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
  
  Space-based segmentation
Mapping by Density Classification, Transfer Functions

\[ TF: \rho(t) = f_{\rho}(d(t)), \quad k(t) = f_{k}(d(t)) \]

- 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

\[ R, G, B, \alpha = f(\text{density}) \]

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 manually selected samples (24 values)

- **Arrangement**
  - Embedding in 2D space, with distances kept
  - Thumbnail images
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)
Two- (multi-)dimensional TFs (3)

- A complex dataset: $|d'|$ vs. $d$ scatterplot
Transfer Functions (TF’s)

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

Human Tooth CT

Shading, Compositing…

Gordon Kindlmann
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 dataset: LH-Histogram

[Šereda 2006]
TF Design by LH-Histograms (3)
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)