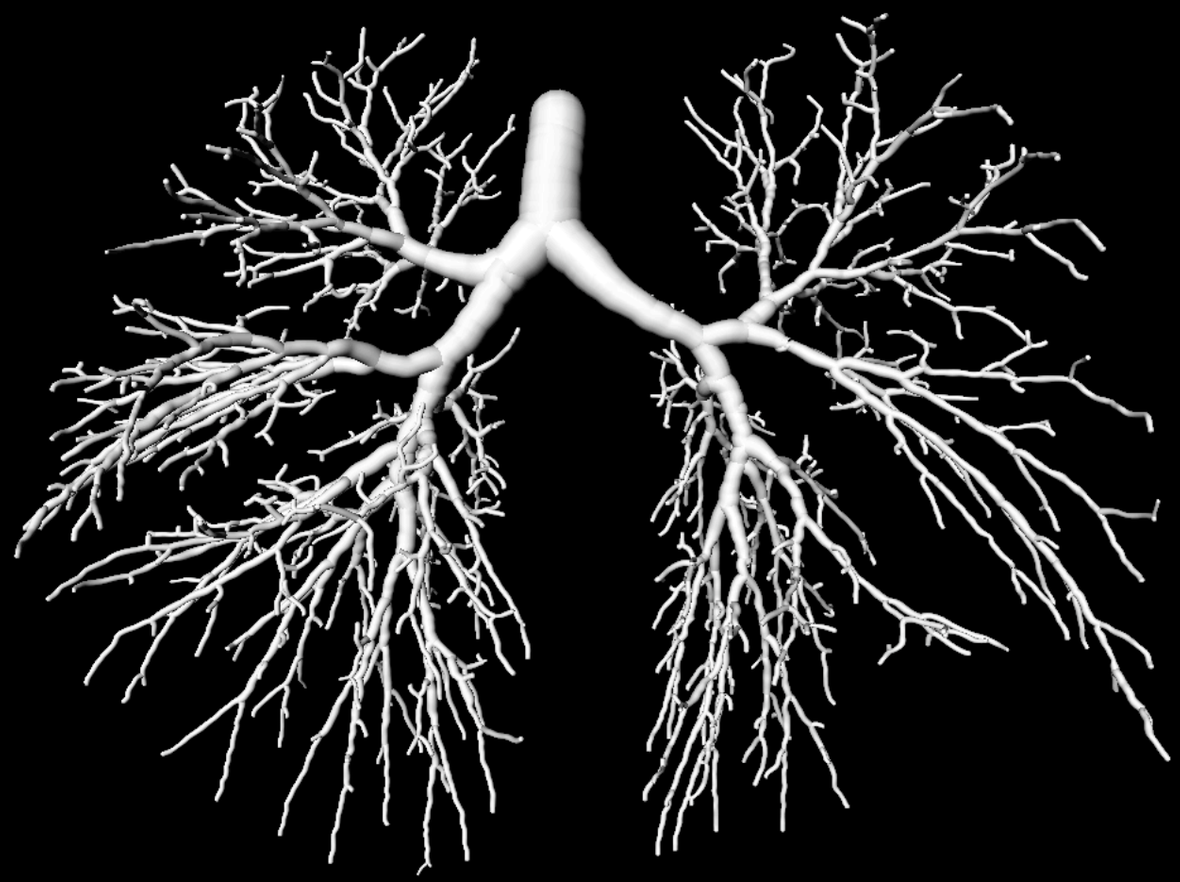


felix ritter

MeVis
RESEARCH

Outline

- Reconstruction of Vascular Structures
- Model-based Surface Visualization
- Model-free Surface Visualization
- Illustrative Visualization of Vascular Structures
- Volume Rendering of Vascular Structures

»Traditional« Visualization Approaches

a – Slice-based Examination

b – Maximum Intensity Projection,
Closest Vessel Projection [Zuiderveld, 1995]

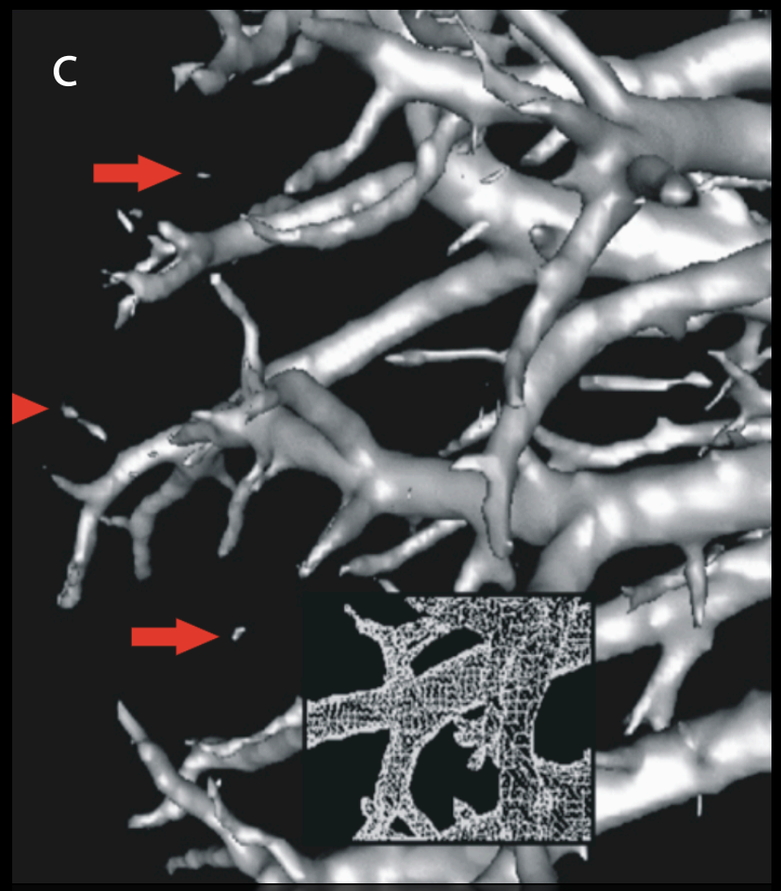
c – Isosurface Rendering

d – Curved Planar Reformation
[Kanitsar, 2001]

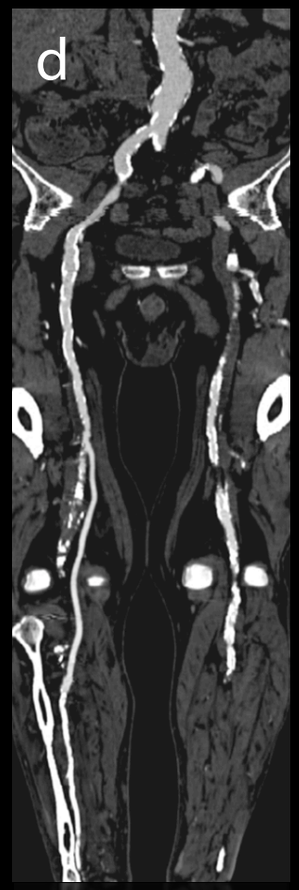
a

b

c

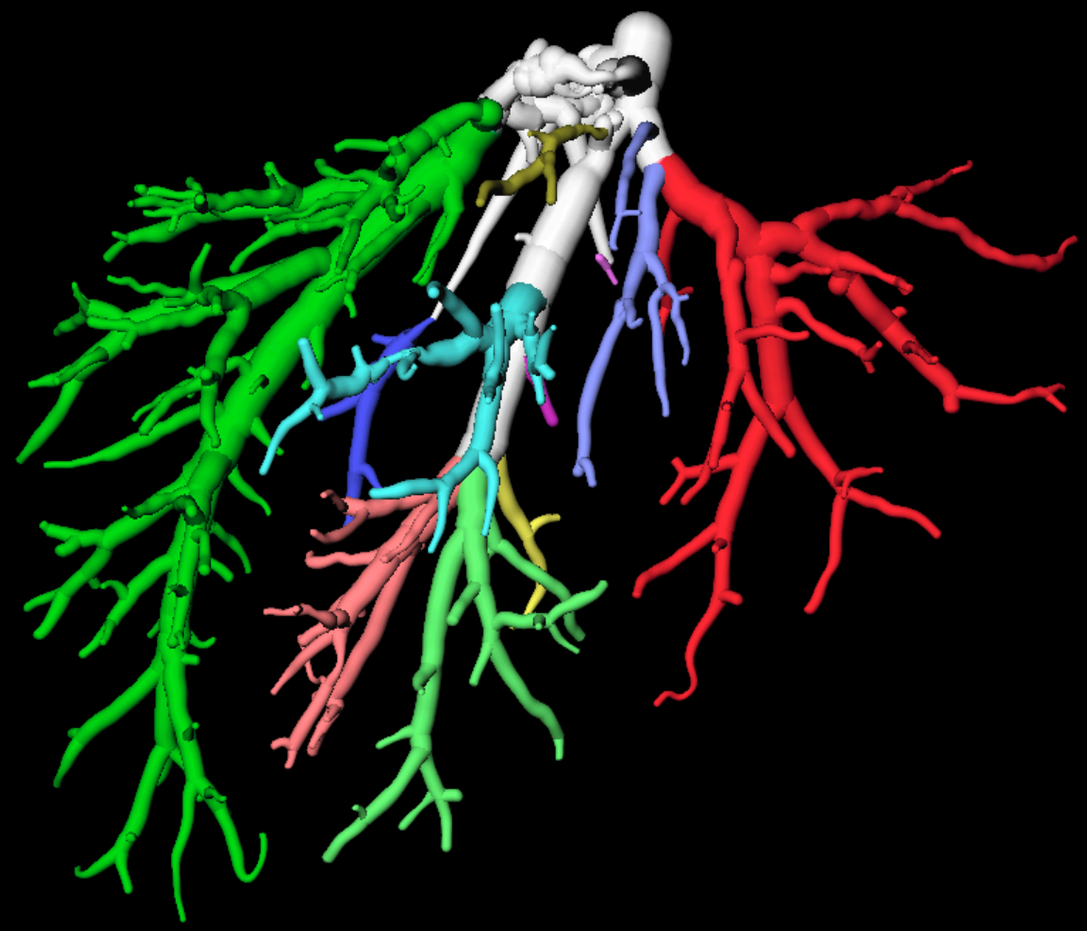


d



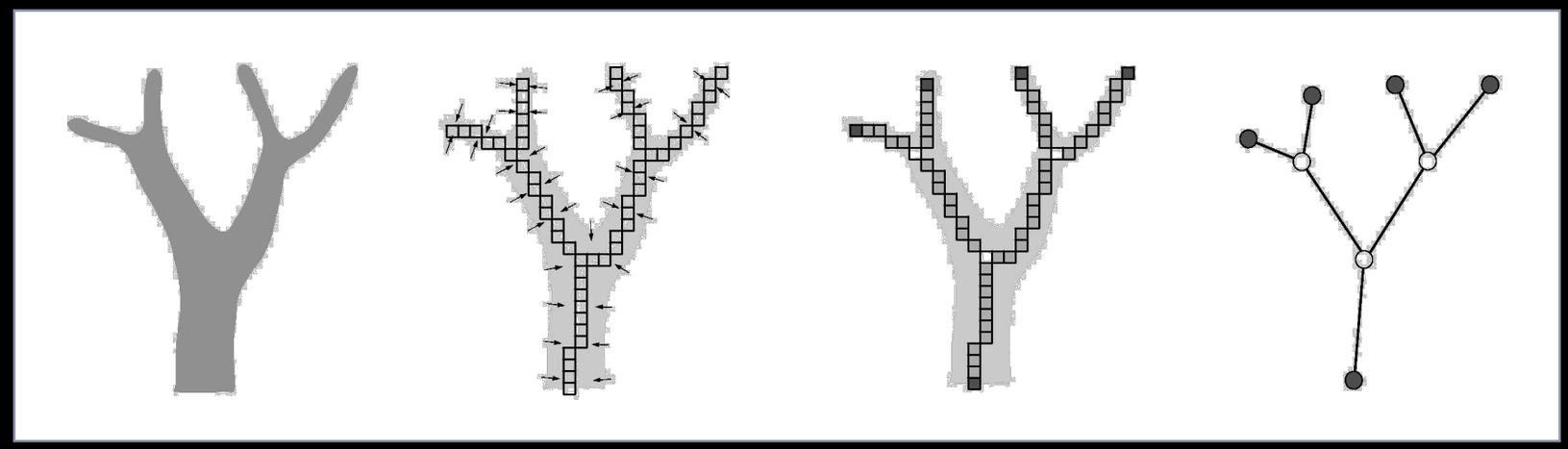
Challenges

- Smooth, organic looking vessel shape
- Clear communication of topology and morphology
- Correct depiction of curvature, depth relations and diminution towards the periphery
- Conveyance of spatial relations to other structures



Model-based Reconstruction of Vasculature

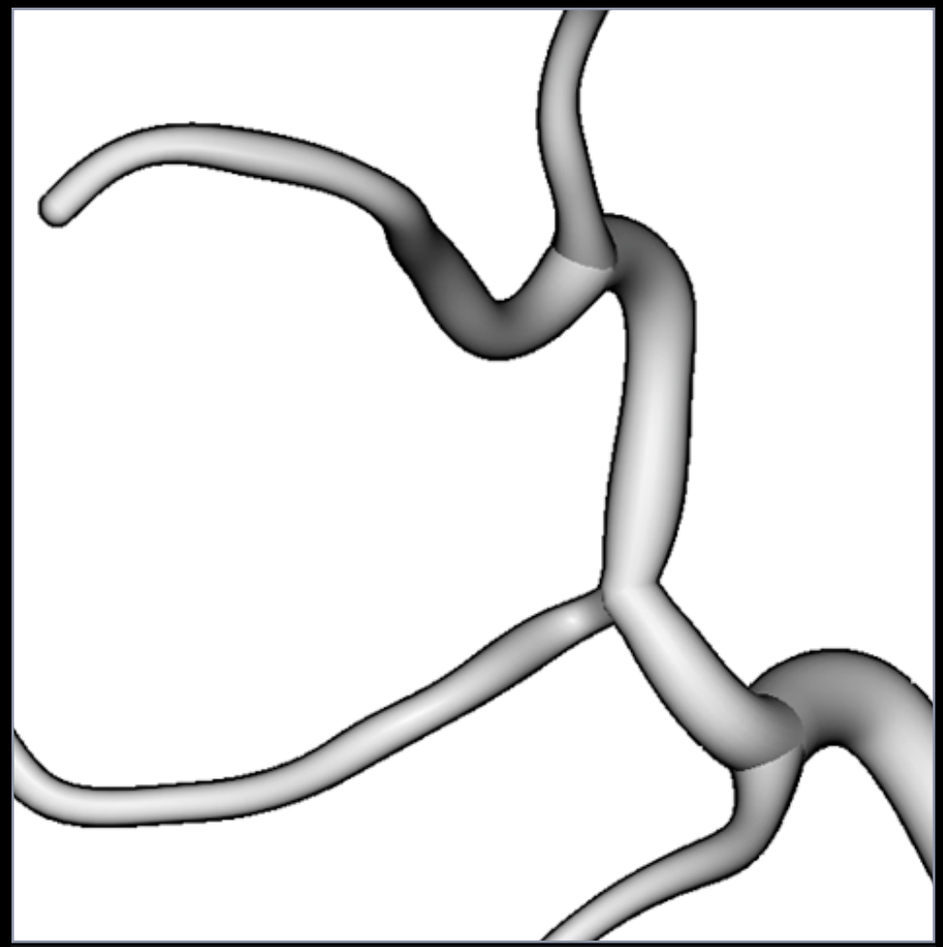
1. Segmentation of vascular structures in images
2. Skeletonization and calculation of diameter
3. Graph analysis
4. Graph simplification (pruning, smoothing)
5. Visualization



[Selle et al. 2000]

Model-based Visualization: Truncated Cones

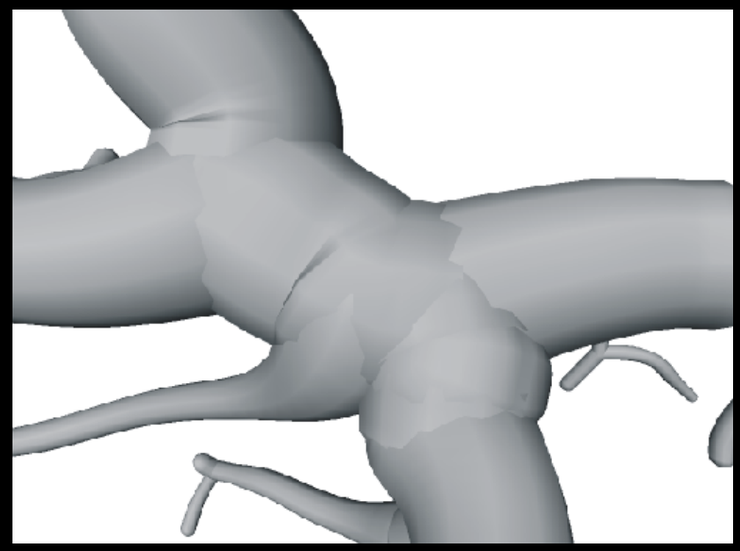
- Representation of graph edges by means of truncated cones
- Branching edges connected by truncated cones too
- Using hemispheres to close edges at root and leaves

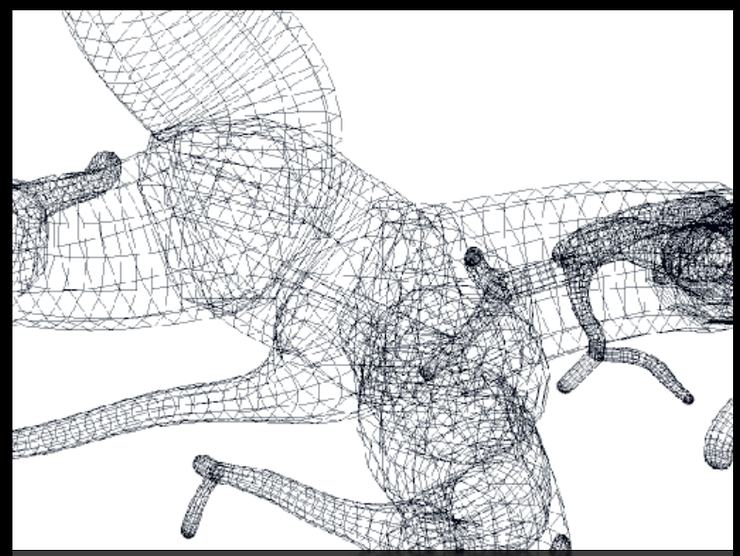


[Hahn et al. 2001]

Truncated Cones: Cons & Pros

- Discontinuities at branchings become obvious at close-up views
- Inner polygons arise and therefore not suitable for virtual angioscopy
- *But:* Very fast method which has been in routine use since 2004 (used for planning ~ 3000 interventions)





[Hahn et al. 2001]

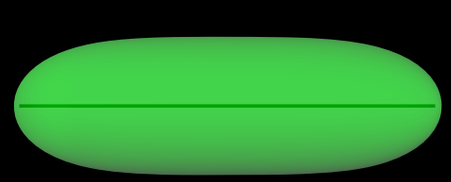
Model-based Visualization: Convolution Surfaces

Convolution Surfaces (Bloomenthal and Shoemake [1991])

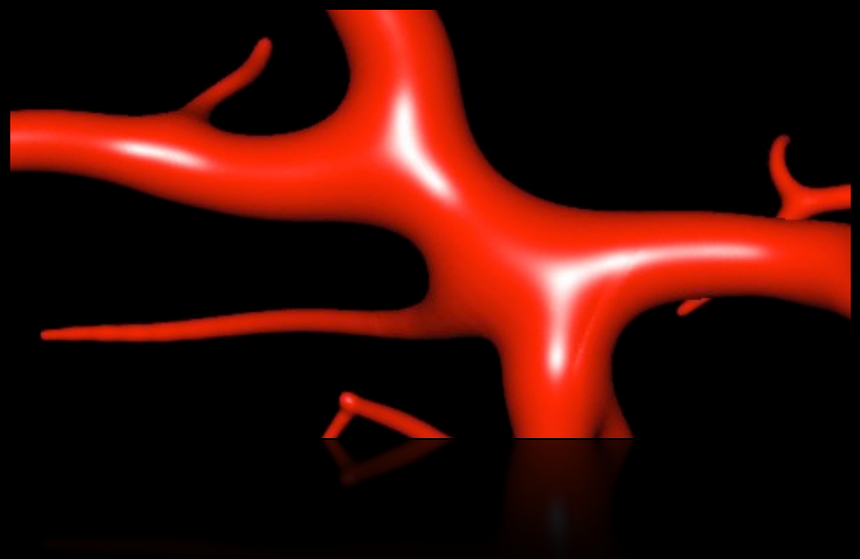
- Convolution of a signal with a filter

  Here: Convolution of line segments with a 3d-lowpass filter

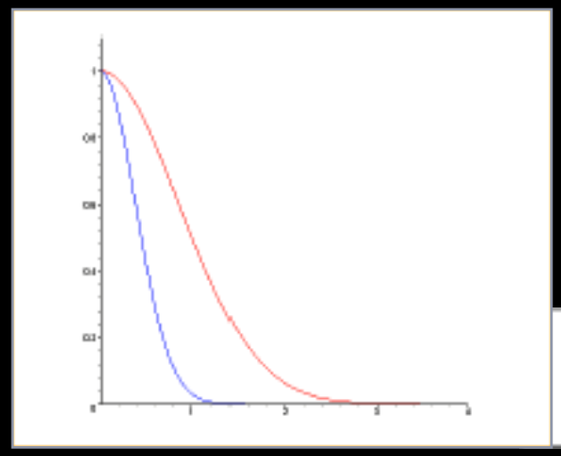
$$F(p) = \int_S h(s-p)ds = (h \otimes S)(p)$$



- Polygonization with isovalue depending on the filter



Convolution Surfaces: Filter Function



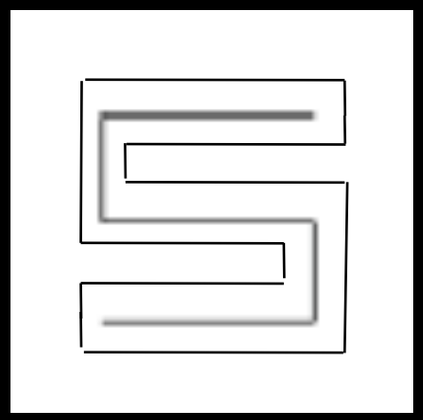
$$h(p) = e^{-d^2\omega},\ \omega = 5\ln 2,\ d > 0$$

normal Gaussian filter

narrow Gaussian filter

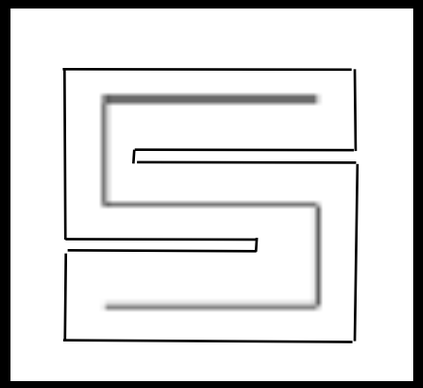
radius: 1 mm

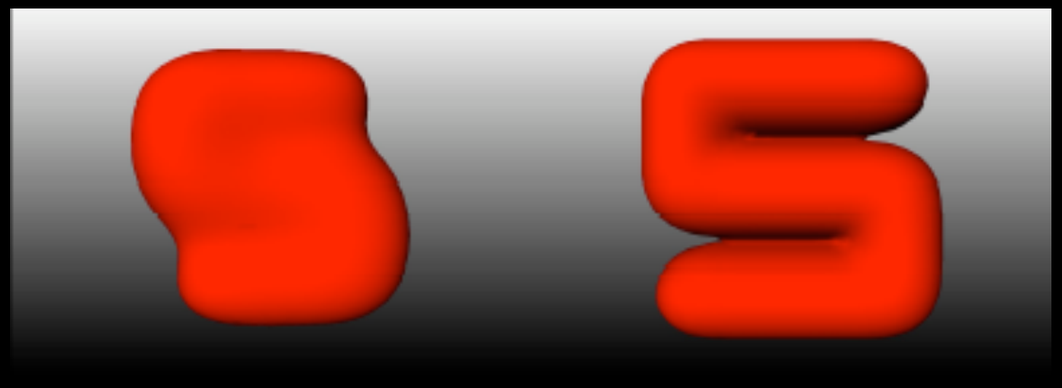
gap: 1 mm



radius: 1.37 mm

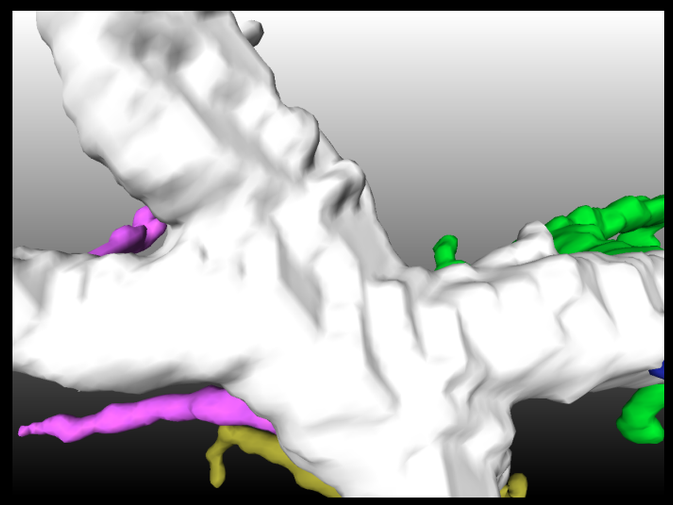
gap: 0.26 mm



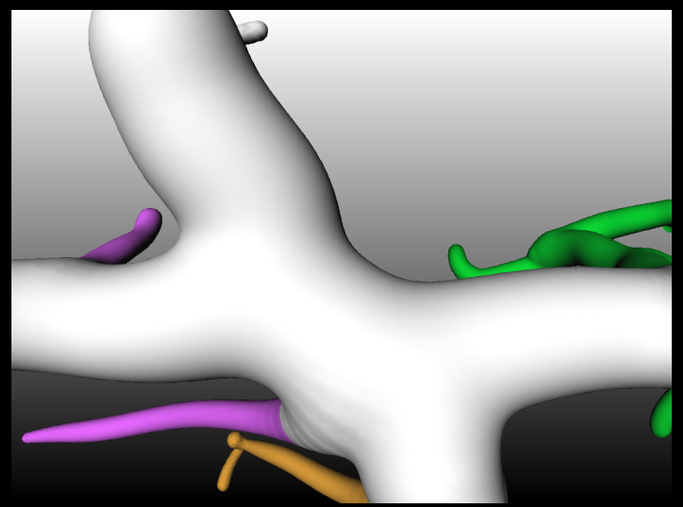


[Oeltze & Preim 2005]

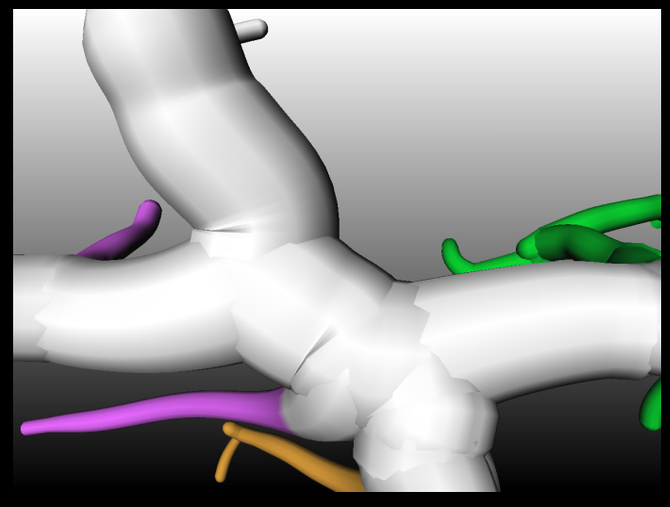
Convolution Surfaces: Evaluation



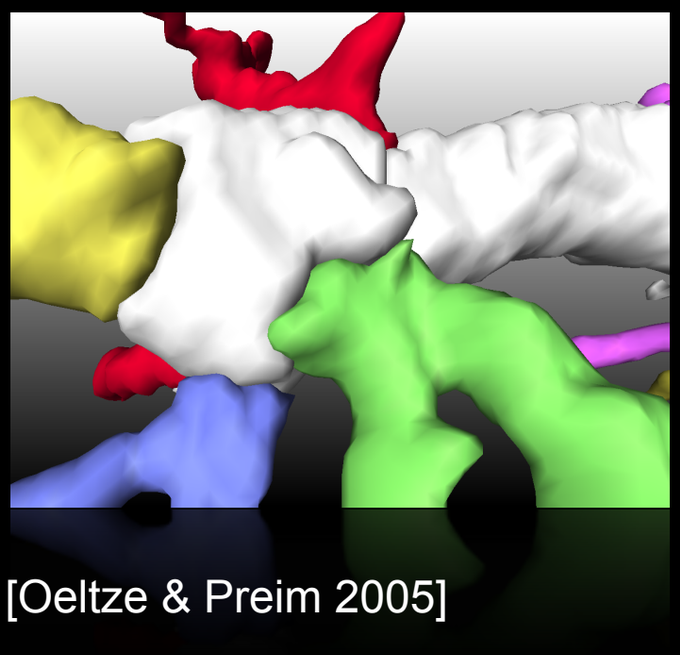
Marching Cubes of Segmentation Result



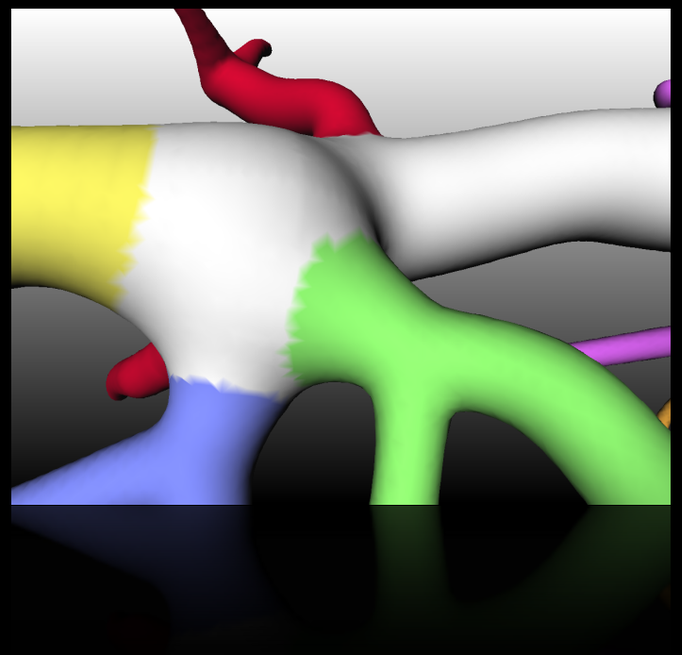
Convolution Surfaces

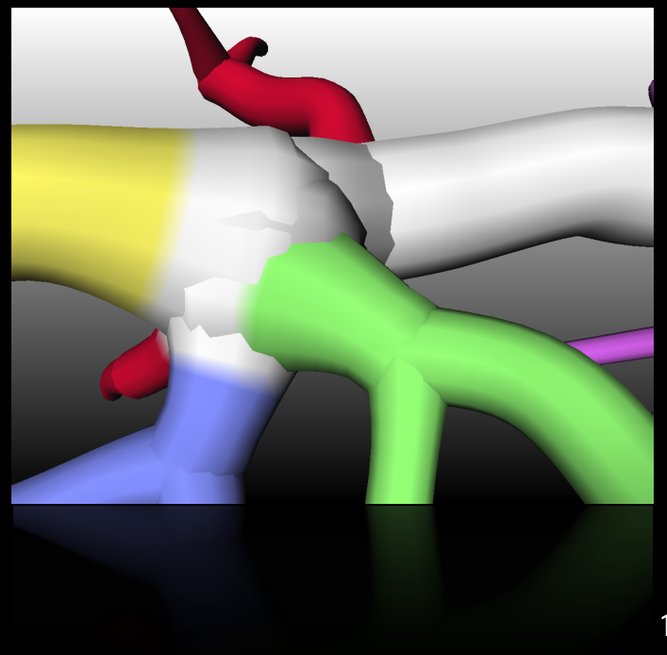


Truncated Cones

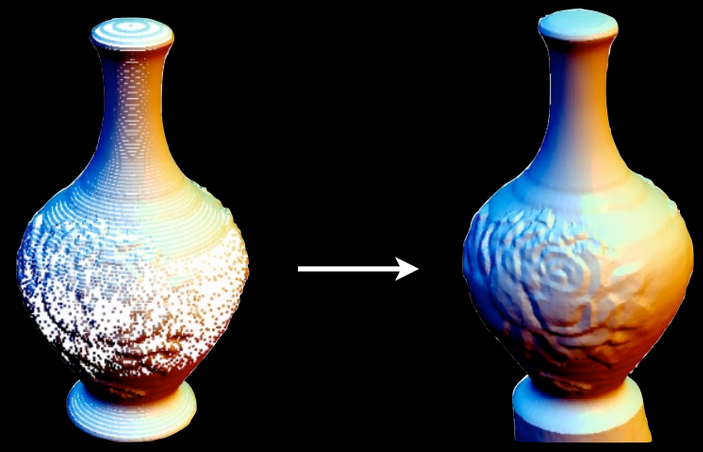


[Oeltze & Preim 2005]





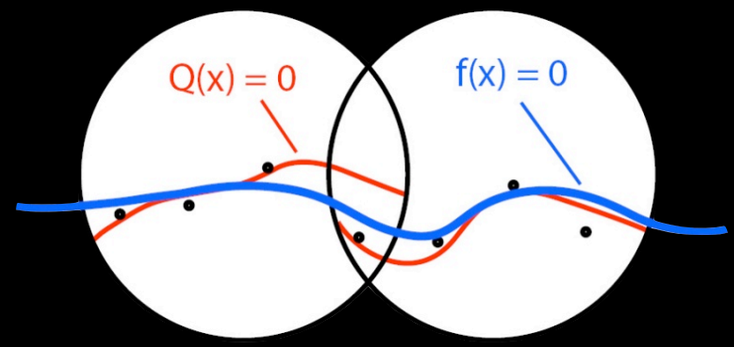
Model-free Visualization: Multi-level Partition of Unity Implicits



[Ohtake et al. 2003]

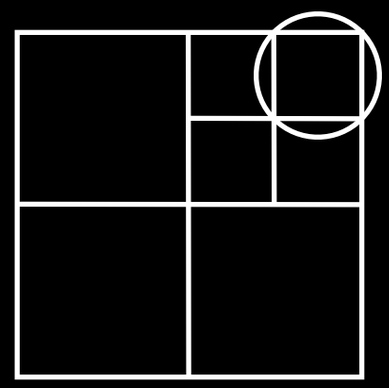
- Fast reconstruction of surfaces from scattered data
- Surface approximation with adaptive error control
- Local approximation Q(x) is blended to global approximation f(x)
- Search for points in spherical regions defined by an octree

Piecewise quadratic local approximation



[Braude 2005]

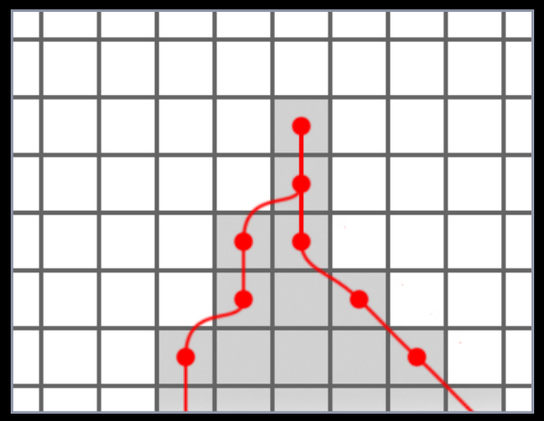
Adaptive refinement



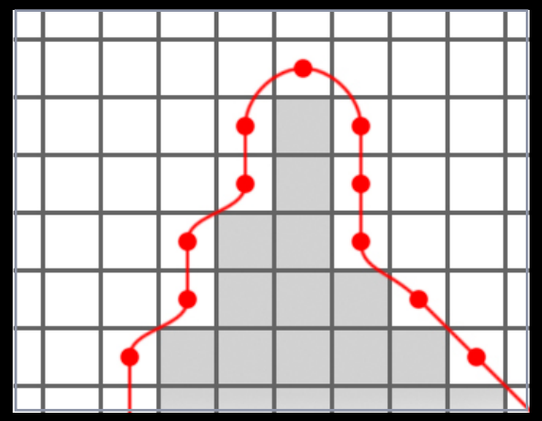
MPU Implicits: Point Generation from Voxels

- Border voxels as initial places for points

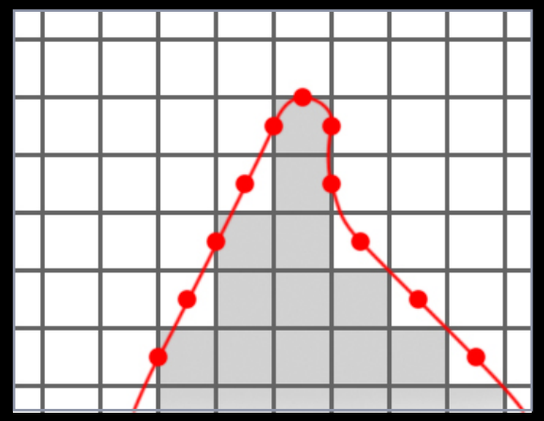
Degeneration of thin vessels

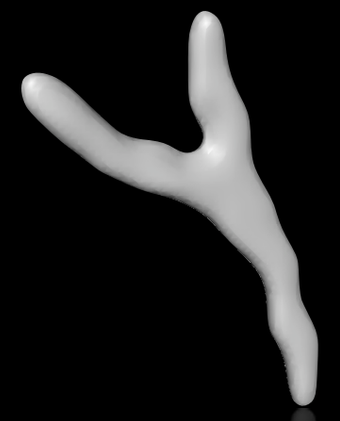


Volume too large

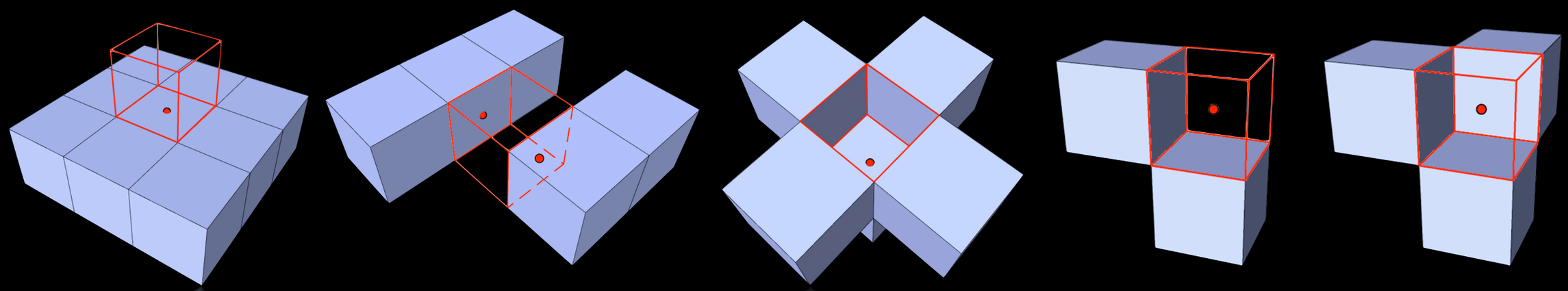


Ideal point distribution





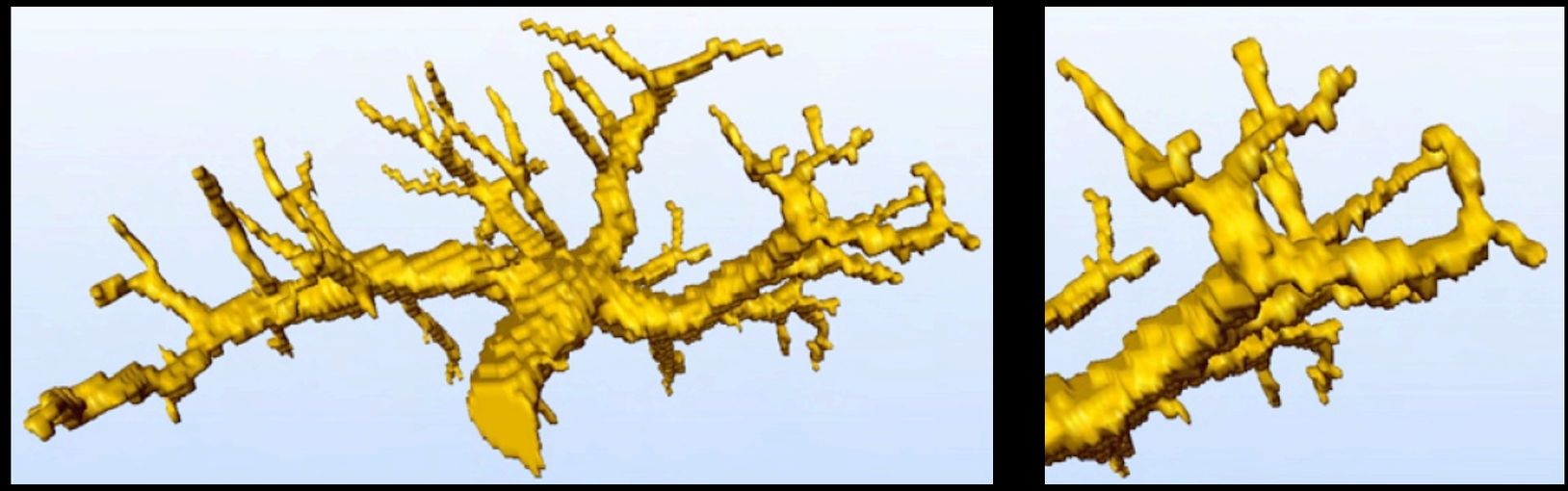
- Different cases for placing points



[Schumann et al. 2007]

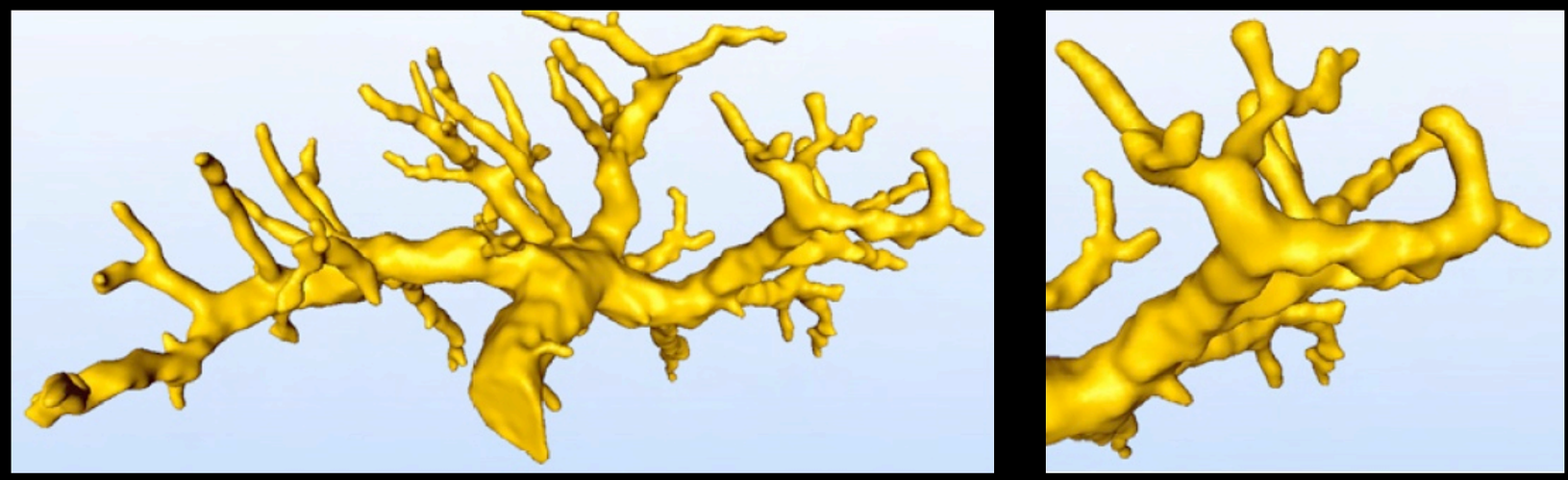
Marching Cubes

Reconstruction time: 2 s



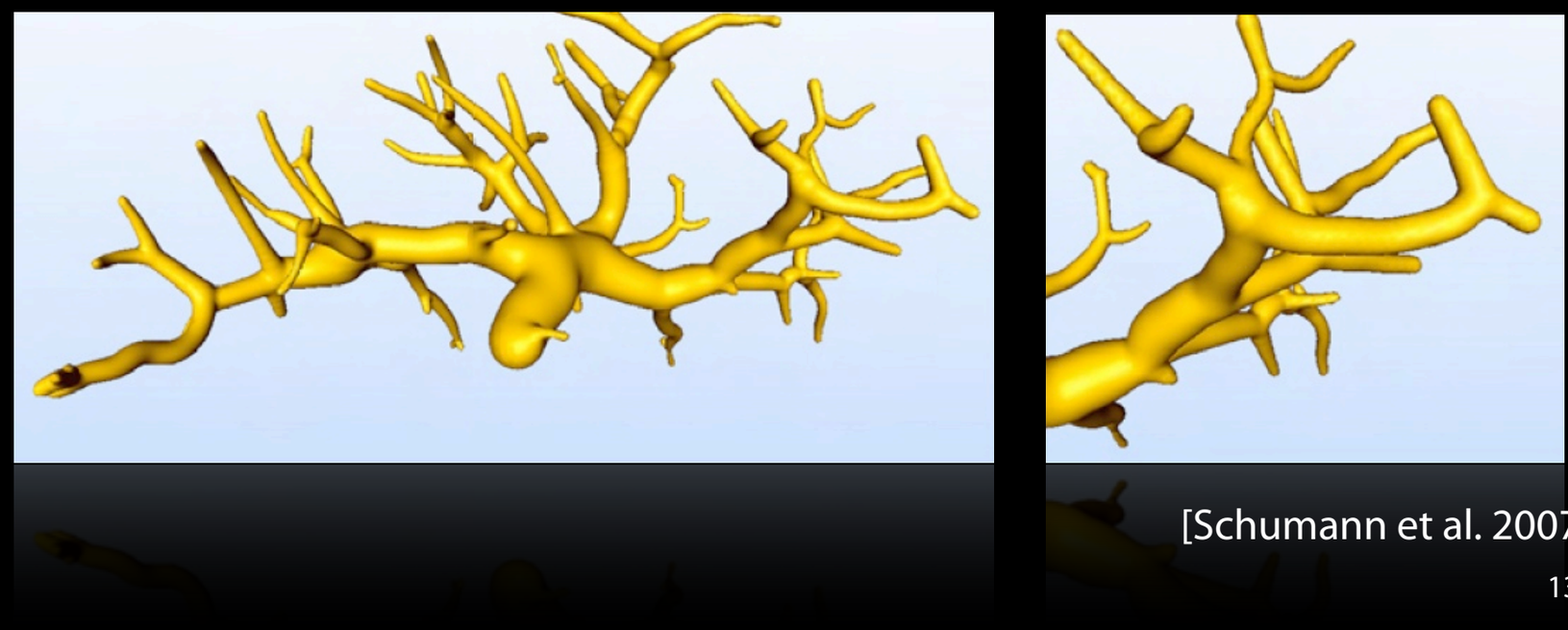
MPU Implicits

Reconstruction time: 14 s



Convolution Surfaces

Reconstruction time: 15 s

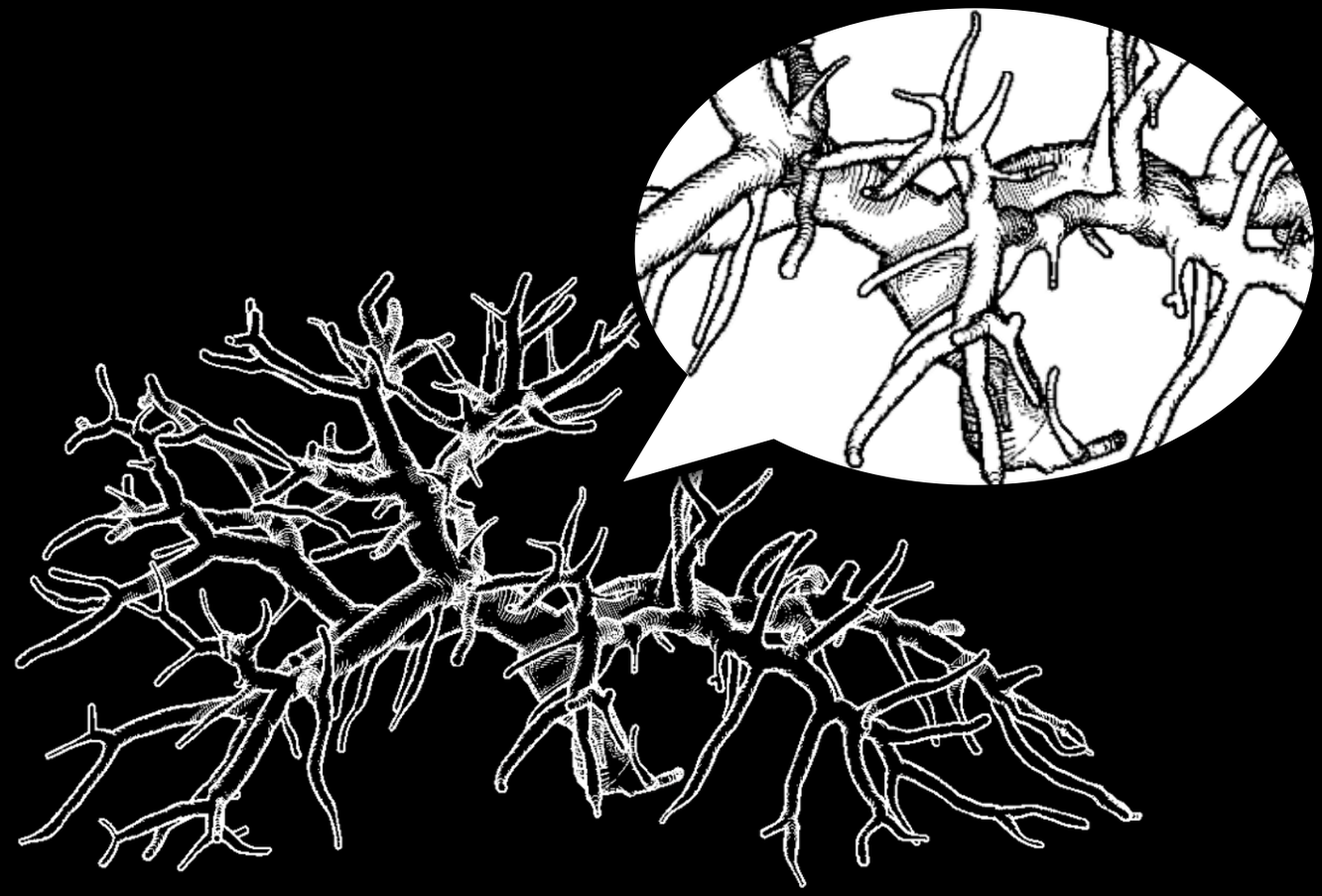


[Schumann et al. 2007]

Illustrative Visualization of Vasculature

Why?

- Communication of specific aspects
- Application of color and shading sometimes limited
- Black and white images provide best contrast



[Ritter et al. 2006]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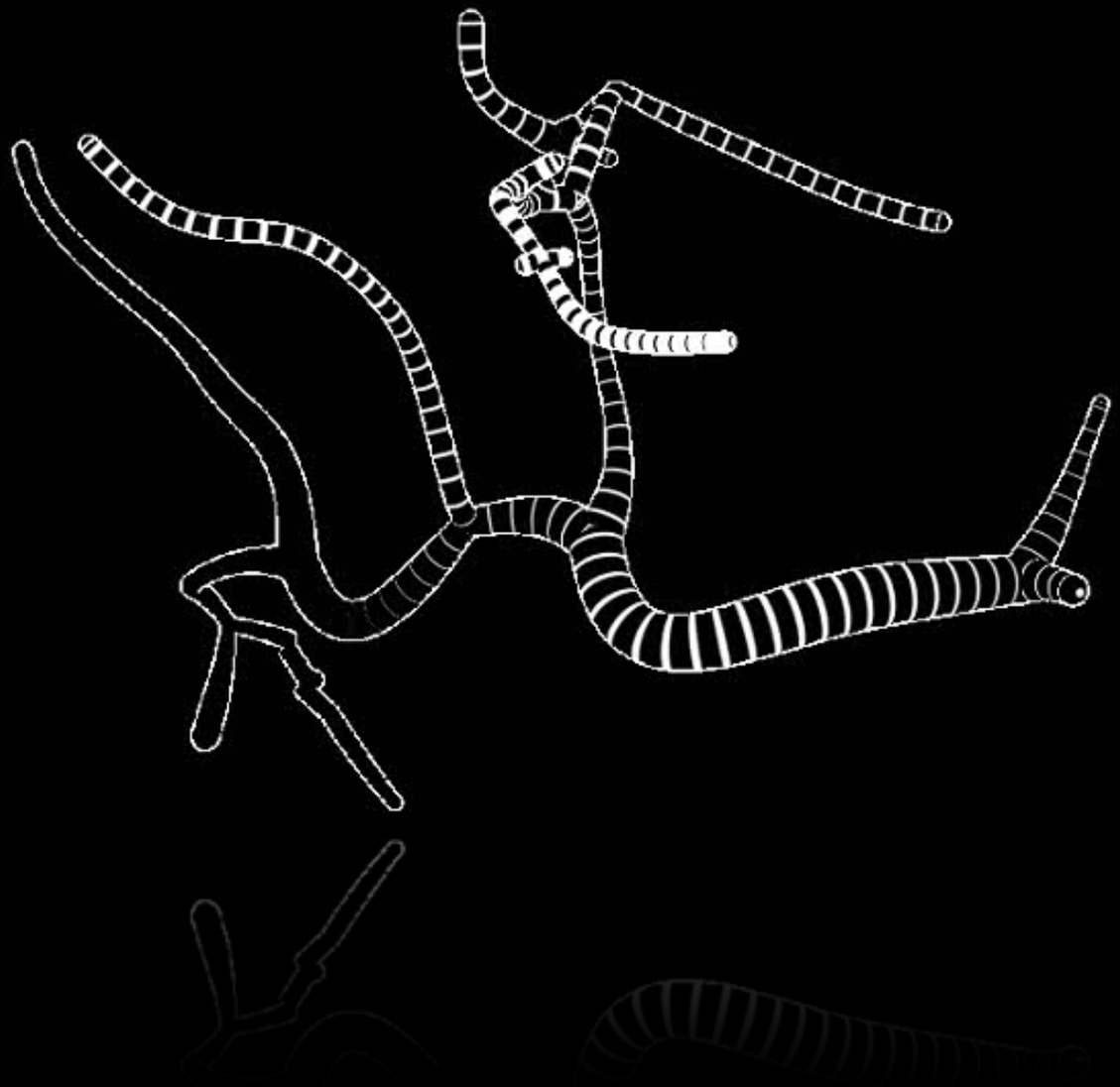
Illustrative Visualization: Depth Accentuation



[Ritter et al. 2006]

Illustrative Visualization of Vasculature: Projection on a Pig-Liver

Volume Rendering of Vasculature

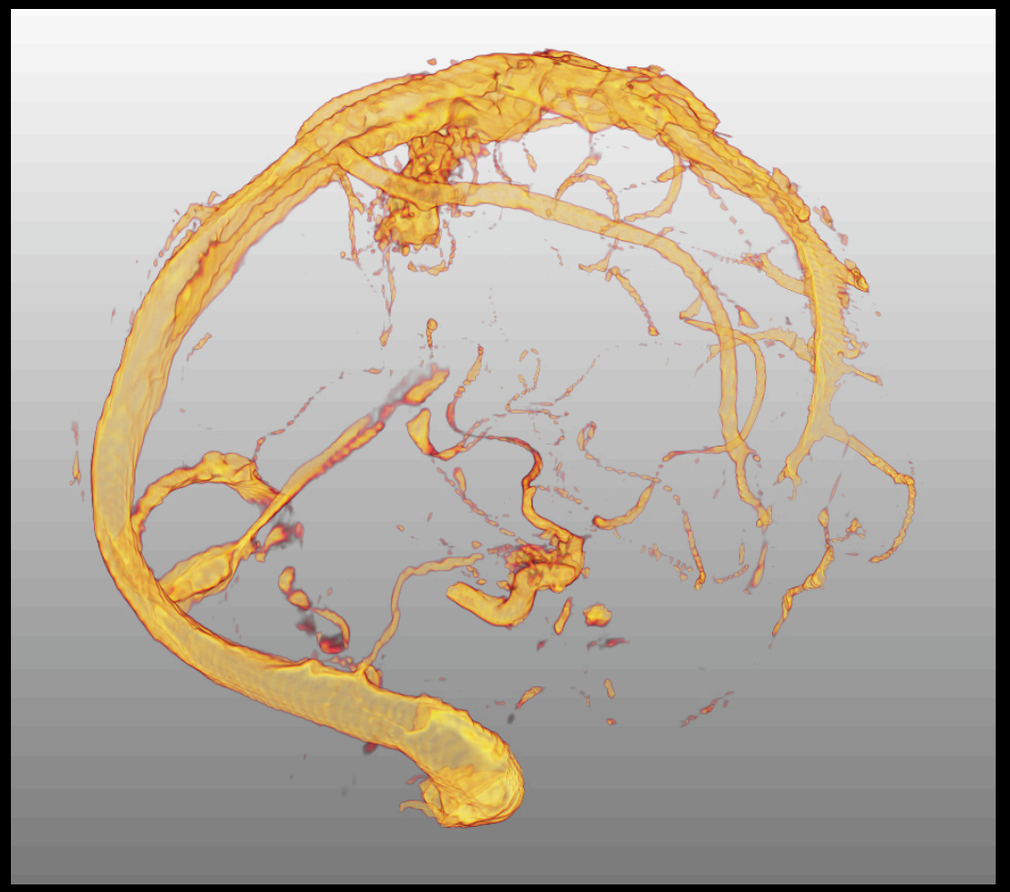
Pros:

- No explicit segmentation required
- Direct visualization of the medical data

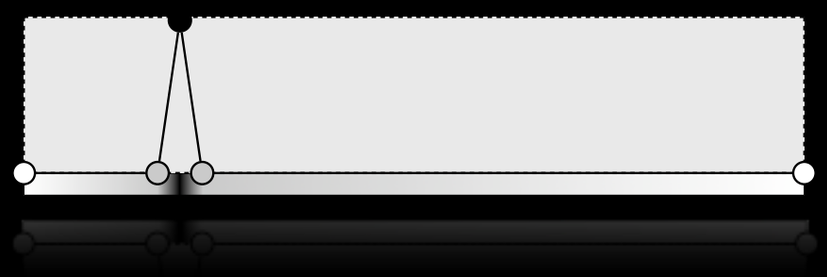
Cons:

- No automatic measurements
- Limited visibility of peripheric branches

pre-integrated volume rendering of brain vasculature

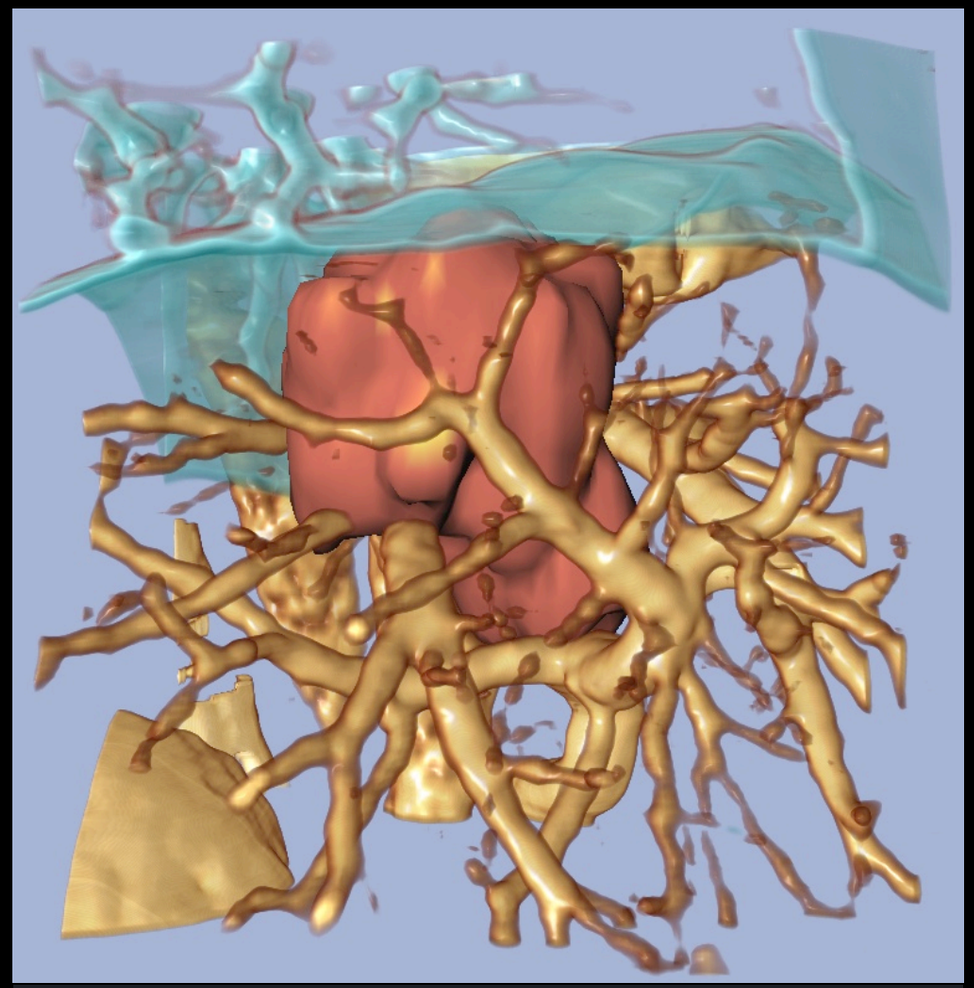


transfer function

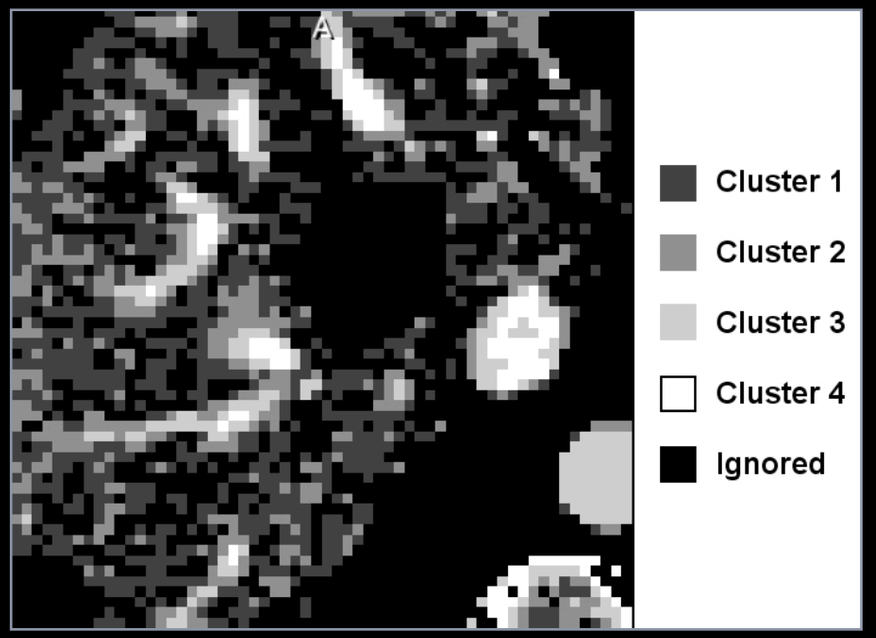


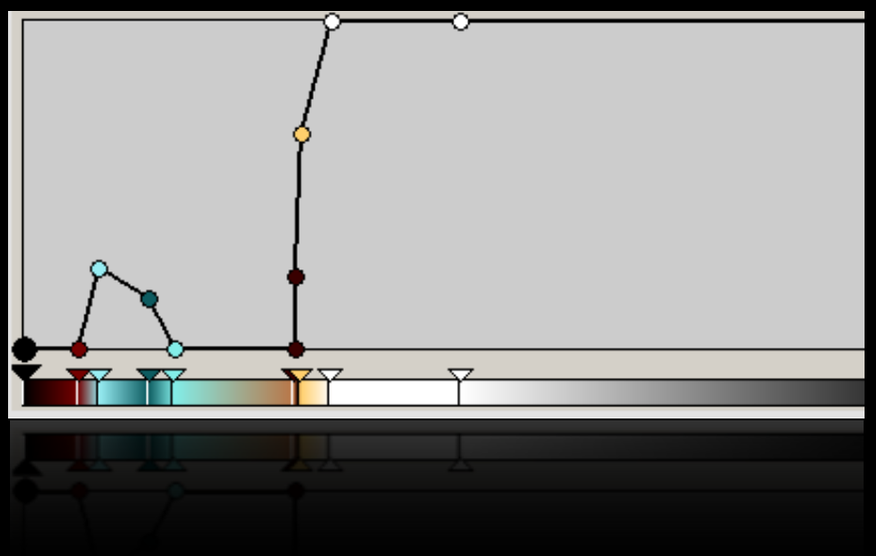
Volume Rendering of Vasculature: Automatic Adaptation of Transfer Function

volume rendering of hepatic vessels



[Schwier et al. 2008]





Summary

- Therapy planning and surgery require clear communication of topology and morphology
- Model-based reconstruction via Convolution Surfaces closely resemble the data and generate smooth, organic looking surfaces (inappropriate for diagnostics)
- Model-free reconstruction by means of MPUs directly from the segmentation result (suited for diagnostics)
- Visualization via Truncated Cones Fitting fast and appropriate for most of the therapy planning tasks

Acknowledgements

Steffen Oeltze,
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