Interactive volume rendering with transfer functions

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Papers presented

• Mastering transfer function specification by using VolumePro technology
  • Andreas H. König and Eduard Gröller
  • Proceedings of the 17th Spring Conference on Computer Graphics (SCCG'01), Budmerice, Slovakia, IEEE, April 2001, pp. 279-286

• Interactive volume rendering using multi-dimensional transfer functions and direct manipulation widgets
  • Joe Kniss, Gordon Kindlmann, and Charles Hansen
  • IEEE Visualization, pp. 255-262, 2001
Outline

• Transfer functions
• 1D transfer function and user interface
• Multidimensional transfer function and user interface
• Conclusion
Transfer function

• Mapping of
  – Voxel data values to
  – Optical properties (ex. color, opacity)
• During direct volume rendering, this is evaluated for each data value
• Essentially classifying data for visualization
• Good TF
  – Reveal the desired structures without obscuring
  – Specifying a good TF is challenging
Transfer function dimension

- Transfer function

\[ \tau : F_1 \times F_2 \times \ldots \times F_n \rightarrow O_1 \times O_2 \times \ldots \times O_m \]

**Scalar fields** → **Optical properties**

- \( F_1 = \) Data value
- \( \ldots \)
- \( F_n = ? \)
- \( O_1 = \) Opacity
- \( O_2 = \) Color
- \( \ldots \)
- \( O_m = ? \)
Transfer function dimension

- Transfer function

\[ \tau : F_1 \times F_2 \times \ldots \times F_n \rightarrow O_1 \times O_2 \times \ldots \times O_m \]

**Scalar fields**
- \( F_1 = \) Data value
- \( \ldots \)
- \( F_n = ? \)

**Optical properties**
- \( O_1 = \) Opacity
- \( O_2 = \) Color

\( n = \) TF dimension \( m = 2 \)

- Higher dimension TF
  - More selectivity
  - User effort to specify TF
Pt 1. 1D transfer function

- Transfer function

\[ \tau : F_1 \times F_2 \times \ldots \times F_n \rightarrow O_1 \times O_2 \times \ldots \times O_m \]

Scalar fields \rightarrow Optical properties

- \( F_1 = \text{Data value} \)
- \( O_1 = \text{Opacity} \)
- \( O_2 = \text{Color} \)
Pt 1. 1D transfer function

1. User selects different ranges of data value ('peaks') that will contribute to the final image
   Ex. ‘Bone’ and ‘tissue’
Pt 1. 1D transfer function

2. Specify color for each peak
Pt 1. 1D transfer function

3. Combine all peaks, and adjust opacity
Pt 1. 1D transfer function

- Real-time rendering of changes
- Thumbnails make it easy
Pt 2. Multidimensional TF

• Transfer function

\[ \tau : F_1 \times F_2 \times \ldots \times F_n \rightarrow O_1 \times O_2 \times \ldots \times O_m \]

**Scalar fields** → **Optical properties**

- \( F_1 = \) Data value
- \( F_2 = \) Gradient
- \( F_3 = 2^{\text{nd}} \) derivative in the gradient direction
- \( O_1 = \) Opacity
- \( O_2 = \) Color
Pt 2. Multidimensional TF

• Data value
Pt 2. Multidimensional TF

- Data value and gradient

[Image of Human Tooth CT]

[Graph showing multidimensional TF representation]

[Image of a 3D model of a tooth]
Pt 2. Multidimensional TF

- Data value and gradient
Pt 2. Multidimensional TF

- Data value, gradient, and 2\textsuperscript{nd} derivative
Pt 2. Multidimensional TF

- Data value, gradient, and 2\textsuperscript{nd} derivative
Pt 2. Multidimensional TF

• **Q**: How can we make this **NOT** hours of trial-and-error in 3 different domains to specify?
Pt 2. Multidimensional TF

- **Q:** How can we make this **NOT** hours of trial-and-error in 3 different domains to specify?
- **A:** Link the TF domain (data value, gradient, 2\textsuperscript{nd} derivatives) to more familiar spatial domain
Pt 2. Multidimensional TF

• **Q**: How can we make this **NOT** hours of trial-and-error in three different dimensions to specify?

• **A**: Link the TF domain (data value, gradient, 2\textsuperscript{nd} derivatives) to more familiar spatial domain

• Traditionally, interact in TF domain and observe change in spatial rendering domain

• Let the user interact in spatial domain too!: *Dual-domain interaction*
Pt 2. Multidimensional TF

1. User probe in spatial domain and query a position
2. The values at the position are graphically represented in TF domain
3. In TF domain, a small region of high opacity is added to the values at the position
4. Render in real time
5. User can also interact in TF domain to specify
6. If satisfied, user can add this region to the final TF
Pt 2. Multidimensional TF

1. Probe and query, explore in spatial domain
Pt 2. Multidimensional TF

2. Specify and refine in TF domain
Pt 2. Multidimensional TF

3. Changes are reflected in both domains
Pt 2. Multidimensional TF

Video!
Conclusion

• Multidimensional transfer function increases flexibility & selectivity in distinguishing different features in volume rendering
• Specifying transfer function is not simple – increased dimension => increased learning curve.
Pt 2. Multidimensional TF

Figures and videos from the author’s website

http://www.cs.utah.edu/~jmk/vis01/