Real-time Illustration of Vascular Structures

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Using NPR techniques to provide functional realism
Outline

- Motivation
- Reconstruction of Vascular Structures
- Enhancing Spatial Perception
- Study in Depth-Encoding
- Illustration Examples
- Summary
Motivation
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Reconstruction of Vascular Structures

1. Segmentation of vascular structures in images
2. Skeletonization and calculation of diameter
3. Graph analysis
4. Graph simplification (pruning, smoothing)
5. Visualization

[Hahn et al. 2001]
Visualization of Vascular Structures

- Representation of graph edges by means of truncated cones
- Branching edges connected by truncated cones too
- Using hemispheres to close edges at root and leaves
OR-Visualization of Vascular Structures

- Application of color and shading limited due to varying absorption and reflection characteristics on organ surfaces
- Black and white images provide best contrast and brightness when projected
Texture-Based Visualization

- Shape and spatial orientation
- Relative distances of depicted vascular segments to observer
- Distances between vascular structures
- Distances to other relevant anatomic structures
Distance of Vascular Structures to the Observer
Distance of Vascular Structures to the Observer

[Freudenberg 2004]
Distance-Encoded Surfaces
Communication of Shape
Communication of Shape
Generation of Hatching Strokes

[Diagram of a cylinder with hatching strokes]
Generation of Hatching Strokes
Generation of Hatching Strokes

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Generation of Hatching Strokes
Generation of Hatching Strokes

Combining z-buffer difference image with color-buffer image of same object textured by a fixed *procedural stripe-texture* yields a more „natural“ look.

- low frequency
- medium frequency
- high frequency
Generation of Hatching Strokes

[Freudenberg 2004]

low frequency  medium frequency  high frequency

Motivation  Reconstruction  Enhancing Spatial Perception  Study  Examples  Summary
Distance between Vascular Structures
Distance between Vascular Structures

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Distance between Vascular Structures

Explicit coding of spatial depth with *Distance-Encoded Shadows*
Study in Depth-Encoding

- 160 subjects
  - 83 male, 77 female (17 – 56 years old)
  - 38 physicians or medical students
- Web-based questionnaire
  - PHP + MySQL
Study in Depth-Encoding

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1 2 4 5 6
7 9 10 8
11
12a
12b
13 15
14
16 17
18 20
19

training
distance-encoded shadow
distance-encoded surface
stroke hatching
no hint
hint
3
??
?? ?? ?? ??
21
Questionnaire
Questionnaire
Questionnaire

Aufgabe 3 (von 21)

Bitte sortieren Sie die durch die roten Ziffern gekennzeichneten Teile des Gefäßbaumes nach ihrer Entfernung. Beginnen Sie mit der Stelle die am weitesten vorne liegt.

Tip: Je breiter die schwarzen Linien an einer Stelle, desto weiter liegt diese vorne.

Reihenfolge: 2 - 3 - 1
Relative distance to observer more accurately judged with explicit coding than with traditional shading
(Wilcoxon signed rank test; 1: p-value < 0.001; 2: p < 0.001)
Study: Shape Communication by Hatching Strokes

- Shape equally good perceived with hatching as with traditional shading
  (Wilcoxon signed rank test; 1: p = 0.99; 2: p = 0.57; slightly worse but not significantly!)
Study: Distance-Encoded Shadow

- Depth distance between vessels more accurately rated with displayed shadows than without (Wilcoxon signed rank test; 1: p < 0.001; 2: p < 0.001)
- Explanation beforehand had no significant impact
Projection on a Pig-Liver
Illustration of Vascular Structures
Illustration of Vascular Structures
Illustration of Vascular Structures
Summary

- Color-reduced coding of spatial information with texture well suited to operation room visualization
- Explicit coding of depth within the displayed vascular structures increases the reliability of depth judgments
- Hatching can communicate shape and topology equally well as Gouraud or Phong Shading
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