# Transfer functions/classification

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# Purpose

- Data is just a set of scalar values
- Transfer function maps raw voxel value to presentable entities
  - Assign each scalar value to a color
  - Exploration important --- want fast on-the-fly updates

# Data classification (CT example)

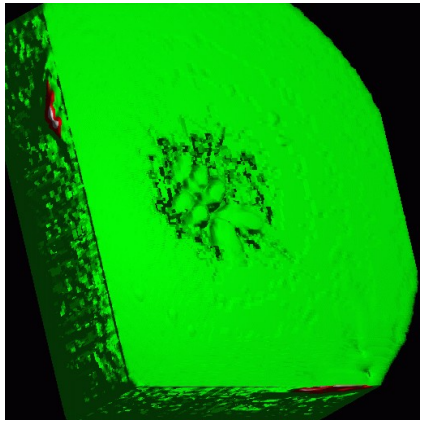
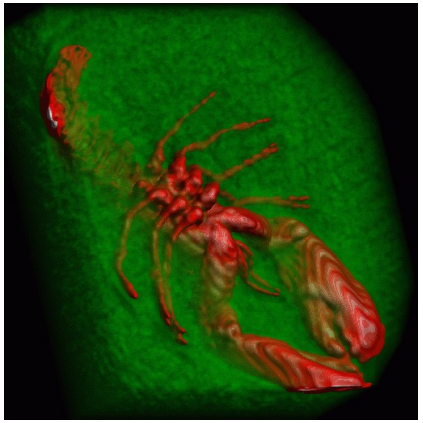
Hounsfield units (HU) for CT data sets

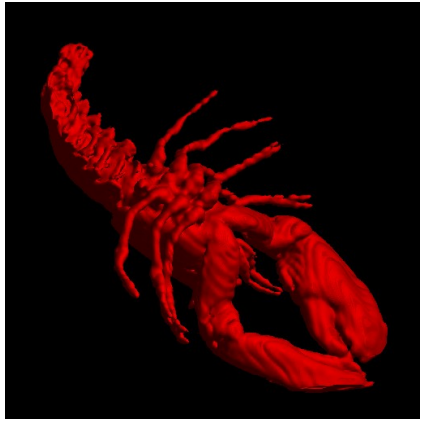
- Describes x-ray attenuation, i.e., density of material
- 12-bit CT-measurements
- Range of values from -1024 to +3071 HU
- Typical values:
  - Air: -1024
  - Fat: -100 to -20
  - Water: 0
  - Soft tissue such as muscle: +20 to +80
  - Bone: > +500
- For visualization, 12 bits are often reduced to 8 bits by windowing (loss of dynamic range)

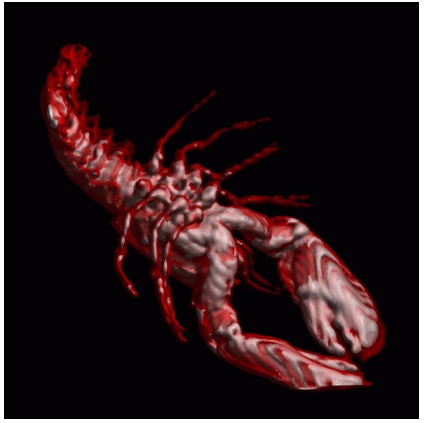
# Classification

- Empowers user to select "structures"
- Extract important features of the data set
- Classification is non trivial
- Histogram can be a useful hint
- Often interactive manipulation of transfer functions needed

# Classification

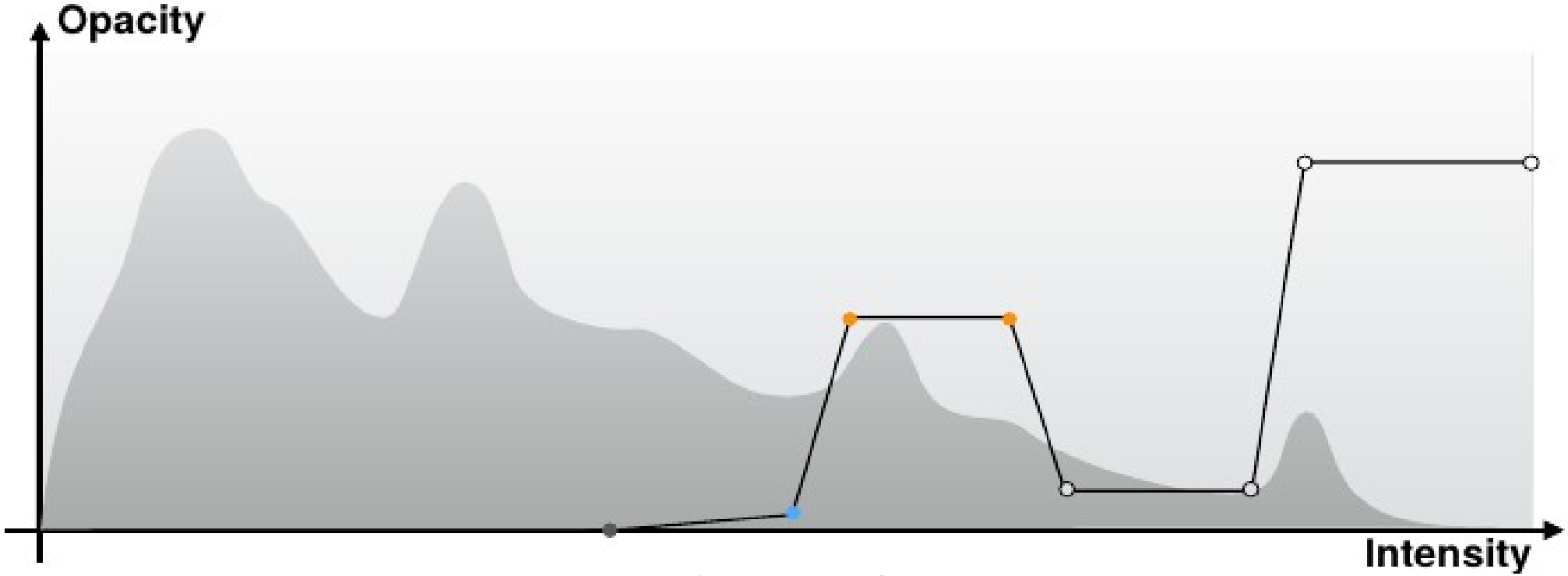



# Transfer functions

# Techniques

- Simplest: 1D transfer function
- 2D transfer function
- Multi-d transfer functions
- Principled exploration
- Segmentation

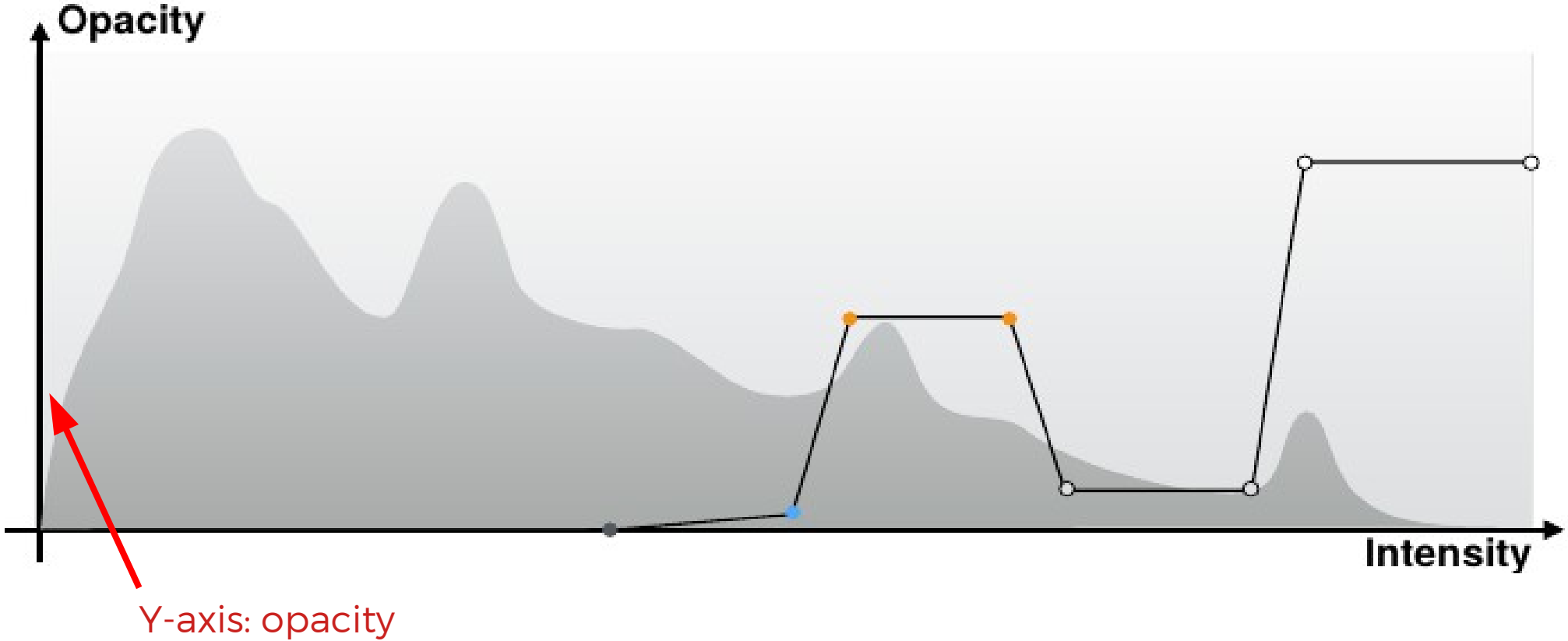
# 1D transfer functions




X-axis: Data values

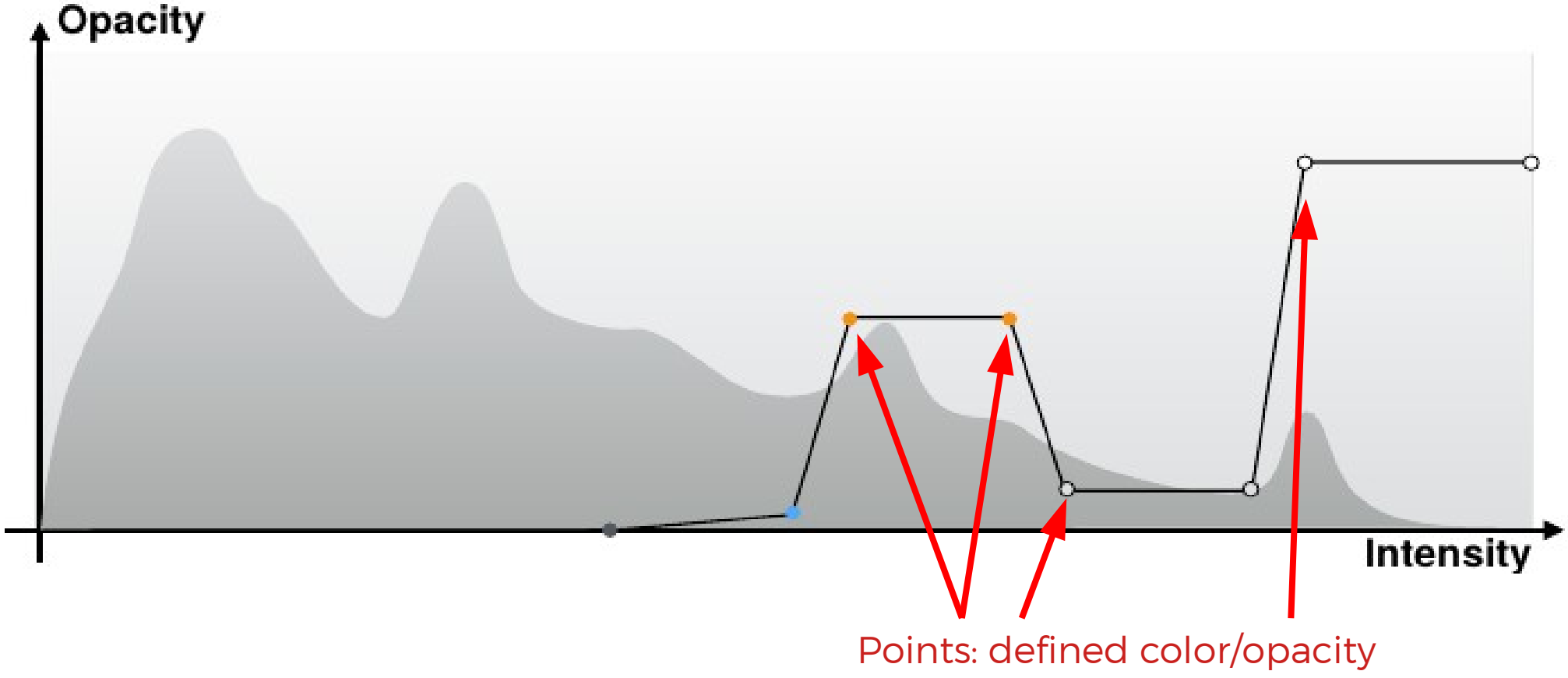
Ljung et al., “State of the Art in Transfer Functions for Direct Volume Rendering.”

# 1D transfer functions



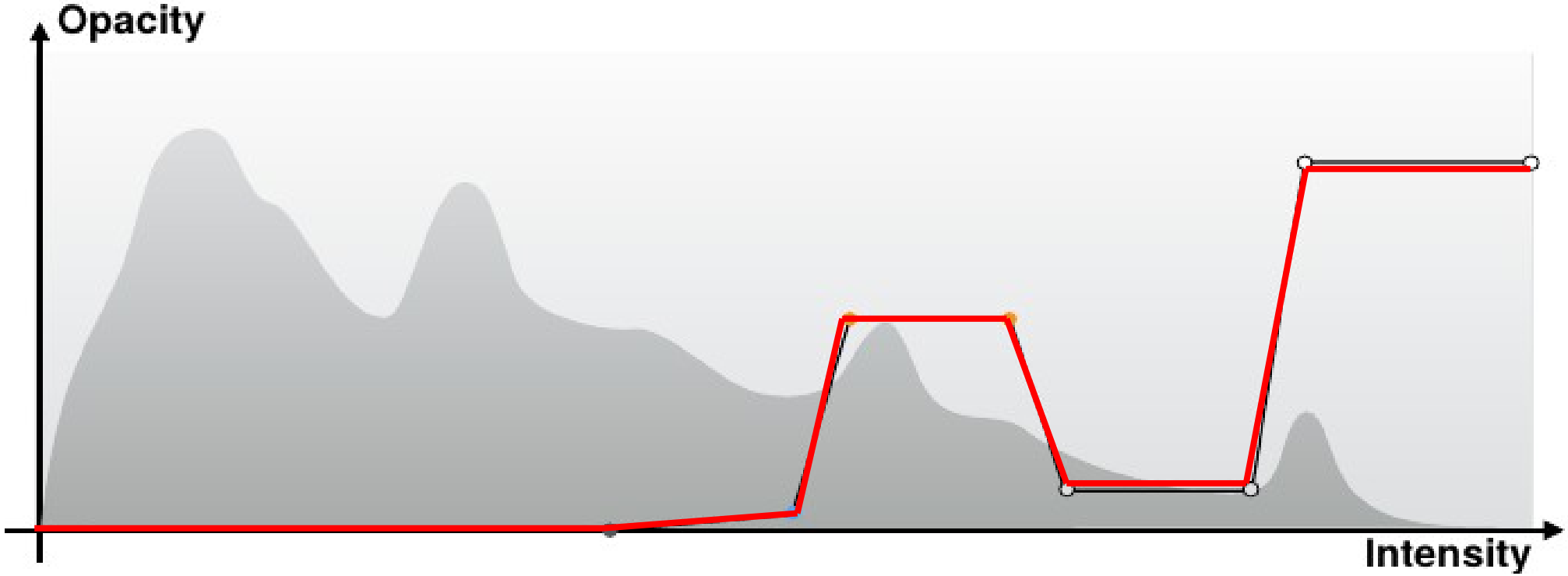

Ljung et al., “State of the Art in Transfer Functions for Direct Volume Rendering.”

# 1D transfer functions




Ljung et al., “State of the Art in Transfer Functions for Direct Volume Rendering.”

# 1D transfer functions

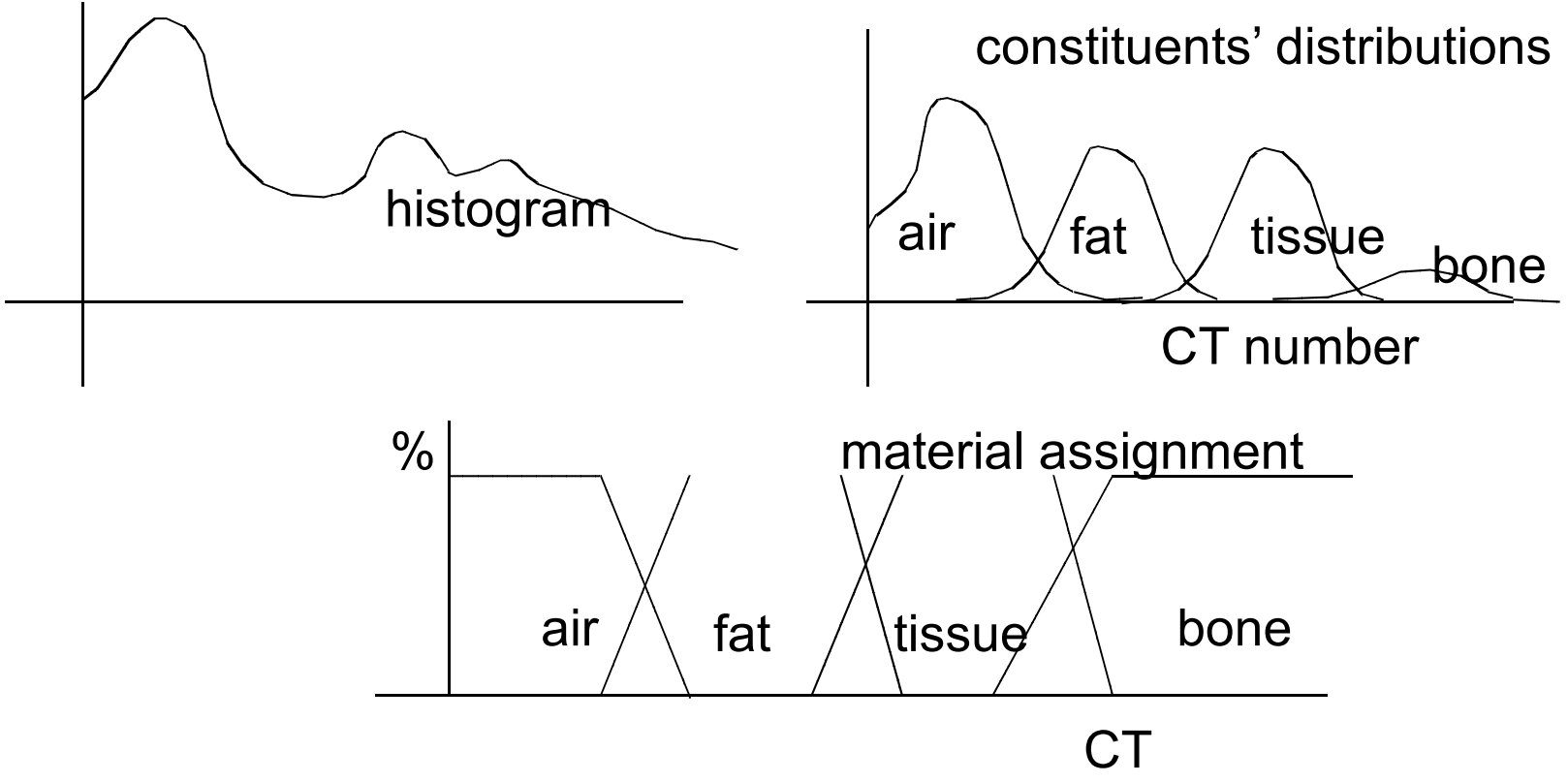



Linear interpolation of color/opacity

Ljung et al., “State of the Art in Transfer Functions for Direct Volume Rendering.”

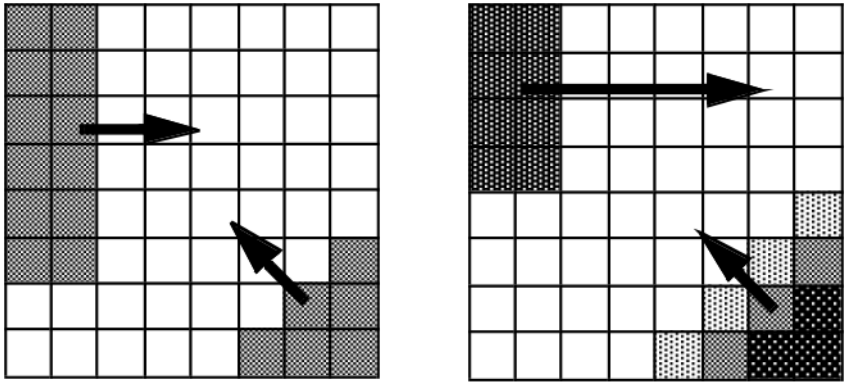
# Histograms

## Inuition for key values in the dataset

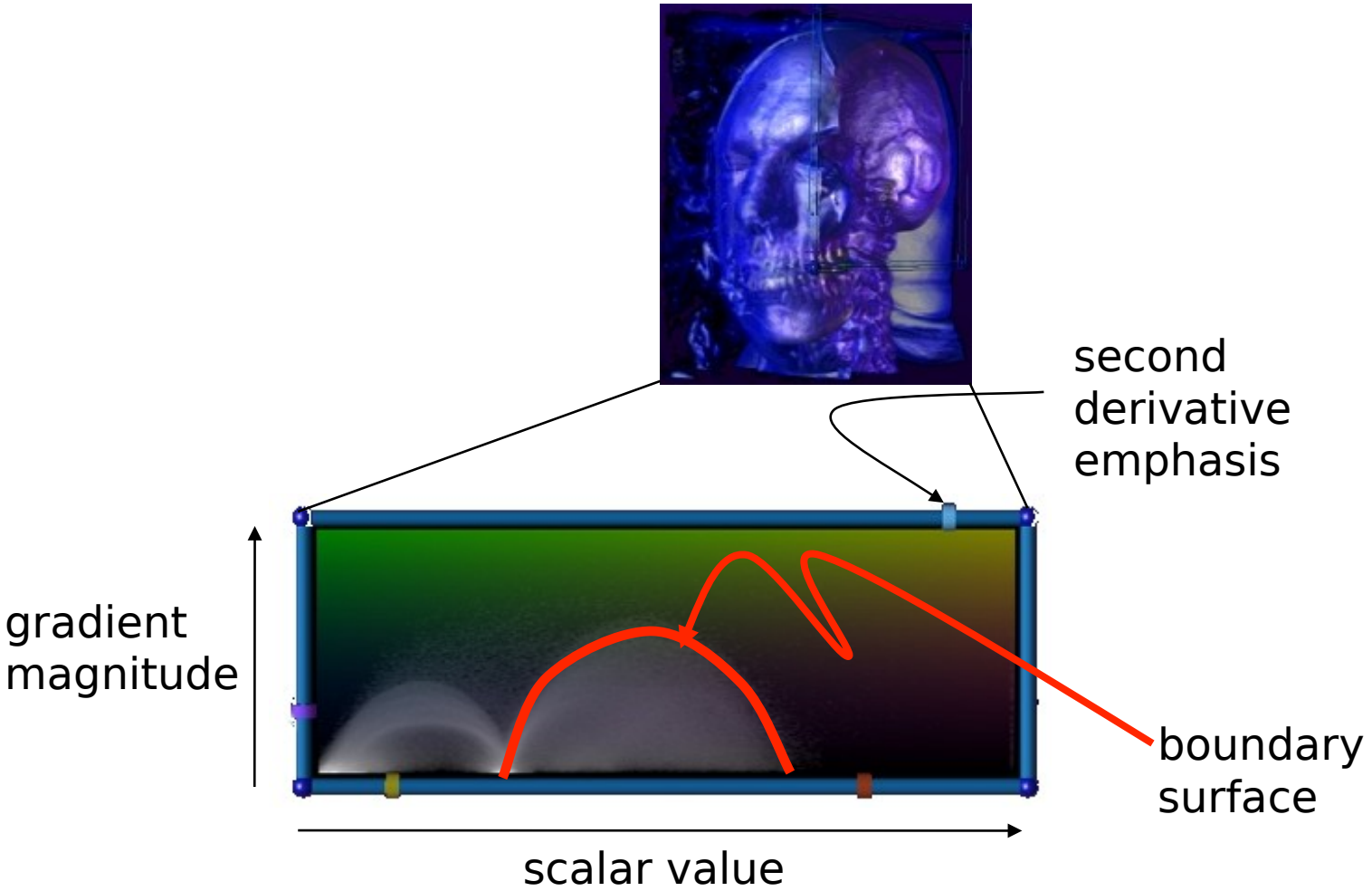


# 2D transfer functions

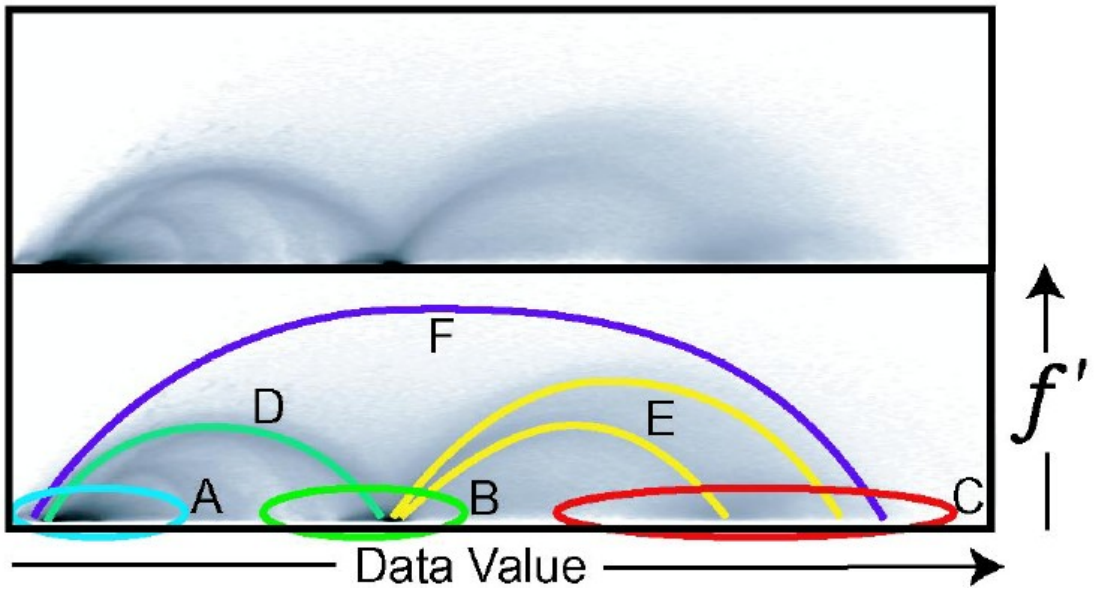
- Usually interested in regions of "change"
- High opacity highlights features
- 2D transfer function determines color/alpha based on value and gradient magnitude

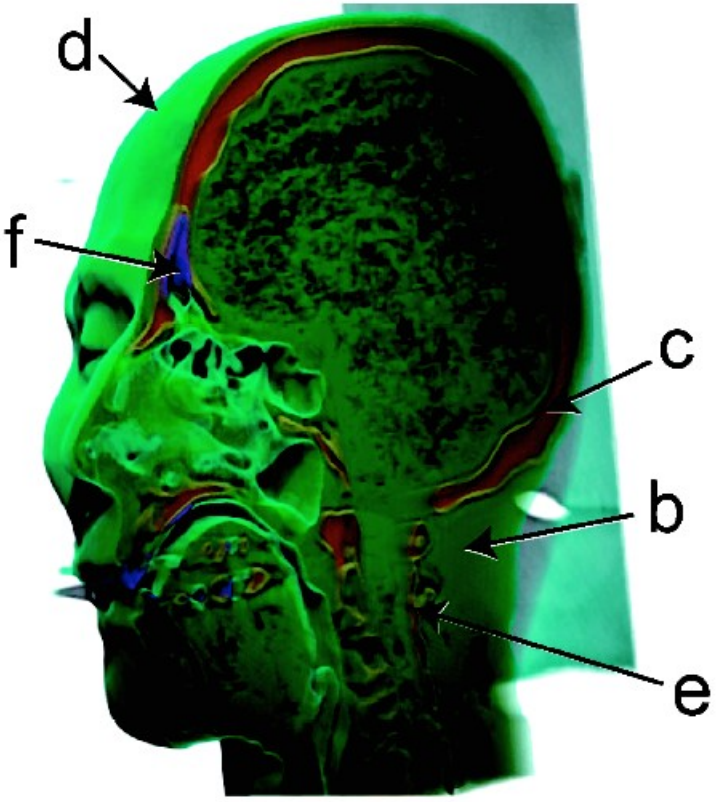


# 2D transfer functions



# 2D transfer functions

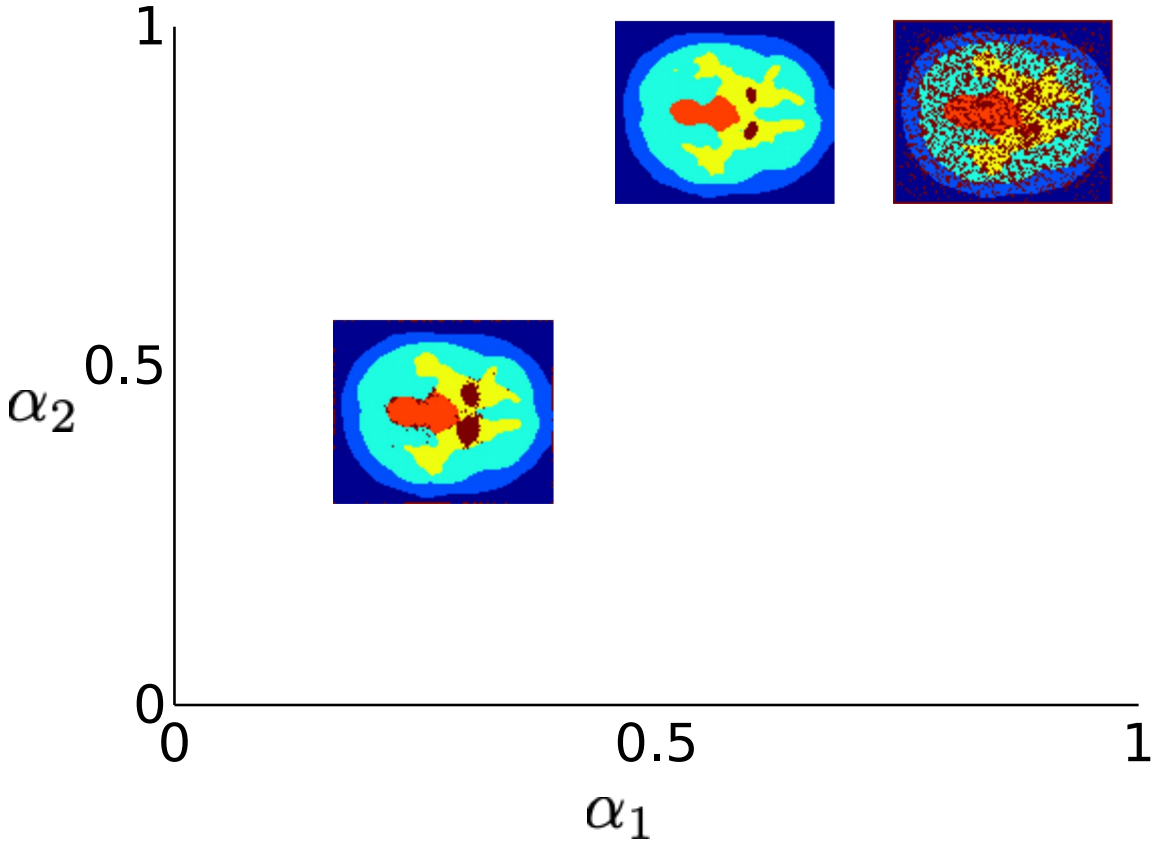


# Multidimensional transfer functions

- Problem: How to identify boundary regions/surfaces
- Approach: 2D/3D/nD transfer functions, depending on
  - Scalar value, magnitude of the gradient
  - Second derivative along the gradient direction
  - Multi-valued fields
  - Derived (statistical values)

# Principled exploration

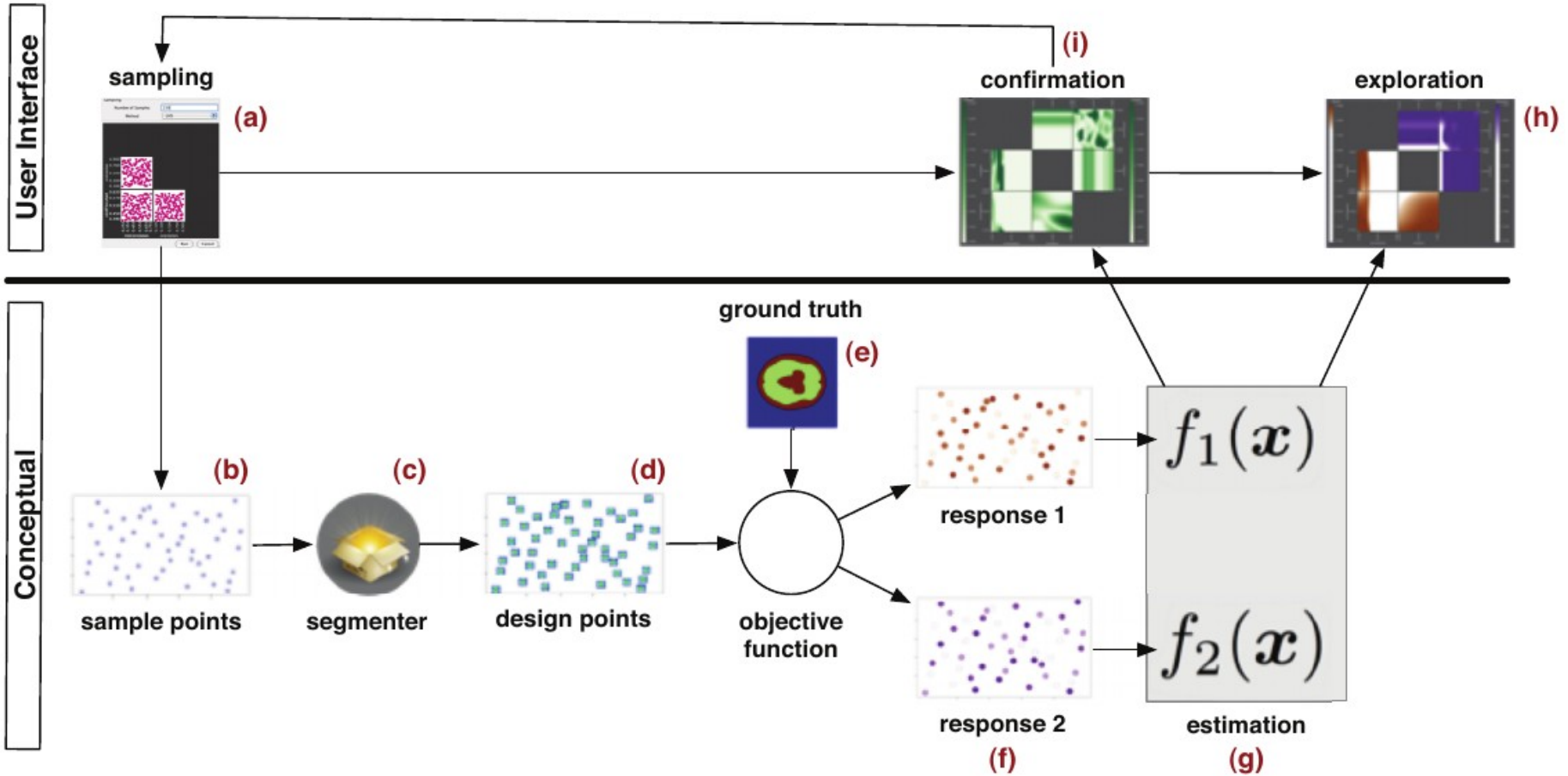


# Principled exploration

Lots of possibilities what to do?

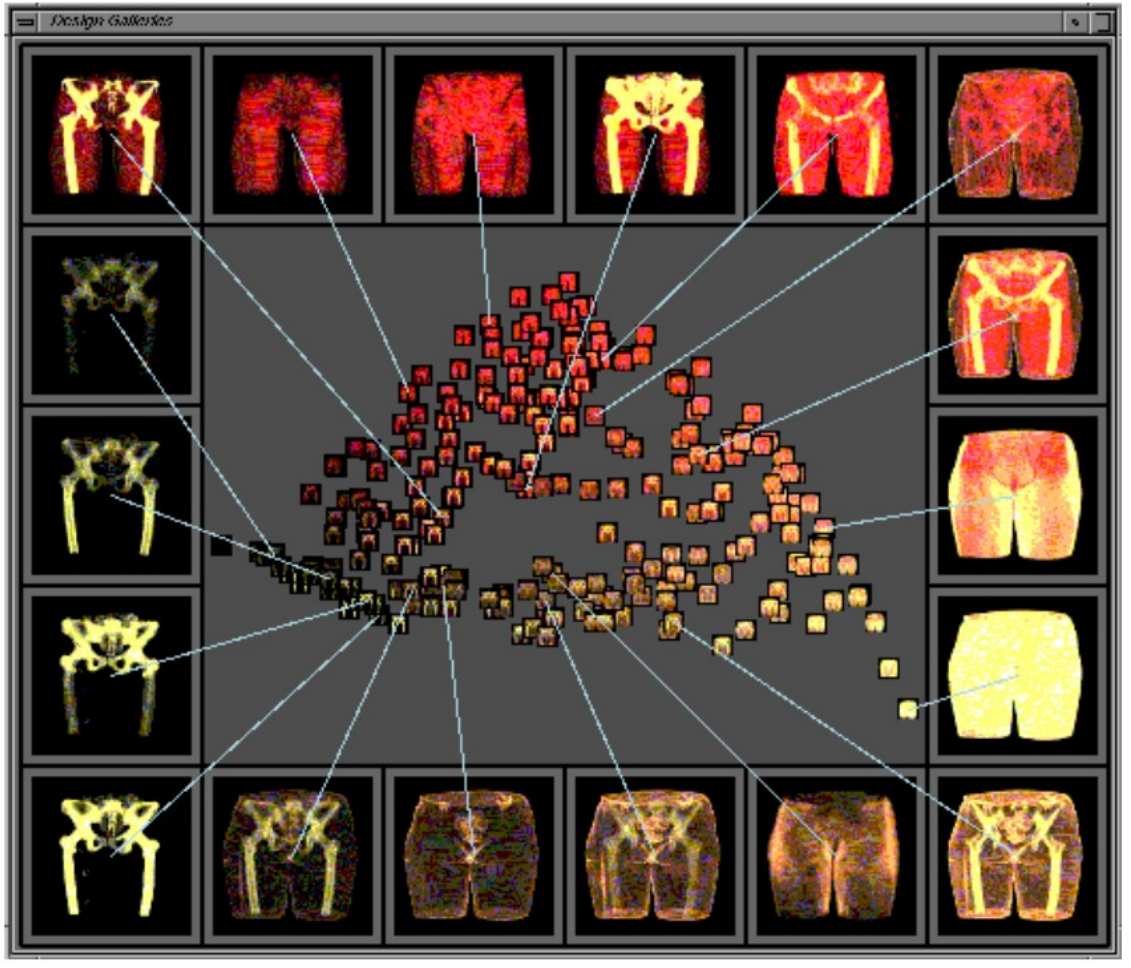
- Use the computer for what it's good at
- Sample offline
- Visual interface to explore possibilities

# Principled exploration



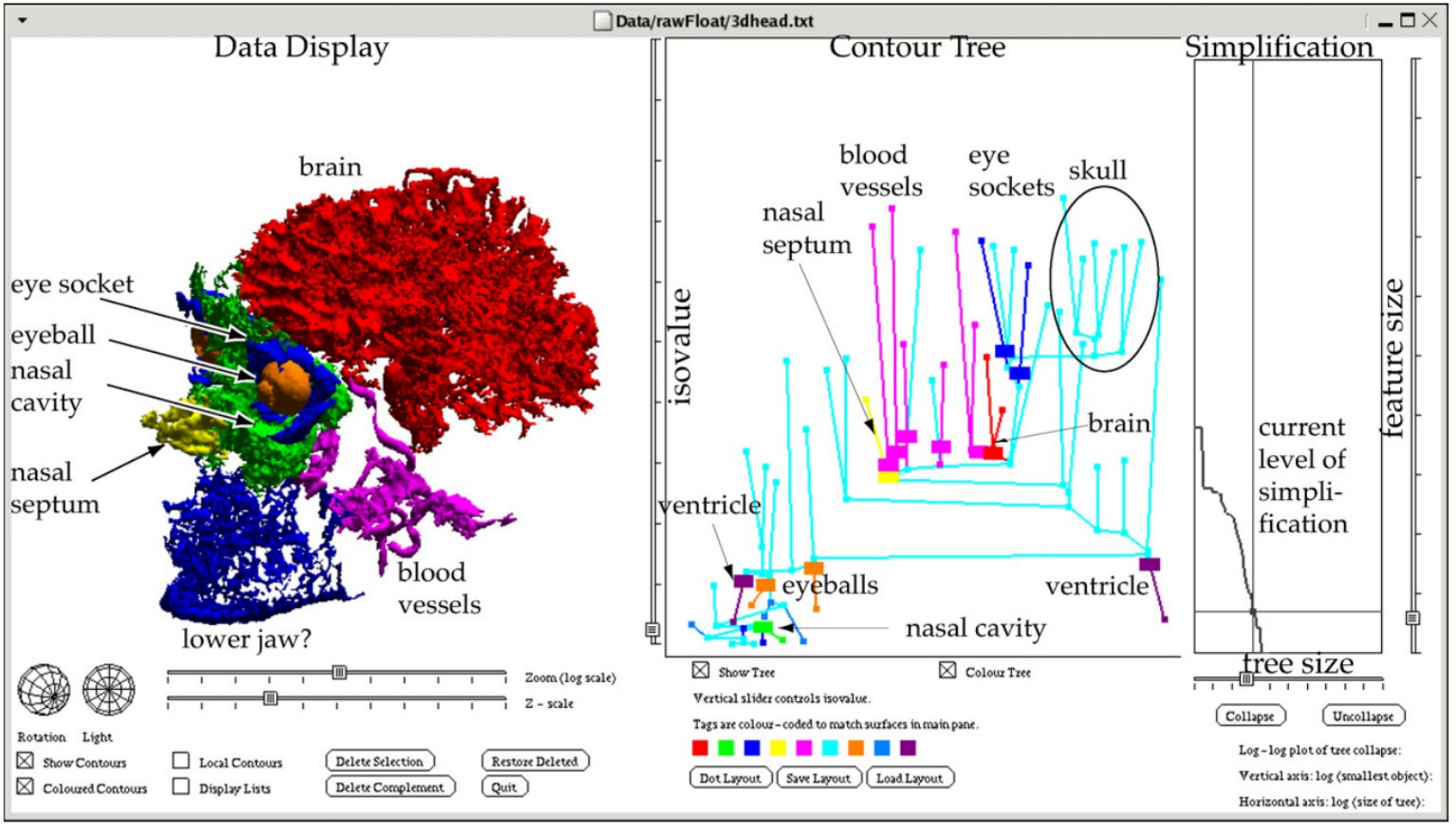

Torsney-Weir et al., "Tuner: Principled Parameter Finding for Image Segmentation Algorithms Using Visual Response Surface Exploration."

# Principled exploration




Marks et al., “Design Galleries: A General Approach to Setting Parameters for Computer Graphics and Animation.”

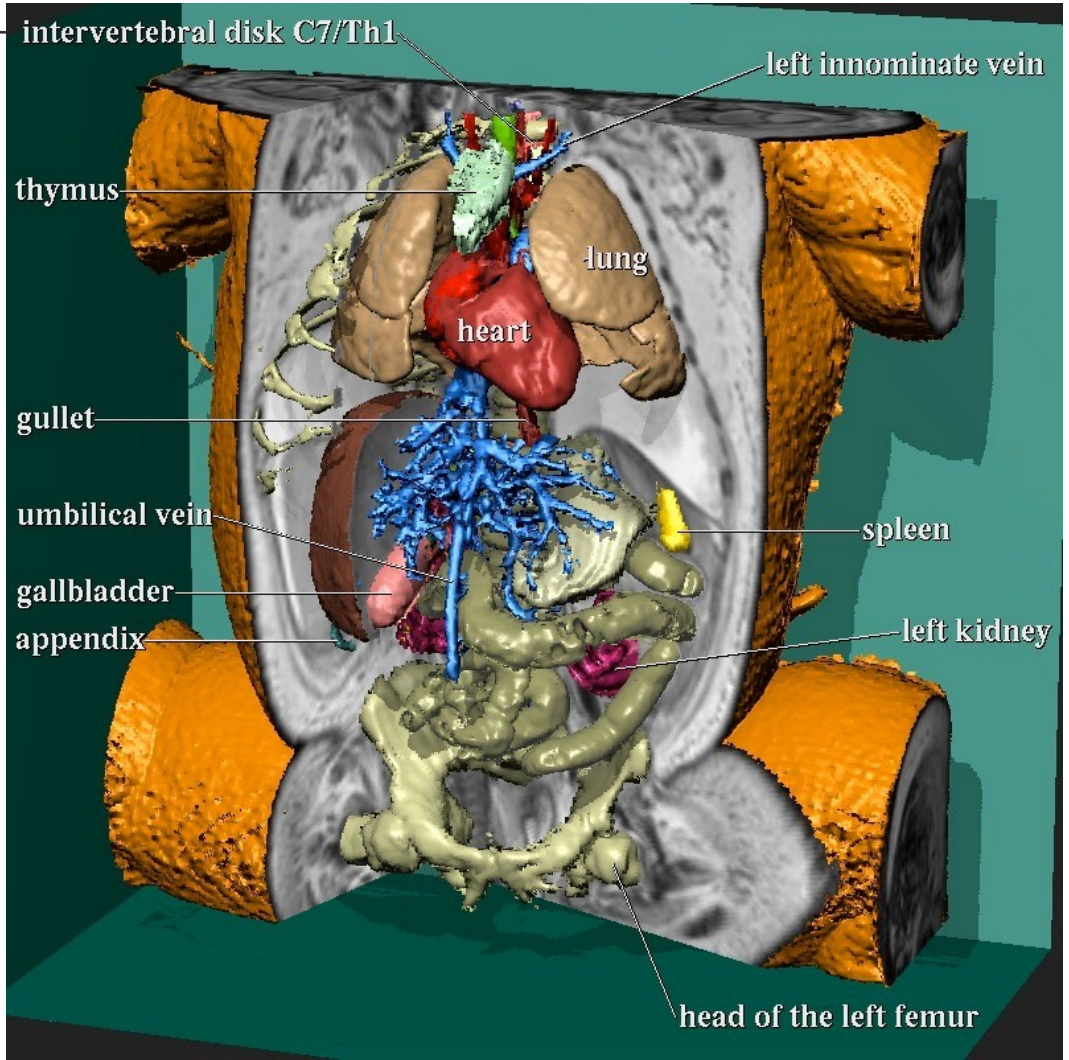
# Contour trees



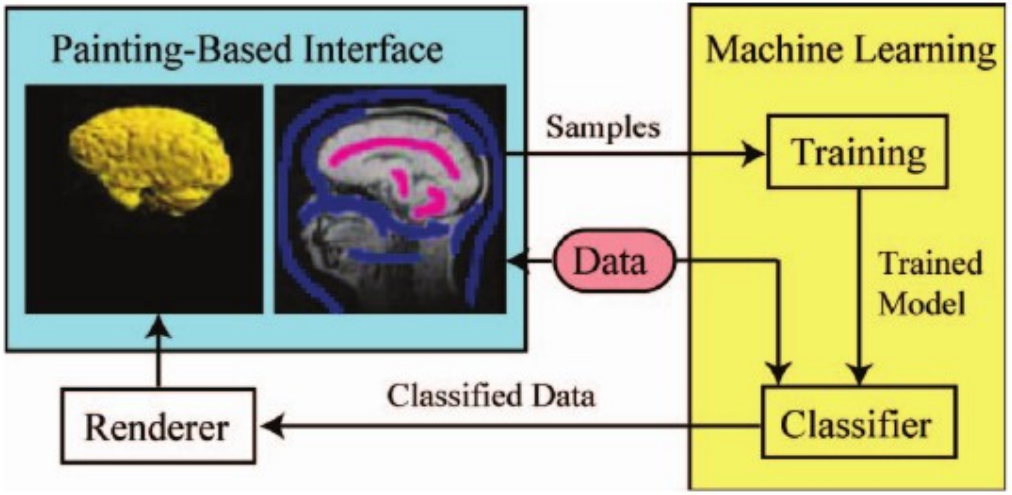

Hamish Carr at al., Flexible isosurfaces: Simplifying and displaying scalar topology using the contour tree, Computational Geometry, Volume 43, Issue 1, 2010,

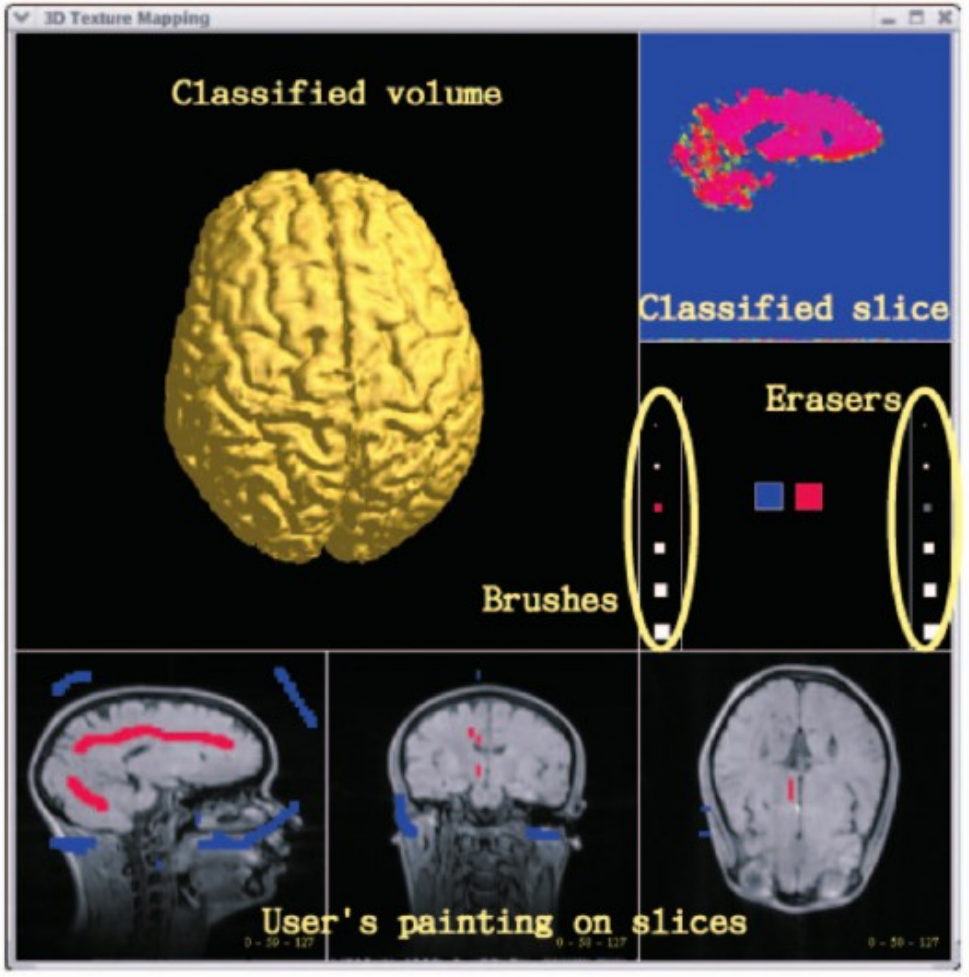
# Segmentation

- Different features with same value
- Label each voxel with a type
- Transfer function maps type to color/ alpha



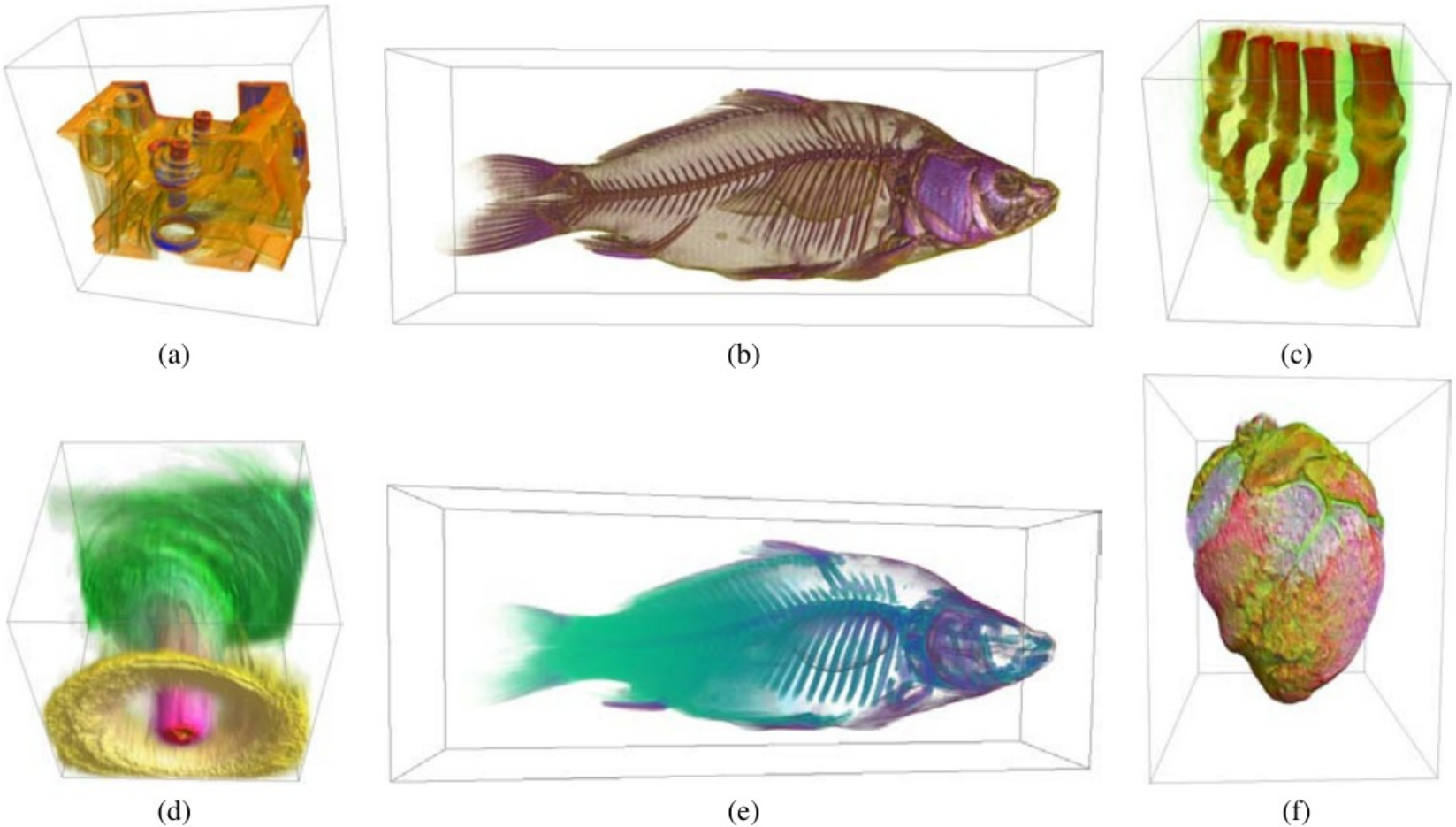
# Segmentation




Tzeng, Lum, and Ma, "An Intelligent System Approach to Higher-Dimensional Classification of Volume Data."

# Unsupervised segmentation




Pinto and Freitas, Design of Multi-Dimensional Transfer Functions Using Dimensional Reduction.

# Conclusion

# Summary

- Histograms give intuition about interesting values
- Gradient in data value to find transitions
- Transfer functions require exploration
- Segmentation is powerful but more investigation needed

# Further reading

Survey paper


- Ljung, Patric, Jens Krüger, Eduard Groller, Markus Hadwiger, Charles D. Hansen, and Anders Ynnerman. “State of the Art in Transfer Functions for Direct Volume Rendering.” Computer Graphics Forum 35, no. 3 (2016): 669–91. https://doi.org/10.1111/cgf.12934.
- Pinto, Francisco de Moura, and Carla M. D. S. Freitas. Design of Multi-Dimensional Transfer Functions Using Dimensional Reduction. The Eurographics Association, 2007. http://dx.doi.org/10.2312/VisSym/EuroVis07/131-138.
- Marks, Joe, Brad Andalman, Paul A. Beardsley, William Freeman, Sarah Gibson, Jessica Hodgins, Thomas Kang, et al. “Design Galleries: A General Approach to Setting Parameters for Computer Graphics and Animation.” In Proceedings of SIGGRAPH 97, 389–400. Annual Conference Series. ACM, 1997. https://doi.org/10.1145/258734.258887.
- Torsney-Weir, Thomas, Ahmed Saad, Torsten Möller, Britta Weber, Hans-Christian Hege, Jean-Marc Verbavatz, and Steven Bergner. “Tuner: Principled Parameter Finding for Image Segmentation Algorithms Using Visual Response Surface Exploration.” IEEE Transactions on Visualization and Computer Graphics 17, no. 12 (November 2011): 1892–1901.
- Carr, Hamish, Jack Snoeyink, and Michiel van de Panne. “Flexible Isosurfaces: Simplifying and Displaying Scalar Topology Using the Contour Tree.” Computational Geometry, Special Issue on the 14th Annual Fall Workshop, 43, no. 1 (January 1, 2010): 42–58. https://doi.org/10.1016/j.comgeo.2006.05.009.
- Tzeng, F.-Y., E.B. Lum, and K.-L. Ma. “An Intelligent System Approach to Higher-Dimensional Classification of Volume Data.” IEEE Transactions on Visualization and Computer Graphics 11, no. 3 (May 2005): 273–84. https://doi.org/10.1109/TVCG.2005.38.