Combining Silhouettes, Surface and Volume Rendering for Surgery Education and Planning

Christian Tietjen, Tobias Isenberg, Bernhard Preim

Department of Simulation and Graphics
Otto-von-Guericke University of Magdeburg
Outline

• Motivation and Related Work
  – Surgery planning and education
  – Medical visualization

• Combination of the Rendering Methods
  – Combining silhouettes, surface and direct volume rendering (DVR)
  – Handling of special cases

• Evaluation

• Conclusion & Future Work
Motivation and Related Work

- Surgery planning and education
  - Surgery planning, radiation treatment planning, tumor ablation planning
  - Computer support (usually) based on image analysis

- Segmentation information available

- Visualization in Intervention Planning Systems
  - More and more visualization options and parameters are available and useful in some cases (direct volume rendering, isosurfaces, colors, opacity maps, silhouettes, …)
Motivation and Related Work

Traditional illustrations

- Expressive visualizations
- No interaction facilities

Motivation and Related Work

Conventional medical visualizations

- 3D-interaction is possible
- Context visualization hampers interpretation
  - Context structures cannot be discriminated or
  - Context is hiding the focus object
Motivation and Related Work

Computer generated line graphics with 3D-models

• Silhouettes, feature lines
  – Abstract visualization of the model
  – Support visual perception

• Hatching
  – Lighting information
  – Clarification of the objects shape
  – Surface structure of the object (like muscle fibres)
Motivation and Related Work

- Most recent publications only apply volume rendering
- No further stylisation of the generated lines possible (without the *shower door effect*)
- No object based approach of generating silhouettes

Goal: Combining object based silhouettes, surface shading and DVR

Combining silhouettes, surface shading and DVR

- **Conventional rendering (surface shading)**

- **Illustrative rendering (silhouettes)**
  - Inspired by traditional medical illustrations
  - Object based approach for line stylisation (requires two rendering steps)

- **Volume rendering**
  - Problematic because of semi-transparent voxels
  - Masking the volume data

- **Combination using a scene graph architecture**
Combination of the Rendering Methods

- Advantages
  - Improved context visualization
  - More comprehensible renditions
- Classification in focus object, near focus object and context (FO, NFO, CO)
Combination of the Rendering Methods
Combination of the Rendering Methods

Silhouette rendering

1. z-buffer rendering
2. Generation of the silhouettes
3. Hidden line removal (HLR)
4. Rendering of the silhouettes
Combination of silhouette and surface rendering

1. Surface rendering
2. Silhouette rendering

Wrong order
Correct order
Combination of the Rendering Methods

Volume rendering

1. Rendering of the polygonal objects
2. Rendering of the Volume dataset

Avoid unwanted occlusions by masking
Combination of all three rendering styles

1. z-buffer rendering
2. Generation of the silhouettes (including HLR)
3. Clear the z-buffer
4. Rendering line- and surface shaded objects
5. Volume rendering
Combination of the Rendering Methods

Removing self-occluding lines

- Method described so far explicitly removes all hidden lines
- Individual HLR solves this problem:
  1. Rendering the z-buffer of the first object
  2. Line generation and HLR
  3. Clearing the z-buffer
  4. Return to step 1 for the second object
Combination of the Rendering Methods

Visualization examples
Smoothing

- Stair artefacts on isosurfaces
- Produces unwanted “feature” lines
- Interpolate intermediate slices or smooth surface afterwards
Is the application of illustrative techniques suitable for medical visualization?

- Informal user study (8 surgeons)
- Context visualization
- Simplifying complex visualizations

- Analysis by decision tree
  - Reference image was compared with all other images
  - Number of votes was counted
### Evaluation

**Auf dieser Seite geht es um die direkte Gegenüberstellung der beiden Visualisierungstechniken.**

<table>
<thead>
<tr>
<th>Frage</th>
<th>links</th>
<th>rechts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welches Bild gefällt Ihnen auf den ersten Blick besser?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wie gut ist die Leber von den umgebenden Strukturen zu unterscheiden?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(gar nicht (--)) bis sehr gut (++))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Können Sie die Lage der Leber zum Brustkorb einschätzen?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(nein, überhaupt nicht (--)) bis ja, sehr gut (++))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wie gut sind die extrahepatischen Strukturen untereinander differenzierbar?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(gar nicht (--)) bis sehr gut (++))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mit welchem Bild würden Sie sich auf eine Tumorresektion vorbereiten wollen?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

Combining Silhouettes, Surface and Volume Rendering 19/23
Evaluation

Interpretation

• In general less context information is preferred
• Basic information about all objects is necessary
• s/w-silhouettes are not sufficient for displaying context
• Emphasize affected vascular territories using silhouettes regarded as appropriate by six of eight surgeons
Conclusion

- Realization of a rendering method to generate enhanced visualizations by combining
  - Surface shading,
  - Silhouette rendering and
  - Volume rendering
- Decoupled stroke extraction and stroke rendering
- Removing self-occluding lines

- Evaluation by surgeons
  - Application of illustrative techniques was assessed as helpful
  - Illustrative techniques cannot replace but enhance conventional rendering techniques
Future Work

• Integration of further illustration techniques
  – Hatching
  – Stippling

• Reducing the interaction effort
  – Determine adequate default settings for parameters
  – Most parameters can be automated

• Smoothing
  – Adequate solutions for different structures and segmentation algorithms

• Resolving problems due to transparency
Thank you for your Attention!

Christian Tietjen
tietjen@isg.cs.uni-magdeburg.de

Department of Simulation and Graphics
Faculty of Computer Science, University of Magdeburg, Germany
Visualization Group
http://wwwisg.cs.uni-magdeburg.de/cv/

ENT Department
University Hospital of Leipzig, Germany
Innovation center for computer assisted surgery
http://www.iccas.de

This work was carried out in the framework of a project supported by the Deutsche Forschungsgemeinschaft (DFG)
(Priority Programme 1124, PR 660/3-1).