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

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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**

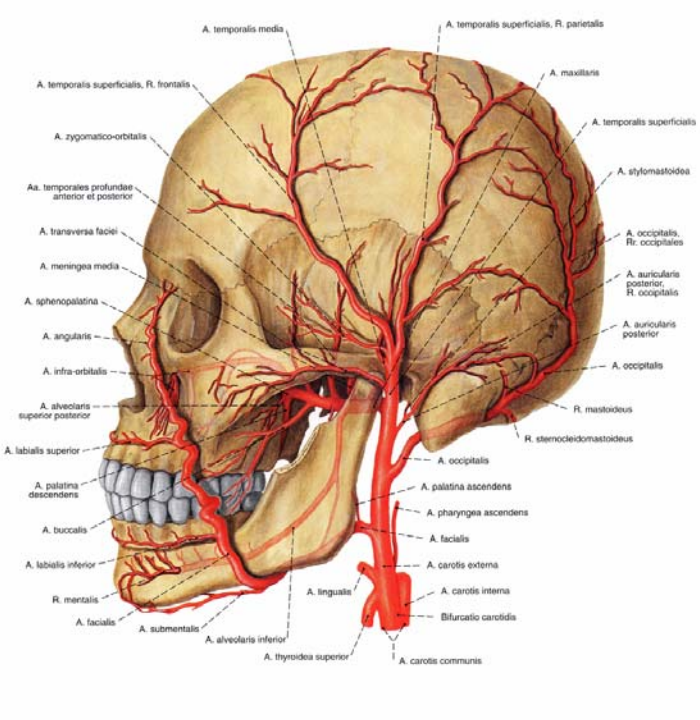
Motivation and Related Work

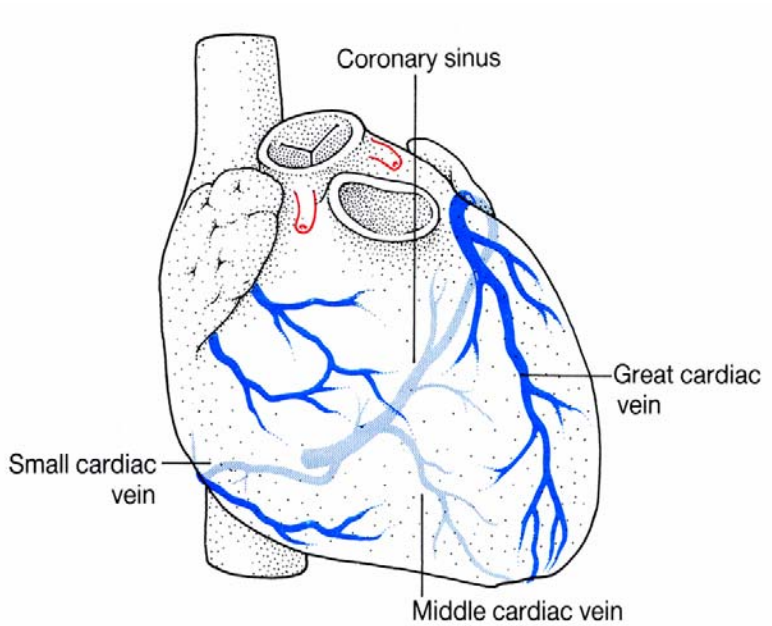
- **Surgery planning and education**
  - **Surgery planning, radiation treatment planning, tumor ablation planning**
  - **Computer support (usually) based on image analysis**
- **Segmentation information available**
- **Visualization in Intervention Planning Systems**
  - **More and more visualization 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**



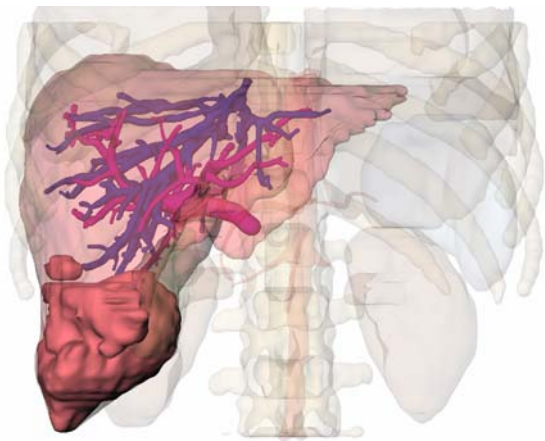


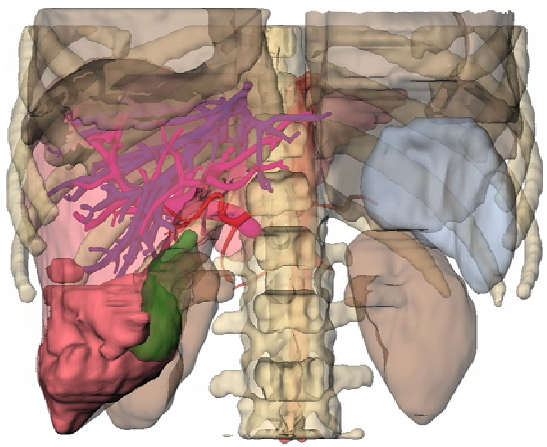
Putz and Pabst (1993) | Rogers (1992)

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**

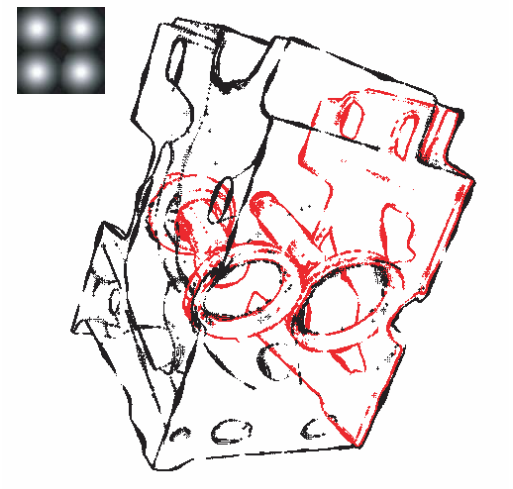
- **Hatching**
  - **Lighting information**
  - **Clarification of the objects shape**
  - **Surface structure of the object (like muscle fibres)**

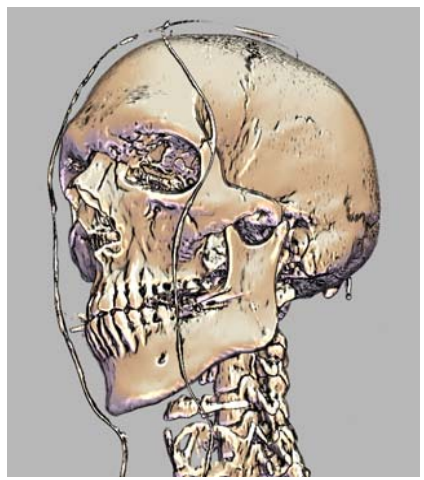
Isenberg et al. (2002) | Praun et al. (2001)

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





Yuan and Chen (2004) | Viola et al. (2004) | Kindlmann et al. (2003)

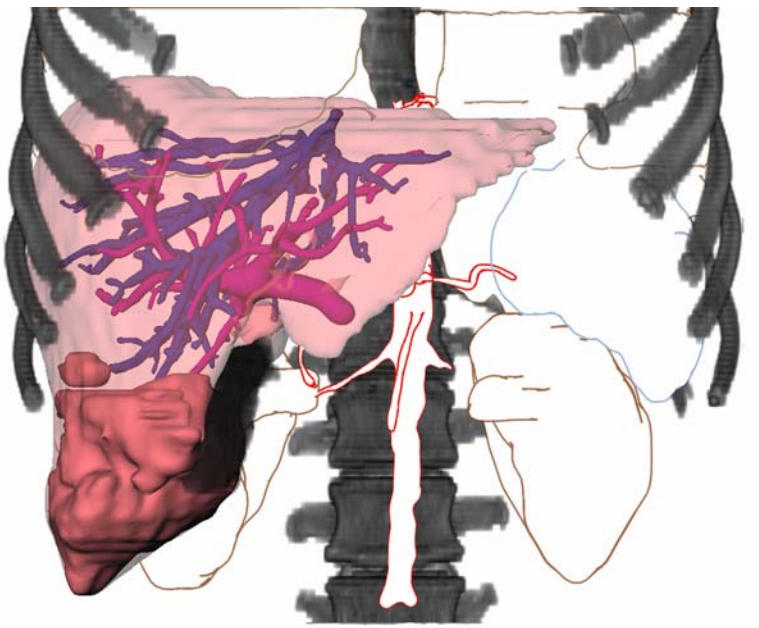
Combination of the Rendering Methods

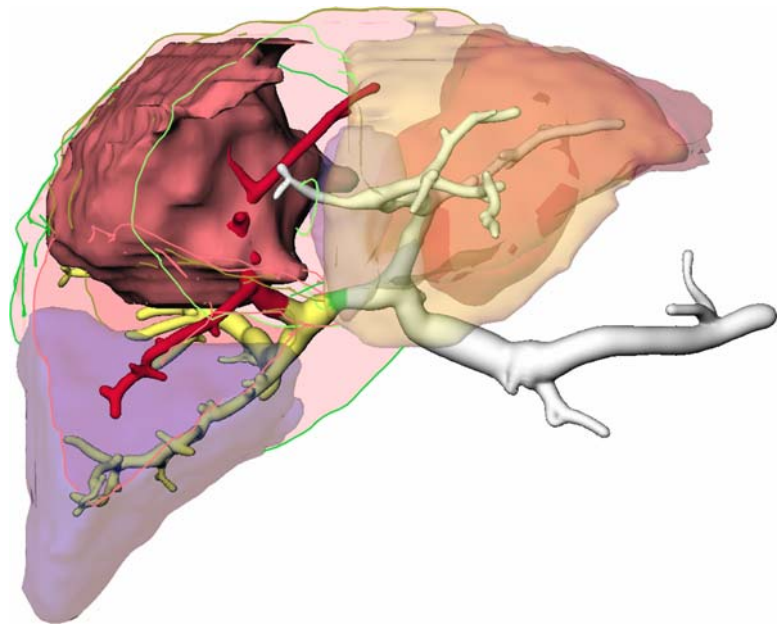
Combining silhouettes, surface shading and DVR

- **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**

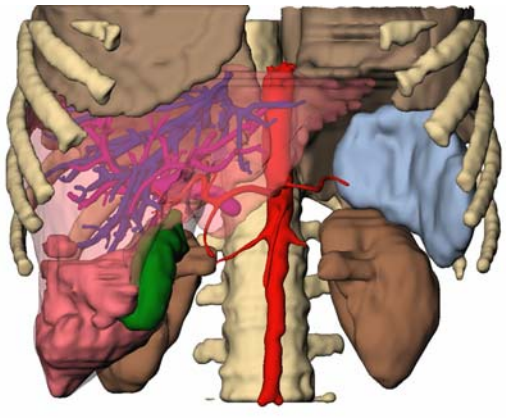
Combination of the Rendering Methods

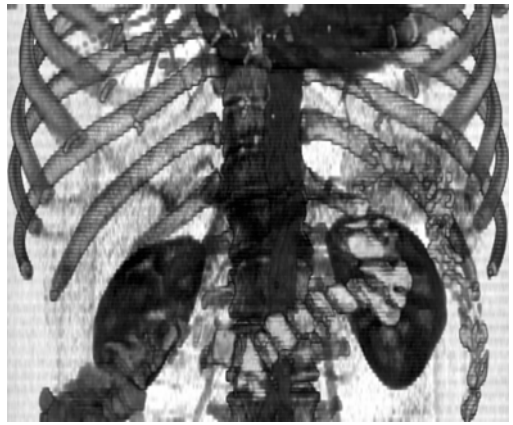
- **Advantages**
  - **Improved context visualization**
  - **More comprehensible renditions**
- **Classification in focus object, near focus object and context (FO, NFO, CO)**

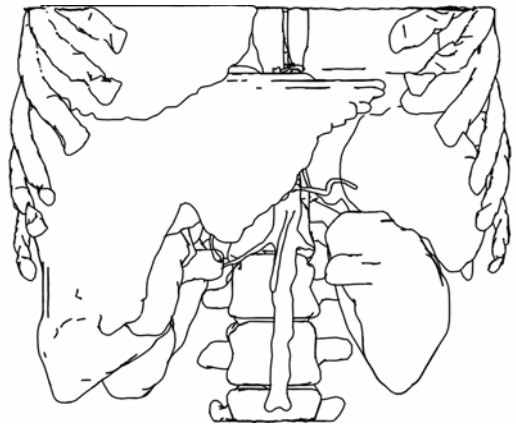


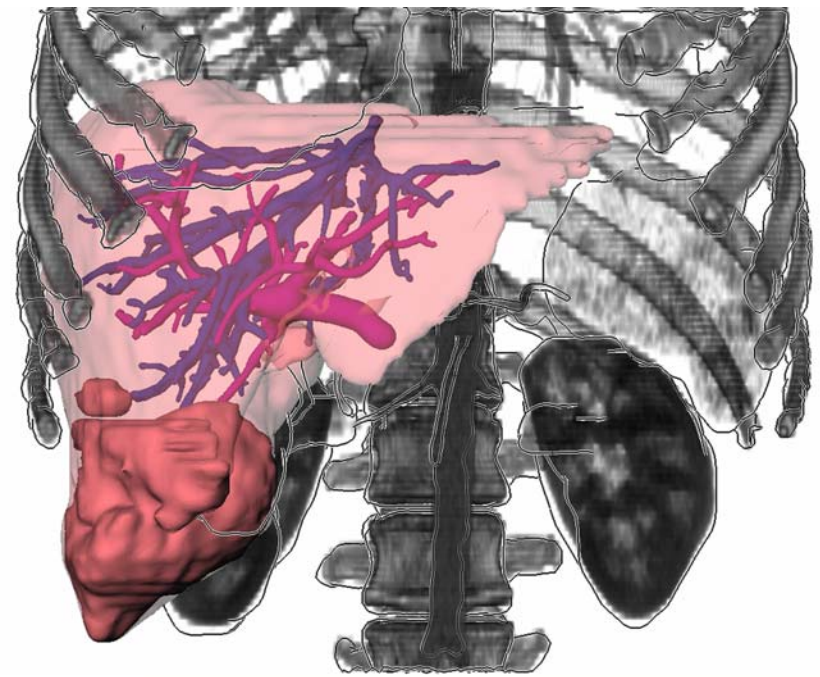


Combination of the Rendering Methods





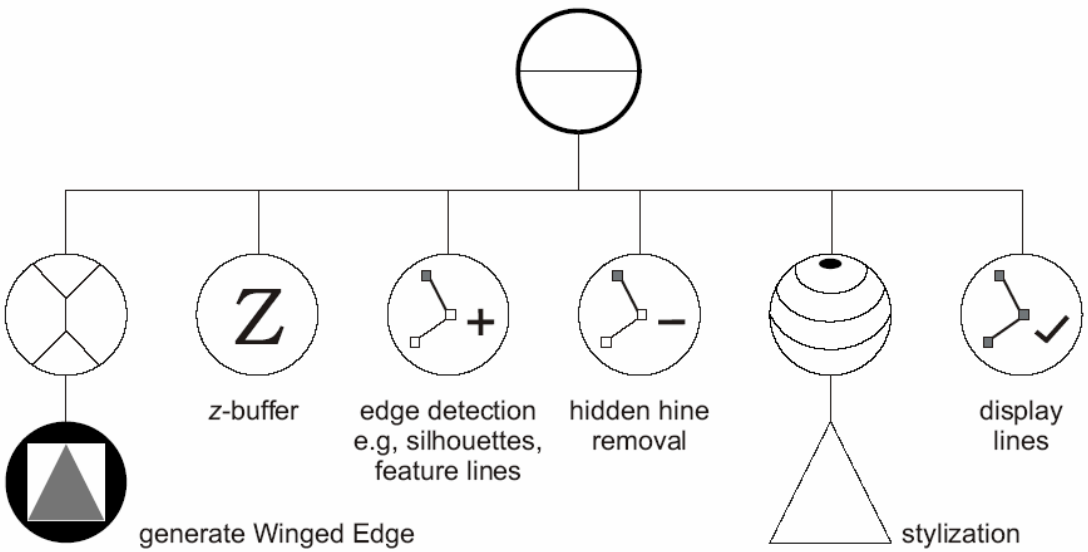


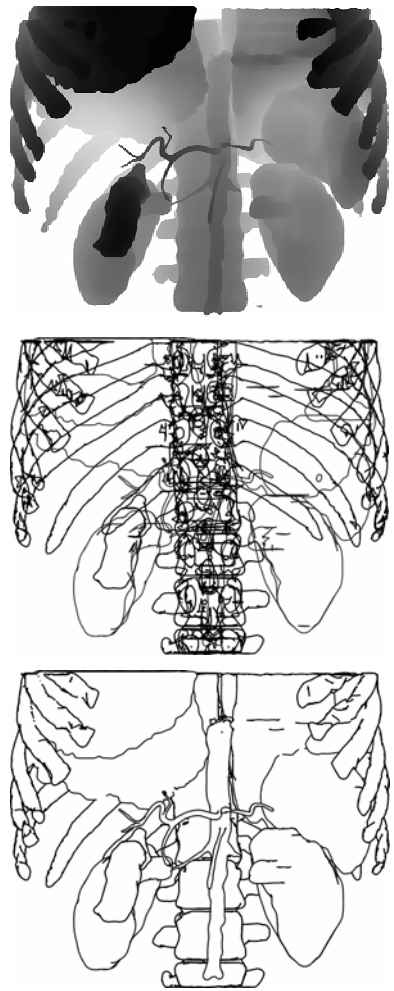


Combination of the Rendering Methods

Silhouette rendering

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

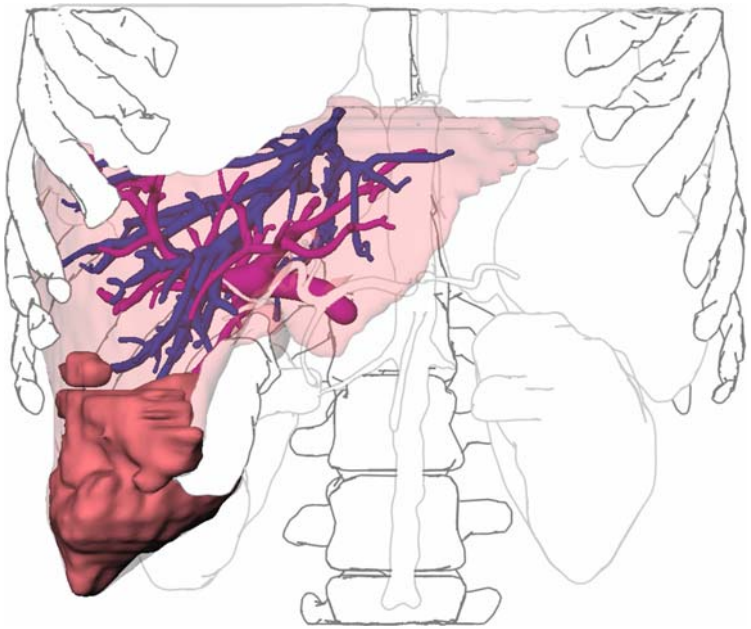




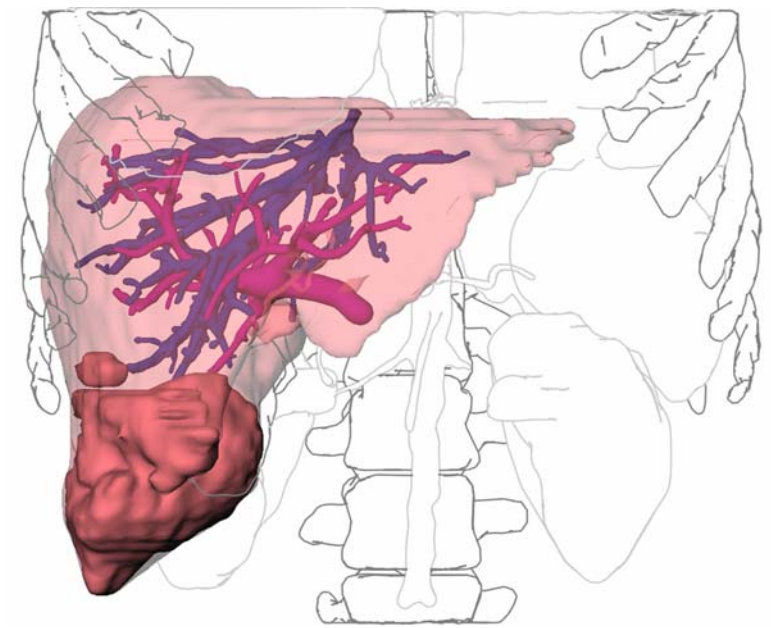
Combination of the Rendering Methods

Combination of silhouette and surface rendering

1. **Surface rendering**
2. **Silhouette rendering**



Wrong order

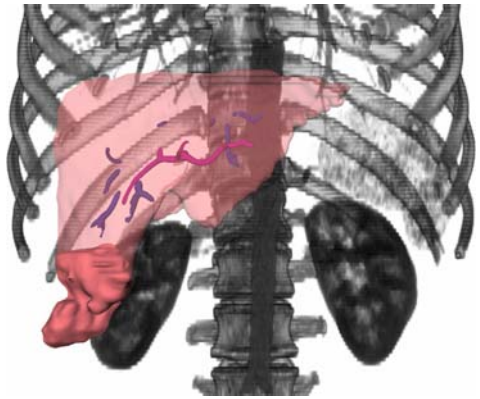


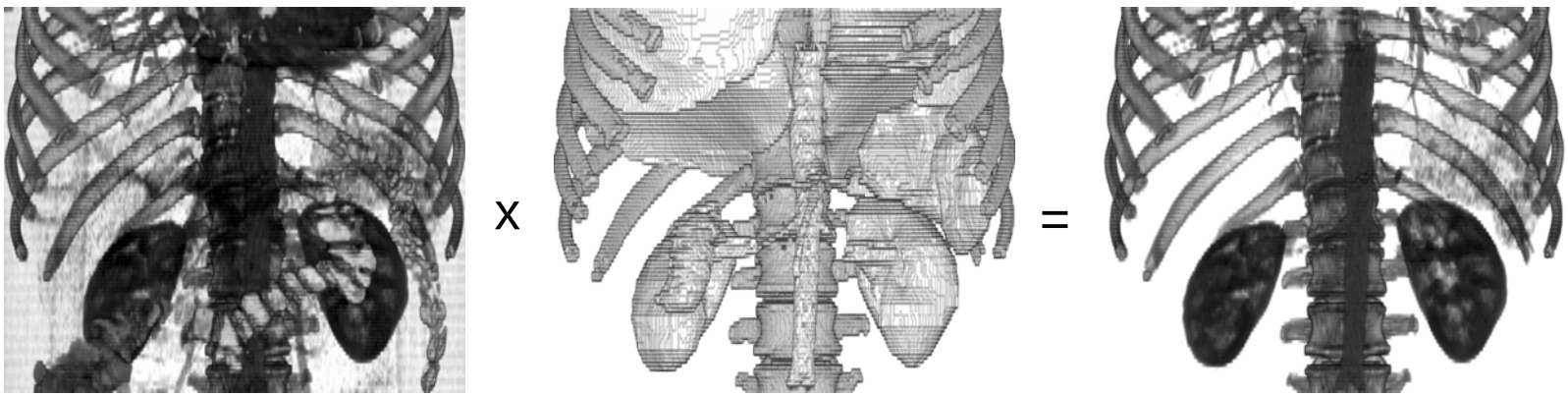
Correct order

Combination of the Rendering Methods

Volume rendering

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



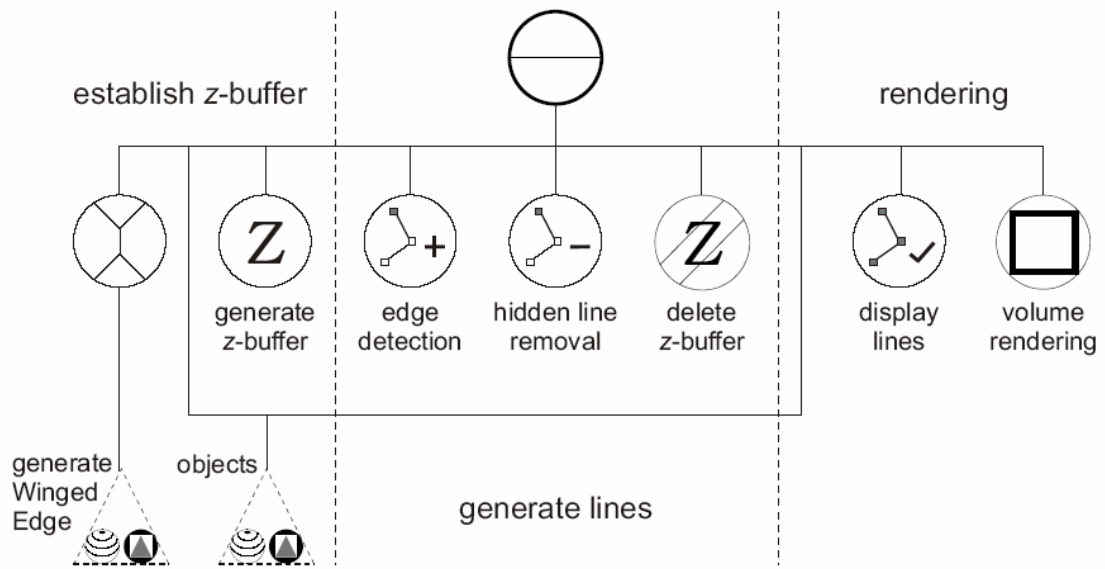


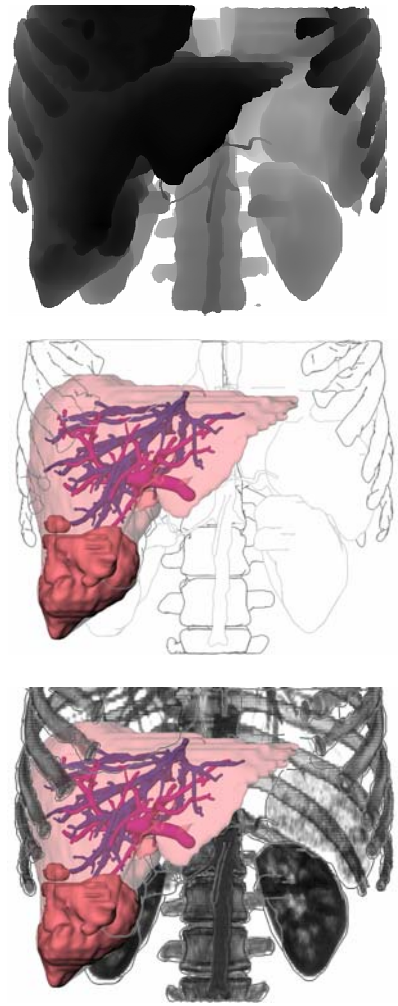
Avoid unwanted occlusions by masking

Combination of the Rendering Methods

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**

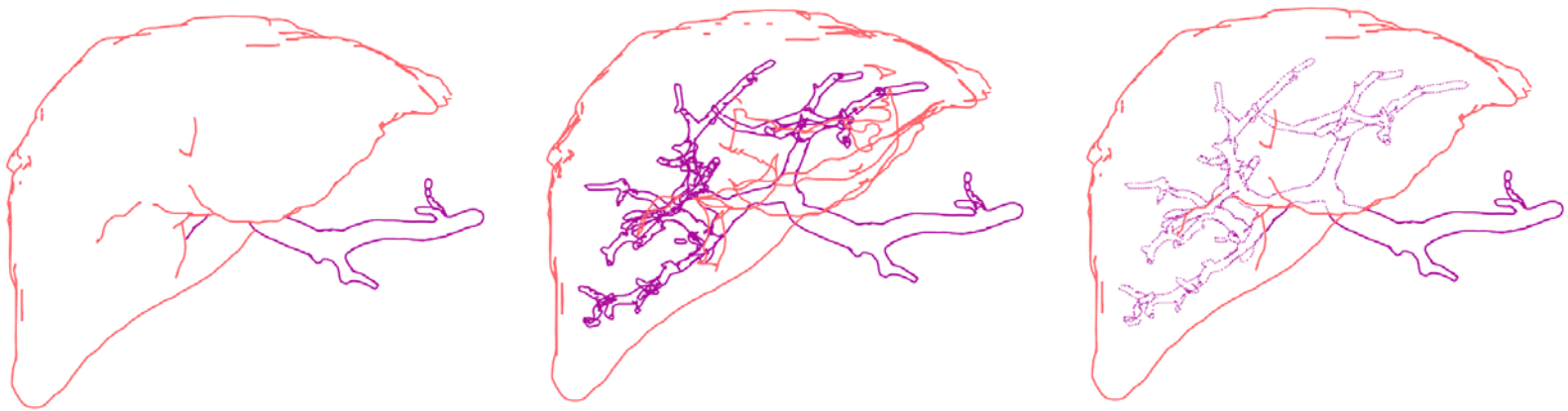




Combination of the Rendering Methods

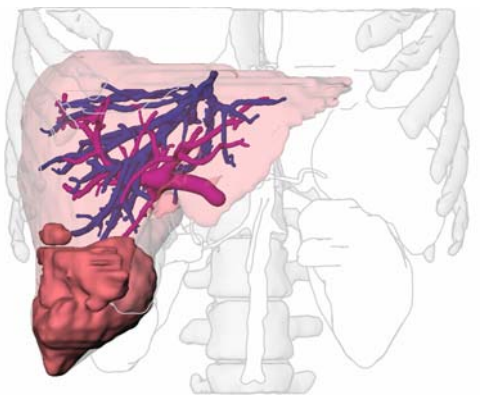
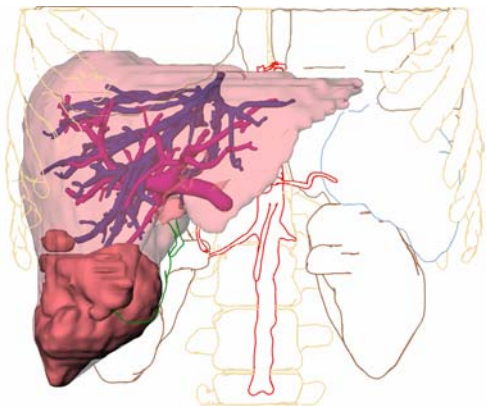
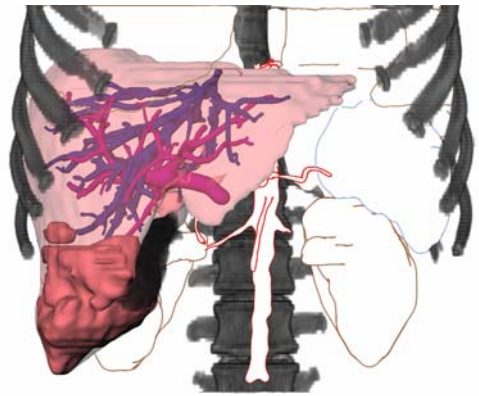
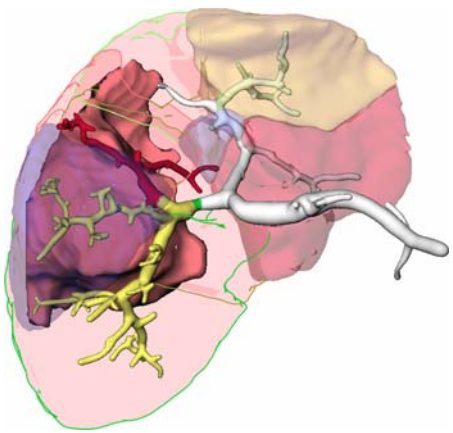
Removing self-occluding lines

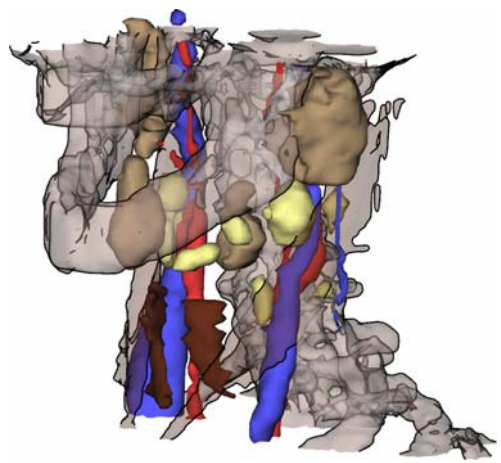
- **Method described so far explicitly removes all hidden lines**
- **Individual HLR solves this problem:**
  1. **Rendering the z-buffer of the first object**
  2. **Line generation and HLR**
  3. **Clearing the z-buffer**
  4. **Return to step 1 for the second object**



Combination of the Rendering Methods

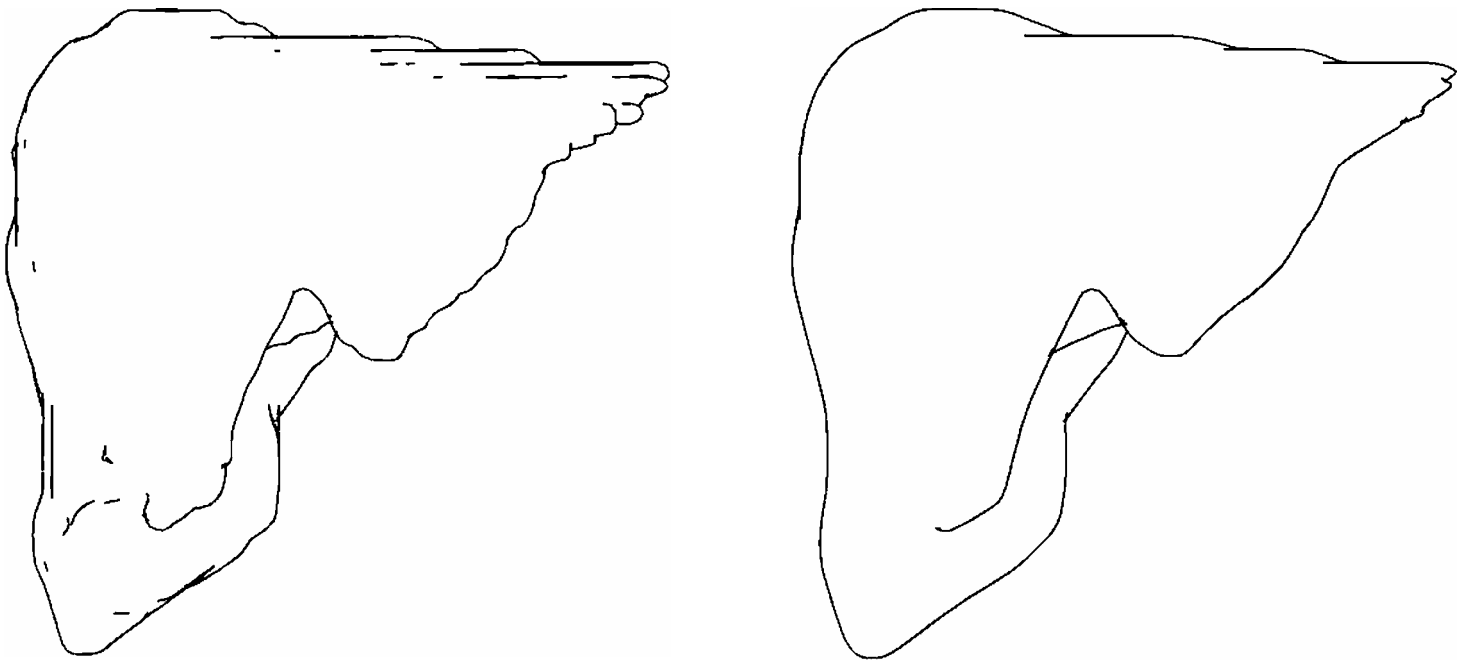
Visualization examples



Smoothing

- Stair artefacts on isosurfaces
- Produces unwanted “feature” lines
- Interpolate intermediate slices or smooth surface afterwards

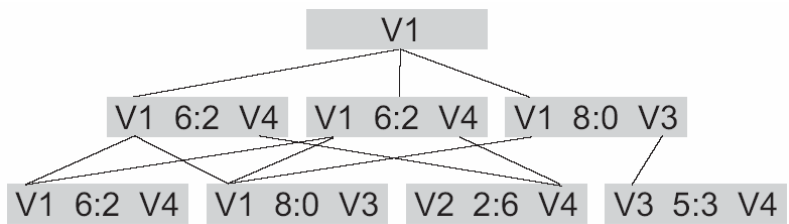


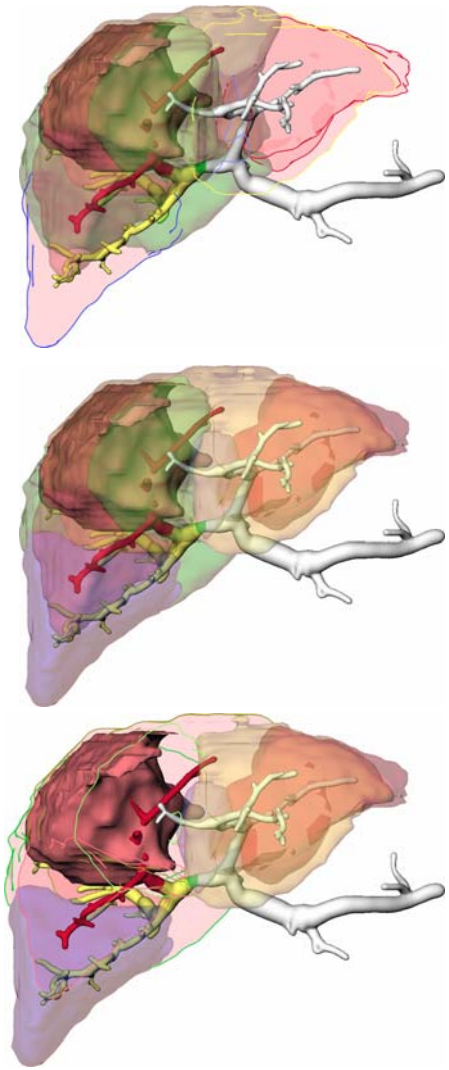
Evaluation

Is the application of illustrative techniques suitable for medical visualization?

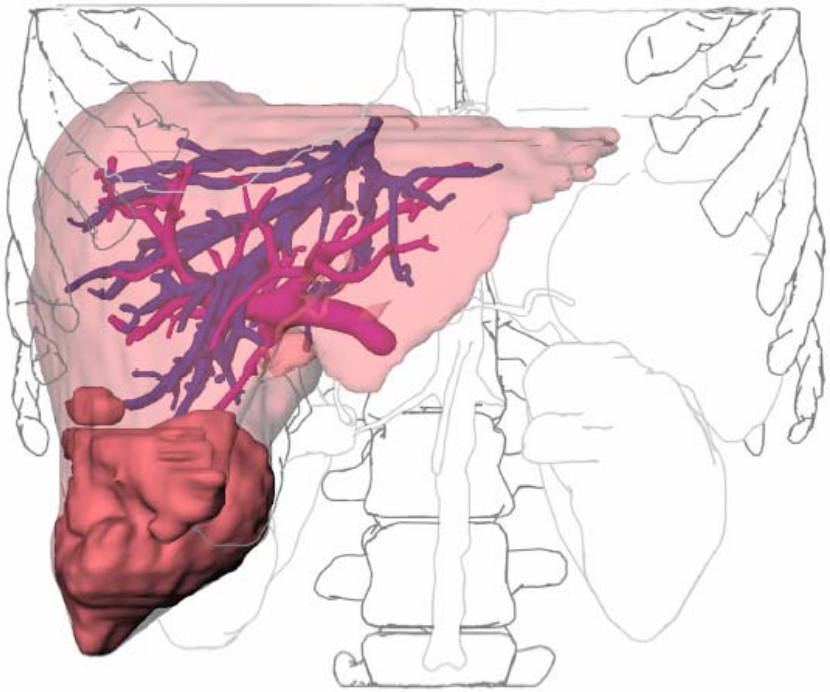
- **Informal user study (8 surgeons)**
- **Context visualization**
- **Simplifying complex visualizations**

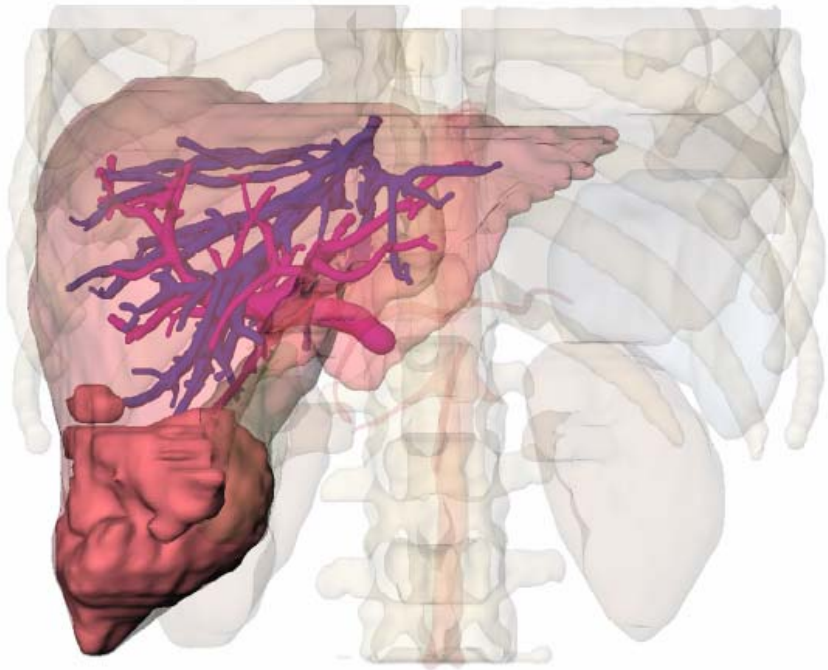
- **Analysis by decision tree**
  - **Reference image was compared with all other images**
  - **Number of votes was counted**





Evaluation



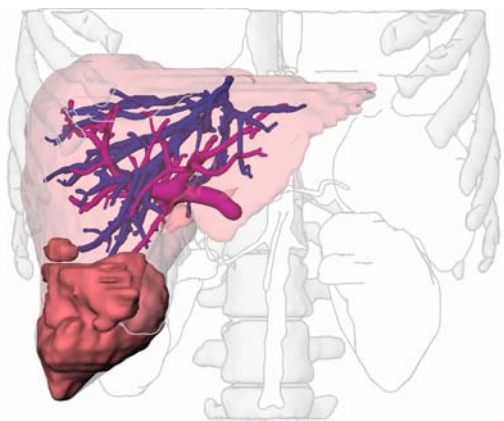


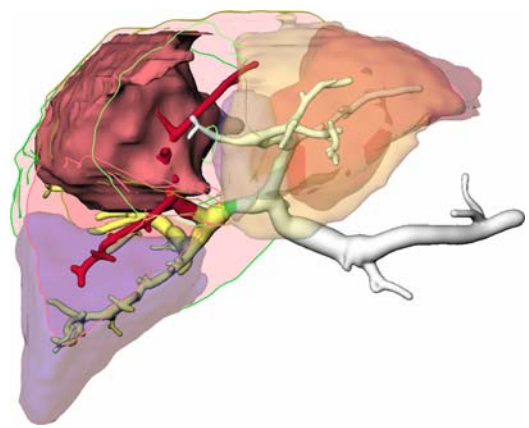
Welches Bild gefällt Ihnen auf den ersten Blick besser?	☐ links	☐ rechts
Auf dieser Seite geht es um die direkte Gegenüberstellung der beiden Visualisierungstechniken.	-- ++	-- ++
Wie gut ist die Leber von den umgebenden Strukturen zu unterscheiden? (gar nicht (--) bis sehr gut (++))	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Können Sie die Lage der Leber zum Brustkorb einschätzen? (nein, überhaupt nicht (--) bis ja, sehr gut (++))	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Wie gut sind die extrahepatischen Strukturen untereinander differenzierbar? (gar nicht (--) bis sehr gut (++))	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Mit welchem Bild würden sie sich auf eine Tumorresektion vorbereiten wollen?	☐	☐

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!

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