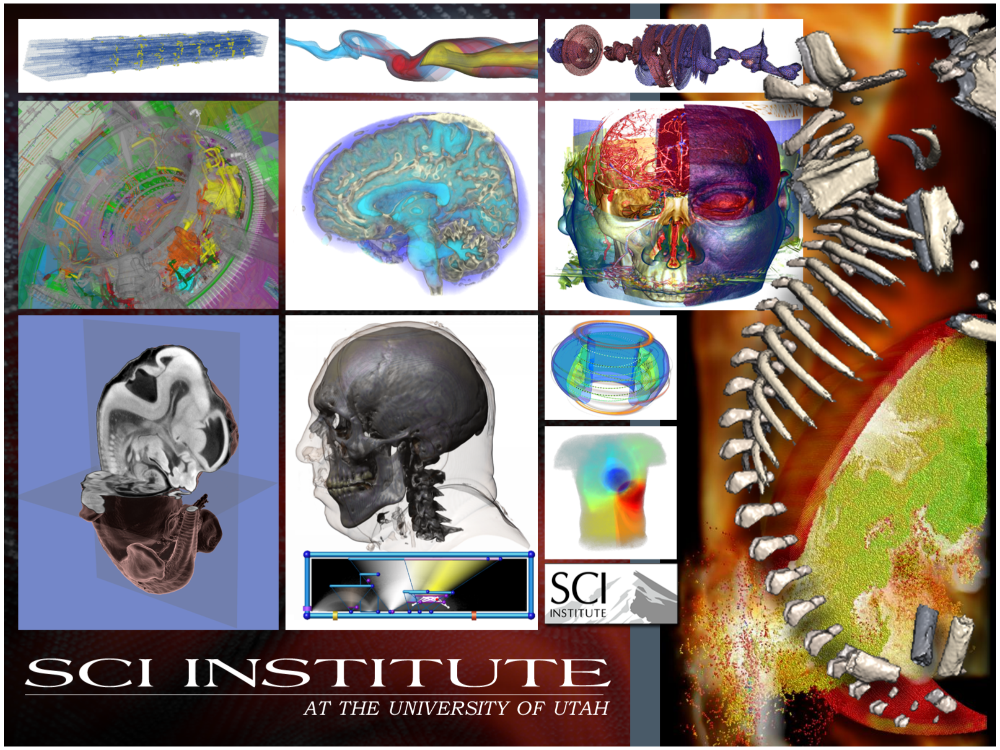
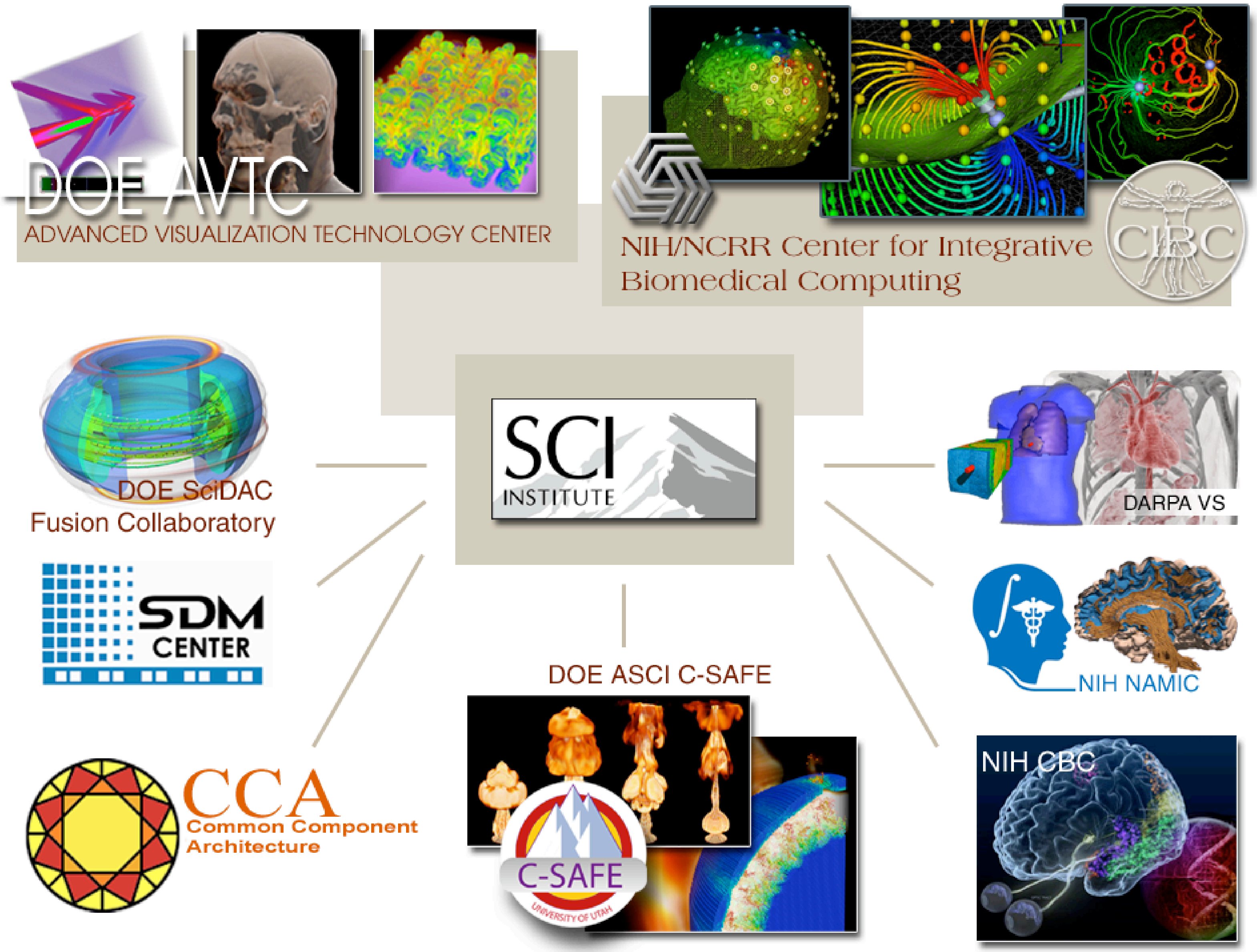
Scalable Techniques for Scientific Visualization



Claudio T. Silva
Scientific Computing and Imaging Institute
University of Utah


DOE AVTC
ADVANCED VISUALIZATION TECHNOLOGY CENTER
NIH/NCRR Center for Integrative Biomedical Computing
CIBC
DOE SciDAC
Fusion Collaboratory
SCI
INSTITUTE
DARPA VS
SDM
CENTER
NIH NAMIC
DOE ASCI C-SAFE
C-SAFE
UNIVERSITY OF UTAH
CCA
Common Component Architecture
NIH CBC

New in 2006:

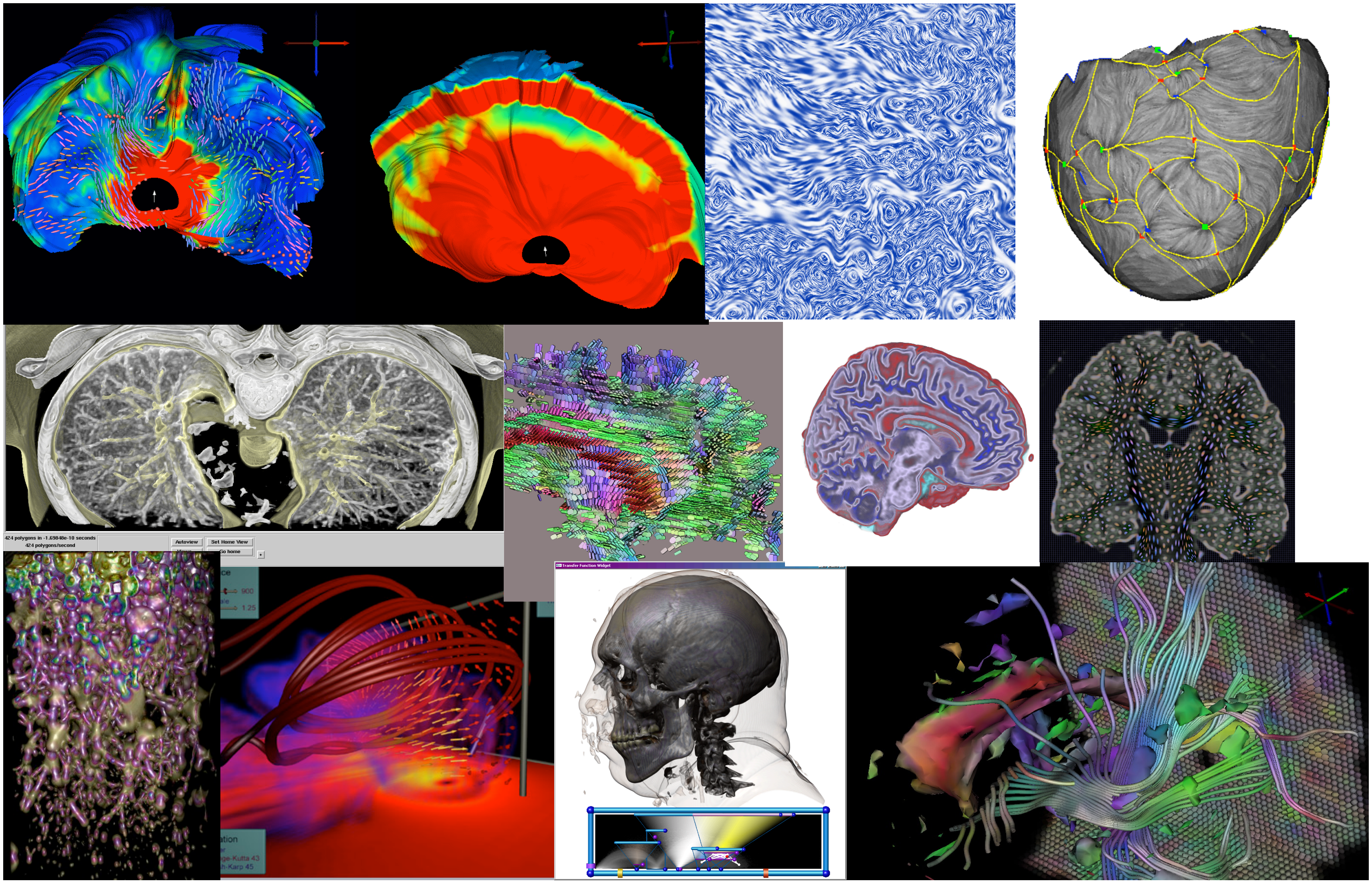
VACET
DOE SciDAC VISUALIZATION AND ANALYTICS CENTER FOR ENABLING TECHNOLOGIES

http://www.vacet.org/

CMOP
Center for Coastal Margin Observation & Prediction

http://www.stccmop.org/

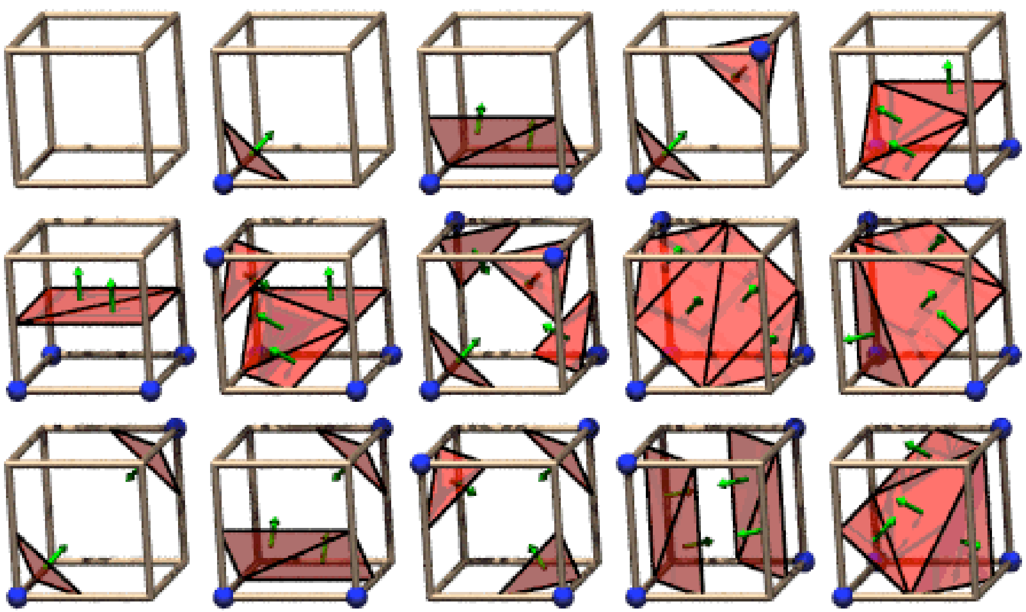
New Visualization Techniques



Isosurface Extraction

How do you create an isosurface?

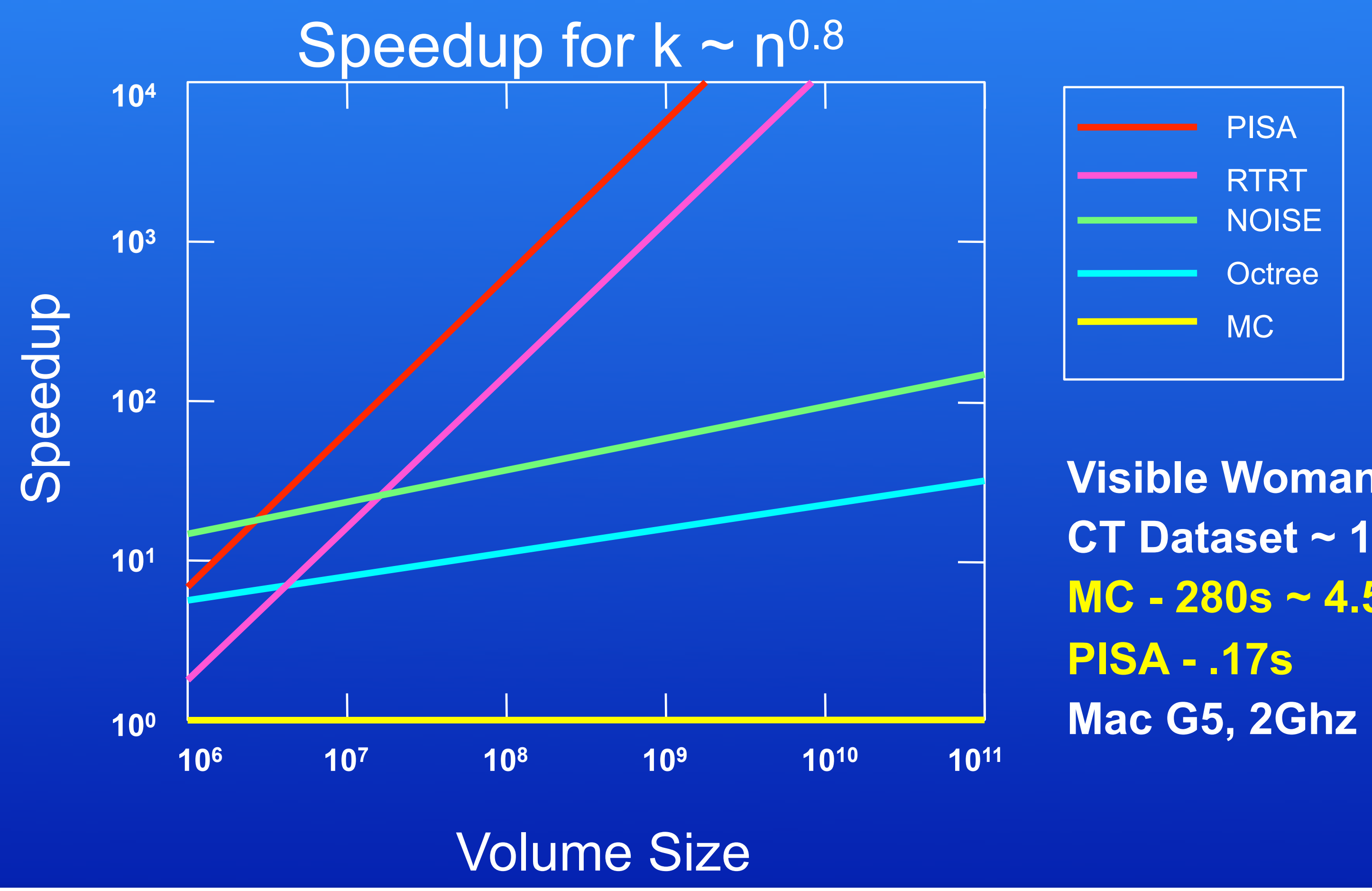
Marching Cubes: Lorensen and Kline, 1987.



The 15 Cube Combinations

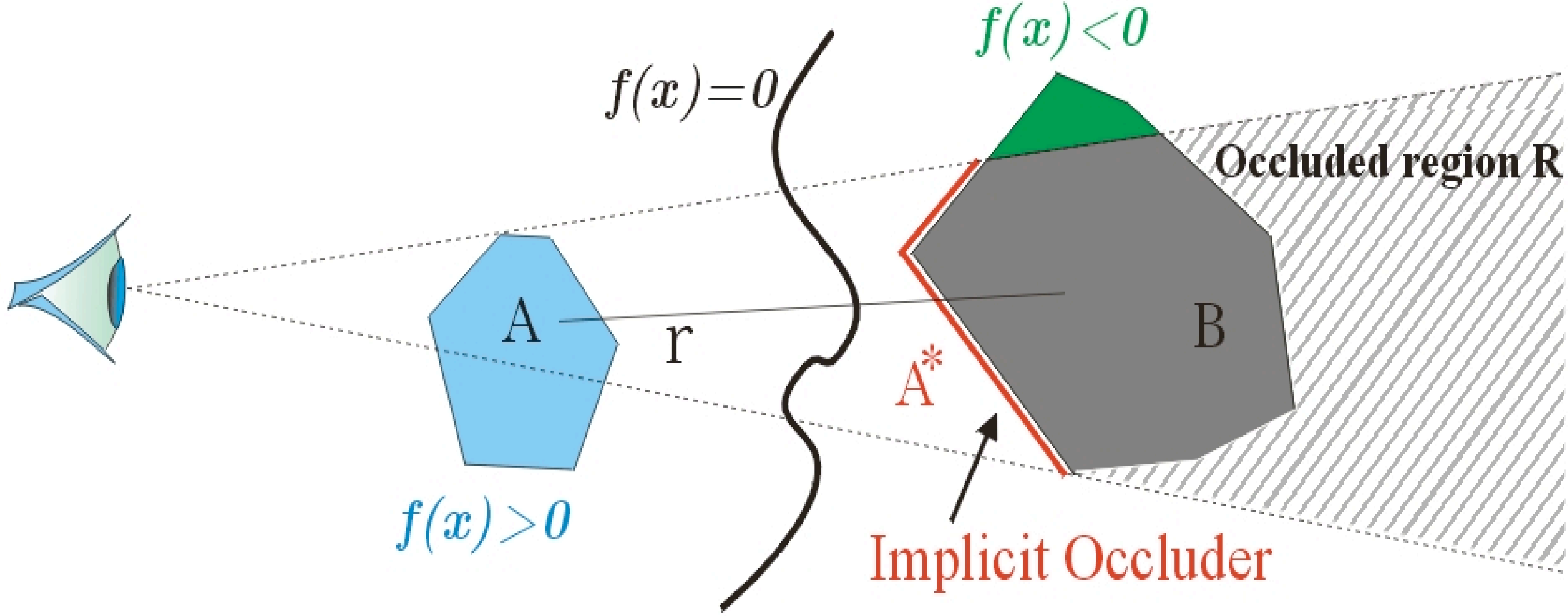
1. Search through each cell
2. Find which cells contain
   a specific isovalue
3. Connect up the pieces
4. Render the surface

Visualization Algorithm Scalability

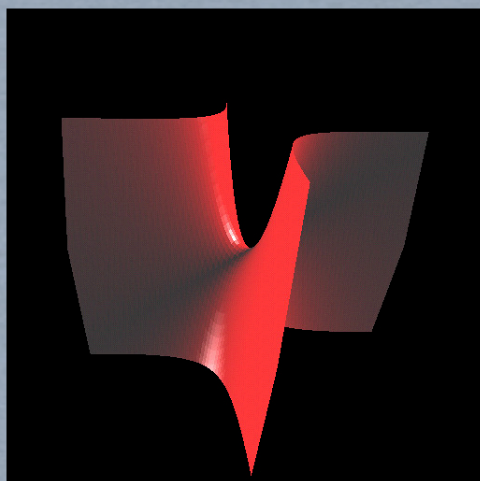


Visible Woman
CT Dataset ~ 1Gb
MC - 280s ~ 4.5m
PISA - .17s
Mac G5, 2Ghz

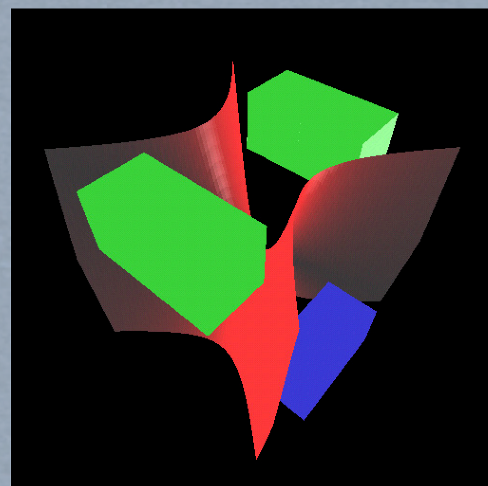
Implicit Occluders



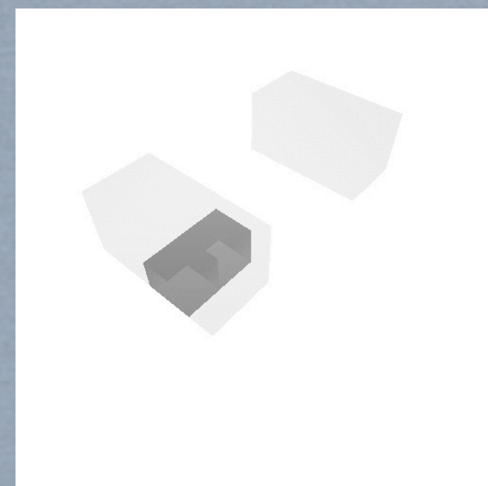
[Pesco, Lindstrom, Pascucci, Silva IEEE VolVis 2004]



Hyperbolic Paraboloid



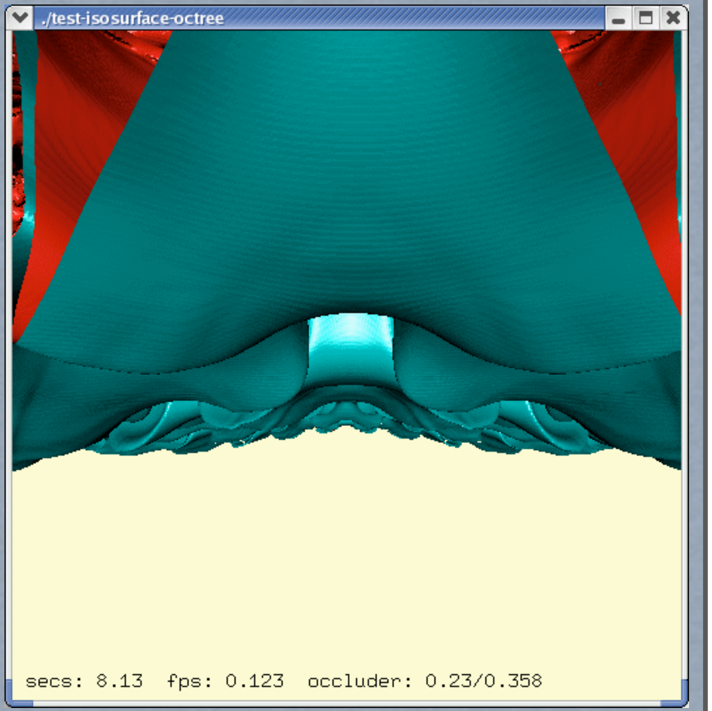
- Negative Node: Green
- Positive Node: Blue

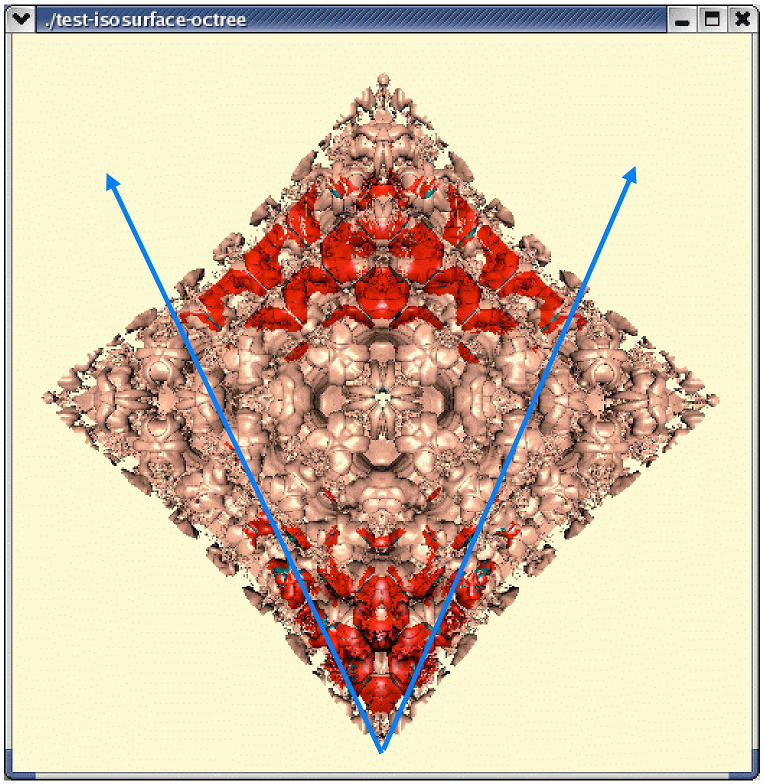


Implicit Occluder

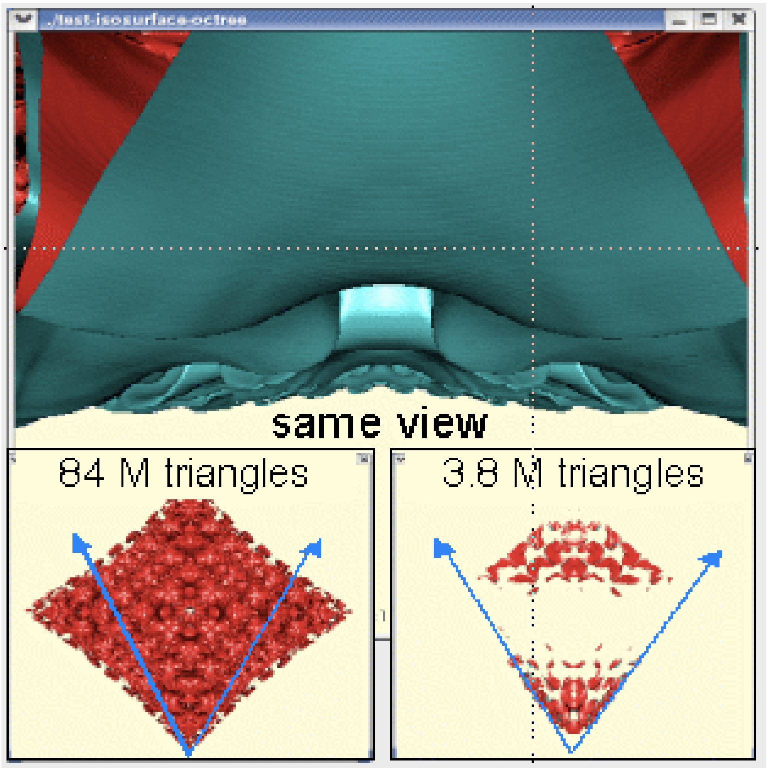
Example 3: PPM (1536 x 1535 x 512)

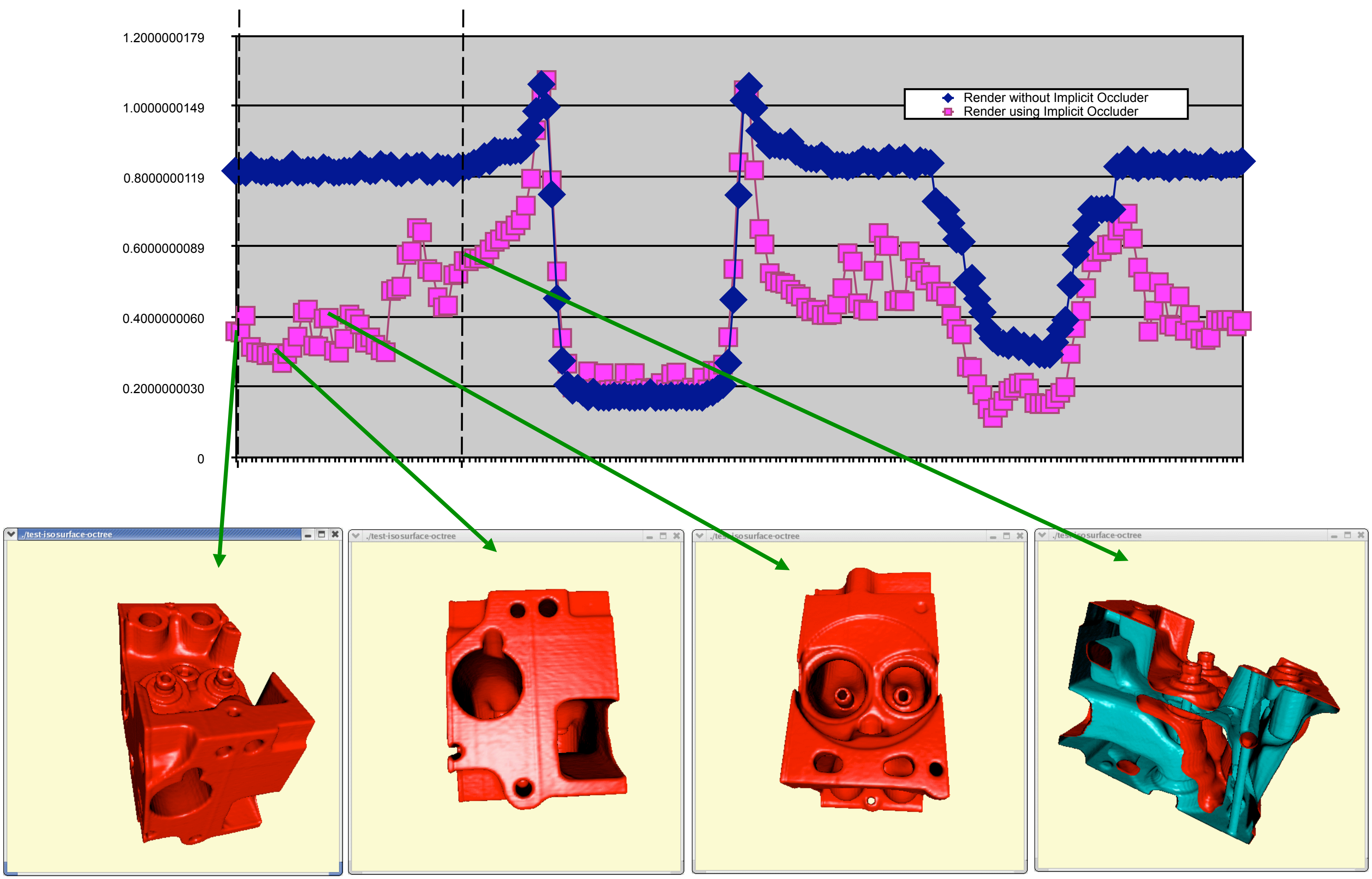
- The isosurface w=127 has 89,083,120.
- Time to compute and render the isosurface in the particular view of the figure:
  - similar to *Wilhelms and Van Gelder, 1992*: 147.50 seconds
  - *using* Implicit Occluder: 8.13 seconds




./test-isosurface-octree

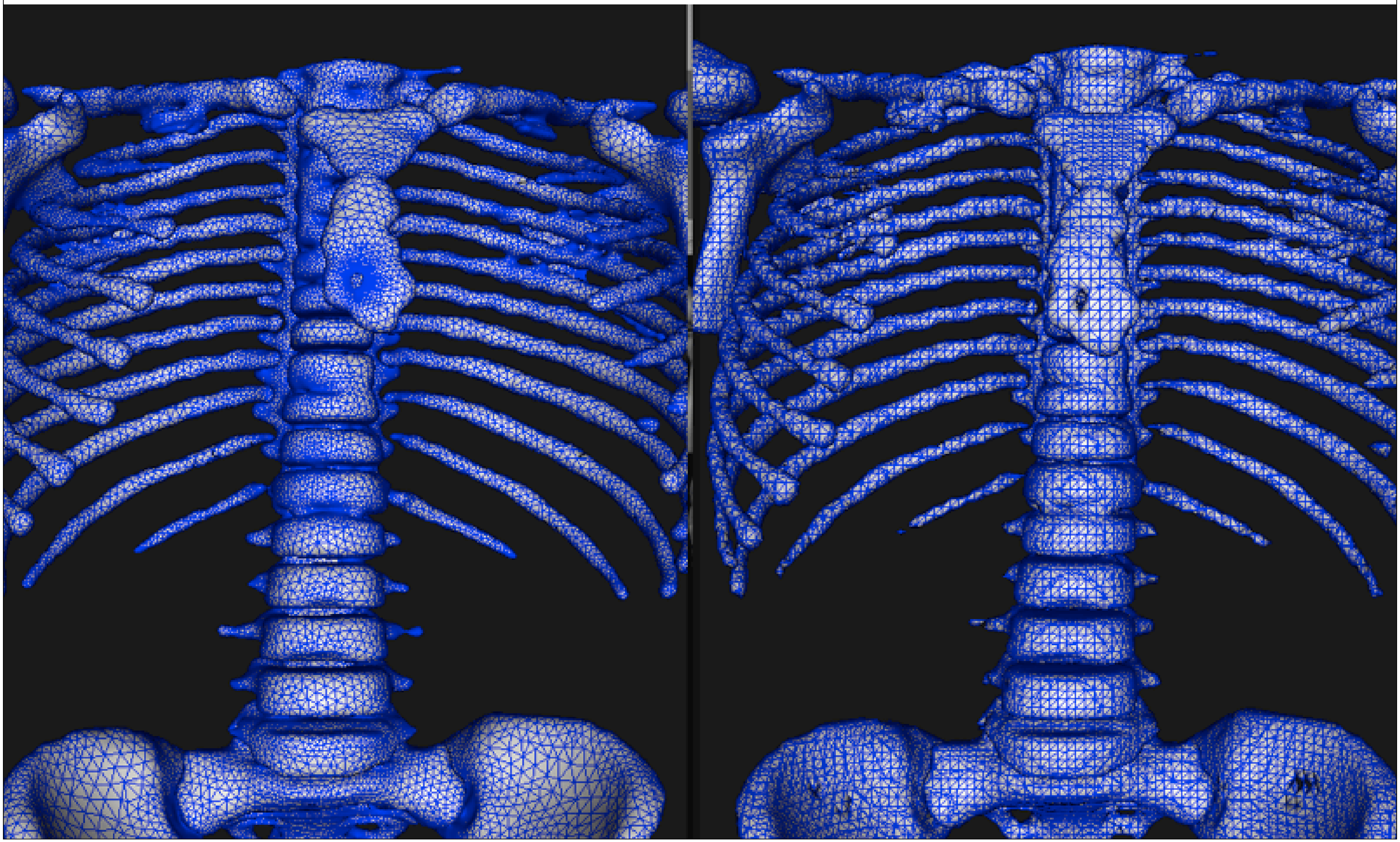
Top view

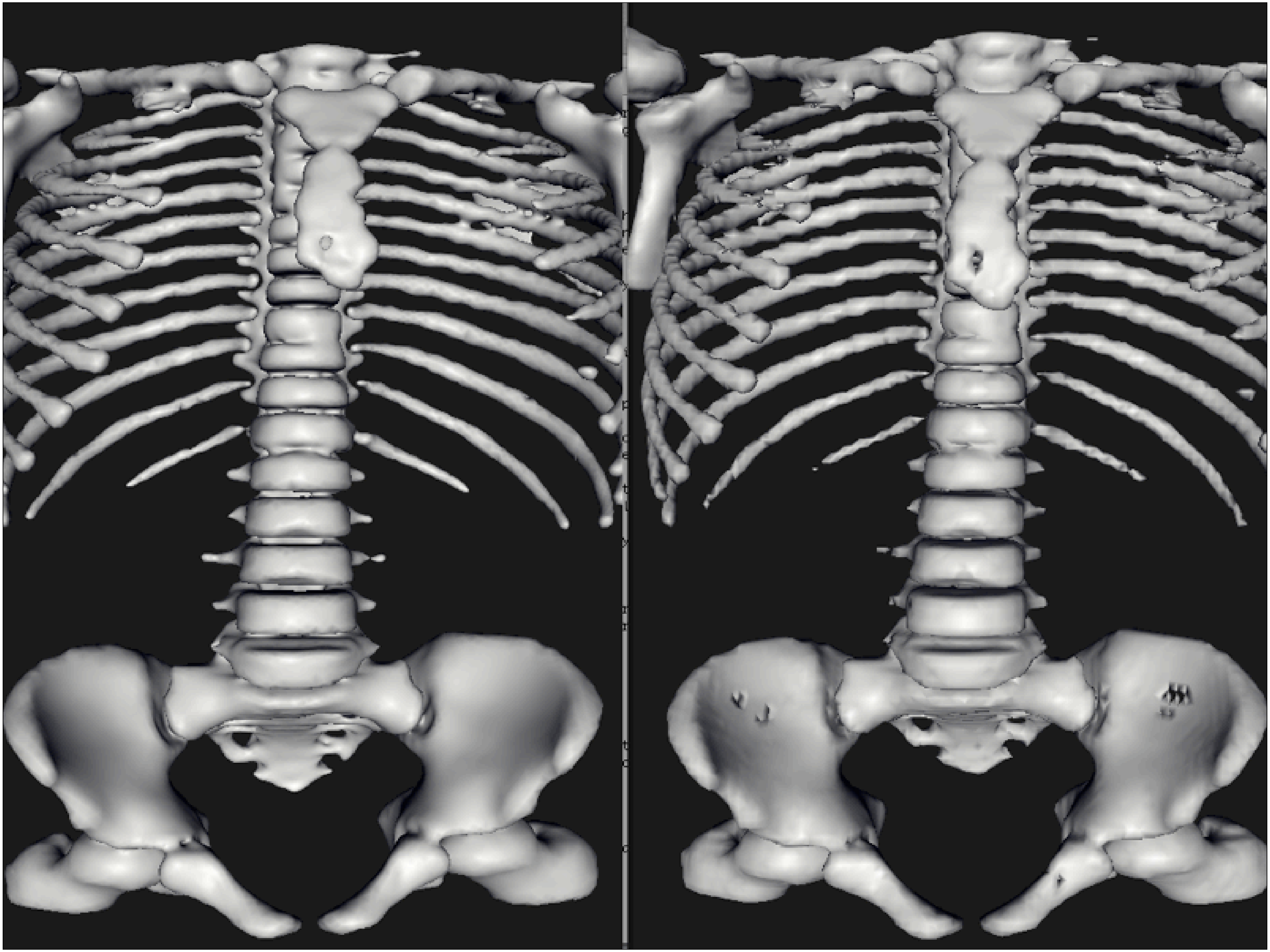

./test-isosurface-octree
same view
84 M triangles
3.8 M triangles

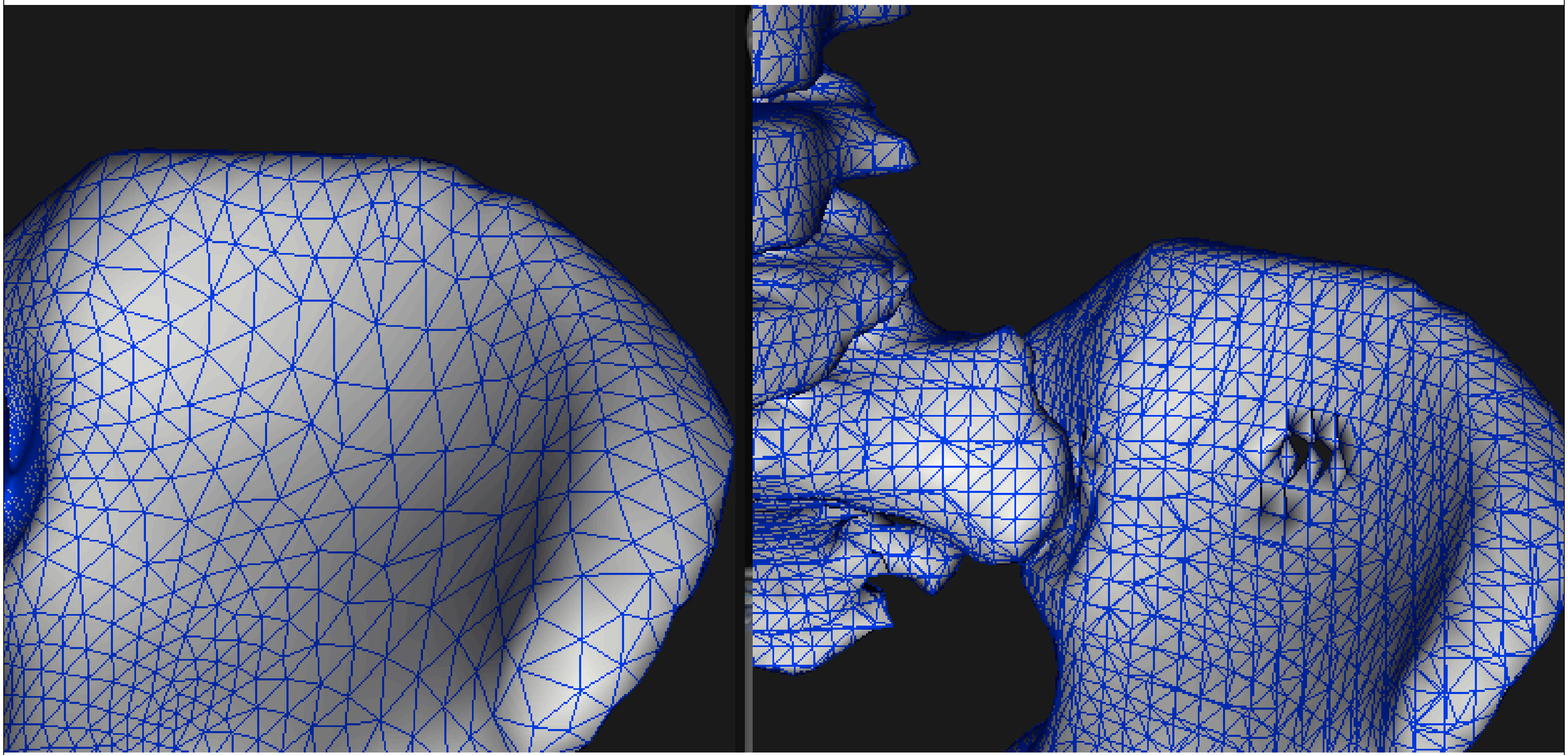


1.2000000179
1.0000000149
0.8000000119
0.6000000089
0.4000000060
0.2000000030
0
Render without Implicit Occluder
Render using Implicit Occluder
./test-isosurface-octree
./test-isosurface-octree

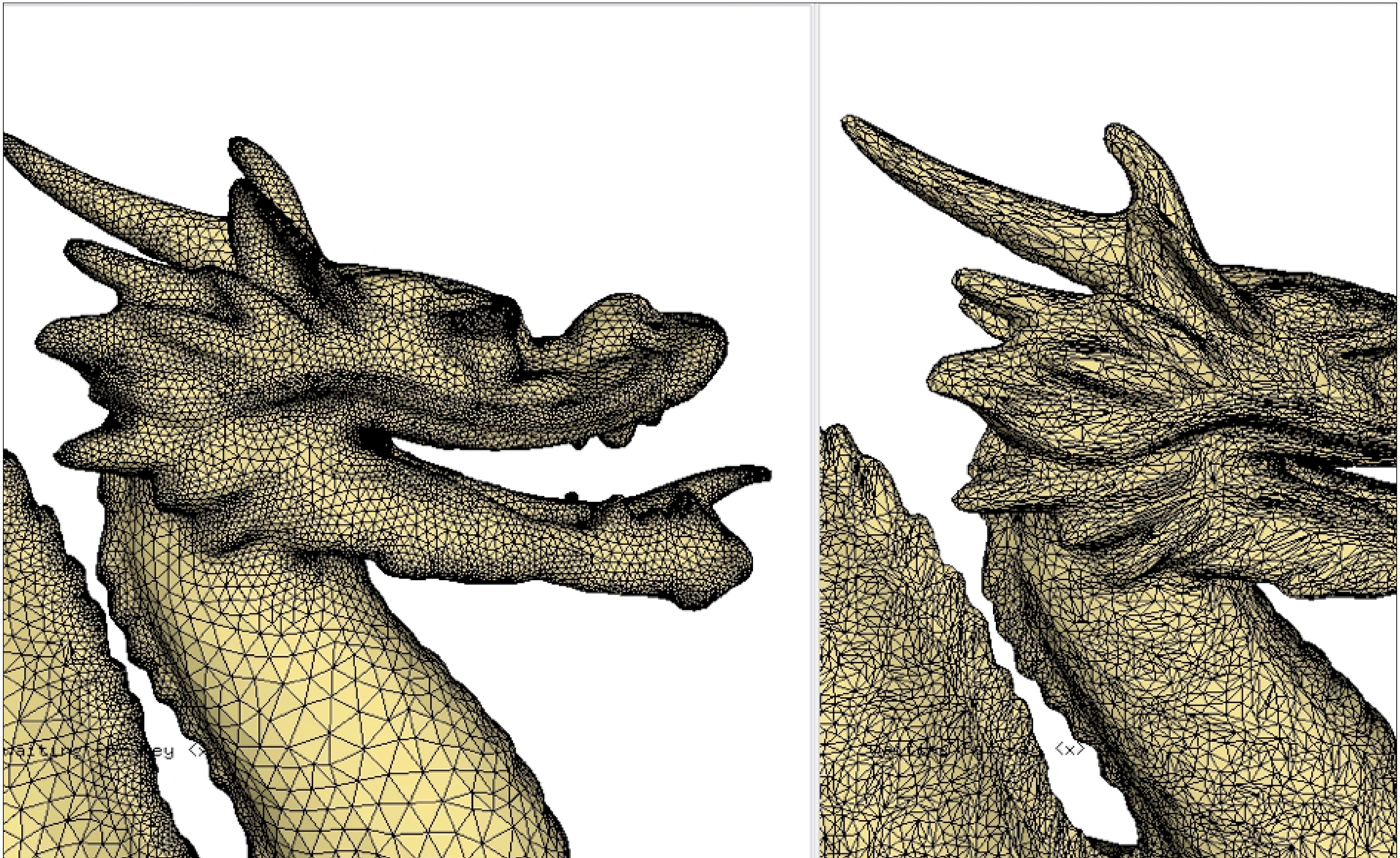
Visualization Algorithm Quality



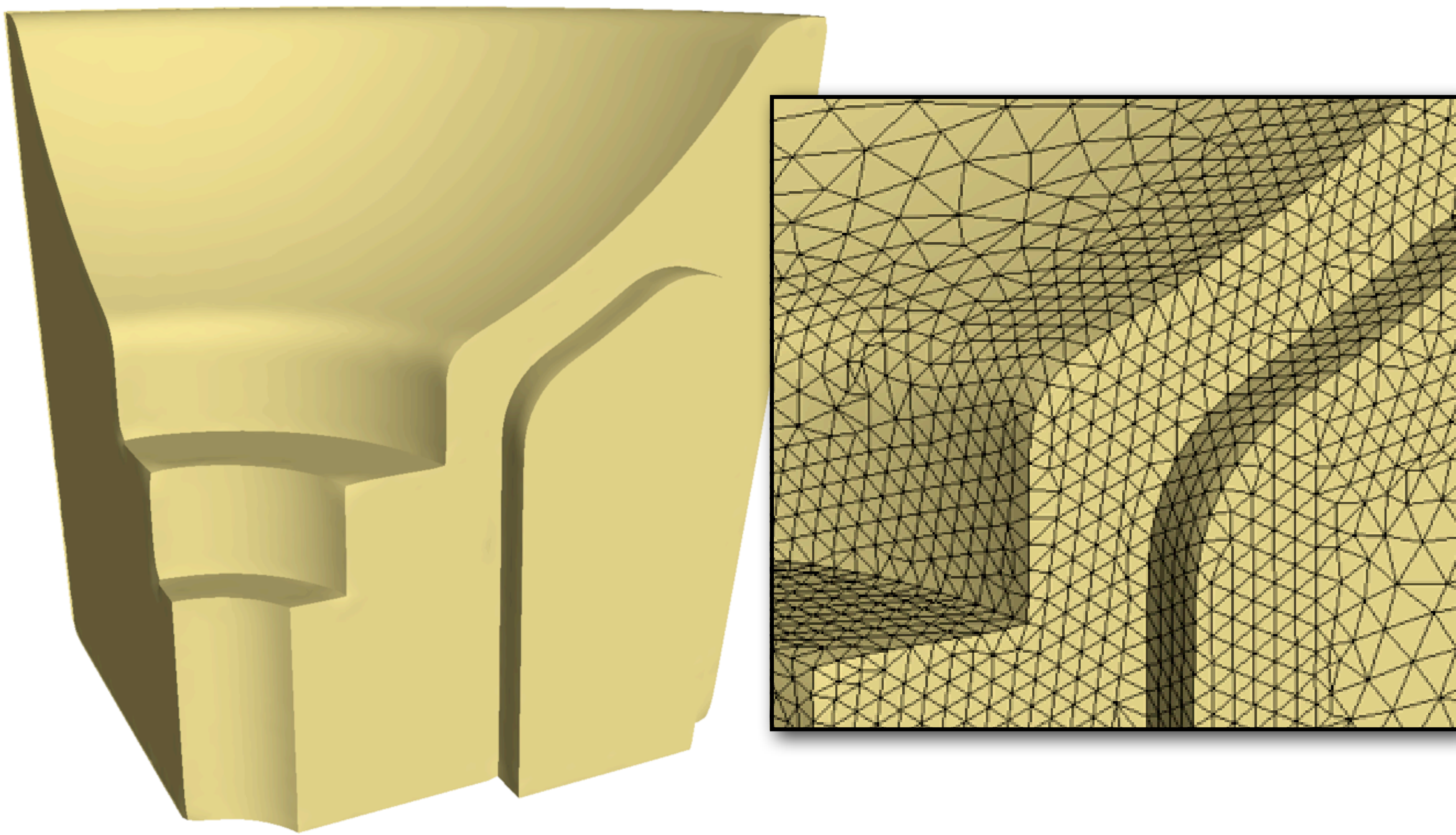




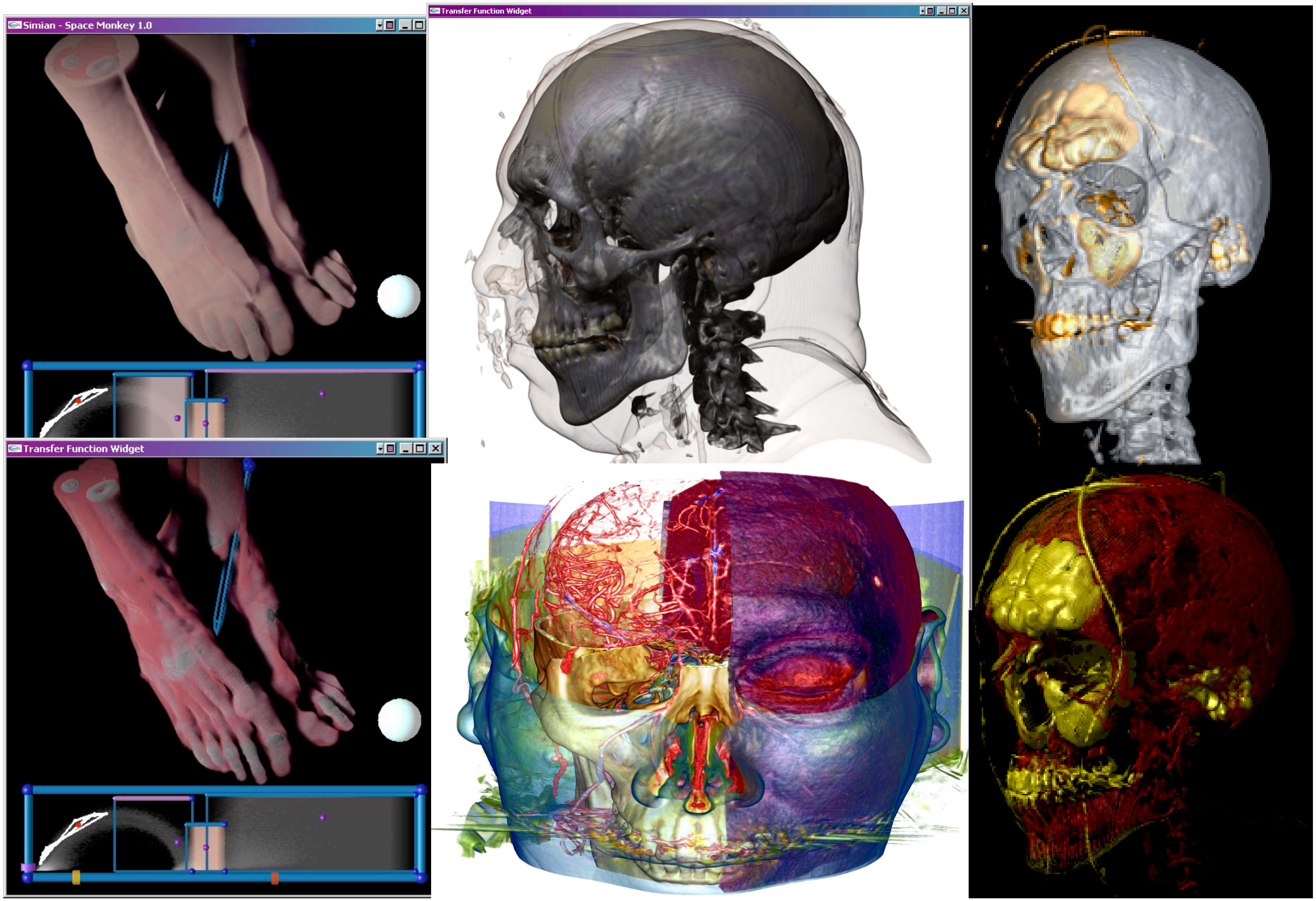
[Schreiner, Scheidegger, Silva IEEE Vis 2006]



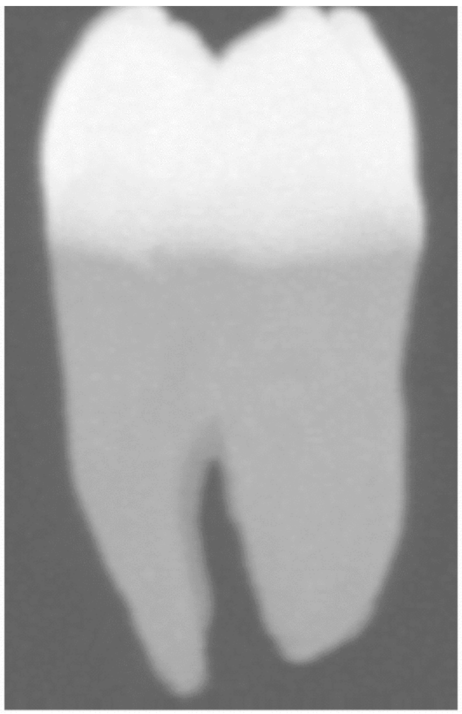
Feature Preservation



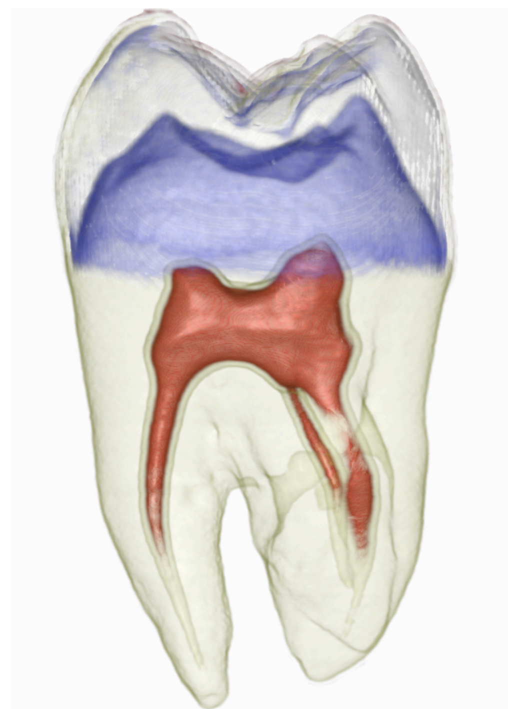
Volume Rendering



Volume Rendering



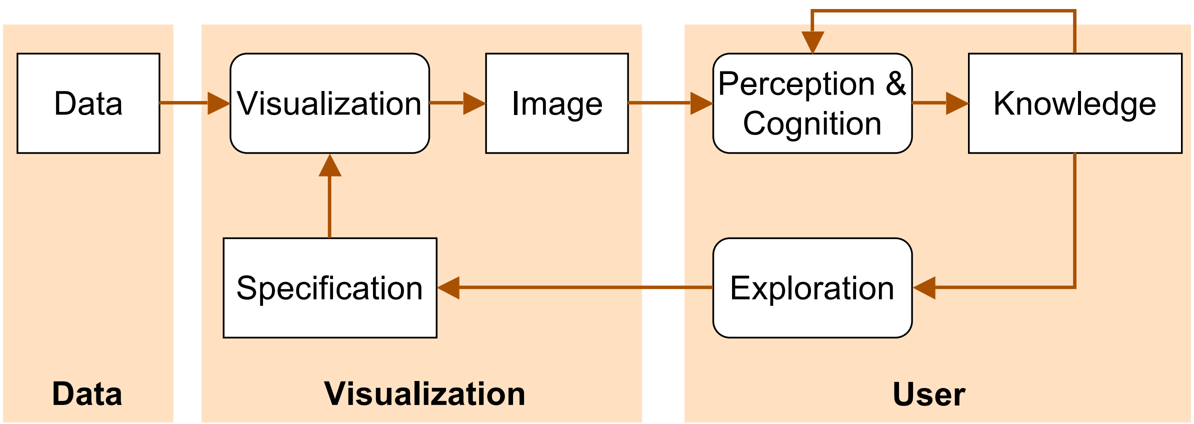
Maximum Intensity Projection (MIP)



Full Volume Rendering

Data Exploration through Visualization

- Insightful visualizations help analyze and validate various hypothesis
- But creating a visualization is a complex, iterative process

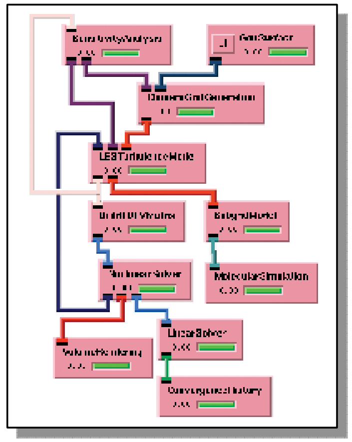


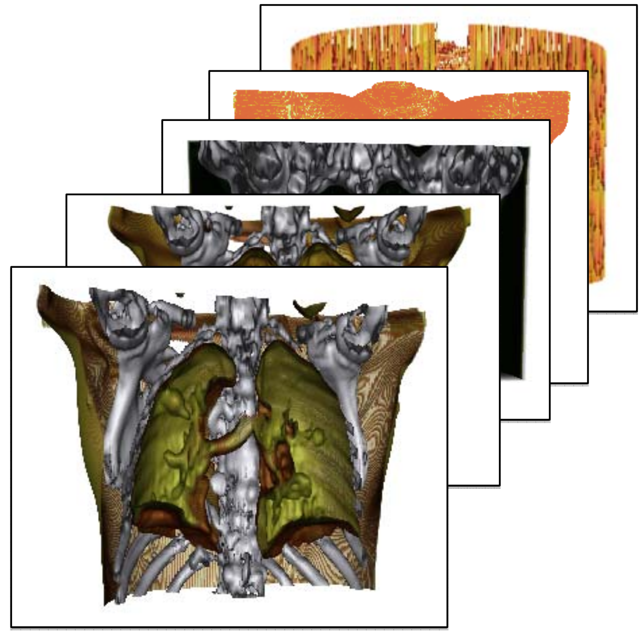
J. van Wijk, IEEE Vis 2005

Provenance Captured Manually

raw data

dataflow





anon4877_voxel_scale_1_zspace_20060331.srn

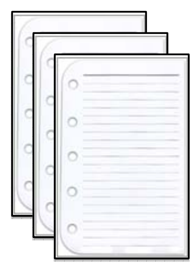
anon4877_textureshading_20060331.srn

anon4877_textureshading_plane0_20060331.srn

anon4877_goodxferfunction_20060331.srn

anon4877_lesion_20060331.srn

Files

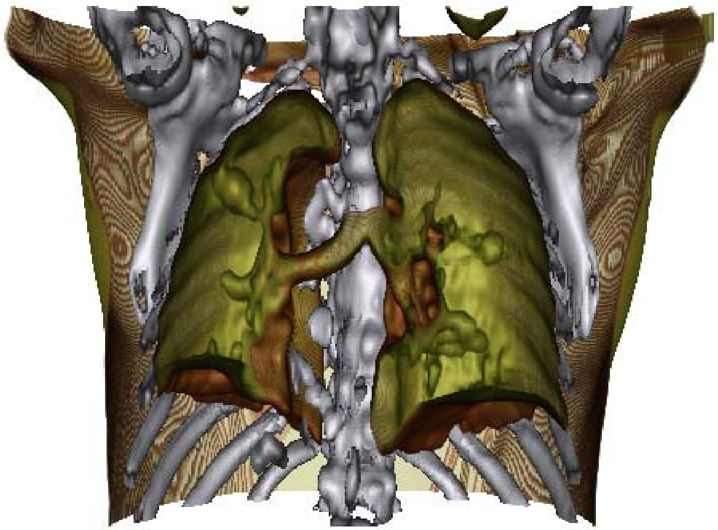


Notes

What's the difference?

anon4877_base_20060331.srn

anon4877_lesion_20060401.srn



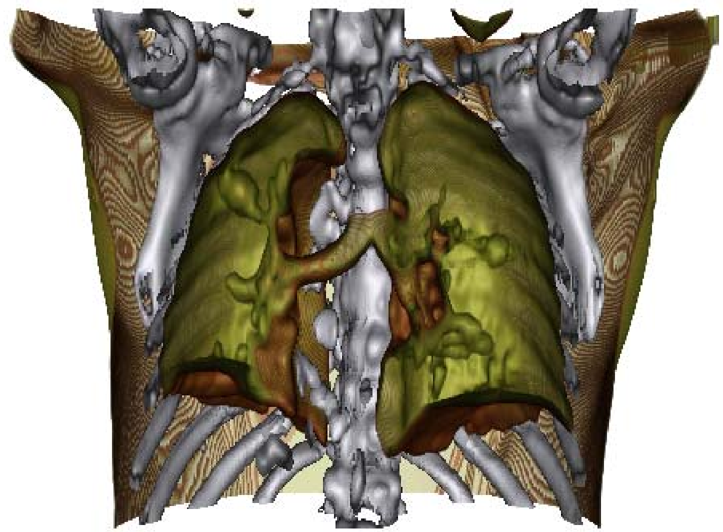
How were these images created?

Are they really from the same patient?

Do they use the same colormaps?

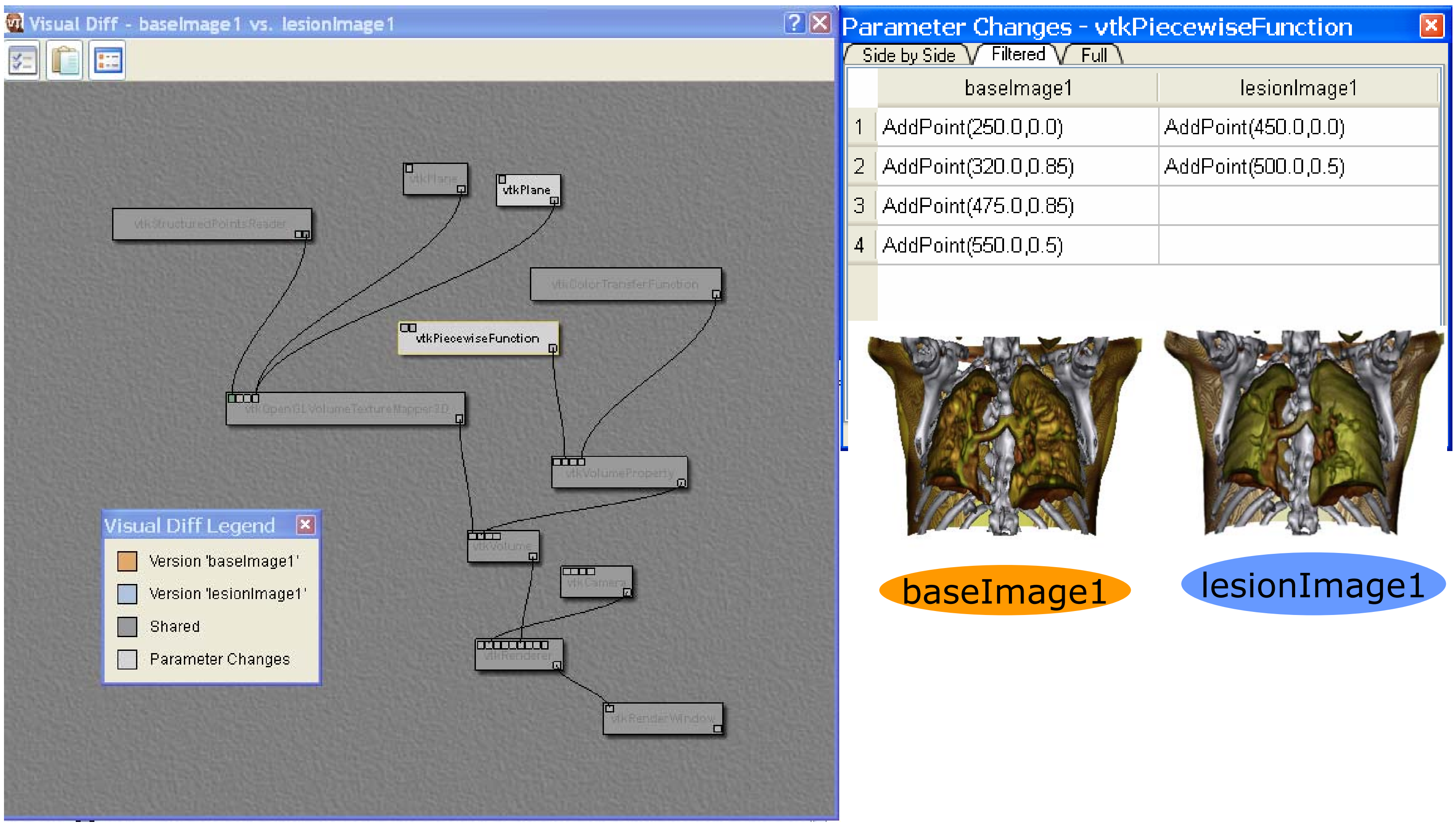
What’s the difference?

baseImage1

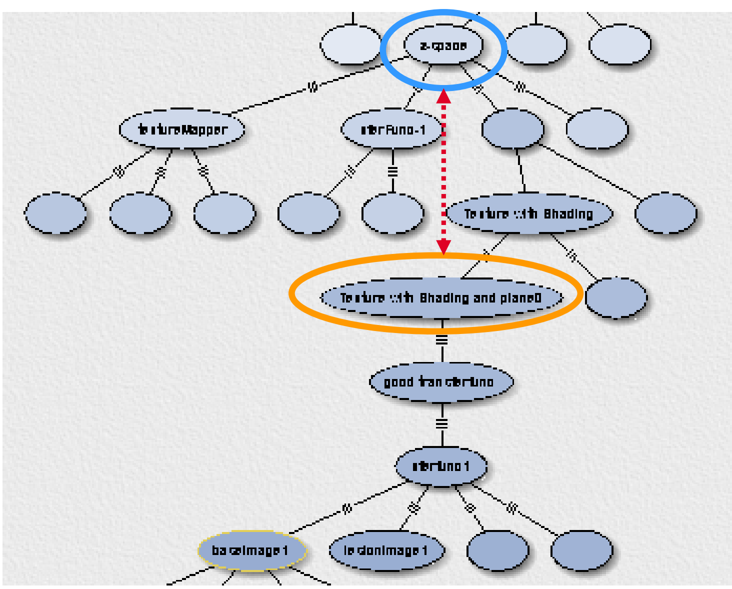


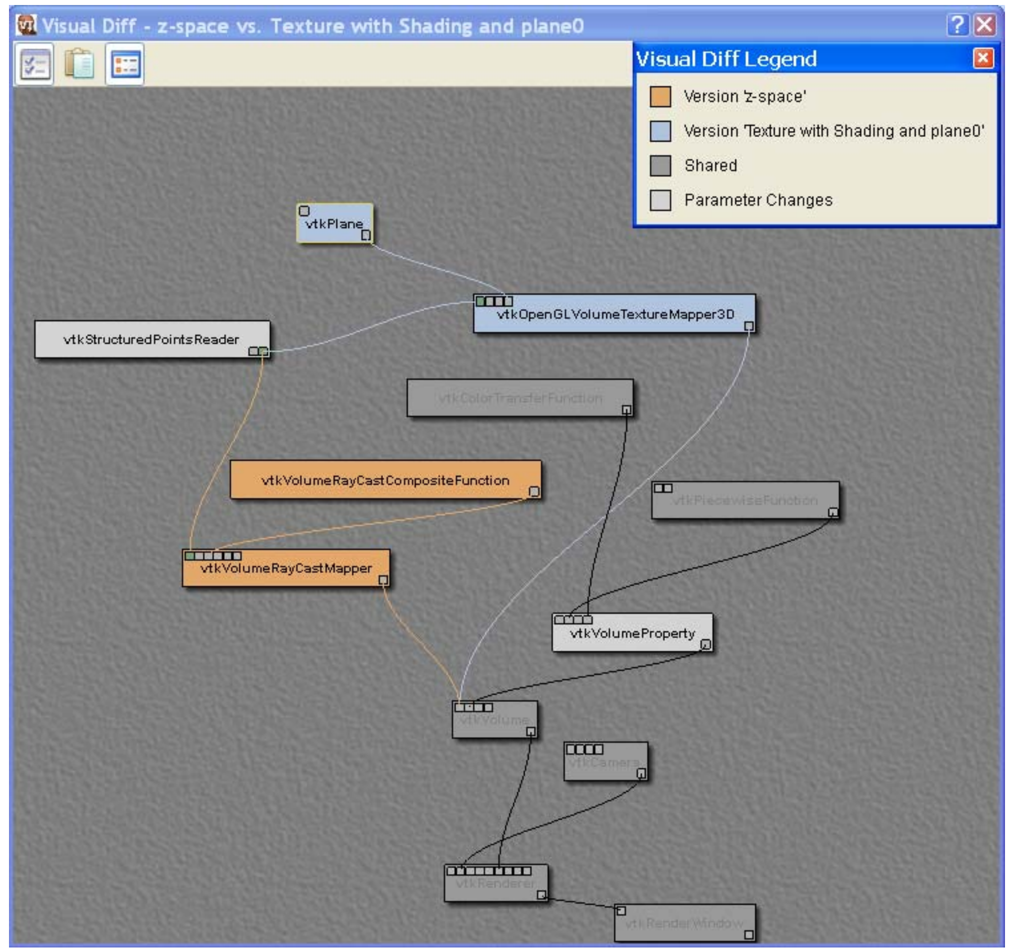
lesionImage1

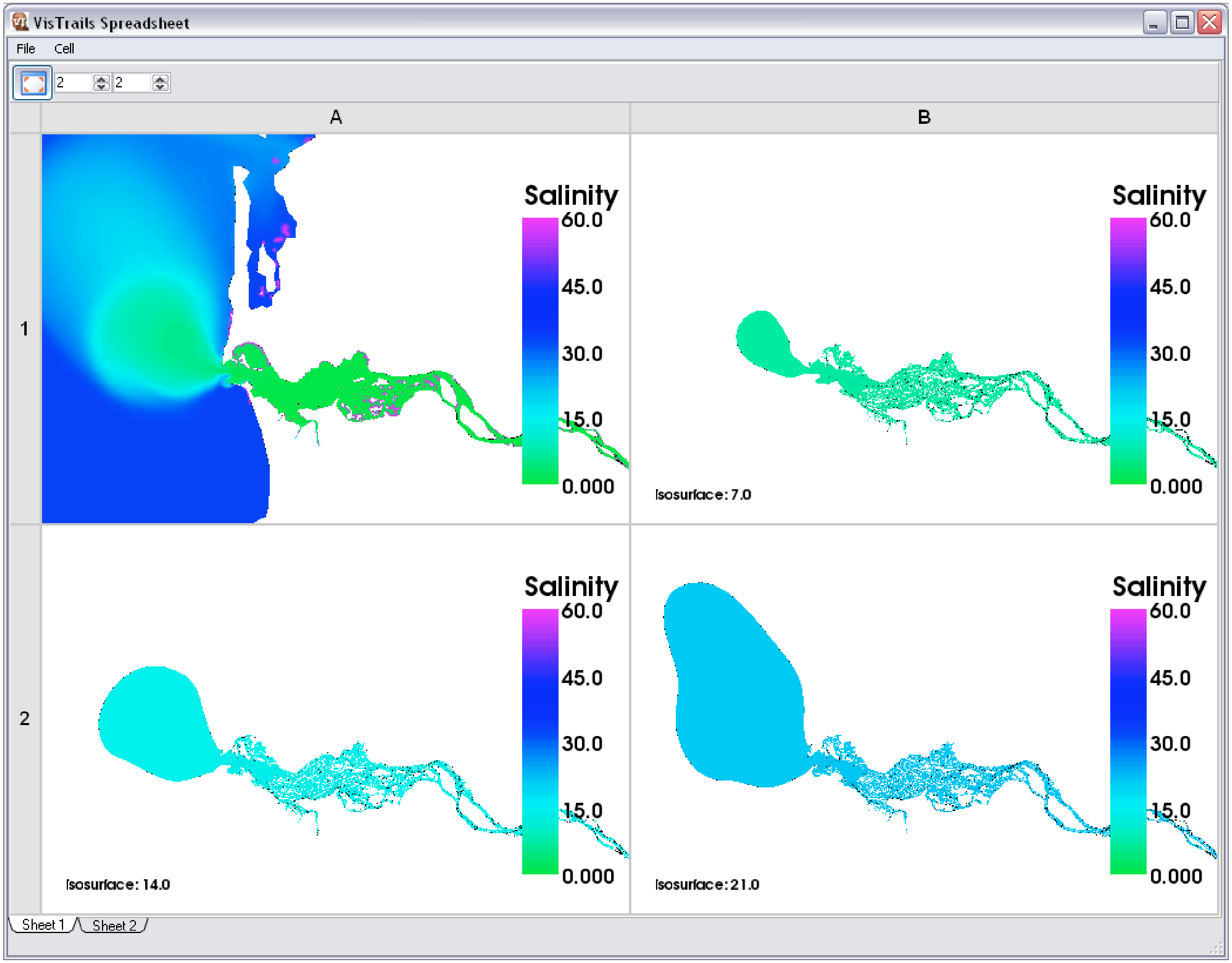
What’s the difference?



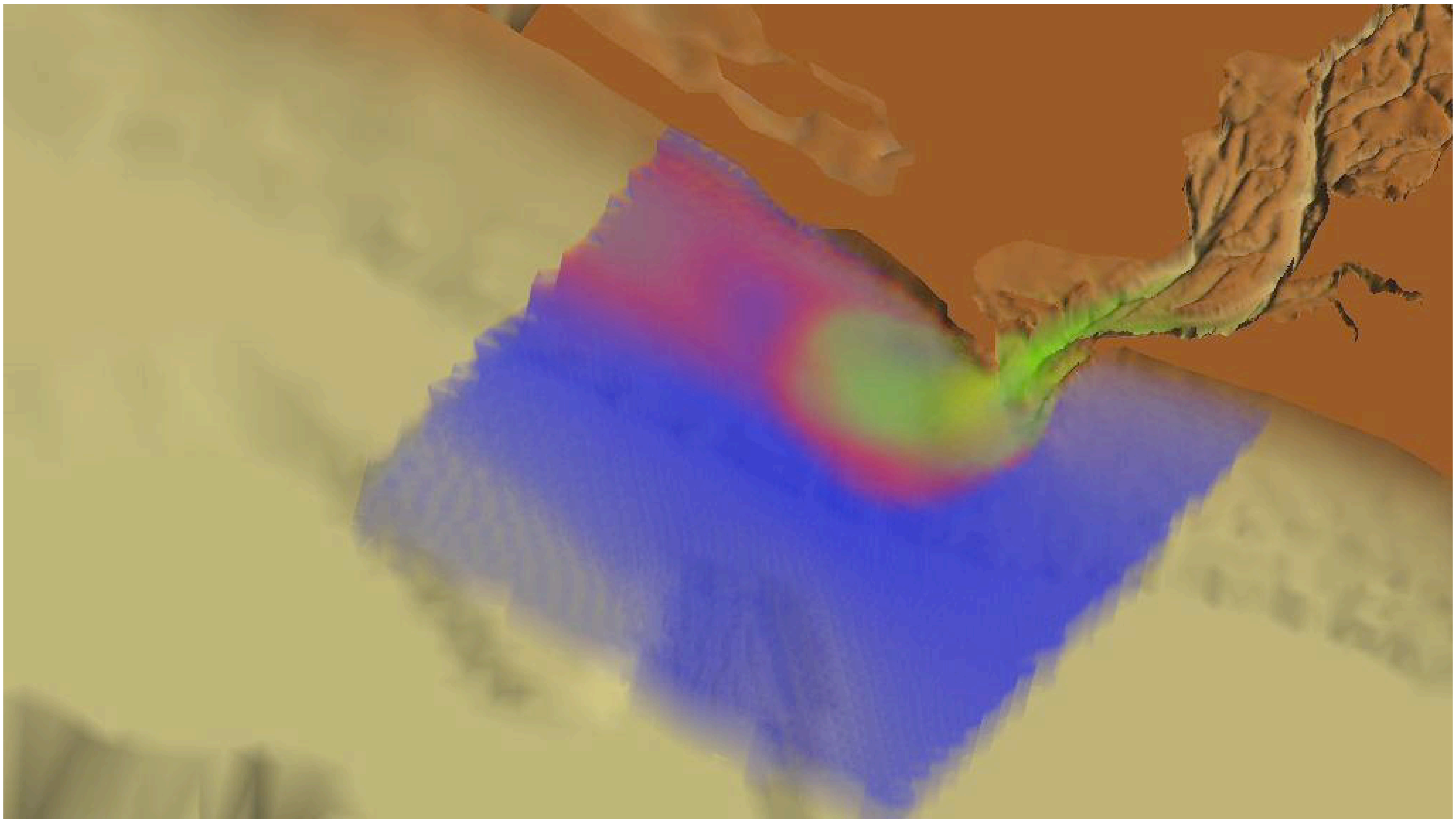
Differences in Specification






VisTrails Spreadsheet
File
Cell
A
B
1
2
Salinity
60.0
45.0
30.0
15.0
0.000
Isosurface: 7.0
Isosurface: 14.0
Isosurface: 21.0
Sheet 1
Sheet 2

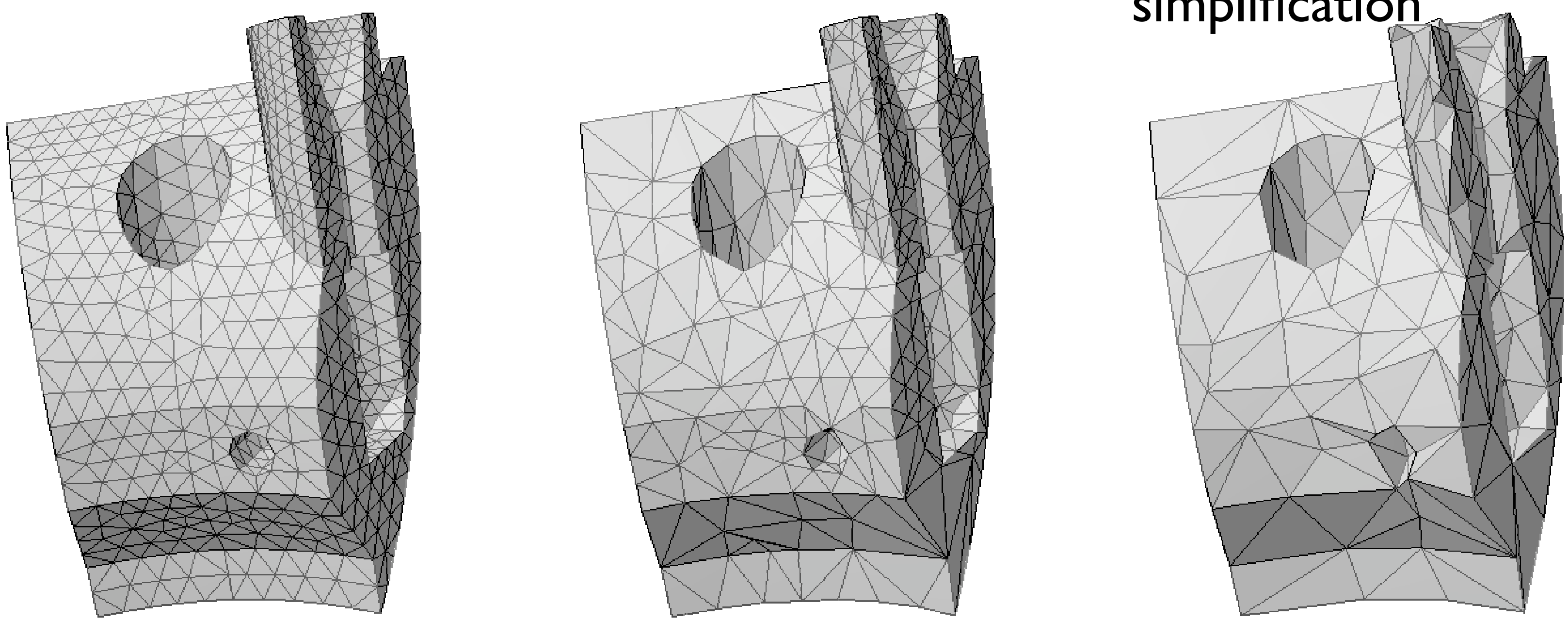
Volume Rendering: Time-Varying Unstructured Grids

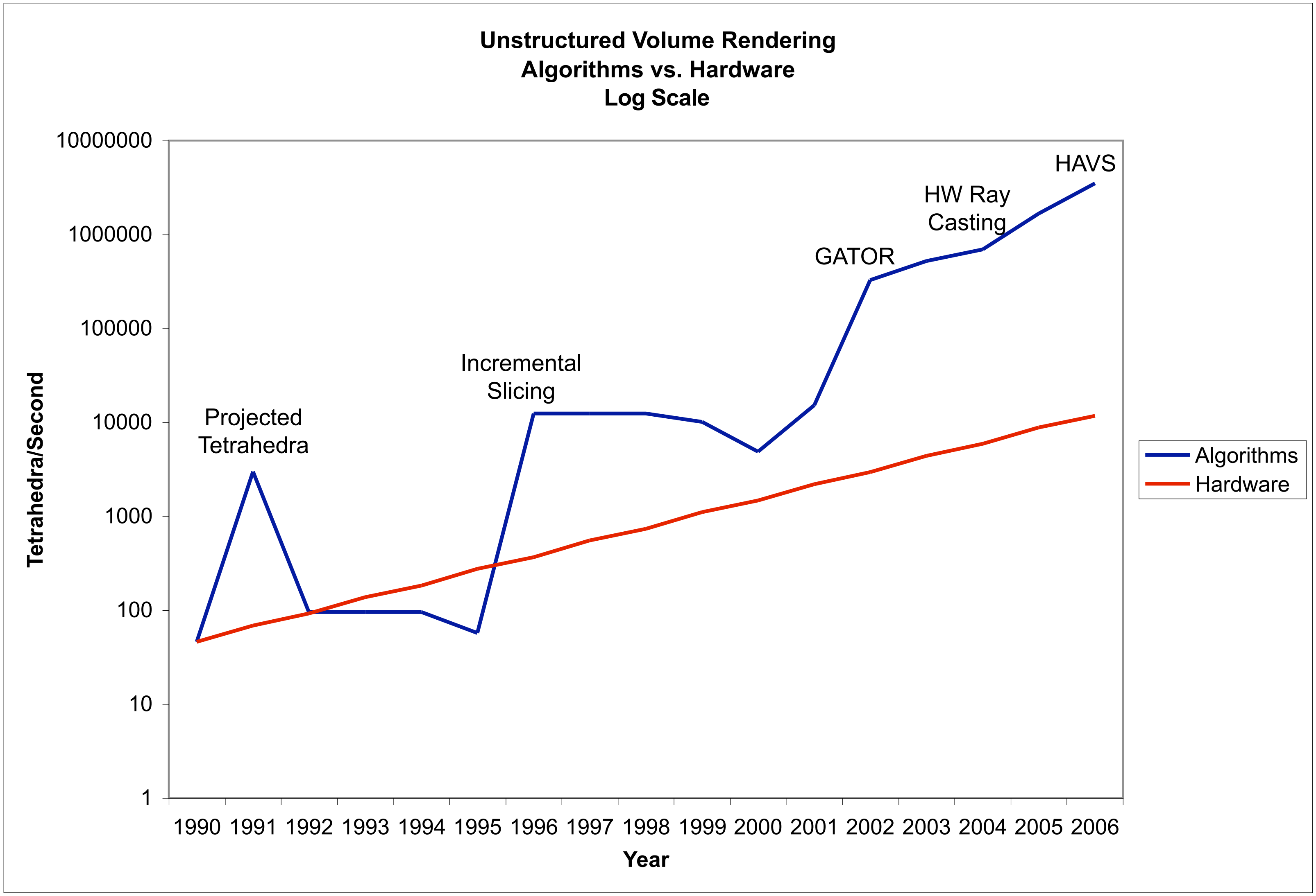


[Jimenez, Correa, Silva, Baptista IEEE Vis 2003]

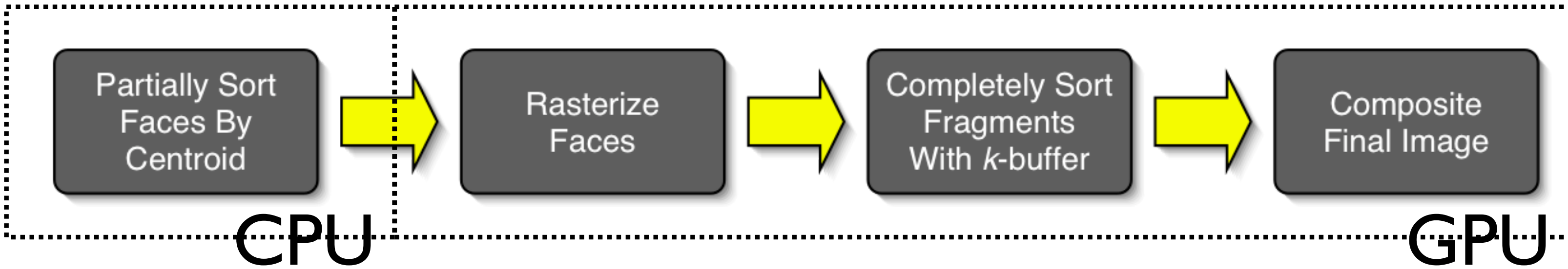
Tet Meshes

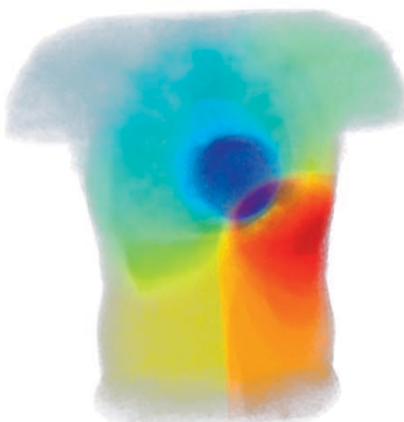
- Larger, multiple time steps, more complex/ geometry is not implicit
- Algorithms need to be more complicated, e.g., simplification

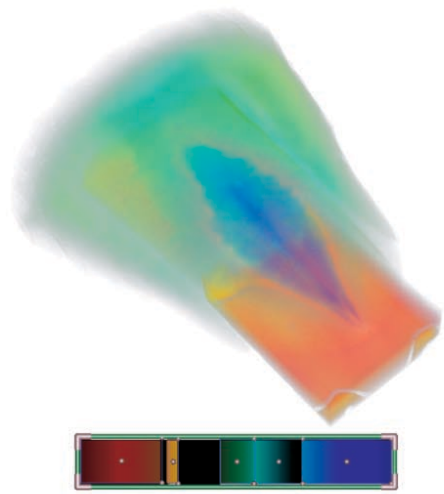



Unstructured Volume Rendering
Algorithms vs. Hardware
Log Scale
Tetrahedra/Second
10000000
1000000
100000
10000
1000
100
10
1
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
Year
Projected Tetrahedra
Incremental Slicing
GATOR
HW Ray Casting
HAVS
Algorithms
Hardware

HAVS - Hardware Assisted Visibility Sorting

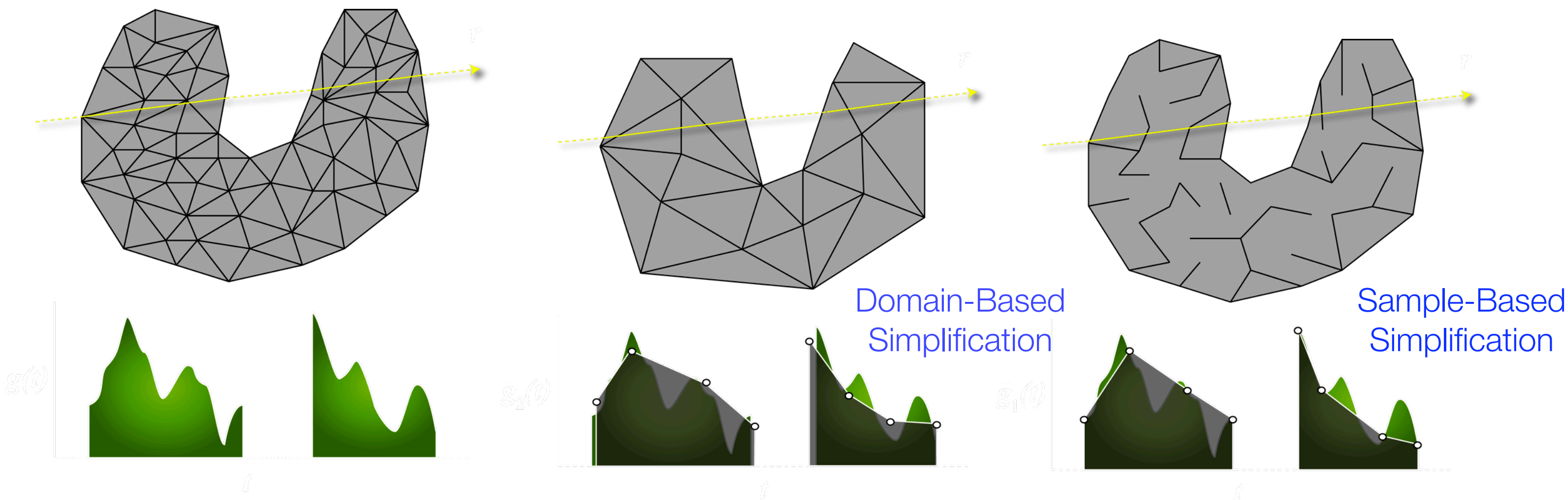


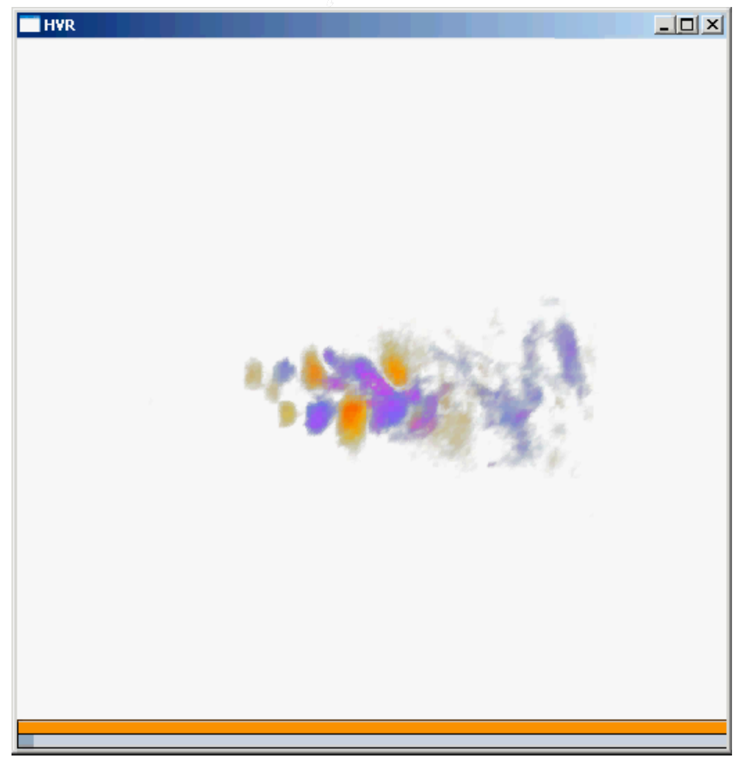




[Callahan, Ikits, Comba, Silva IEEE TVCG 2005]

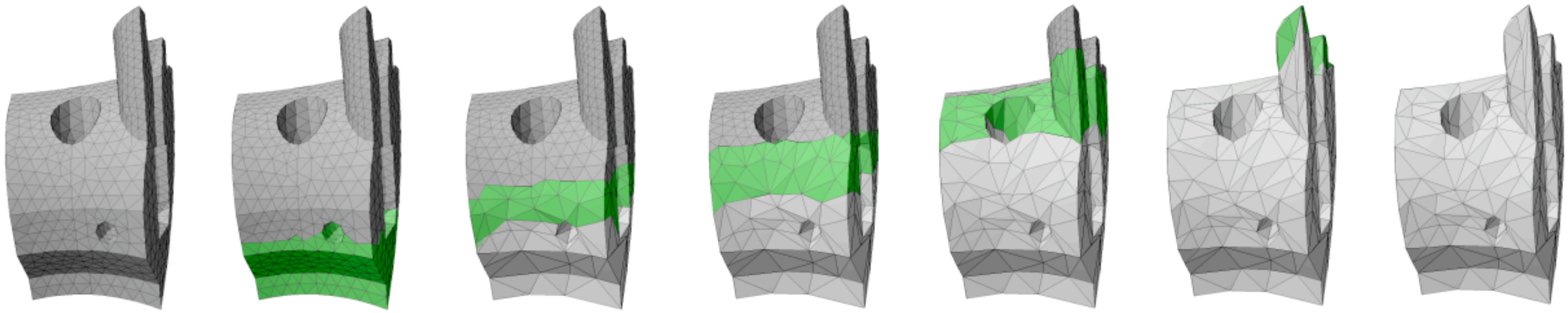
Dynamic Level-of-Detail

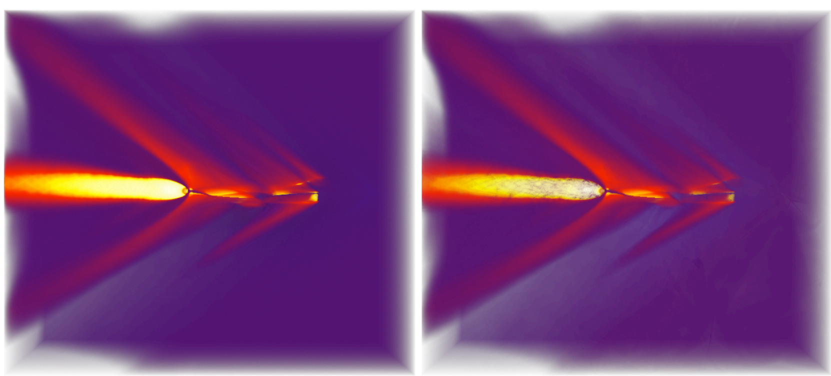


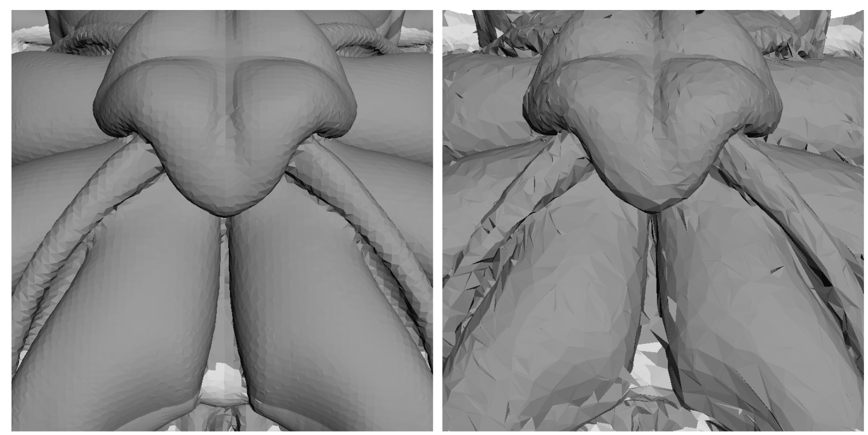


[Callahan, Comba, Shirley, Silva IEEE Vis 2005]

Streaming algorithms: Handling extremely large datasets





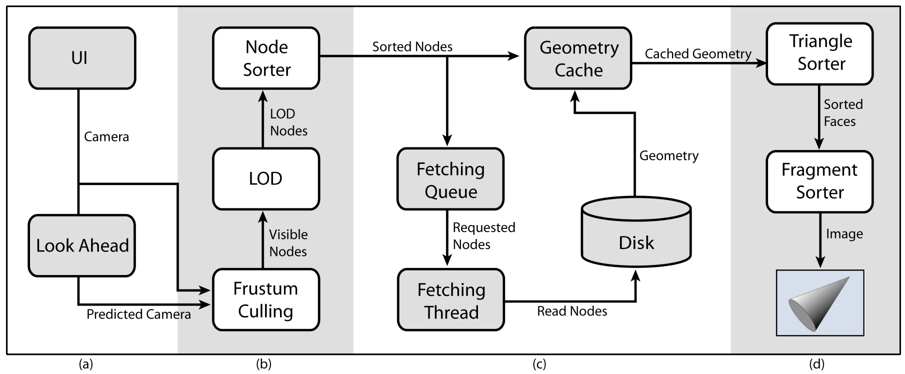


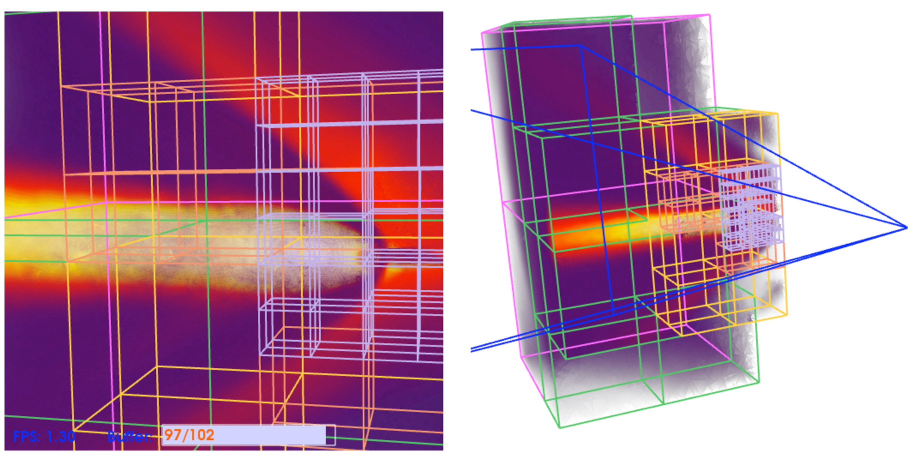
over 1 Billion tets

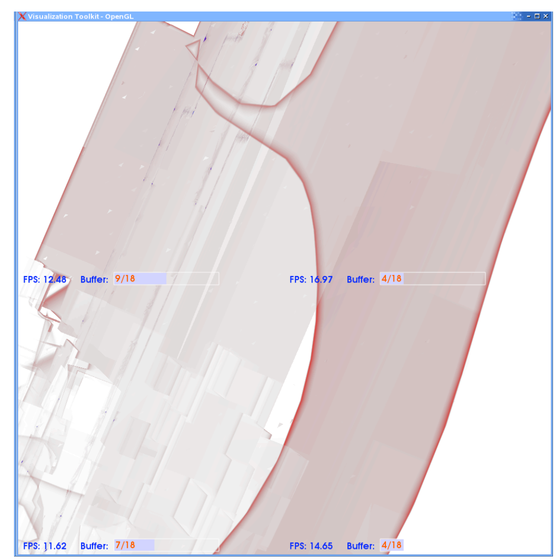
12 Million tets
1.57% RMS

[Vo, Callahan, Lindstrom, Pascucci, Silva IEEE TVCG to appear]

iRun: Out-of-core multi-view rendering







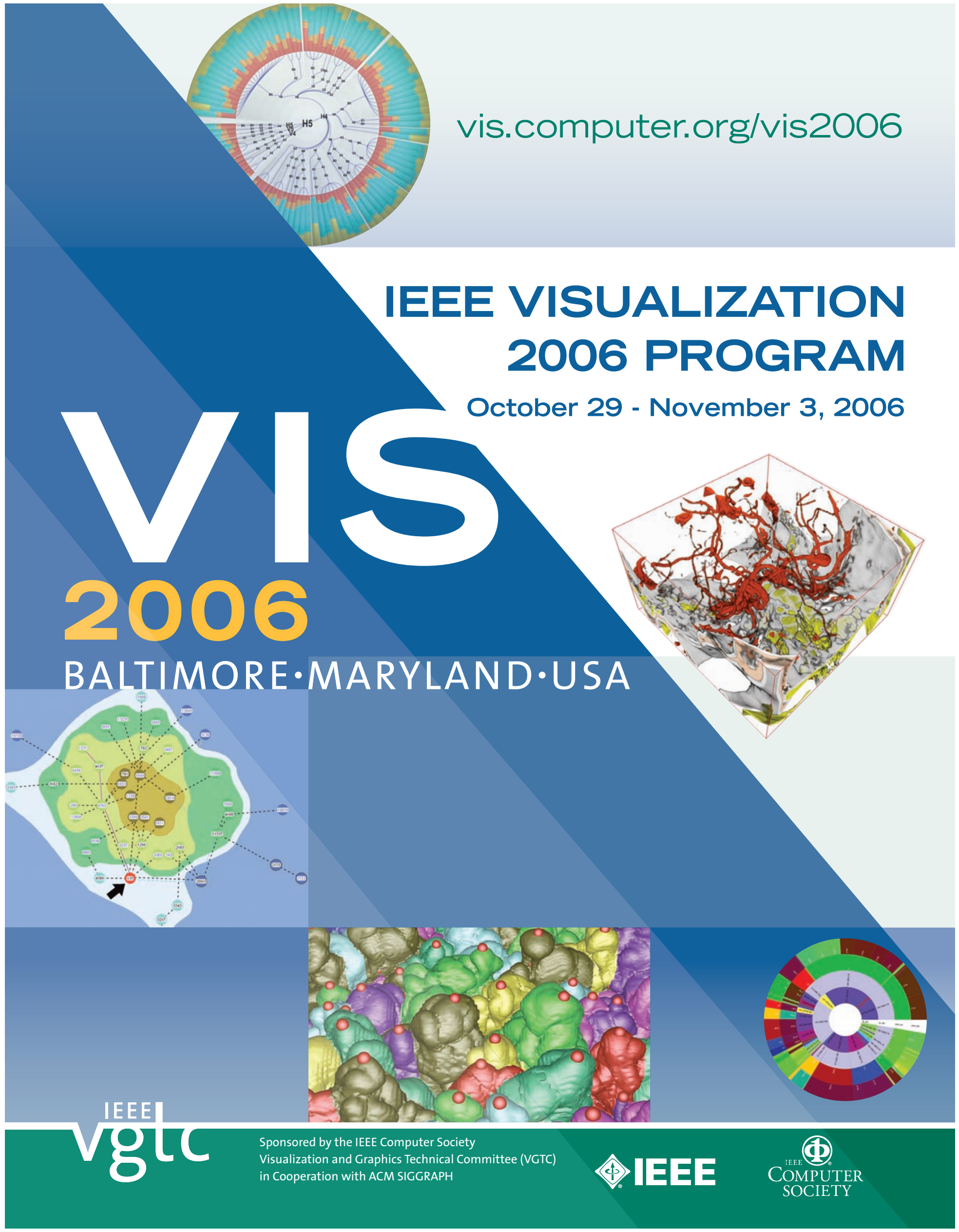
[Vo, et al; to be submitted]

Deployment

- http://havs.sourceforge.net
- http://www.vtk.org
  - vtkHAVSVolumeMapper
  - vtkUnstructuredGridVolumeZSweepMapper
  - vtkUnstructuredGridBunykRayCastFunction
- http://www.paraview.org
- SCIRUN http://software.sci.utah.edu

Summary

- Visualization is an iterative process that should be integrated into the scientific process.
- Visualization techniques have advanced substantially since the late 80s, with some sub-areas more advanced than others (eg, medical). Continuing research is key to sustaining the rate of progress.
- State-of-the-art techniques are (slowly) being implemented into widely available packages. There is a real need of more work on deployment.
- Visualization researchers are always looking for collaborators. Visit our lab! (or the lab of one of your Visualization colleagues)


vis.computer.org/vis2006
IEEE VISUALIZATION
2006 PROGRAM
October 29 - November 3, 2006
VIS
2006
BALTIMORE·MARYLAND·USA
IEEE
vgtc
Sponsored by the IEEE Computer Society
Visualization and Graphics Technical Committee (VGTC)
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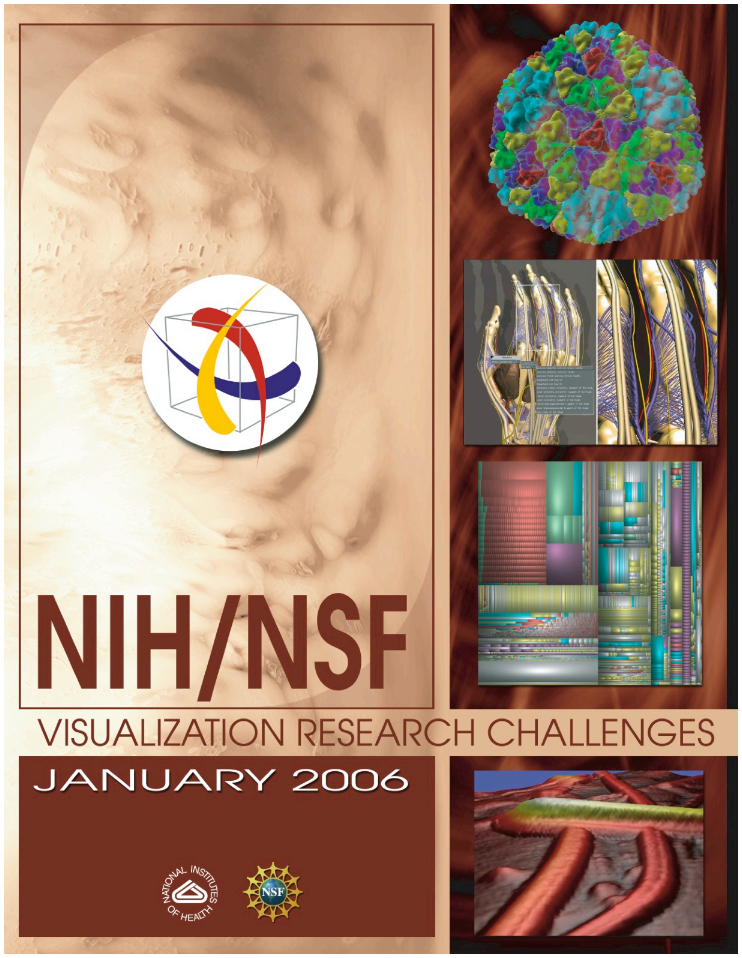
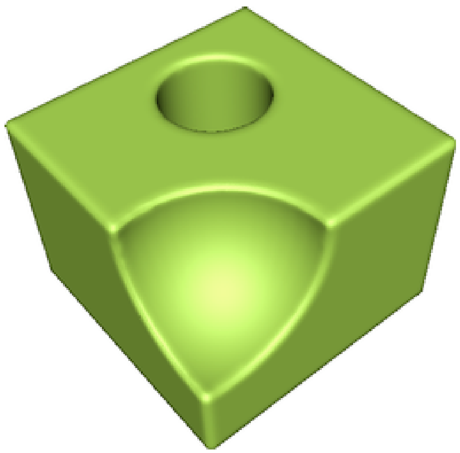
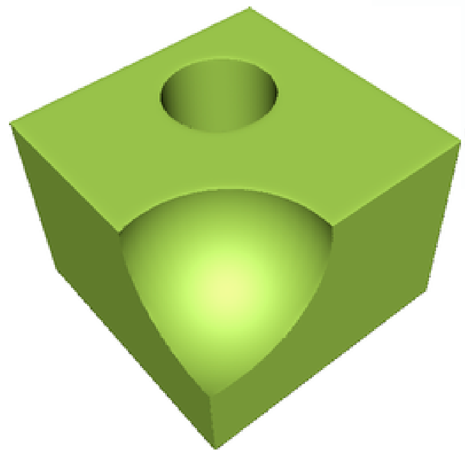
SOCIETY

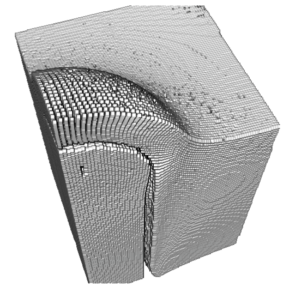


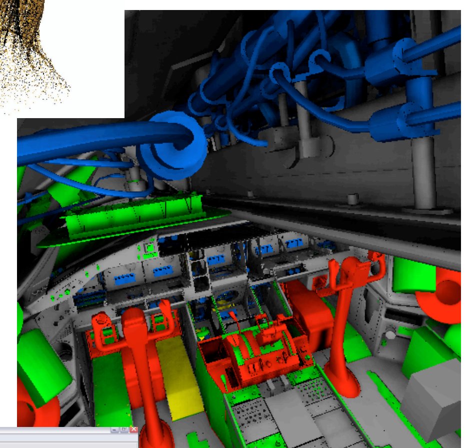
http://tab.computer.org/vgtc

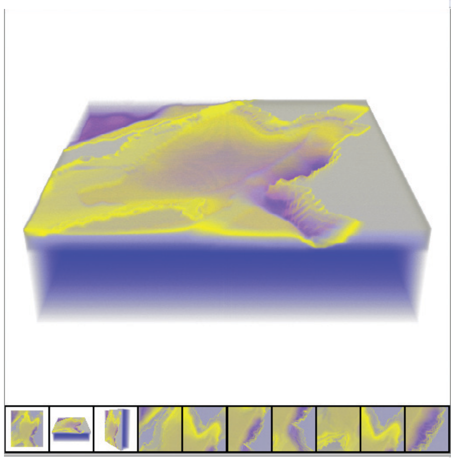
Things I did not have time to talk about...

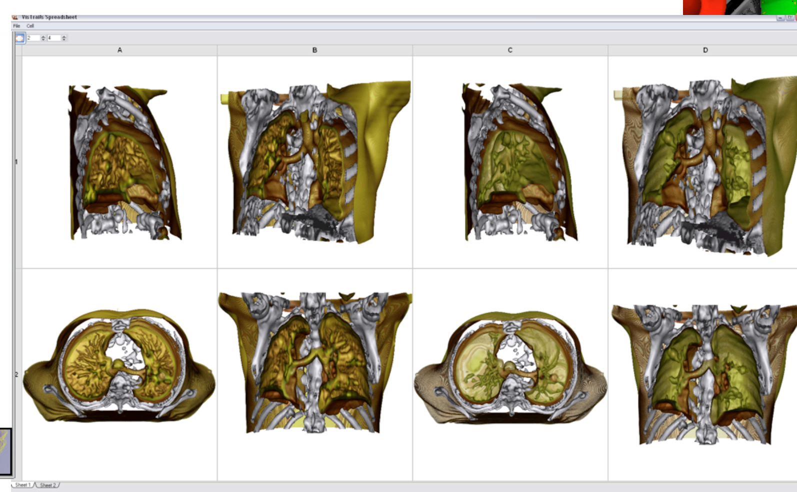


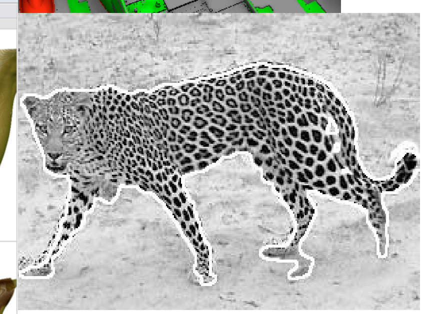












SCI FACULTY


SCIENTIFIC COMPUTING AND IMAGING
INSTITUTE
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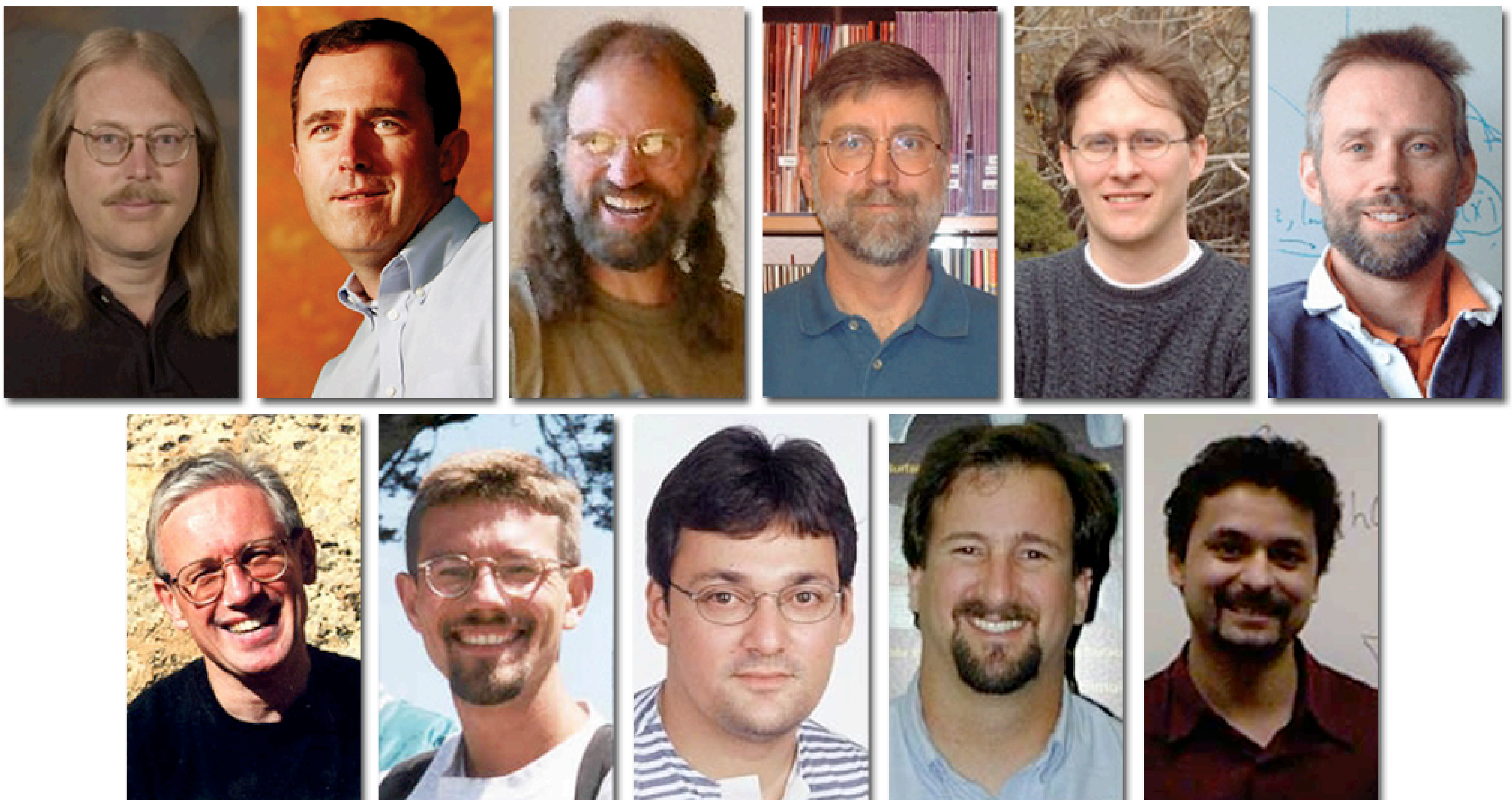
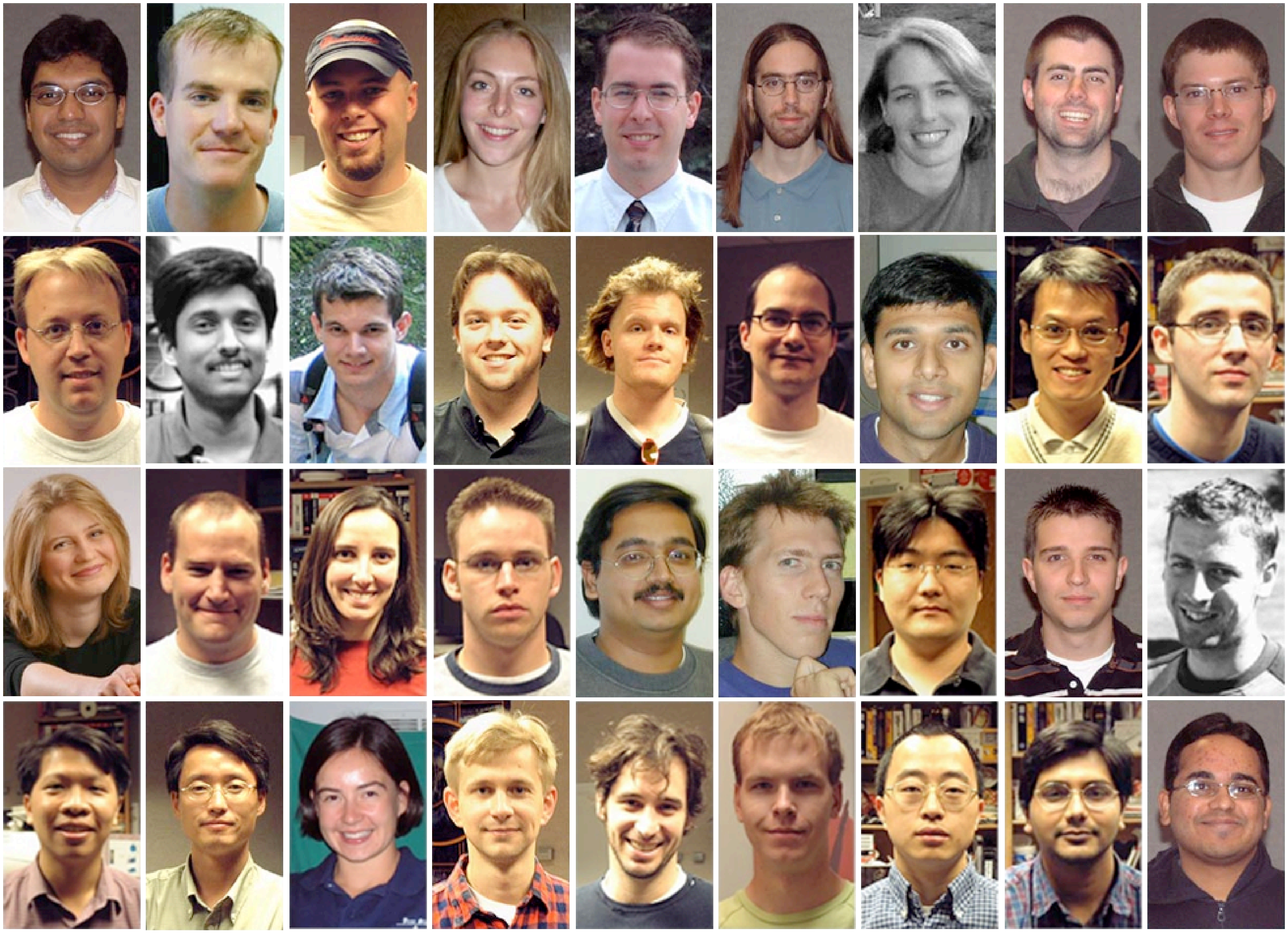


SCI GRADUATE STUDENTS



2006

Acknowledgments

- National Science Foundation
- Department of Energy
- IBM Faculty Award
- University of Utah Seed Grant
- National Institutes of Health
- Army Research Office