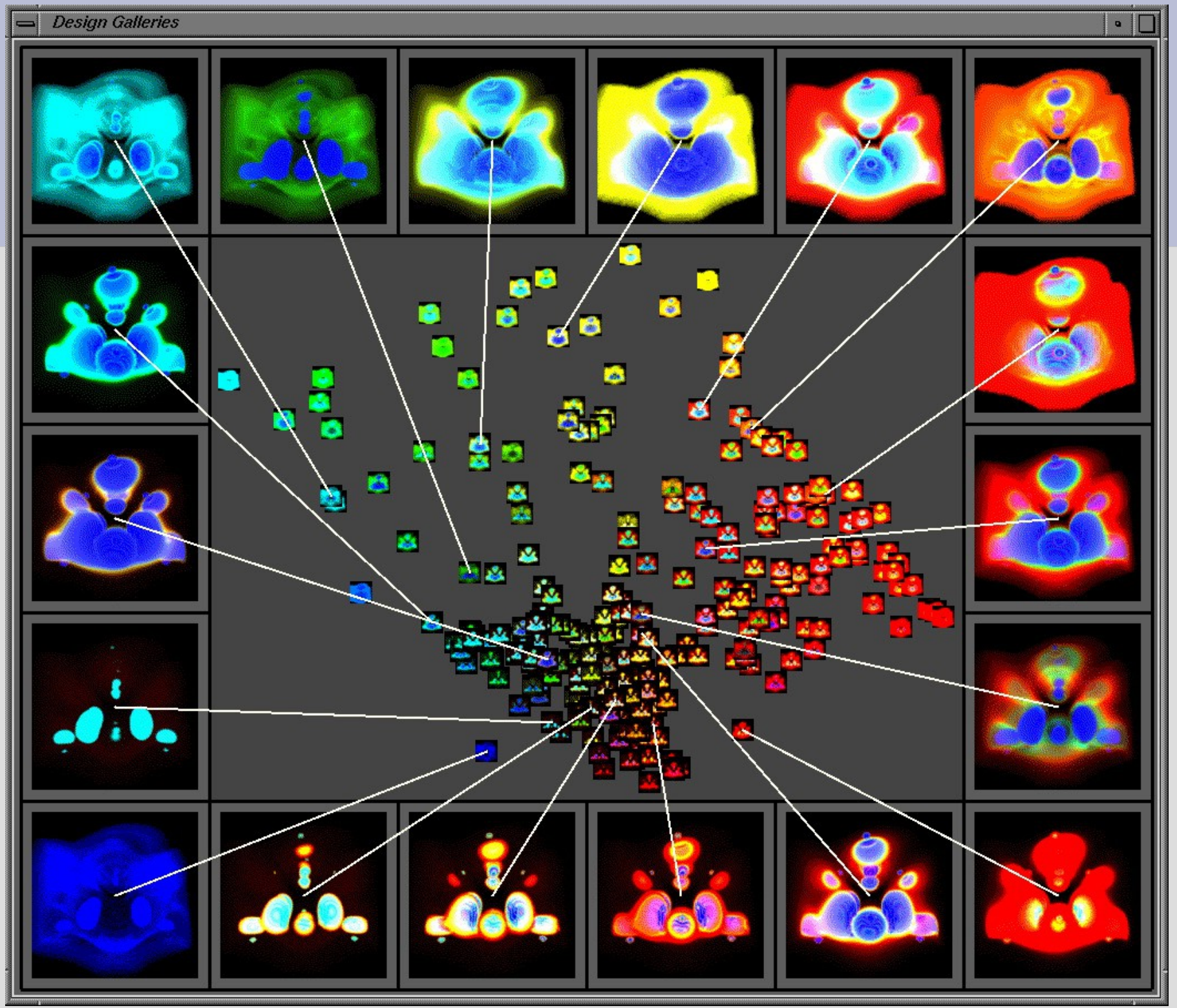
Design Galleries (DG)

- Automatically generated selection of perceptually different images
  - Generated off-line
  - Requires similarity measure (distance between images)
  - No optimality measure required

TF generation by means of Design Galleries



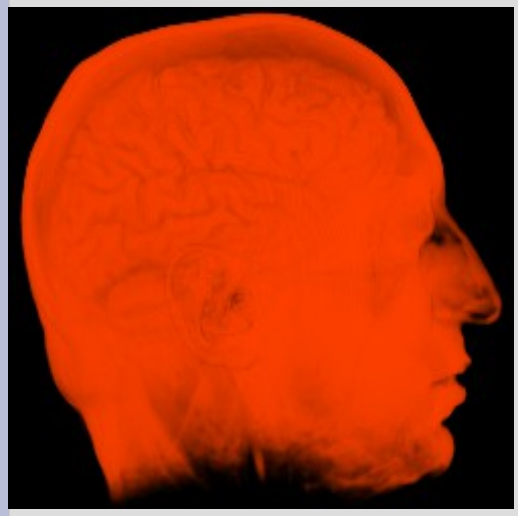
- Input vector:
  - Opacity TF: 8 control points parameters)
  - Color TF 6 subranges (red, green, cyan, blue, magenta)
- Mapping: A volume rendering technique
- Output vector: 8 manualy selected samples (24 values)
- Arrangement
  - Embedding in 2D space, with distances kept
  - Thumbnail images

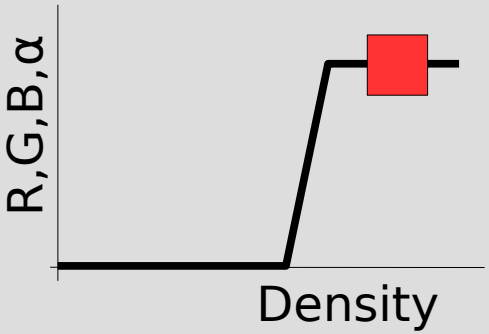

Design Galleries

DG - Labor Division

- DG Designer
  - Input and output vectors, metrics, dispersion and arrangement
  - Must understand the visualization technique
- Computer
  - Does the work
- User
  - Uses the results
  - No deeper insight is necessary

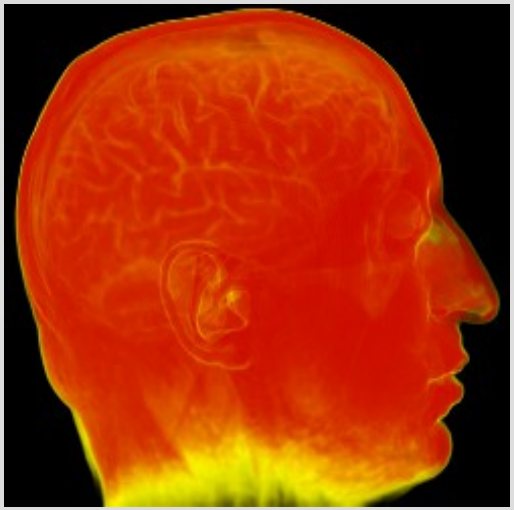
Density Transfer Functions with General Data

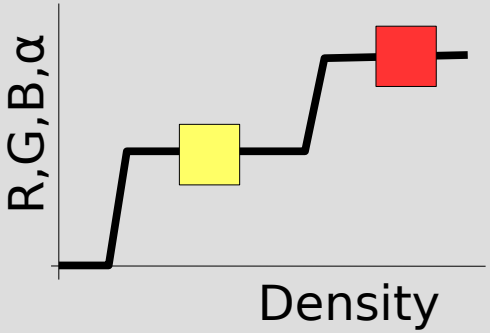


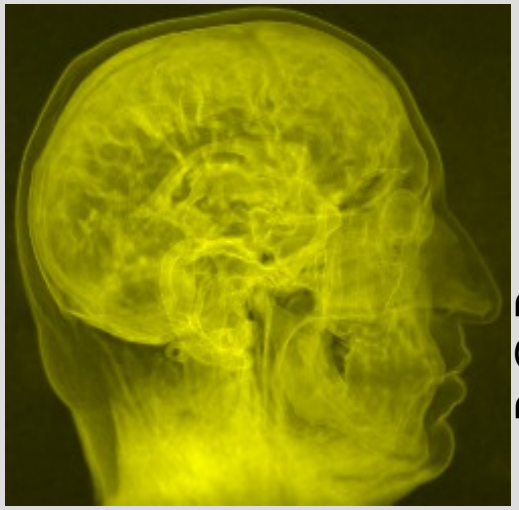


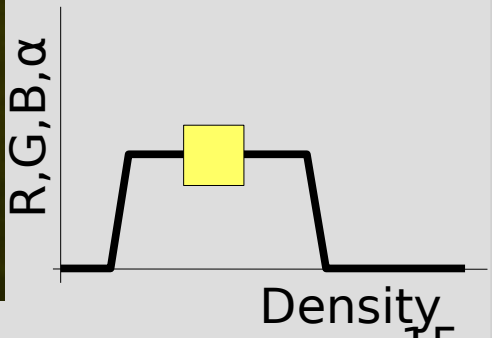
MRI Data:

- The histogram/position model not fulfilled
- No TF can separate the tissues
- Additional info required









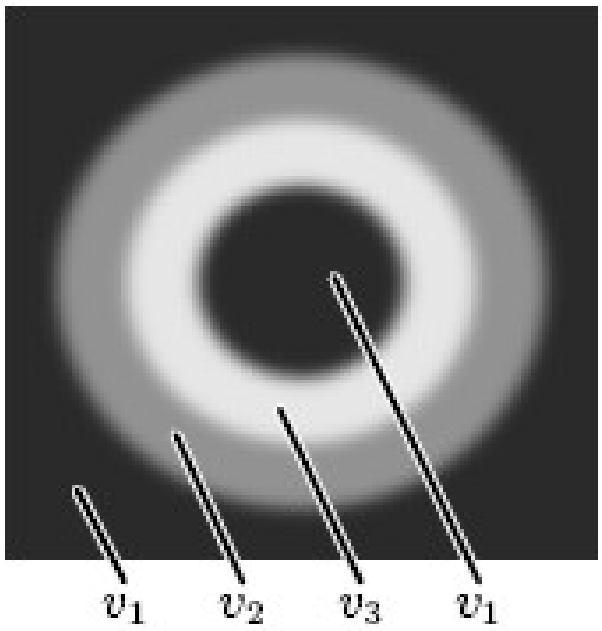
Additional Information for Better Rendering

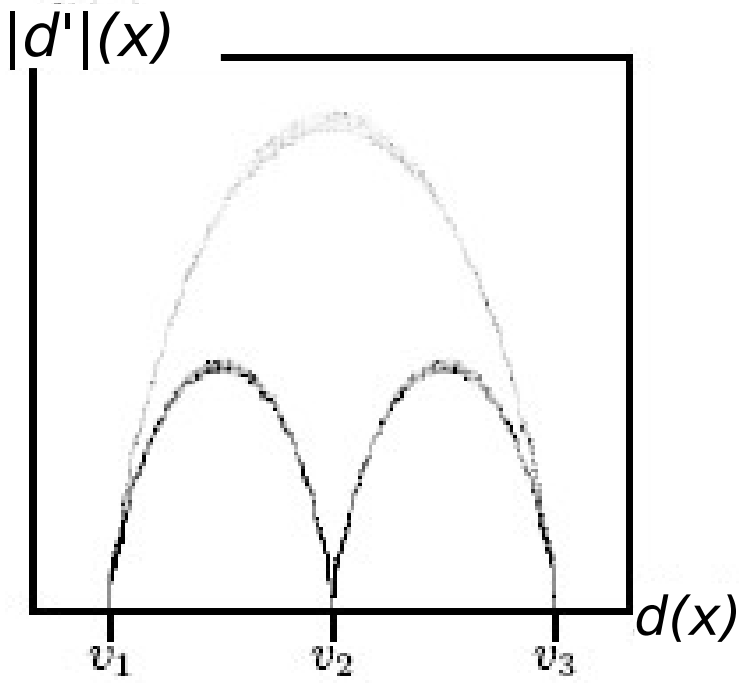
We need to localize the Tfs

- Partial problem solution by multidimensional TFs:
  - $|d'|$ *vs.* d scatterplots
  - LH-histograms
- Full solution by segmentation

Two- (multi-)dimensional TFs (1)

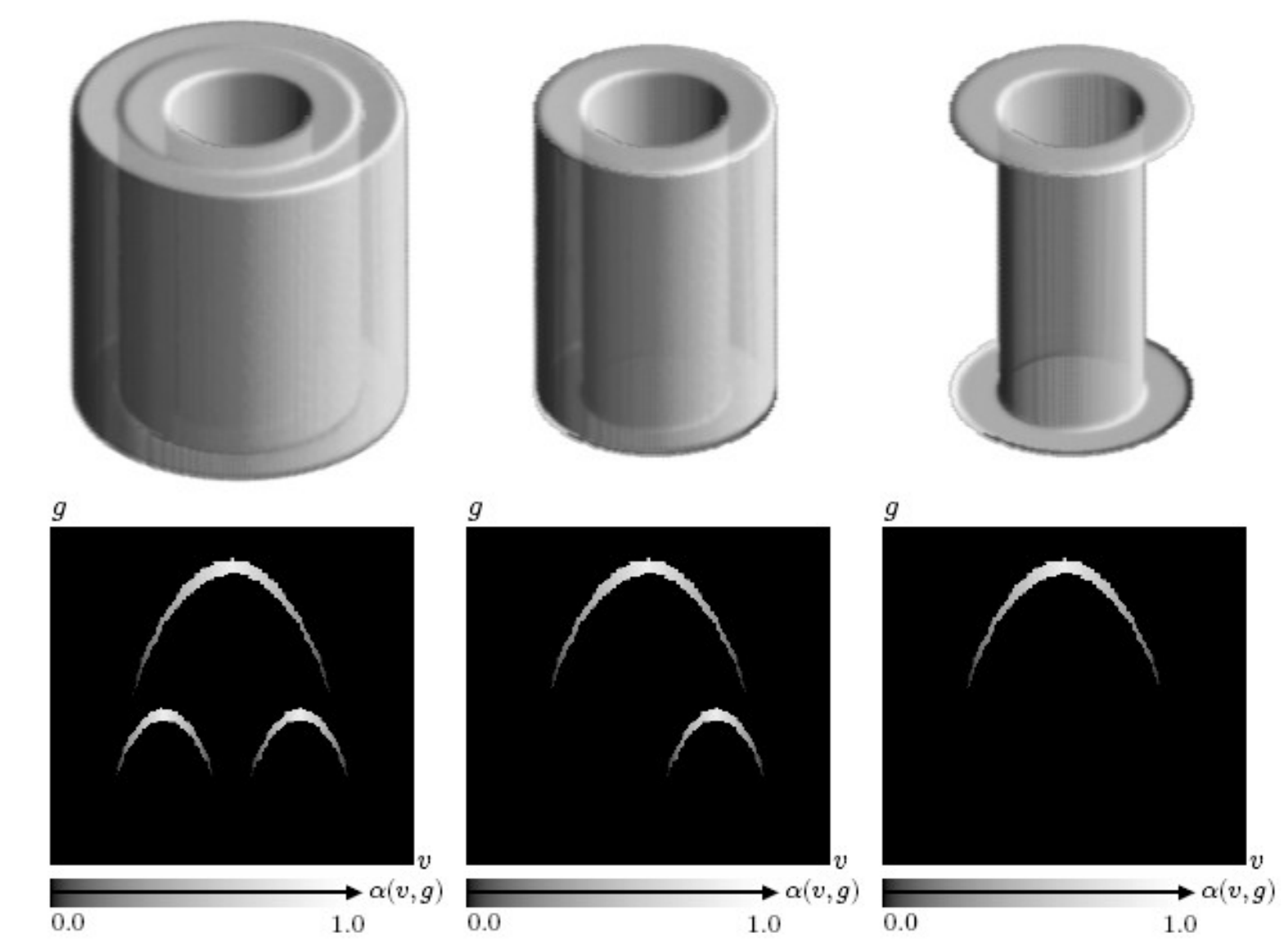
- TF design paradigm based on
  |*d*'| *vs. d* scatterplot analysis
- Observation: special arc-shaped d/d' scatterplot of blurred data





[Kindlmann 1998]

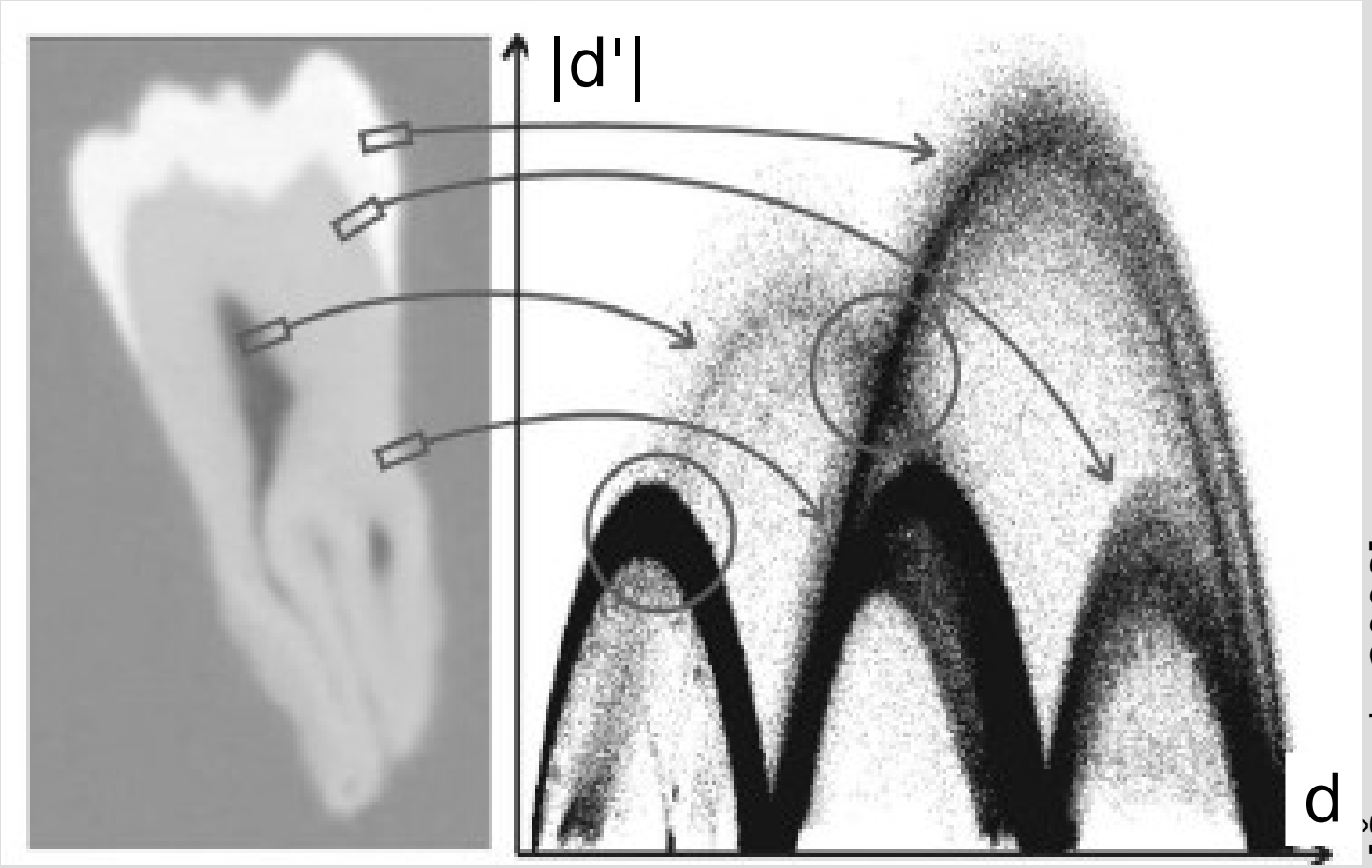
Two- (multi-)dimensional TFs (2)



[Kindlmann 1998]

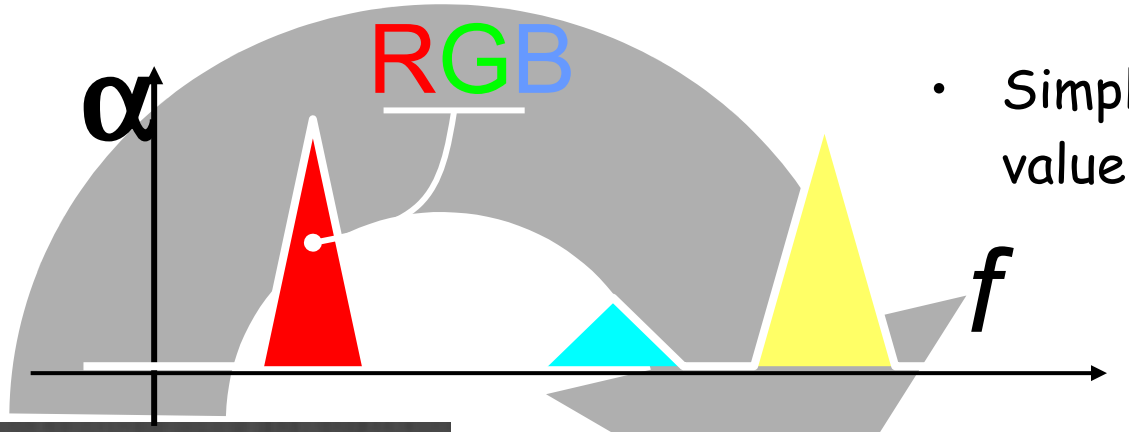
Two- (multi-)dimensional TFs (3)

- A complex datased: |*d*'| *vs. d* scatterplot

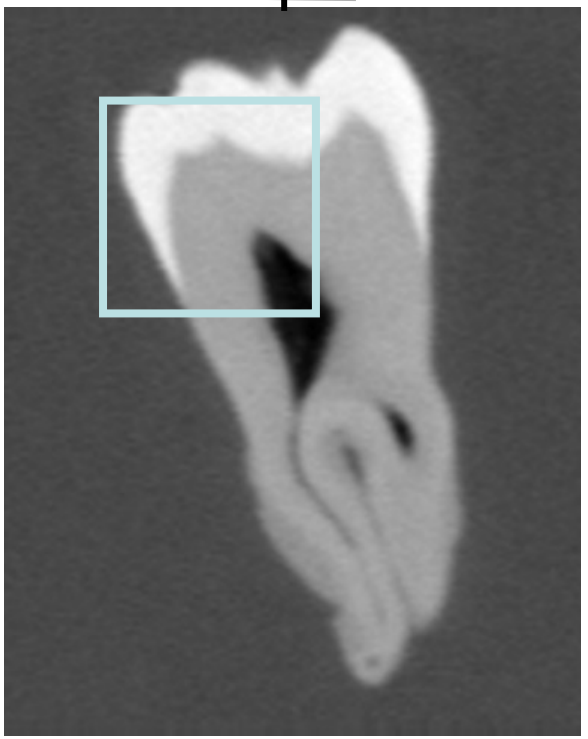


[Šereda 2006]

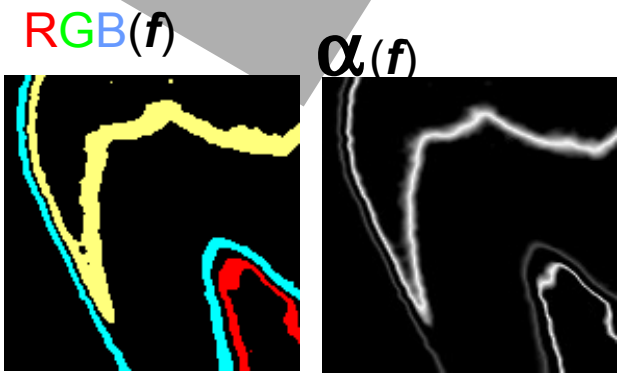
Transfer Functions (TF's)



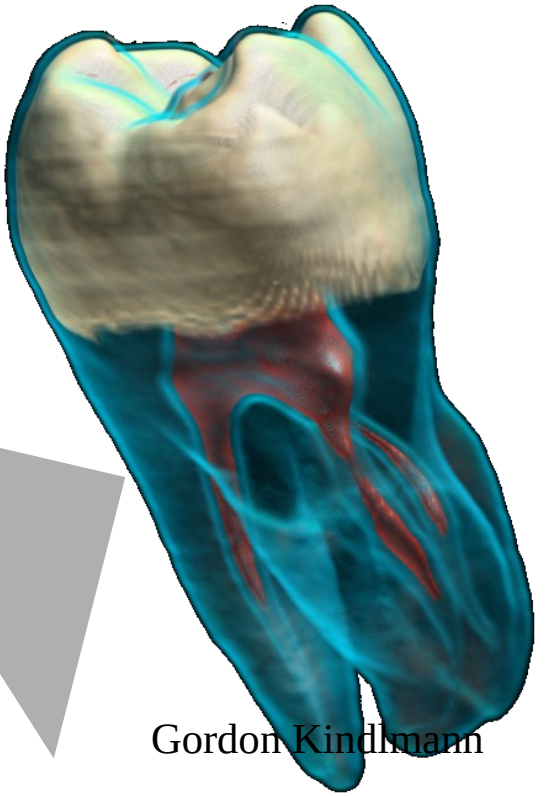
- Simple (usual) case: Map data value *f* to color and opacity



Human Tooth CT



Shading,
Compositing…

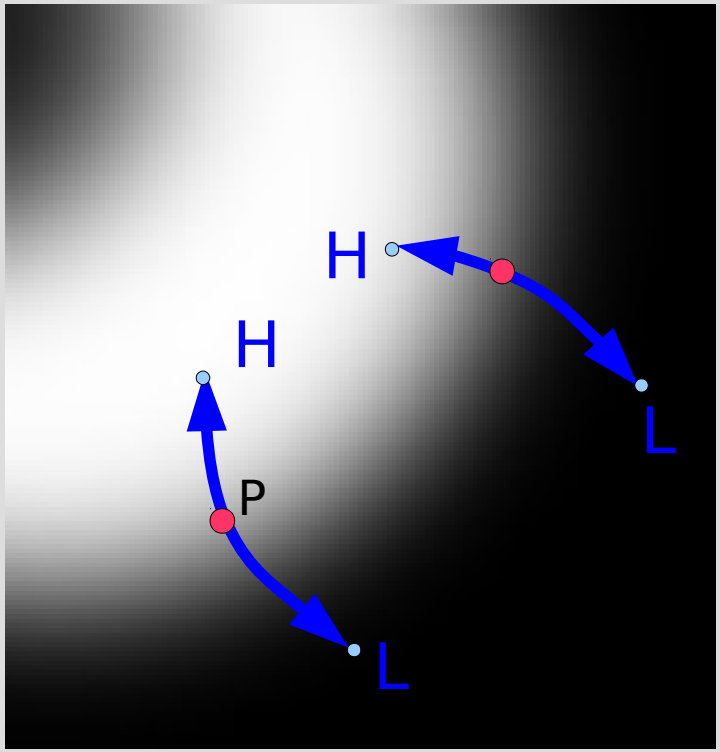


Gordon Kindlmann

TF Design by LH-Histograms (1)

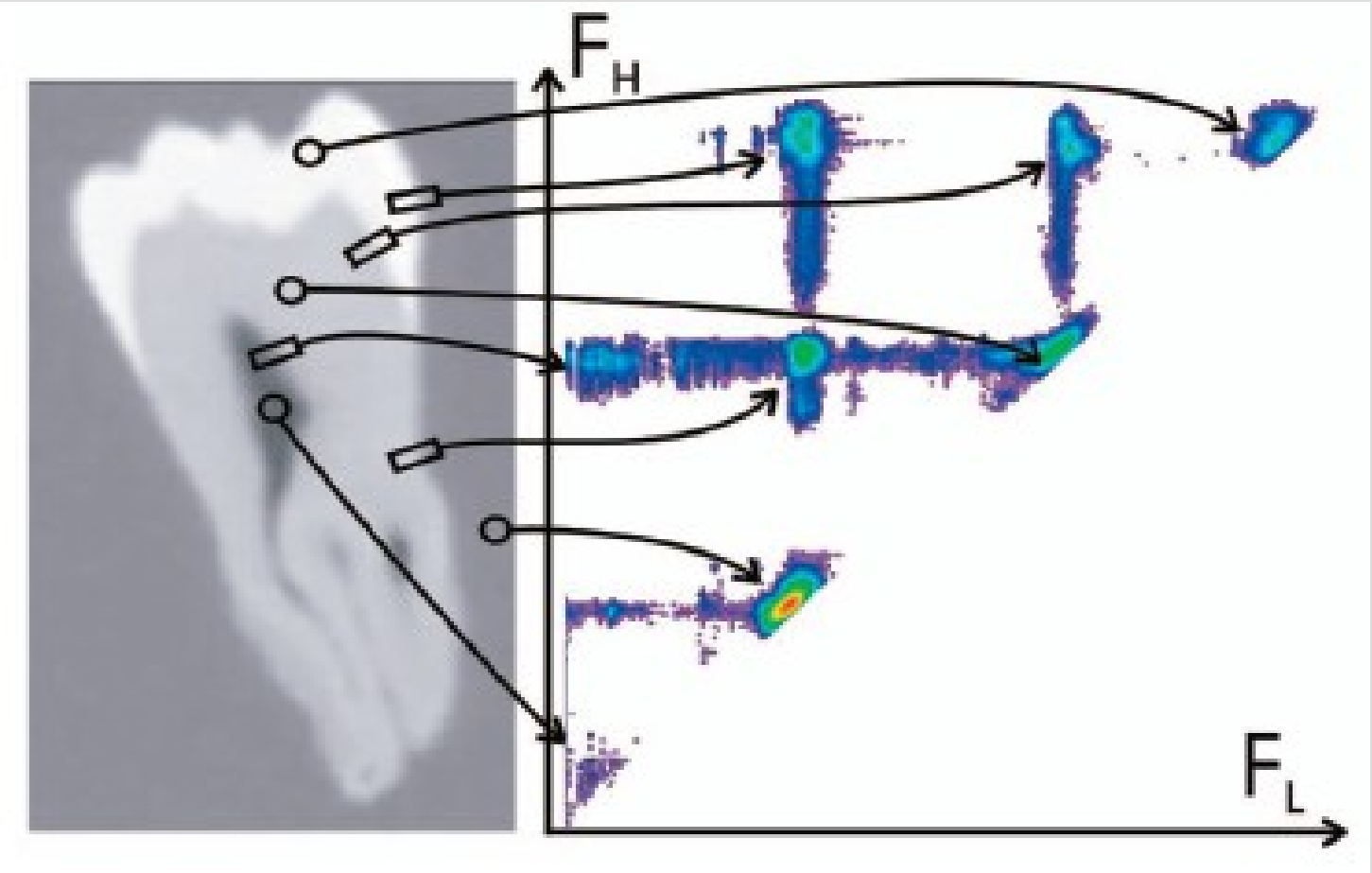
LH (Low-High) Histogram:

- Downhill and uphill stationary values
- A boundary is represented by a single point in LH histogram



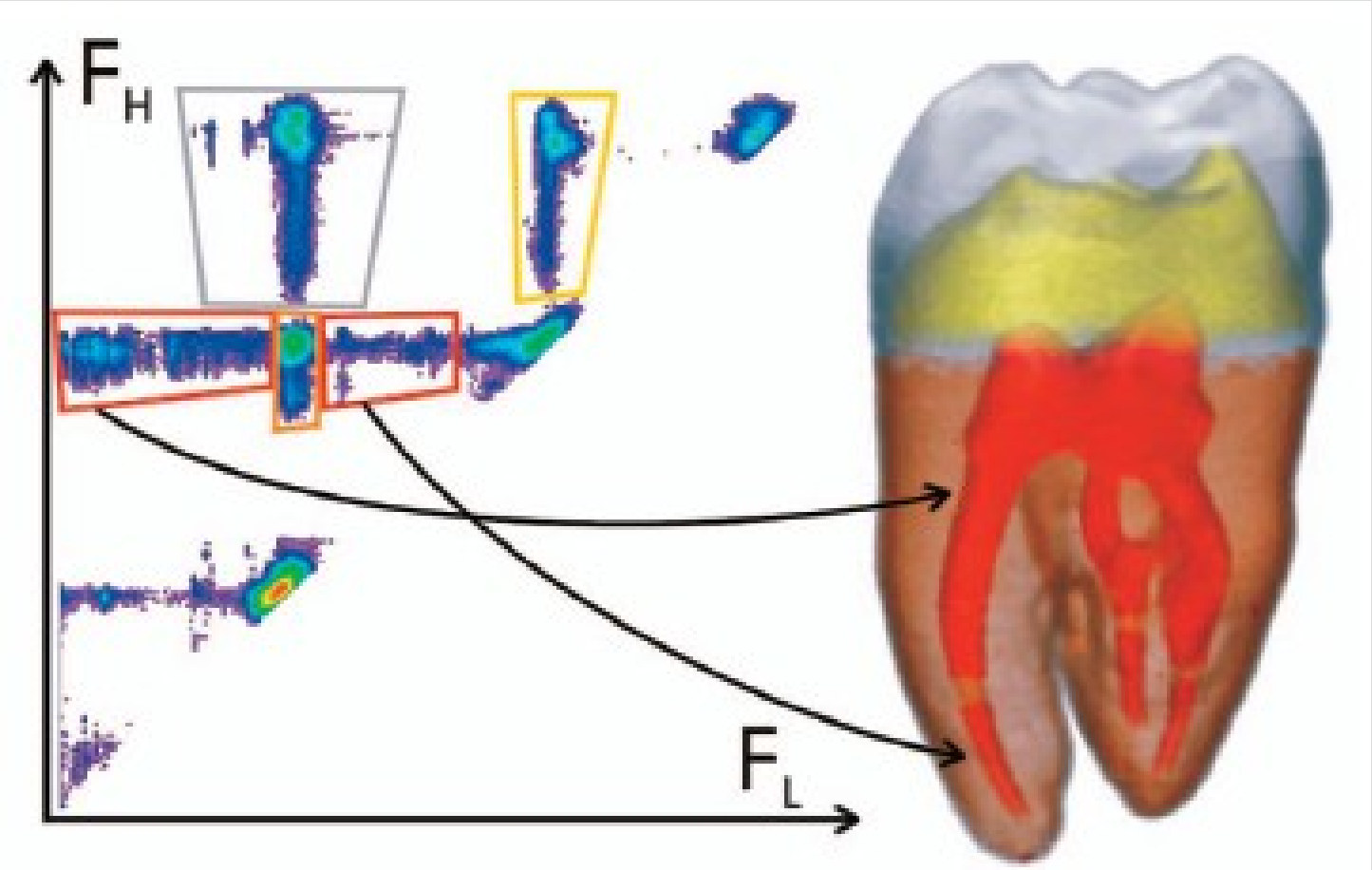
TF Design by LH-Histograms (2)

- A complex datased: LH-Histogram



[Šereda 2006]

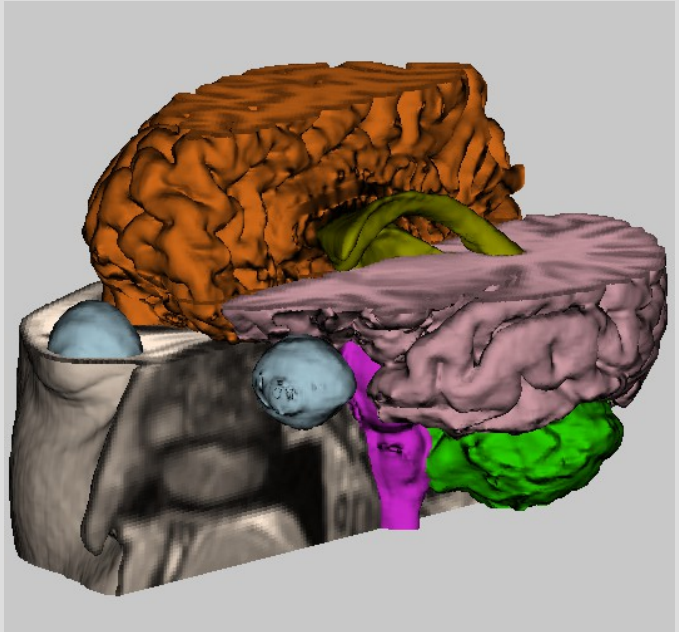
TF Design by LH-Histograms (3)

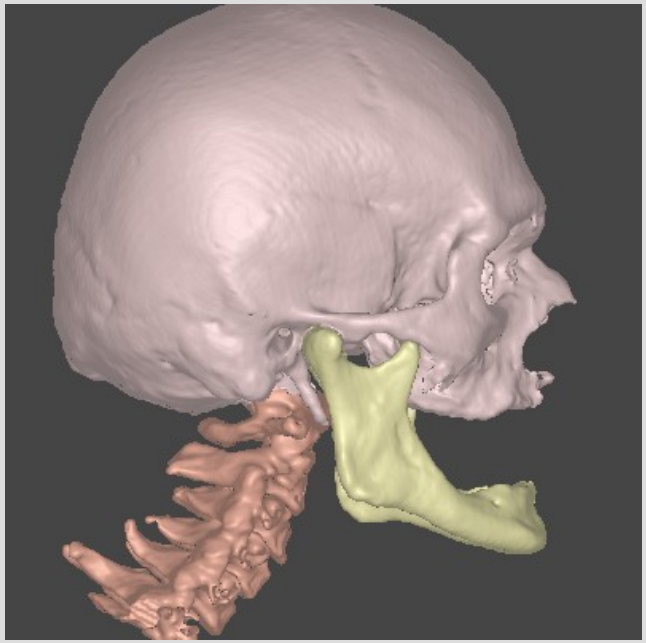


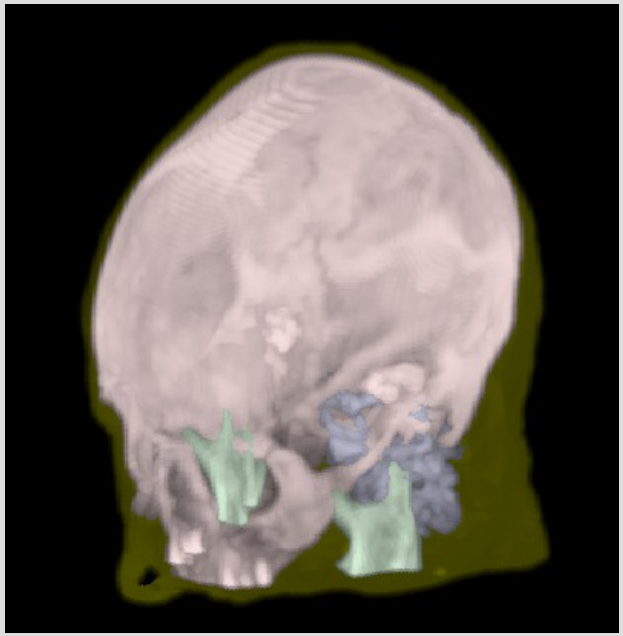
[Šereda 2006]

Mapping by Spatial Segmentation

- The process of isolating objects of interest from the rest of the scene (Castleman, 1979)
- Full control over property assignment







Mapping: Summary

- **Transfer function based:**
  - Color & transparency assigned to voxels
  - Semitransparent volumes
  - Display of volumes, volume rendering

- **Segmentation-based**
  - Unambiguous object definition
  - Display of surfaces
    - surface rendering (model based)
    - isosurfacing (no model, directly from 3D data)