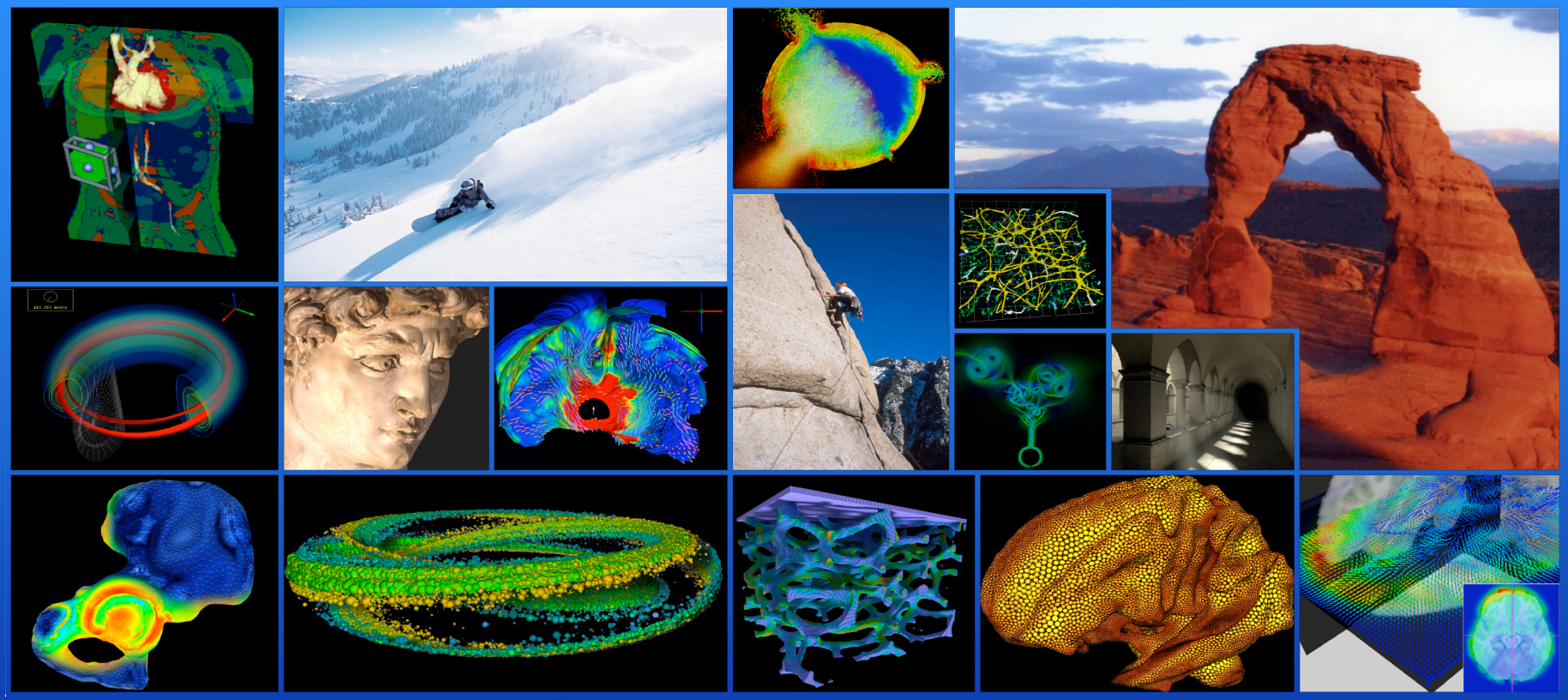
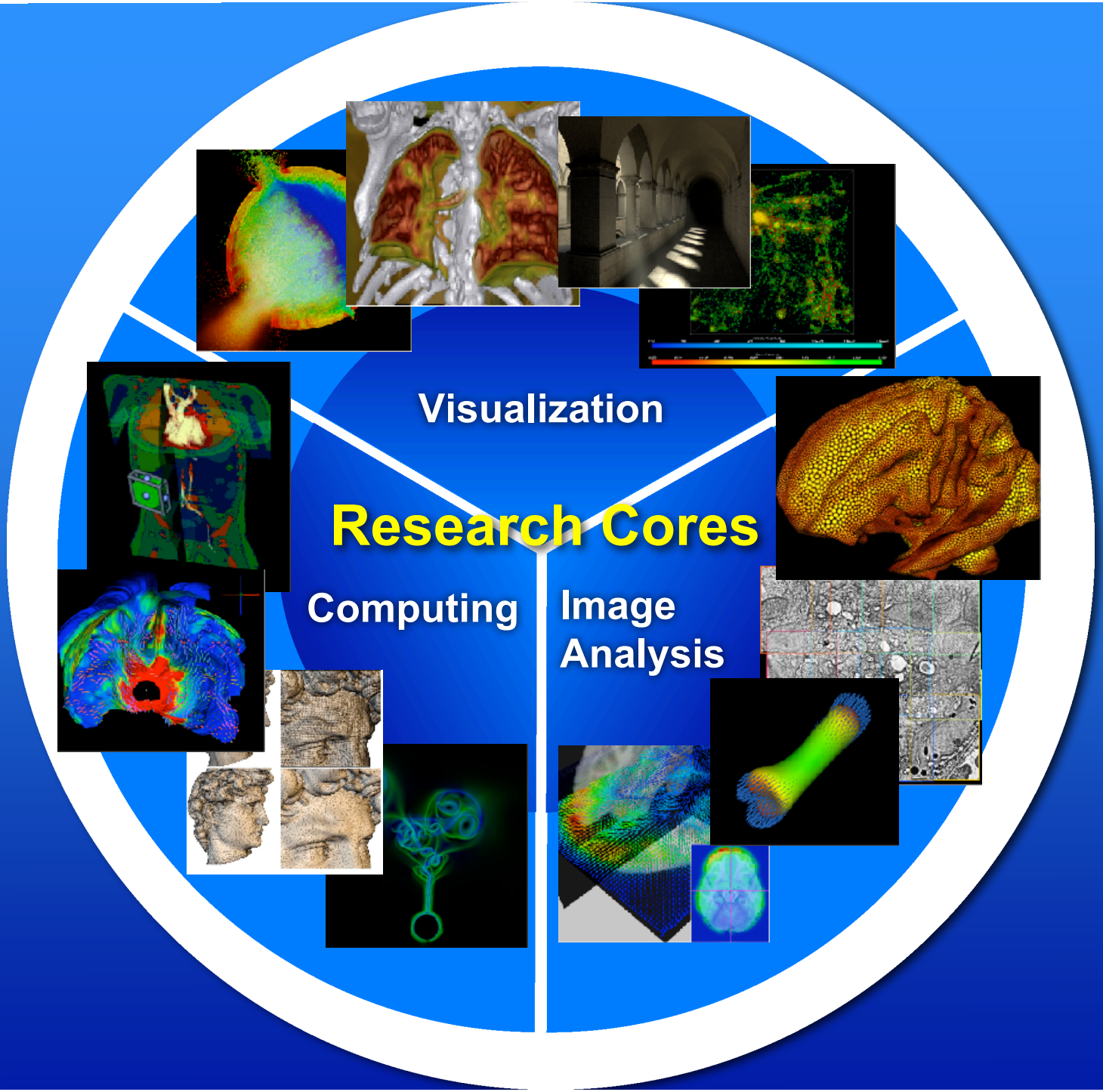
Image Based Modeling, Simulation, and Visualization

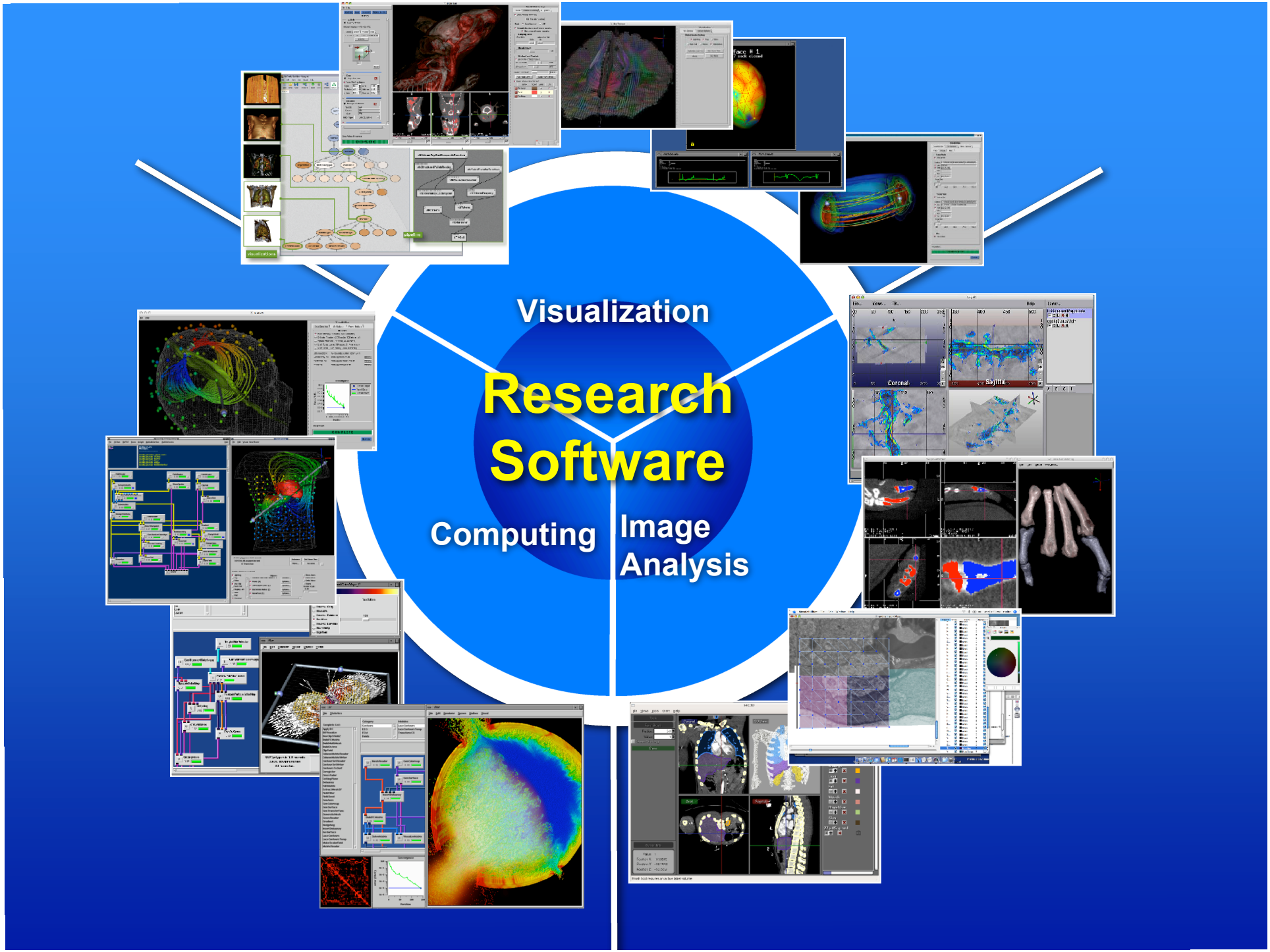


Chris Johnson

Scientific Computing and Imaging Institute

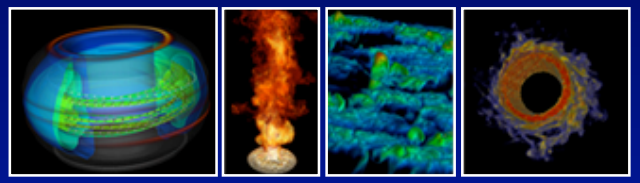
University of Utah


Research Cores
Visualization
Computing
Image Analysis

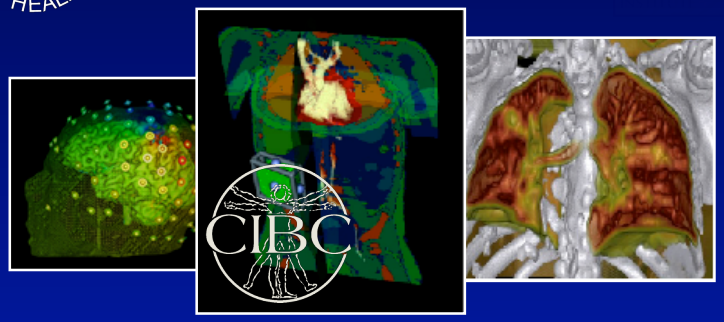

Visualization
Research Software
Computing
Image Analysis

VACET

DOE/SciDAC Visualization and Analytics Center for Enabling Technologies



NIH/NCRR Center for Integrative Biomedical Computing



UTAH Center for Computational Earth Sciences

SCI
www.sci.utah.edu

THE UNIVERSITY OF UTAH

NATIONAL SCIENCE FOUNDATION

CMOP Center for Coastal Margin Observation & Prediction

DOE/SciDAC
Scientific Data Management

SDM CENTER

WFM
Open Wildland Fire Modeling e-community

NIH NAMIC

NIH NAMIC

NIH CBC

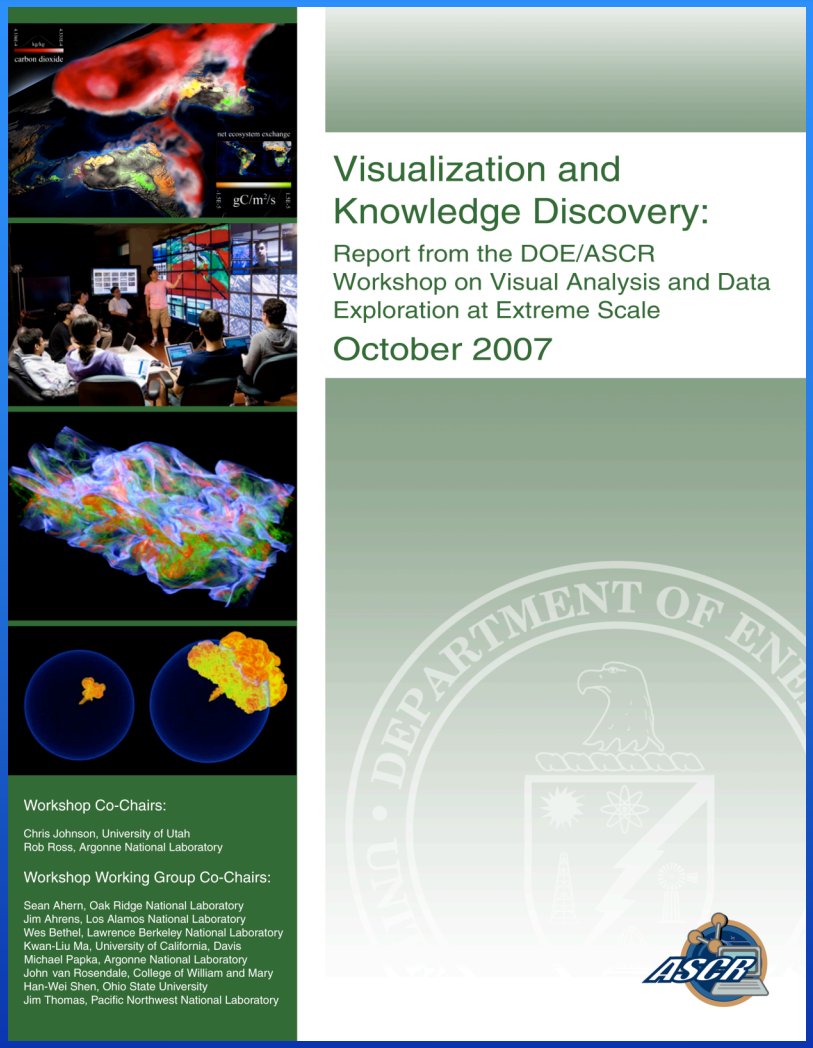
DOE/SciDAC CCA

CCA Common Component Architecture

KAUST

IAMCS
Institute for Applied Mathematics and Computational Science

DOE Visualization Report

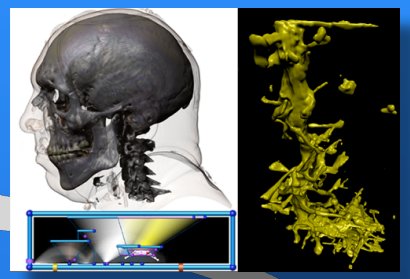


http://www.sci.utah.edu/vaw2007/

Biomedical Computing Pipeline

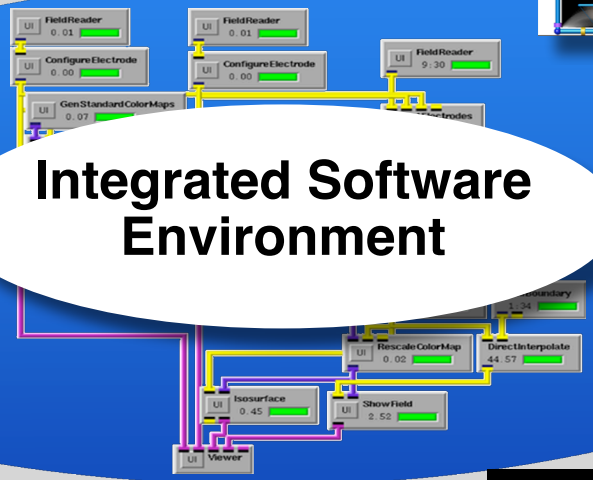
Image & Data Acquisition

Image Processing

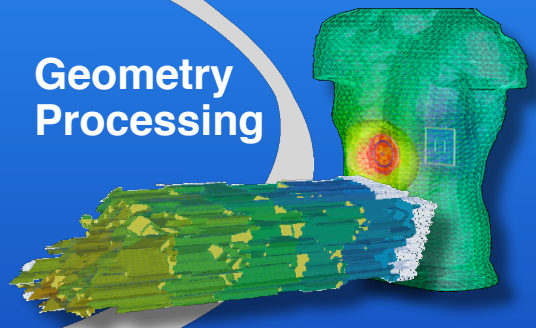


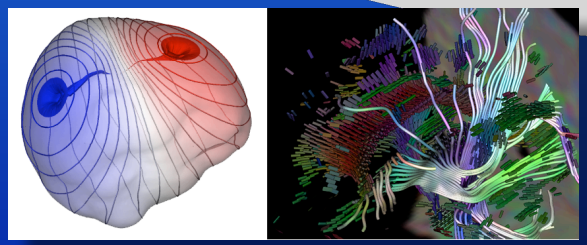
Validation

Integrated Software Environment

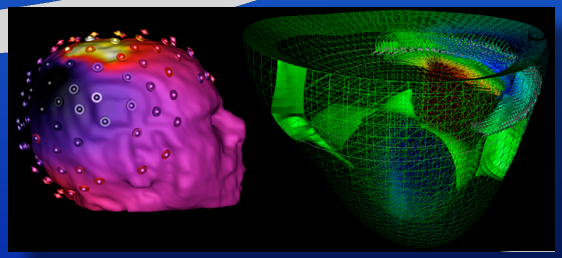


Geometry Processing



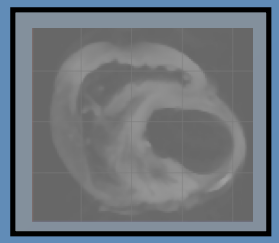


Visualization

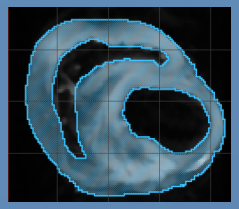


Mathematical Modeling & Simulation

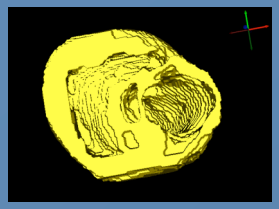
MRI



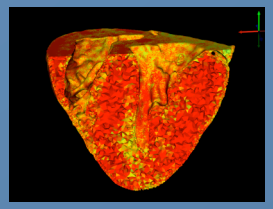
Segmentation



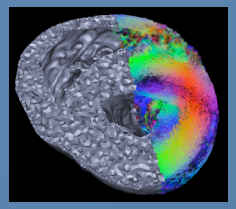
Surfacing



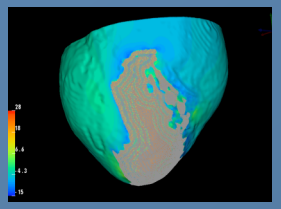
Meshing



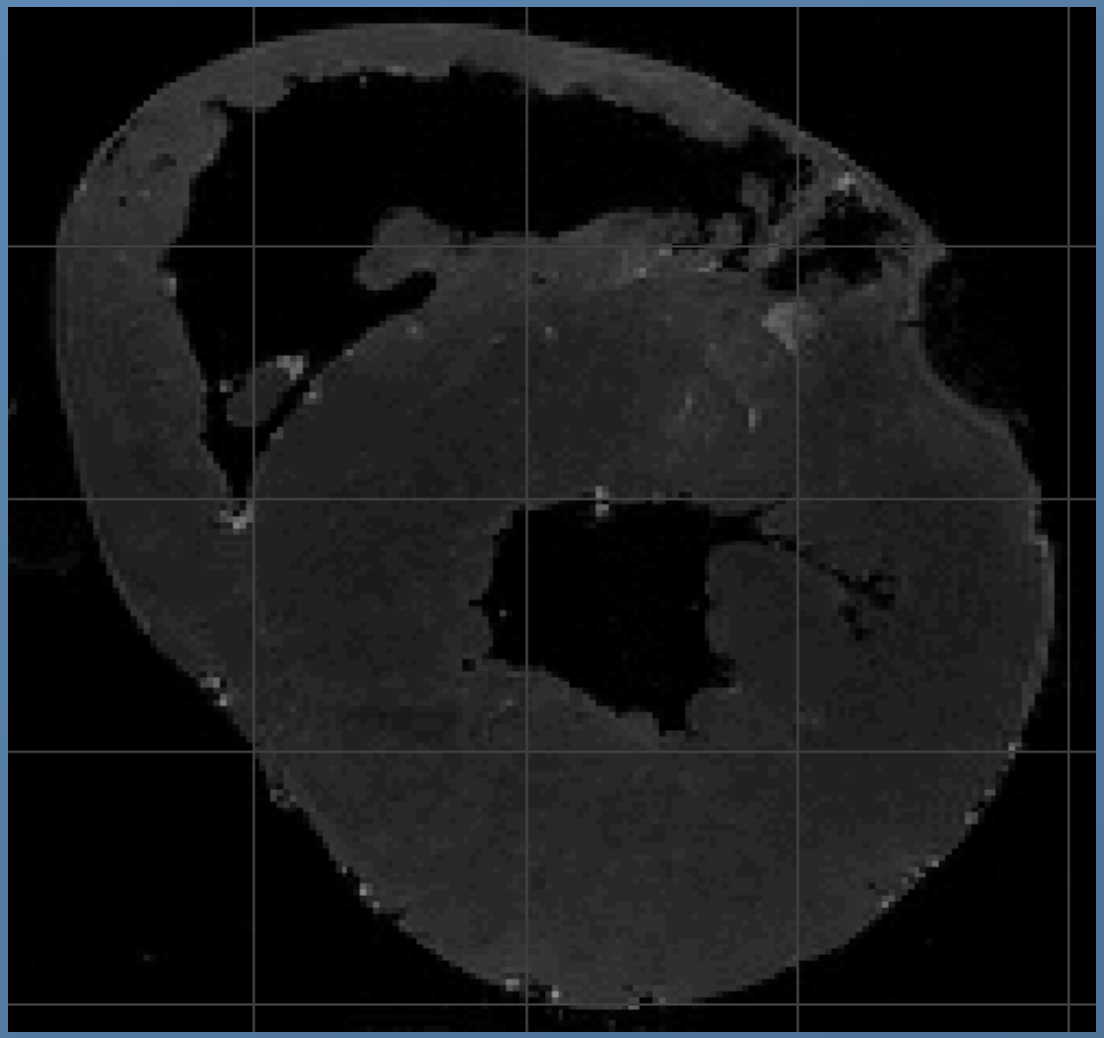
DTI



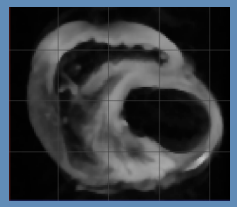
Surface Potentials



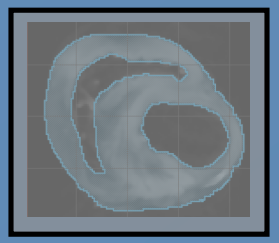
- MRI
- The small animal imaging facility
- 7 tesla scanner
- High resolution and DTI scans
- Gd markers used for registration



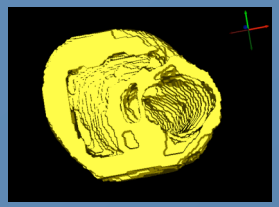
MRI



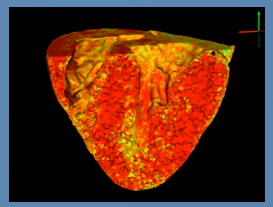
Segmentation



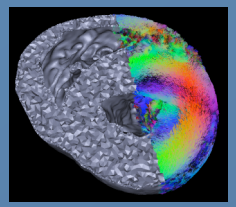
Surfacing



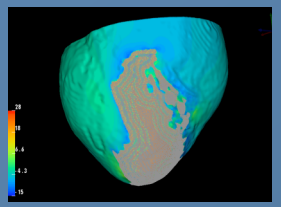
Meshing



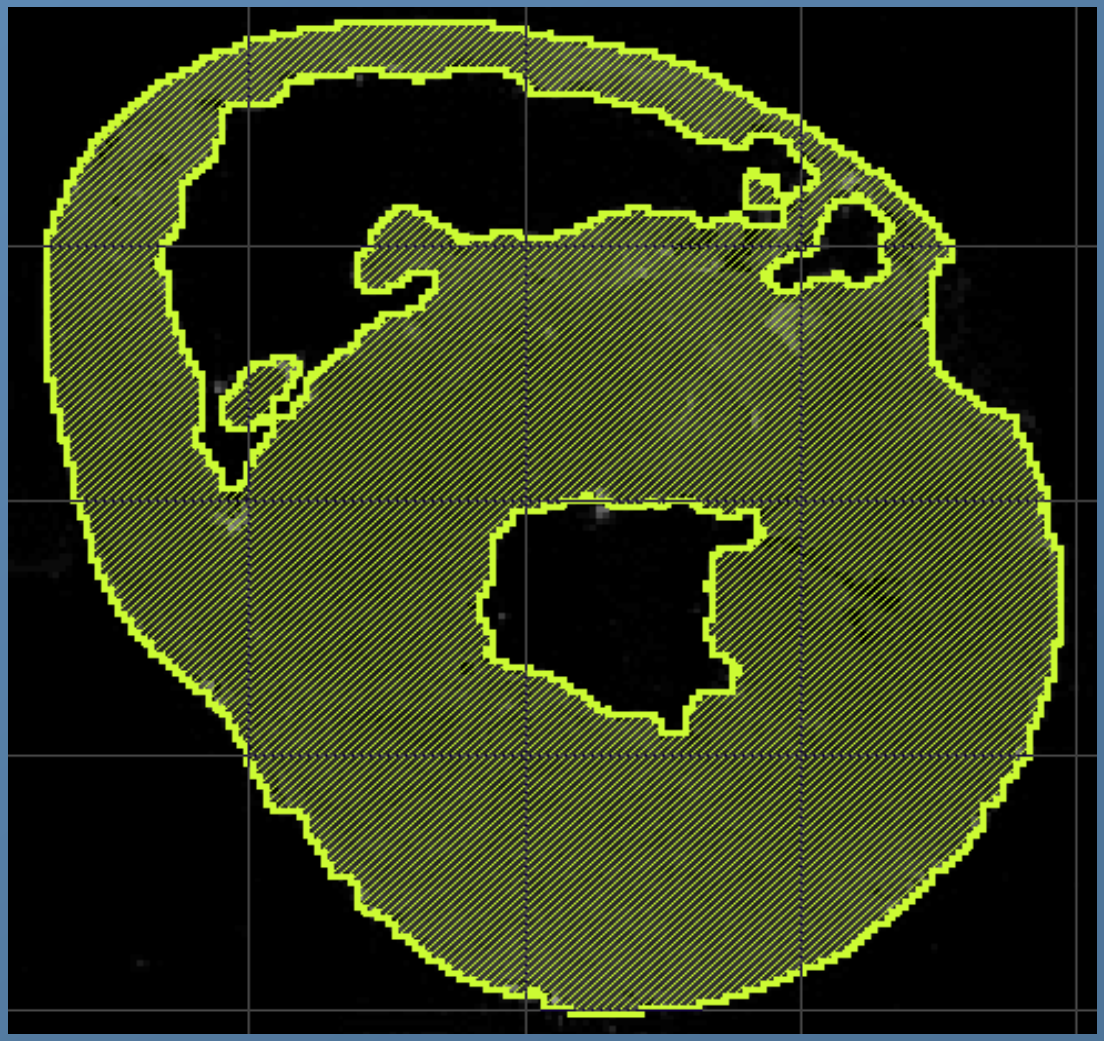
DTI



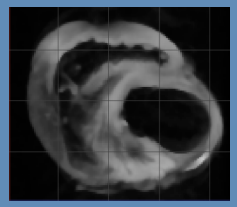
Surface Potentials



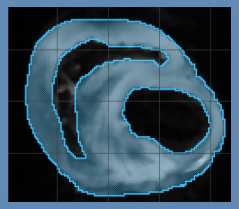
- Segmentation
- Seg3d
- Automated 3d segmentation
- Most scans are done with little to no manual clean up.



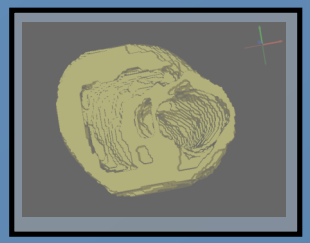
MRI



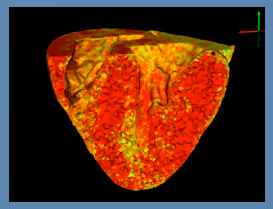
Segmentation



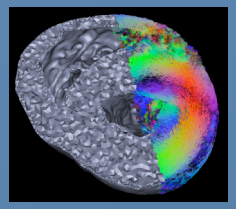
Surfacing



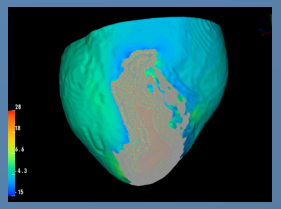
Meshing



DTI

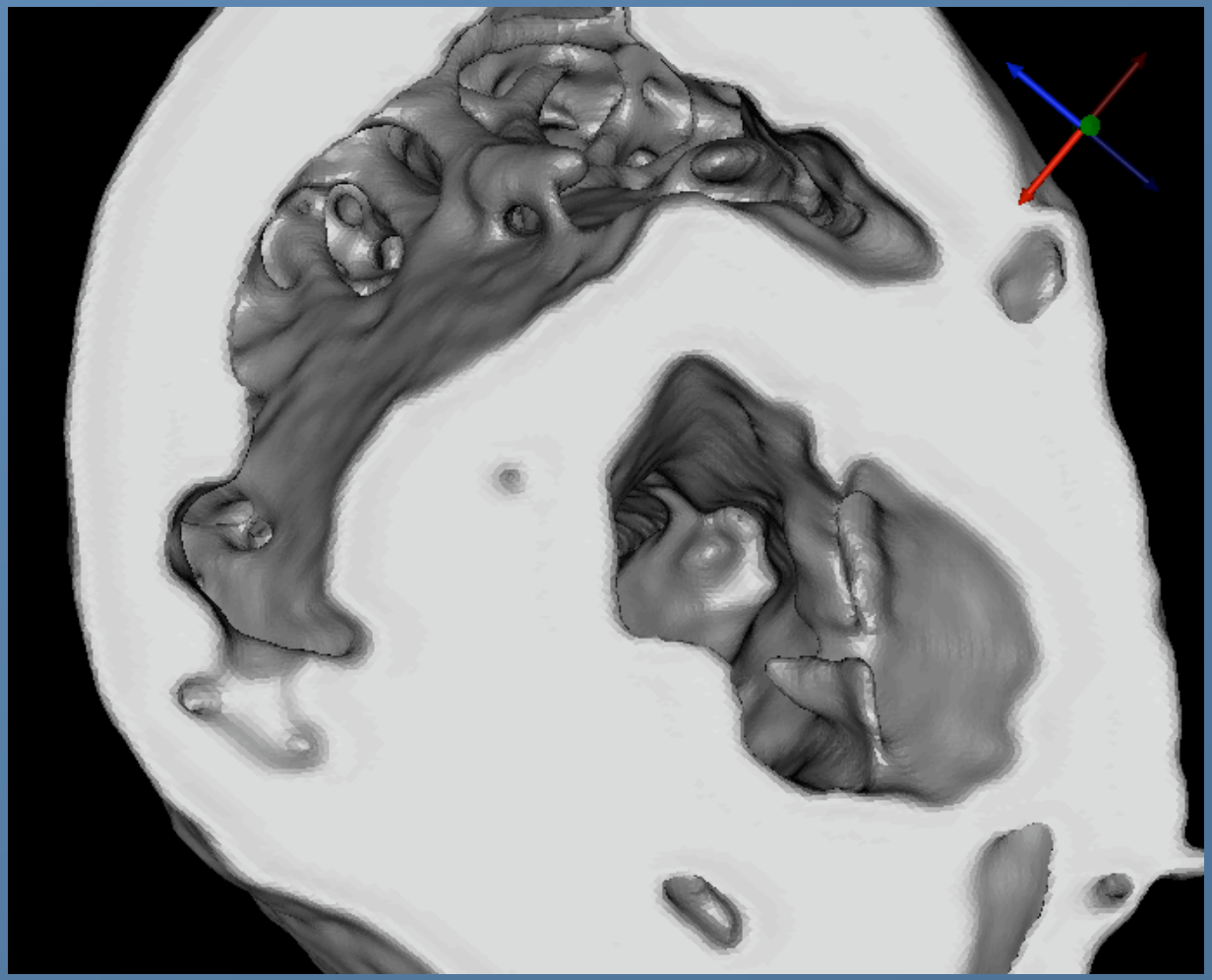


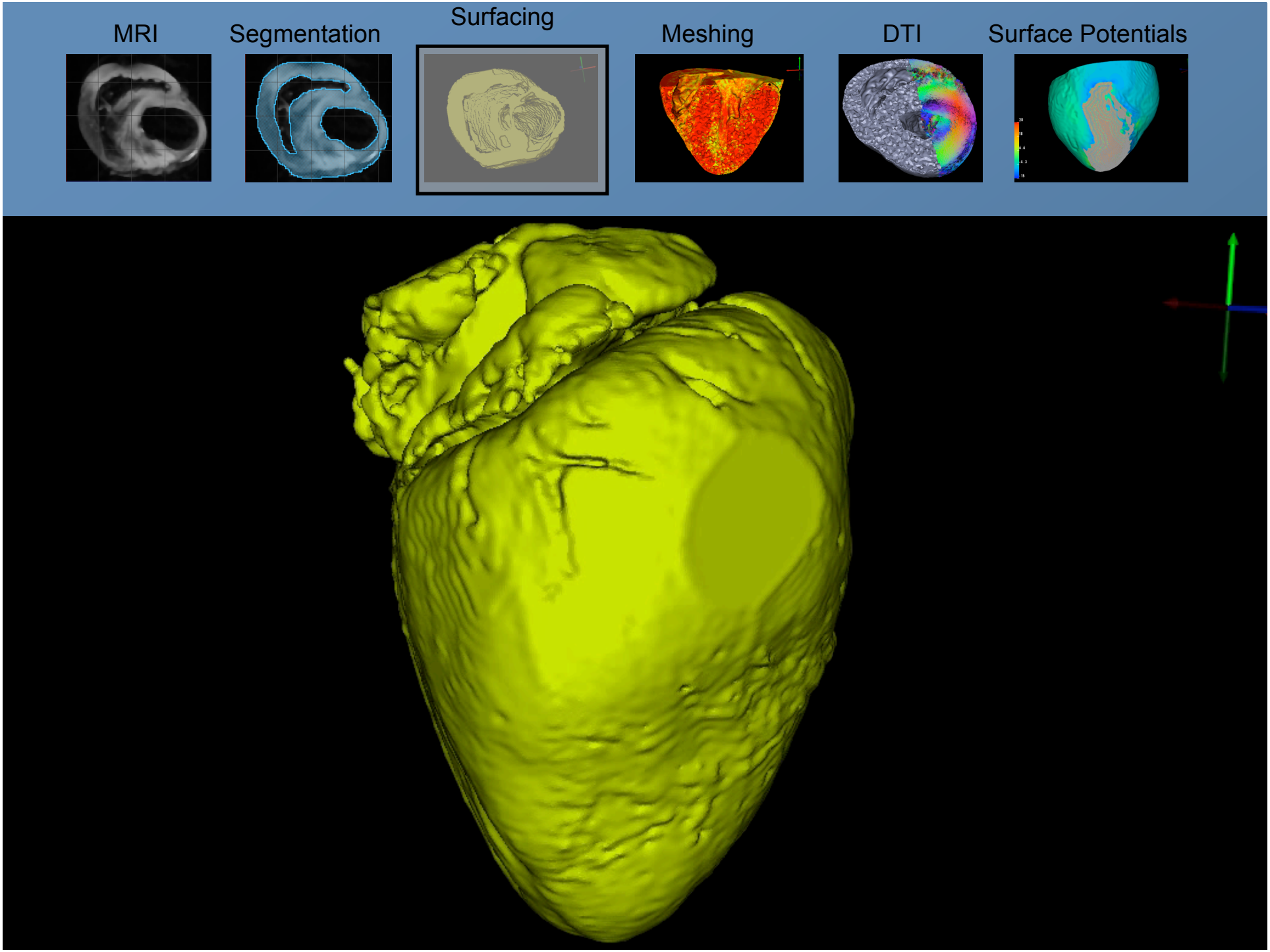
Surface Potentials



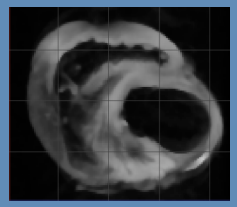
- Marching Cubes
- Fairmesh smoothing
- Includes small geometric detail
- ~400,000 elements

- Particle System
- Includes small geometric detail
- Uses tetgen to generate surface from optimized points

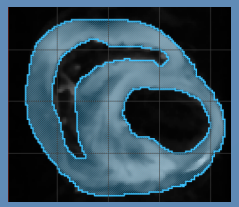



MRI
Segmentation
Surfacing
Meshing
DTI
Surface Potentials

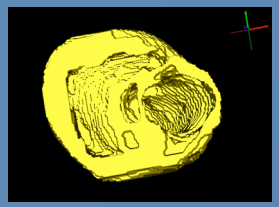
MRI



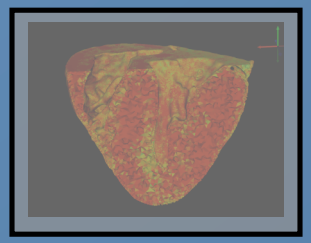
Segmentation



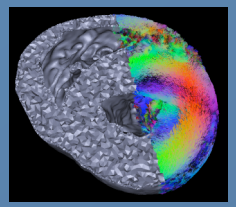
Surfacing



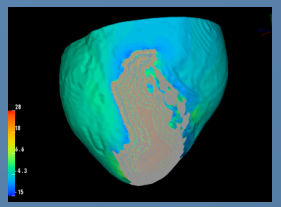
Meshing



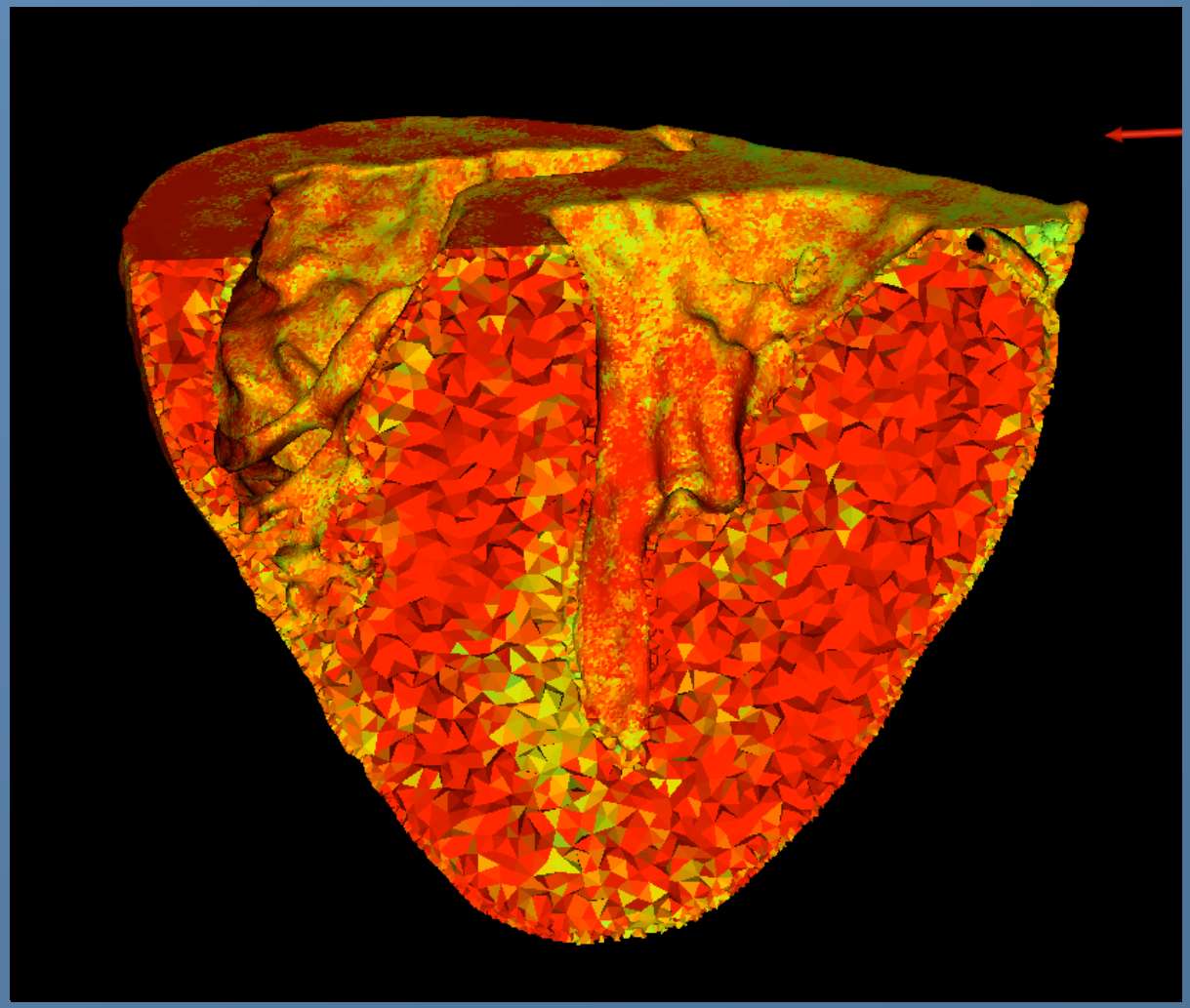
DTI



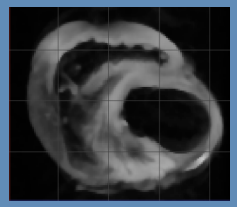
Surface Potentials



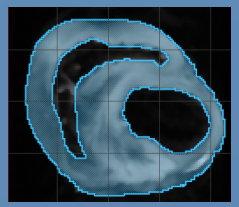
- Meshing
- 1,400,000 Elements
- BioMesh3D



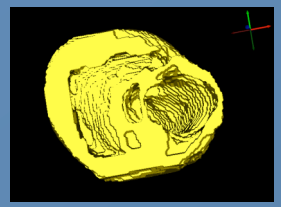
MRI



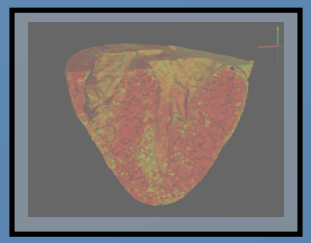
Segmentation



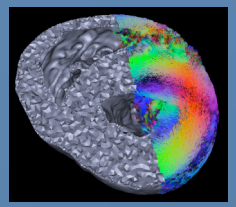
Surfacing



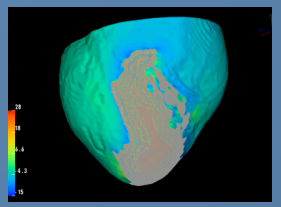
Meshing

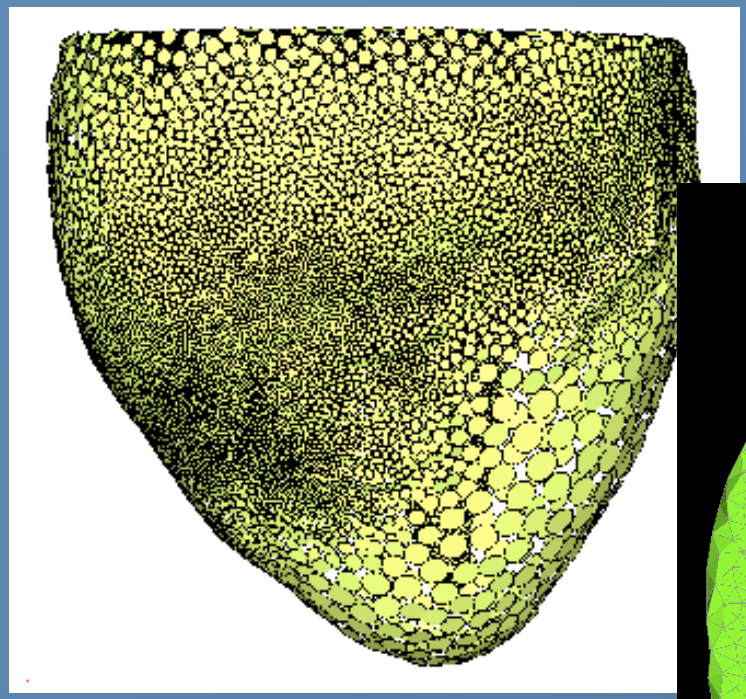


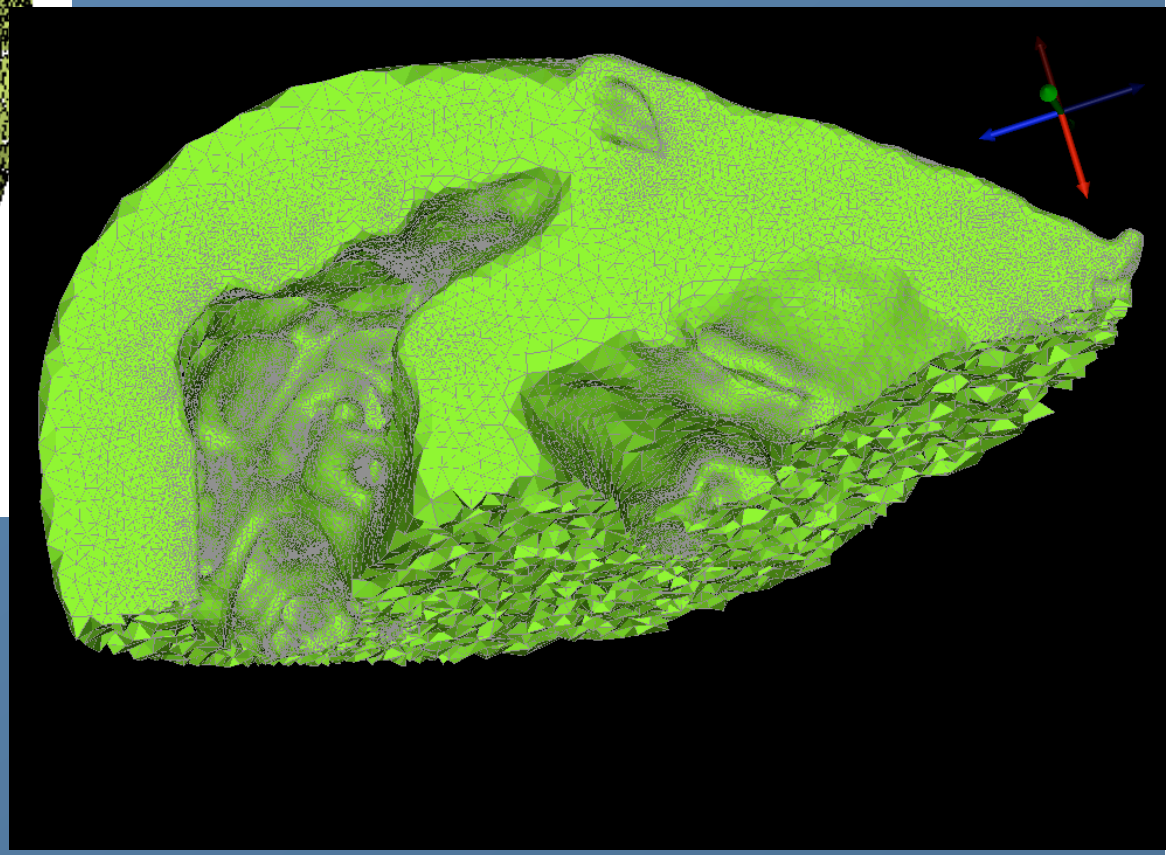
DTI



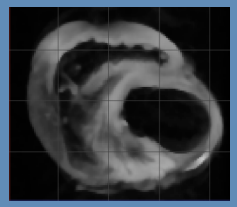
Surface Potentials



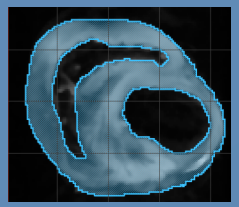




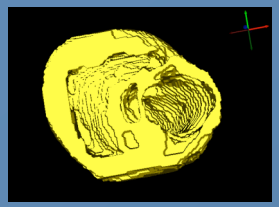
MRI



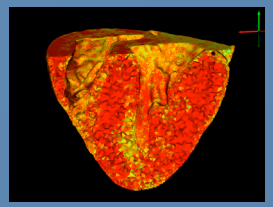
Segmentation



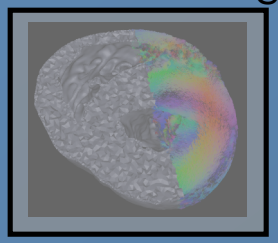
Surfacing



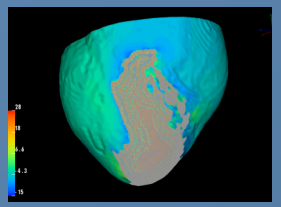
Meshing



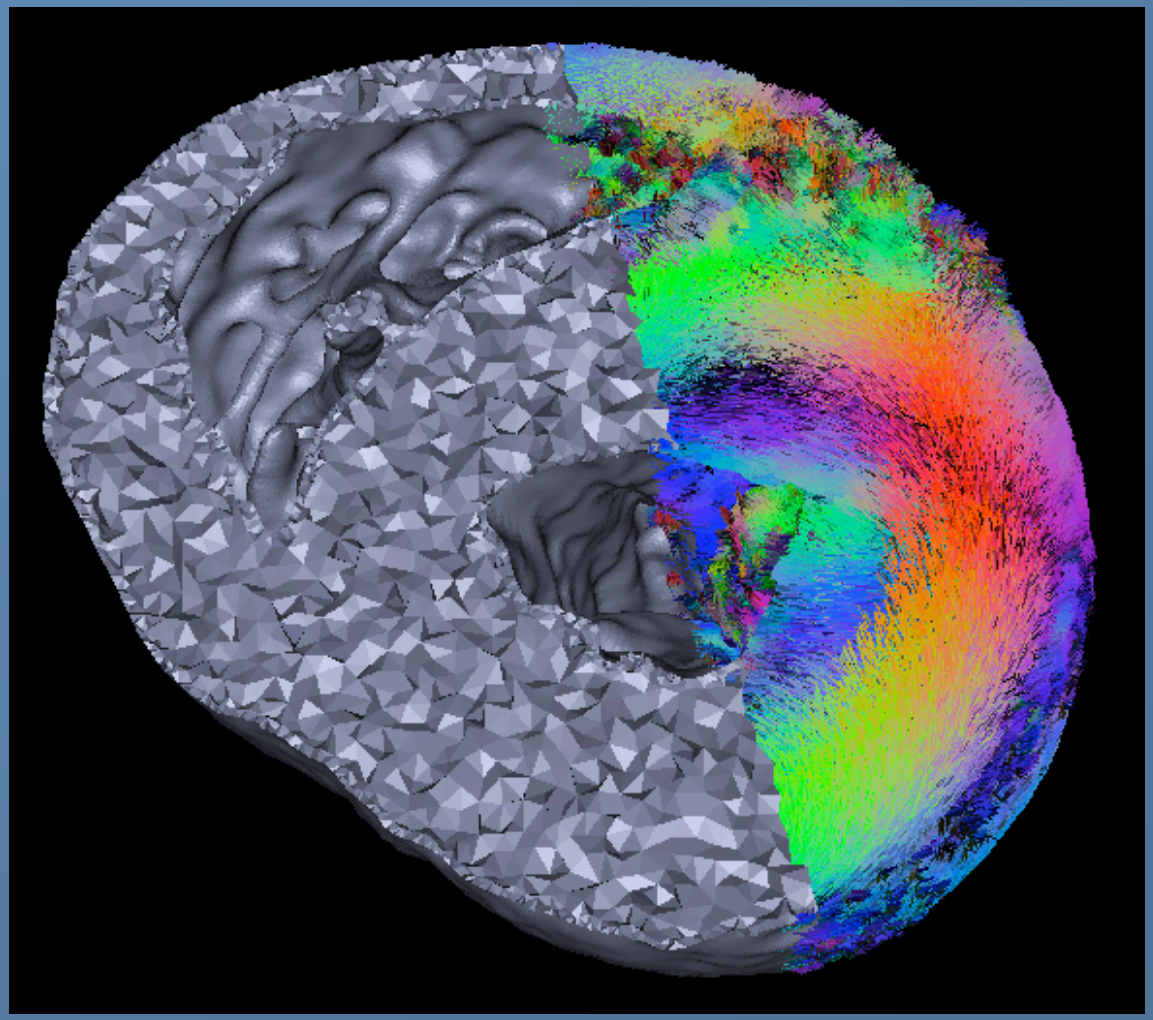
DTI

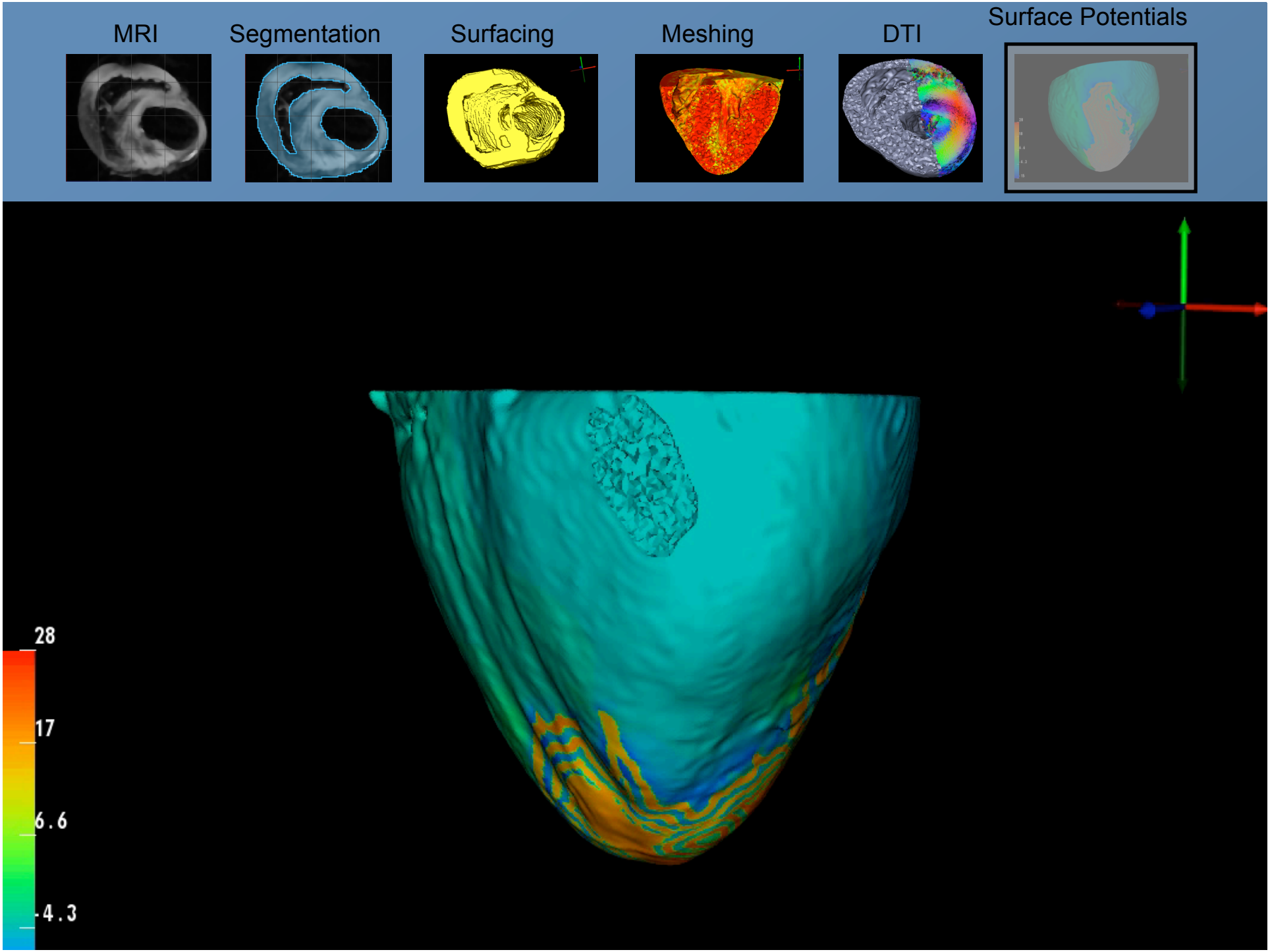


Surface Potentials



- Fiber Direction
- Diffusion tensor imaging
- Anisotropic properties
- Tensor interpolation




MRI
Segmentation
Surfacing
Meshing
DTI
Surface Potentials
28
17
6.6
-4.3

Internal Cardiac Defibrillation

Personalized Medicine

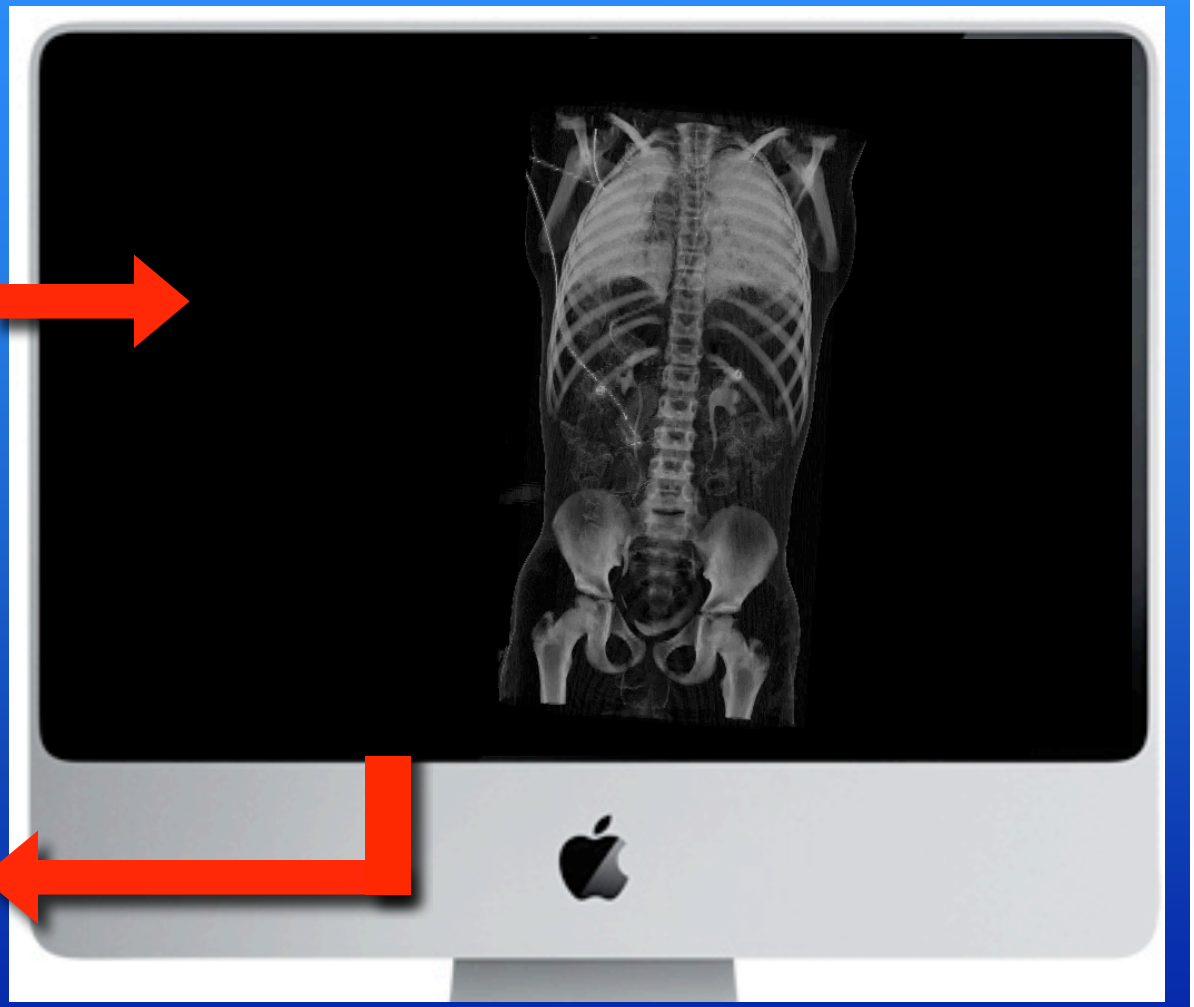
Information underlying cardiac disease

Patient specific anatomy

Existing implanted leads

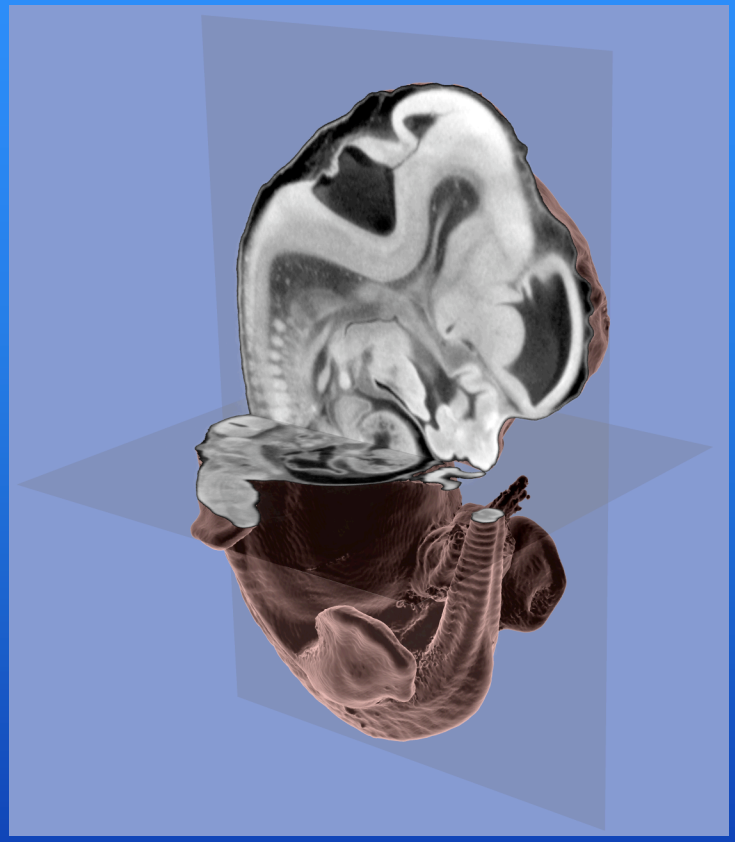
Accessible locations

Patient growth



Predicted Defibrillation thresholds and lead locations

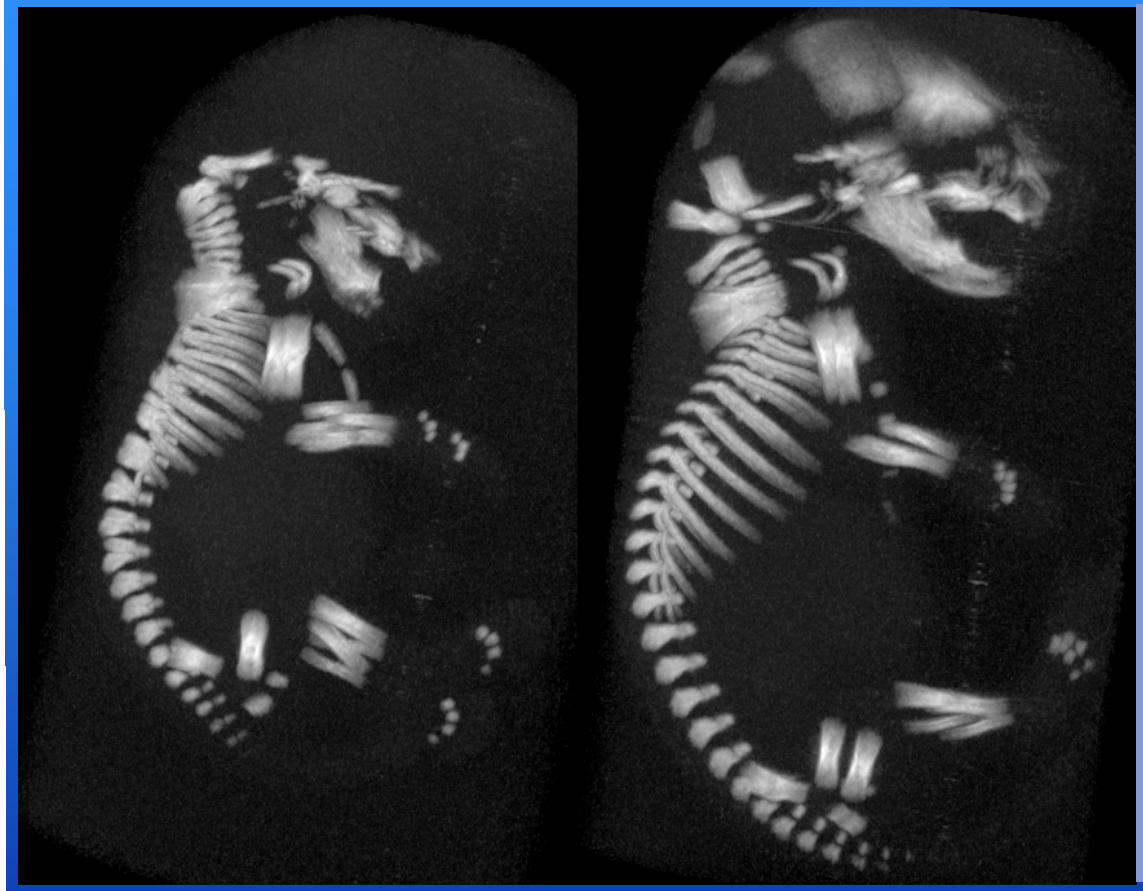
Personalized Biology

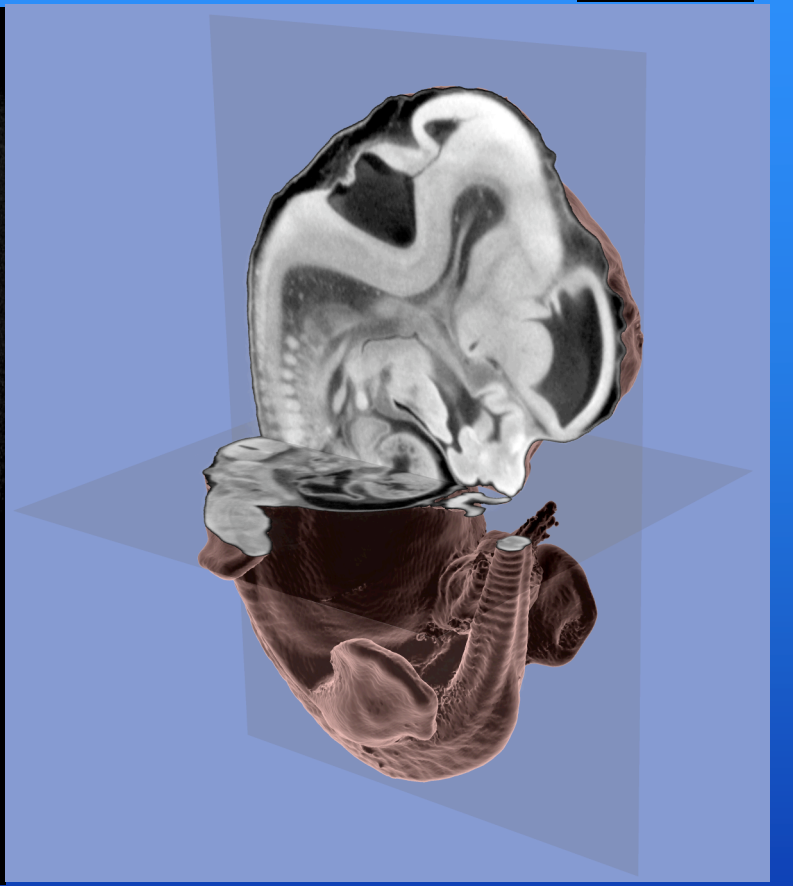


Mario Capecchi - Nobel Prize 2007

Mario R. Capecchi, Ph.D., distinguished professor of human genetics and biology at the University of Utah's Eccles Institute of Human Genetics has won the 2007 Nobel Prize in Physiology or Medicine.

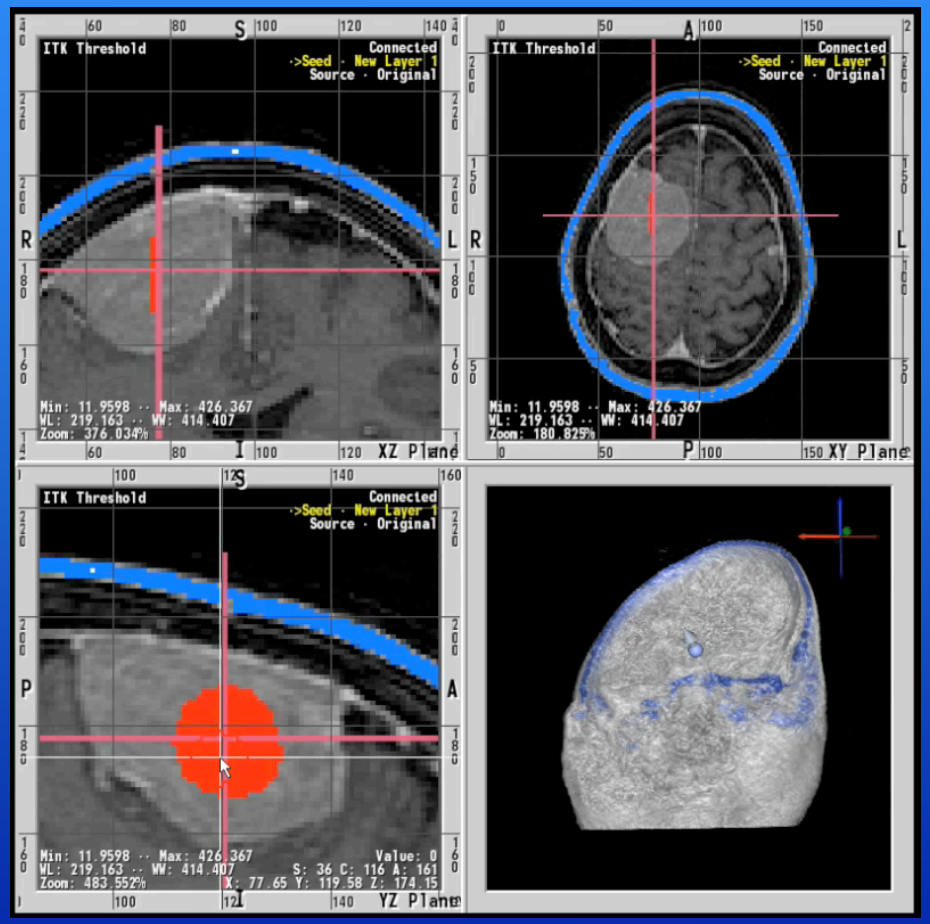
Virtual Histology





J.T. Johnson III, M.S. Hansen, I. Wu, L.J. Healy, C.R. Johnson, G.M. Jones, M.R. Capecchi, C. Keller.
"Virtual Histology of Transgenic Mouse Embryos for High-Throughput Phenotyping,"
In PLoS Genetics, Vol. 2, No. 1, pp. 471-477. April, 2006.

Seg3D - 3D Segmentation

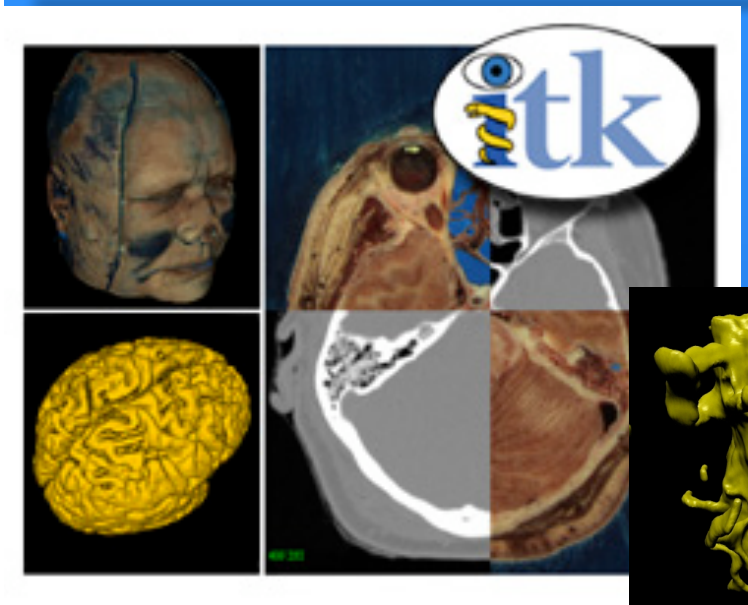


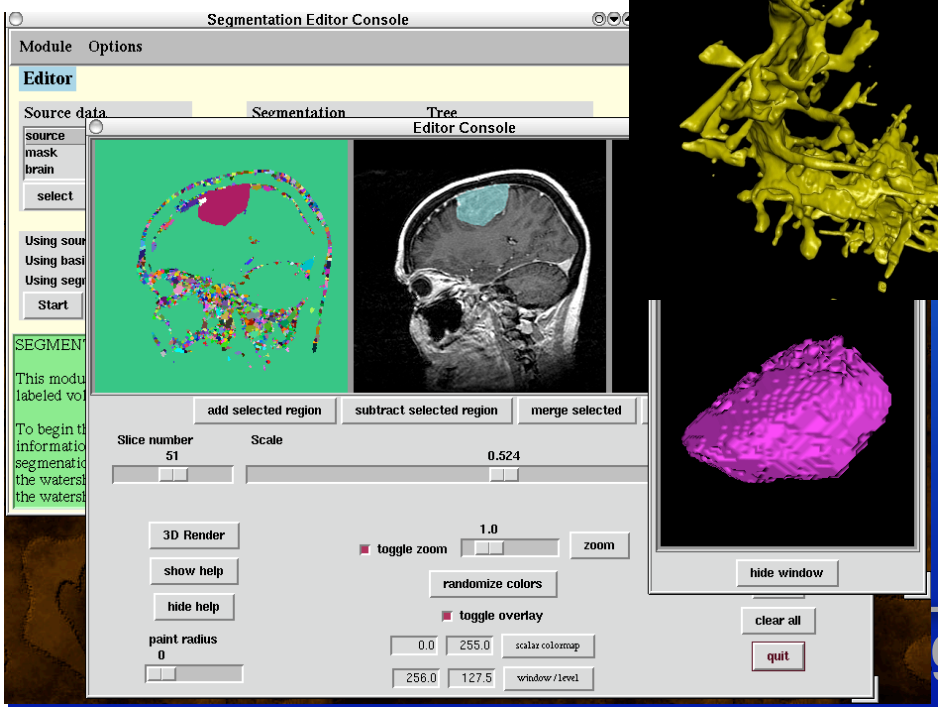
www.seg3d.org

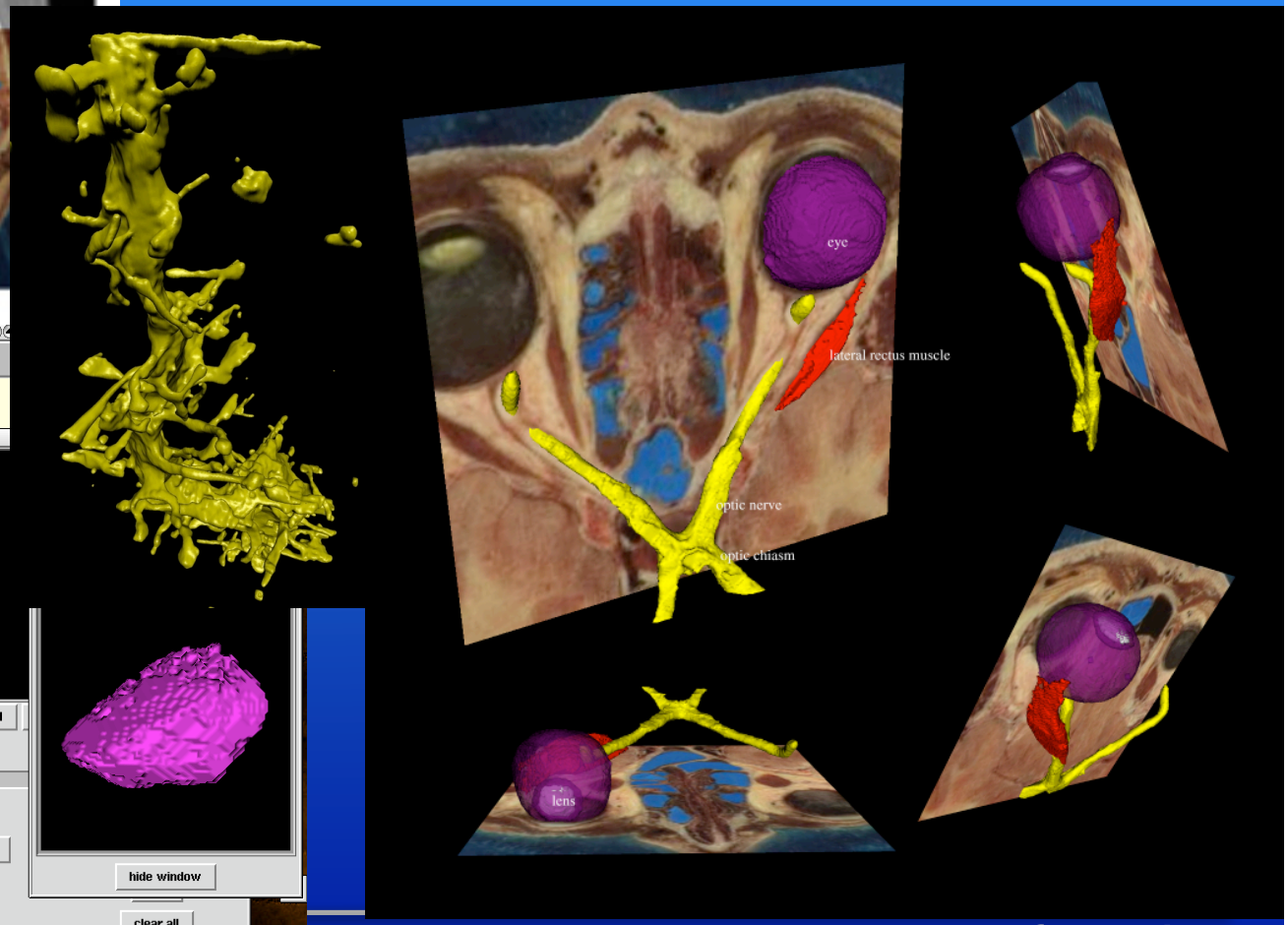
ITK: Insight Toolkit

SCI INSTITUTE

www.itk.org







ging Institute, University of Utah

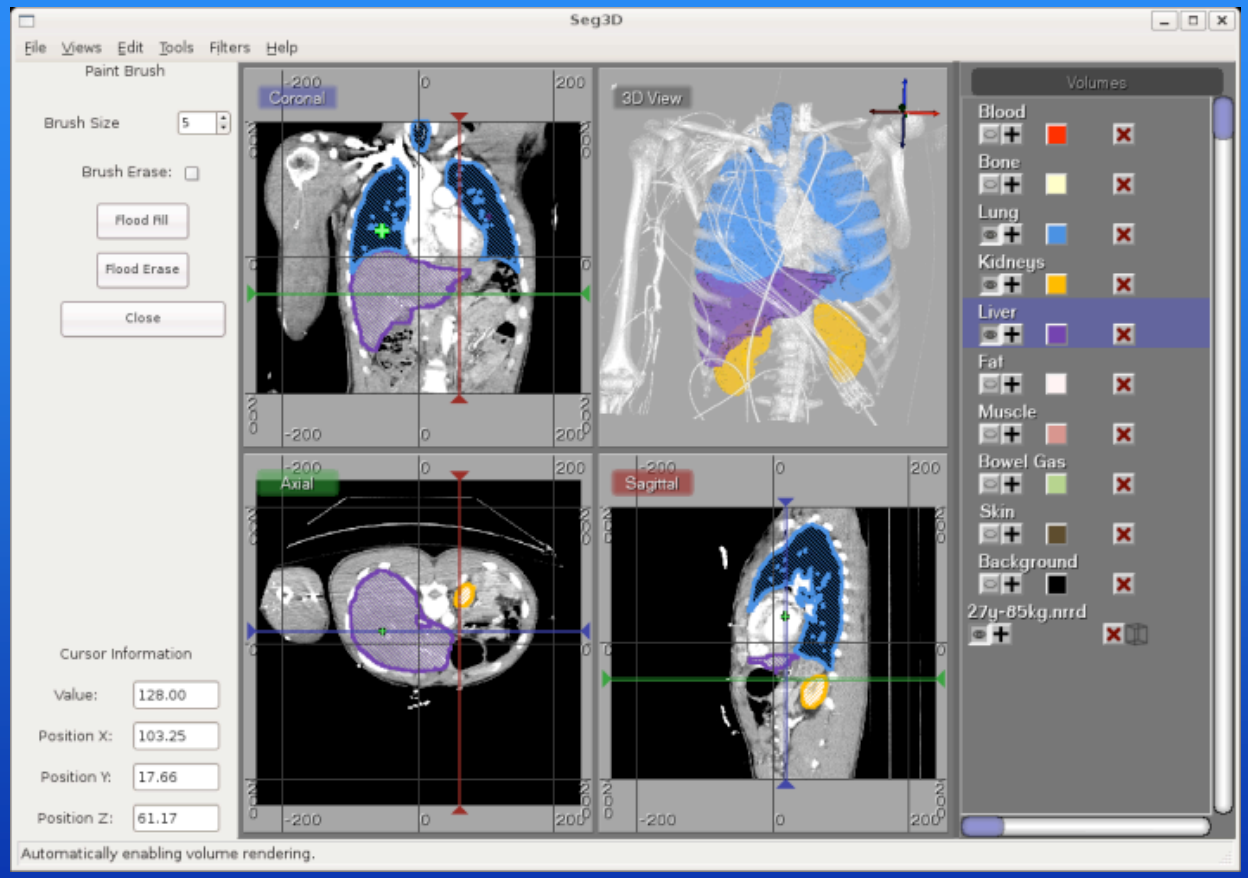
Seg3D - 3D Segmentation

ITK-based

Layers (like Photoshop)

Light-weight

Open Source

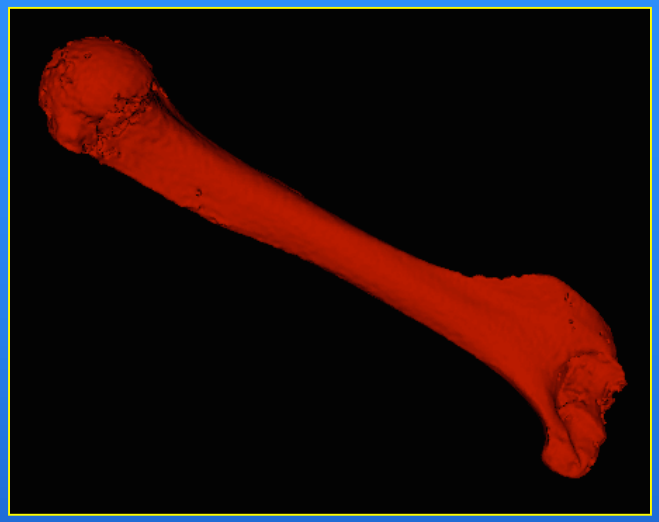


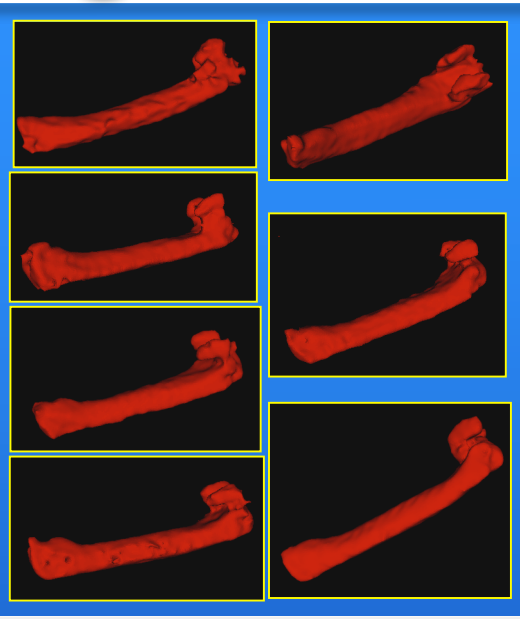
software.sci.utah.edu

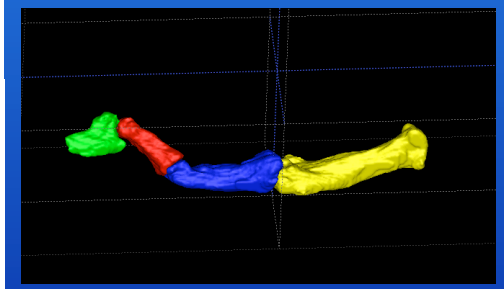
Bone Segmentation - Seg3D

8 bones paw

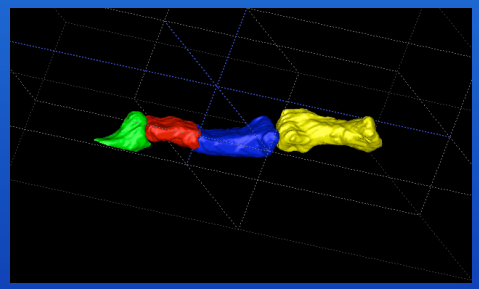
Humerus





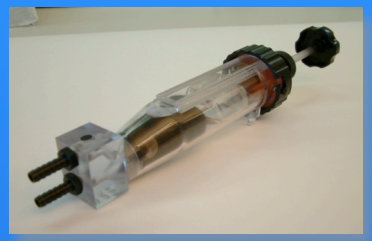


Wild Type



Homozygous Mutant

Tumor Vessel Imaging and Visualization



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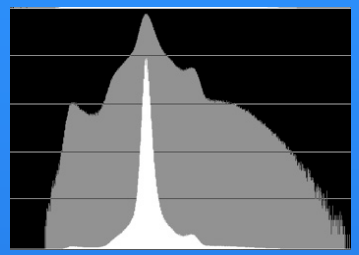

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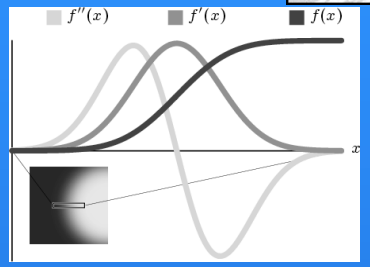
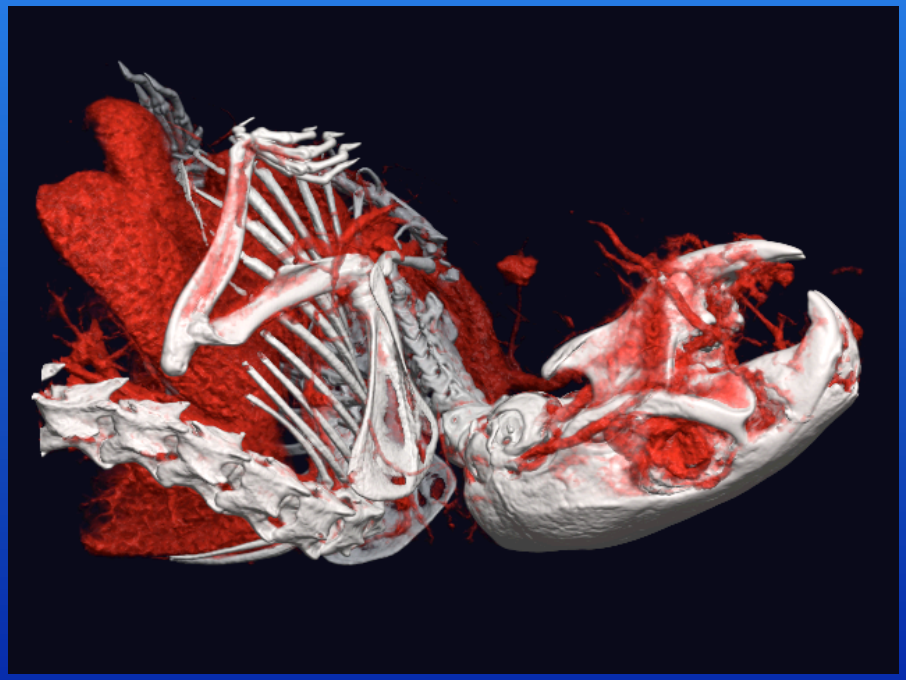


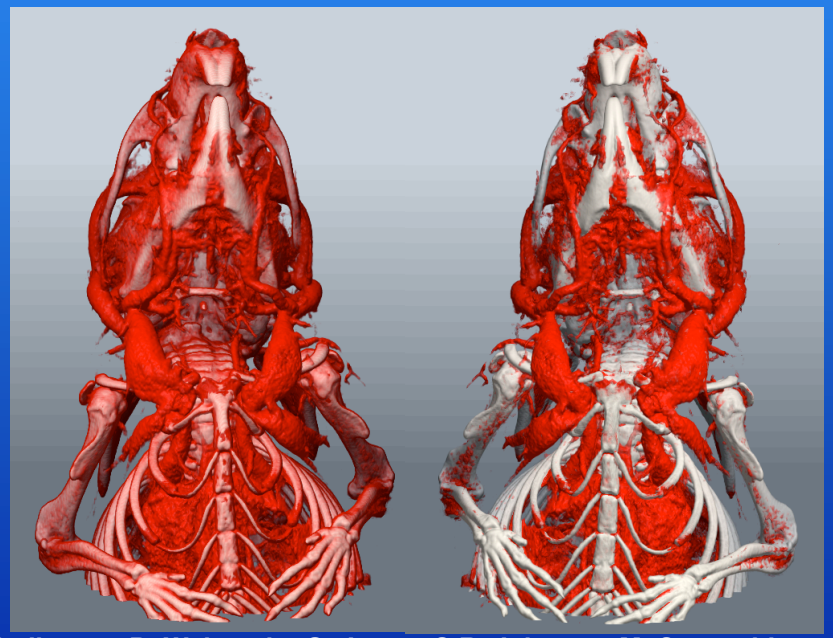
Immobilize.
Dose Contrast

Optimize
Signal : Noise vs Time

Discern Contrast

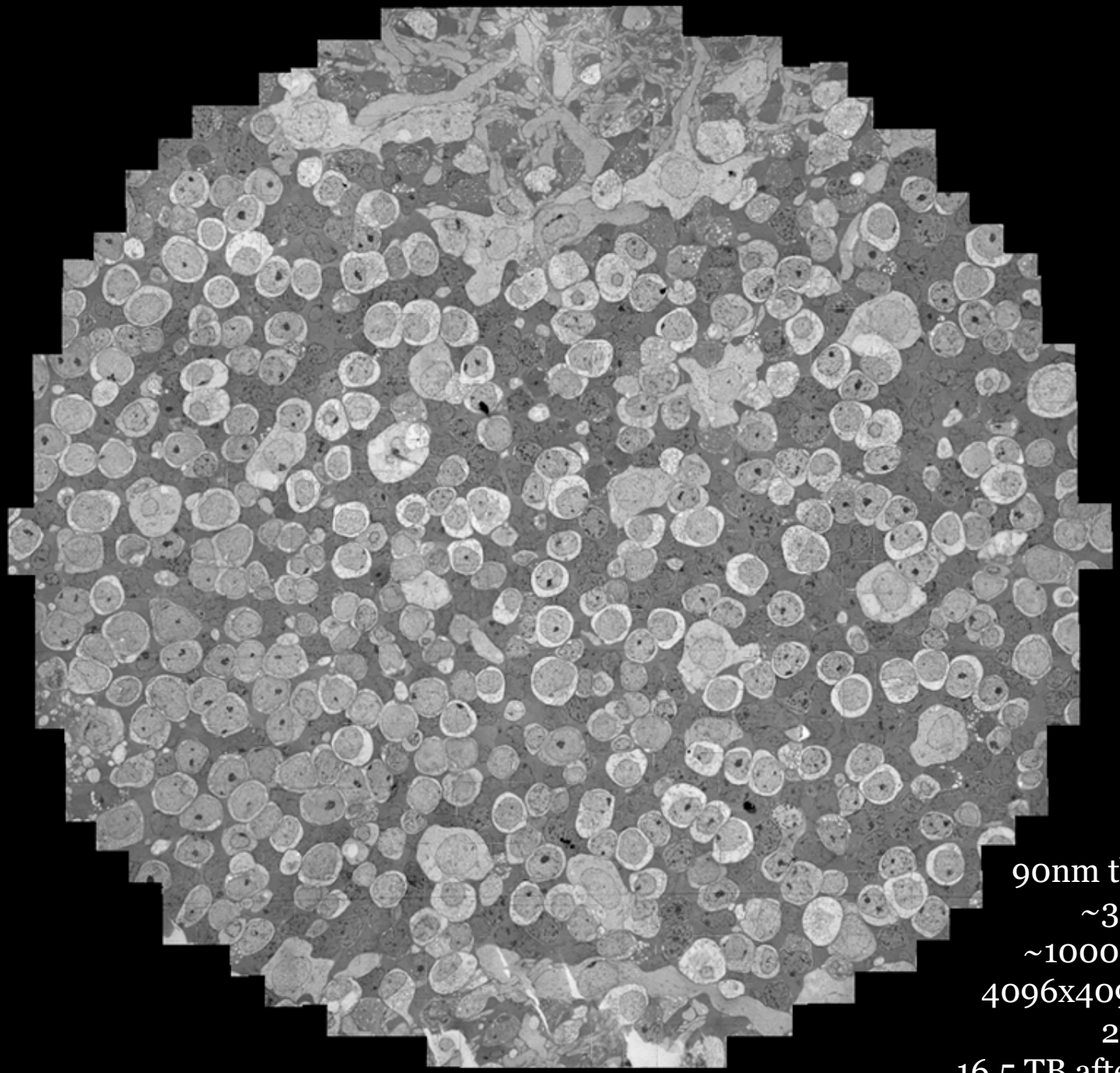
Detect Boundaries





G. Kindlmann, D. Weinstein, G. Jones, C.R. Johnson, M. Capecchi, and C. Keller. Practical Vessel Imaging by Computed Tomography in Live Transgenic Mouse Models for Human Tumors, *Journal of Molecular Imaging*, 2005.

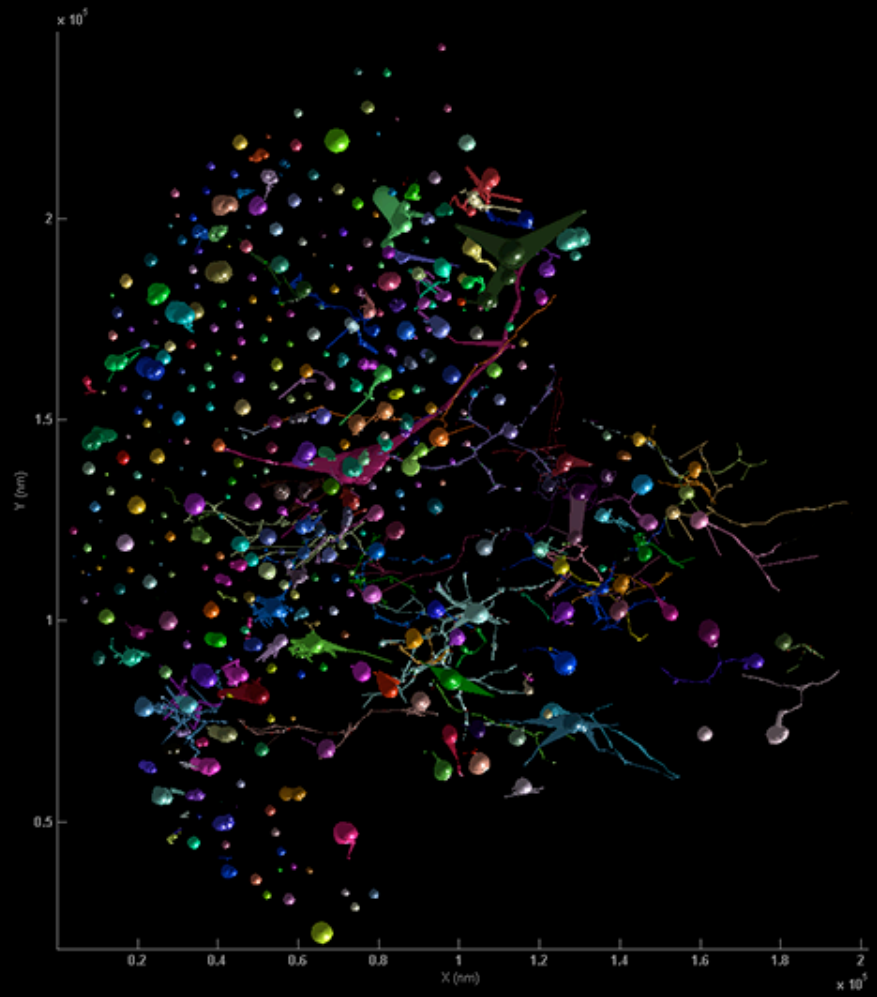
Large-Scale Biological Imaging



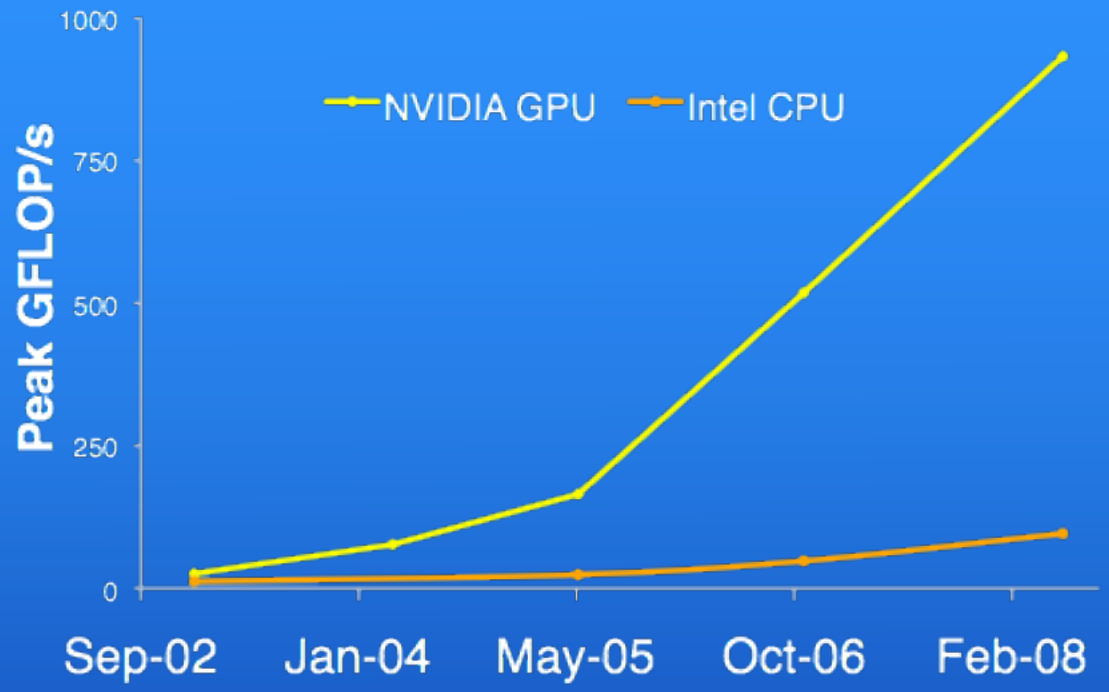
341 Sections
90nm thick sections
~32GB/Section
~1000 tiles/section
4096x4096 pixels/tile
2.18 nm/Pixel
16.5 TB after processing

We built the volume

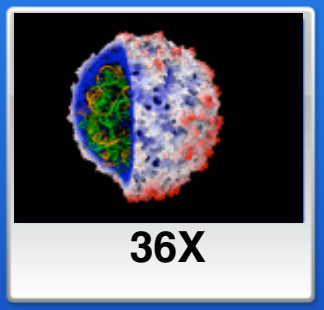
- ... but even if you could track all processes, mark all synapses and gap junctions on a 1600 x 1200 screen every five seconds it would still take eight working years to annotate the volume.


x 10^5
2
1.5
1
0.5
Y (nm)
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
X (nm)
x 10^5

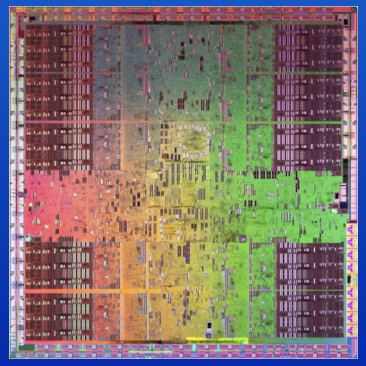
Simulation and Visualization with GPUs

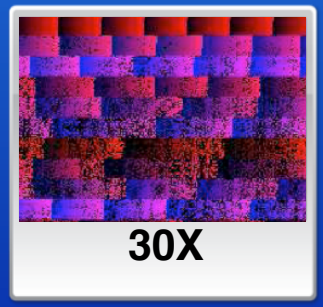


Medical Imaging
U of Utah



Molecular Dynamics
U of Illinois





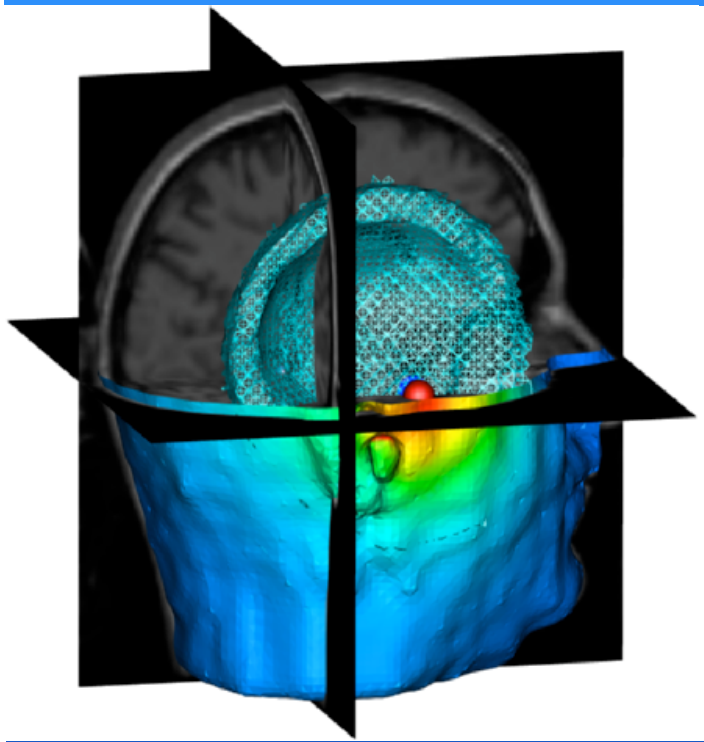
Gene Sequencing
U of Maryland

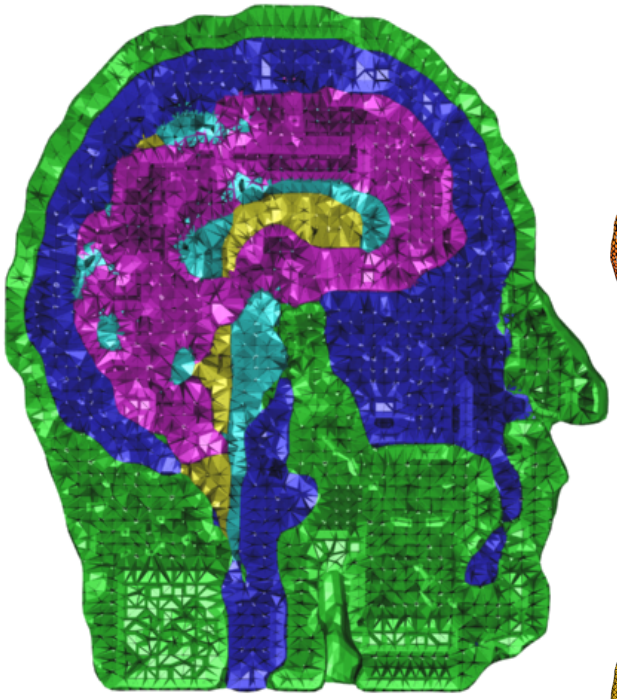
TSUBAME Supercomputer

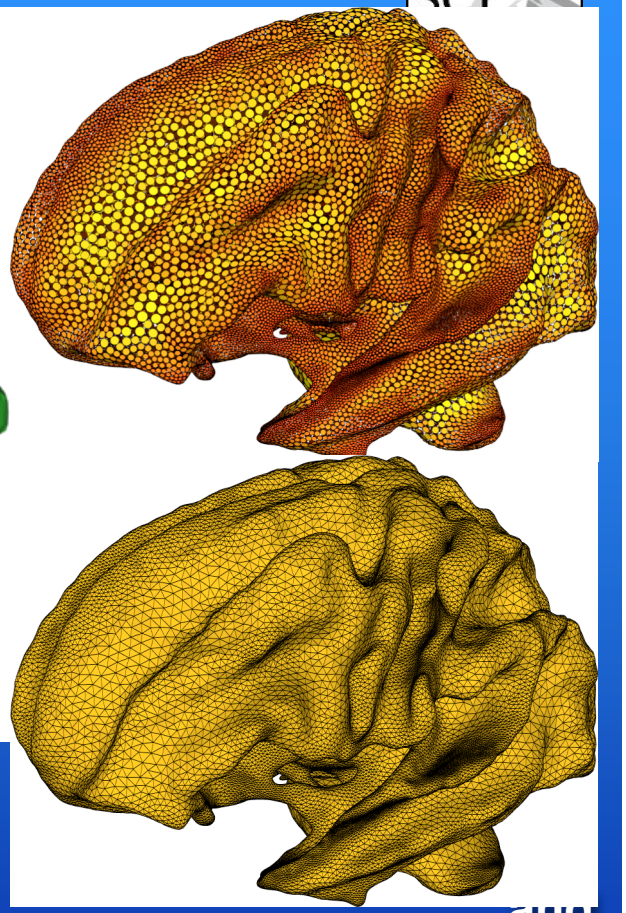
Tokyo Institute of Technology

30,000 Cores and 680
NVIDIA GPUs

Mesh Generation - BioMesh3D

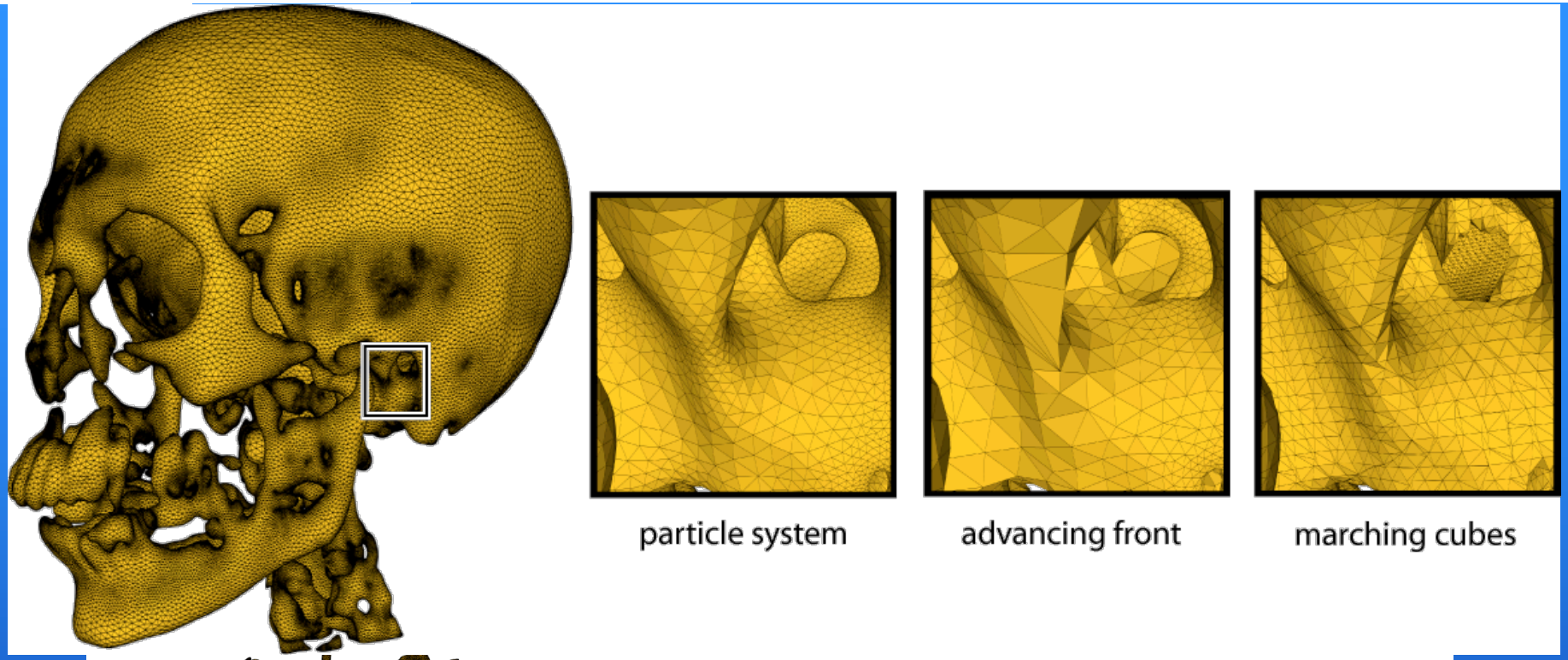


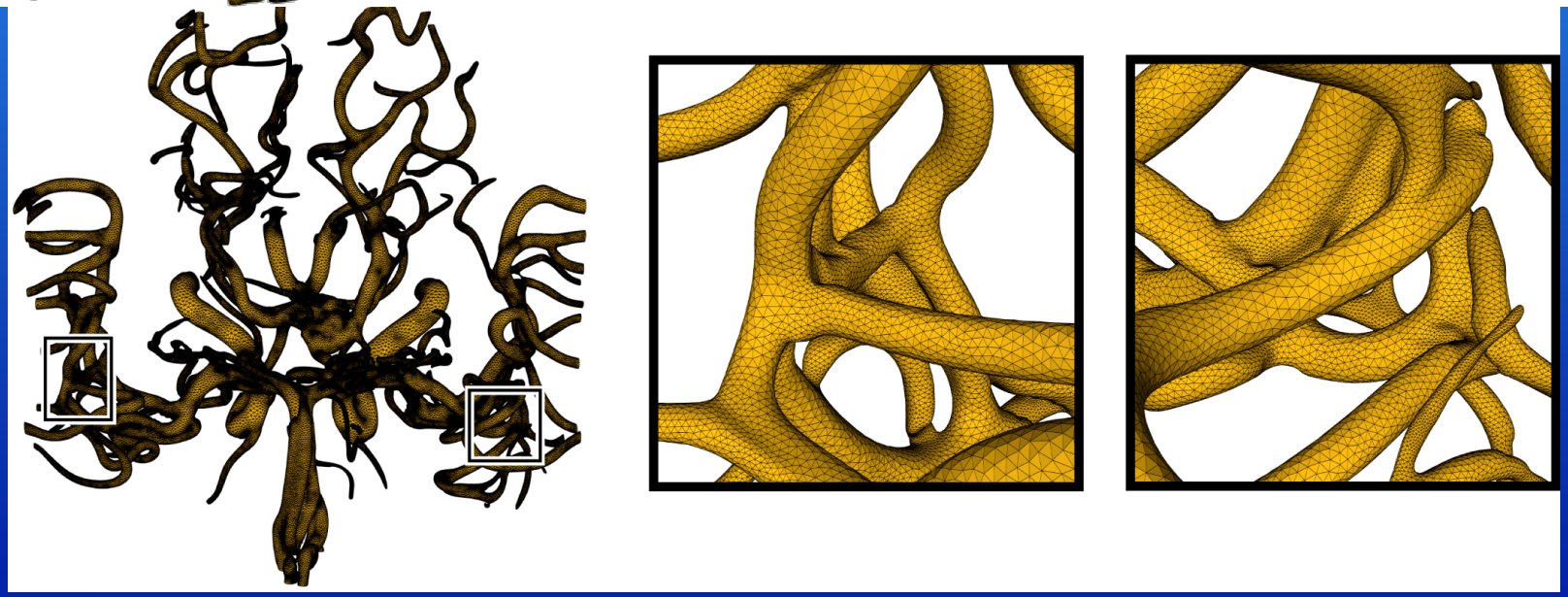




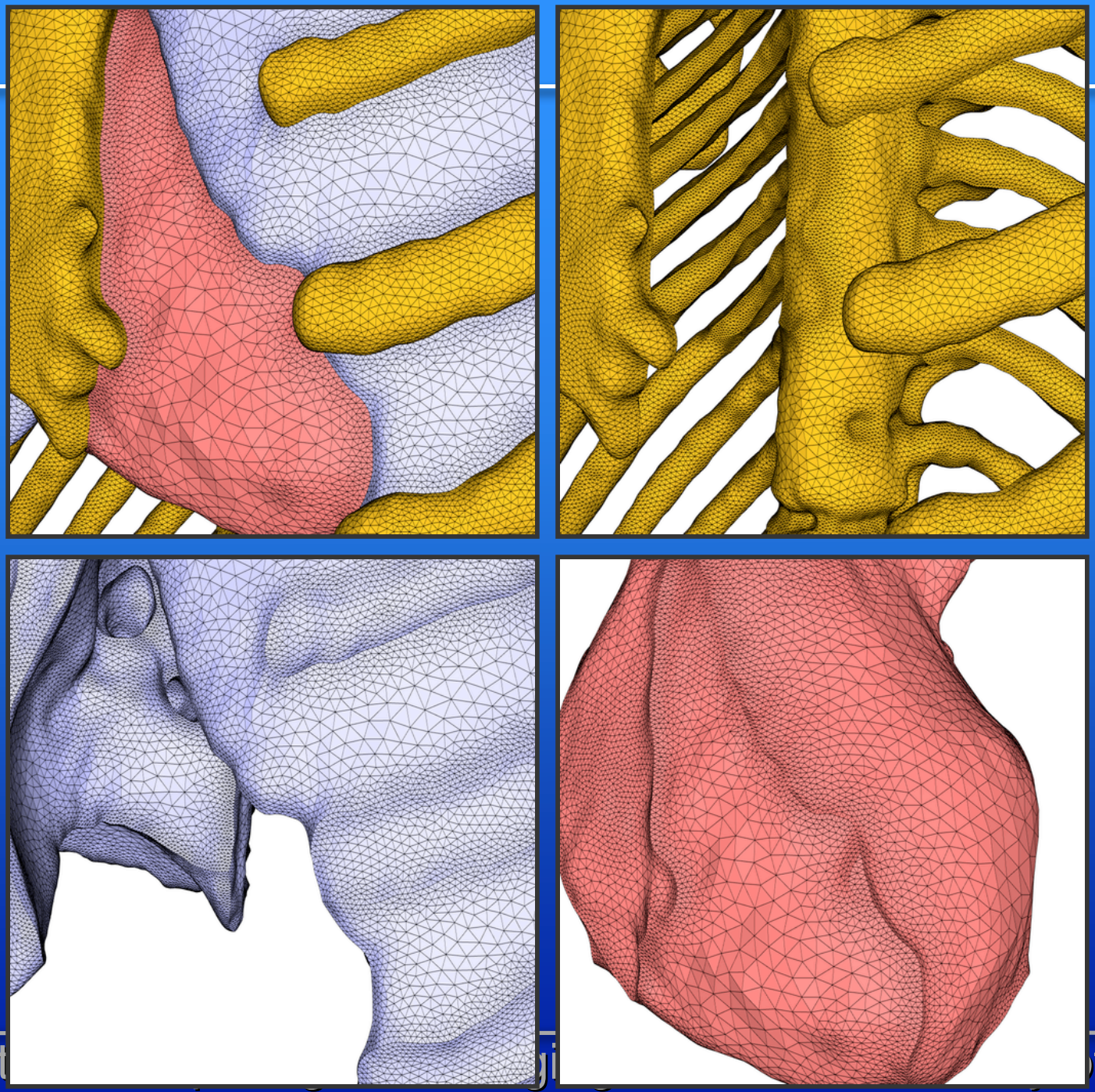
M. Callahan, M.J. Cole, J.F. Shepherd, J. Stinstra, and C.R. Johnson. "BioMesh3D: A Meshing Pipeline for Biomedical Models"

J.F. Shepherd and C.R. Johnson. "Hexahedral Mesh Generation for Biomedical Models in SCIRun"

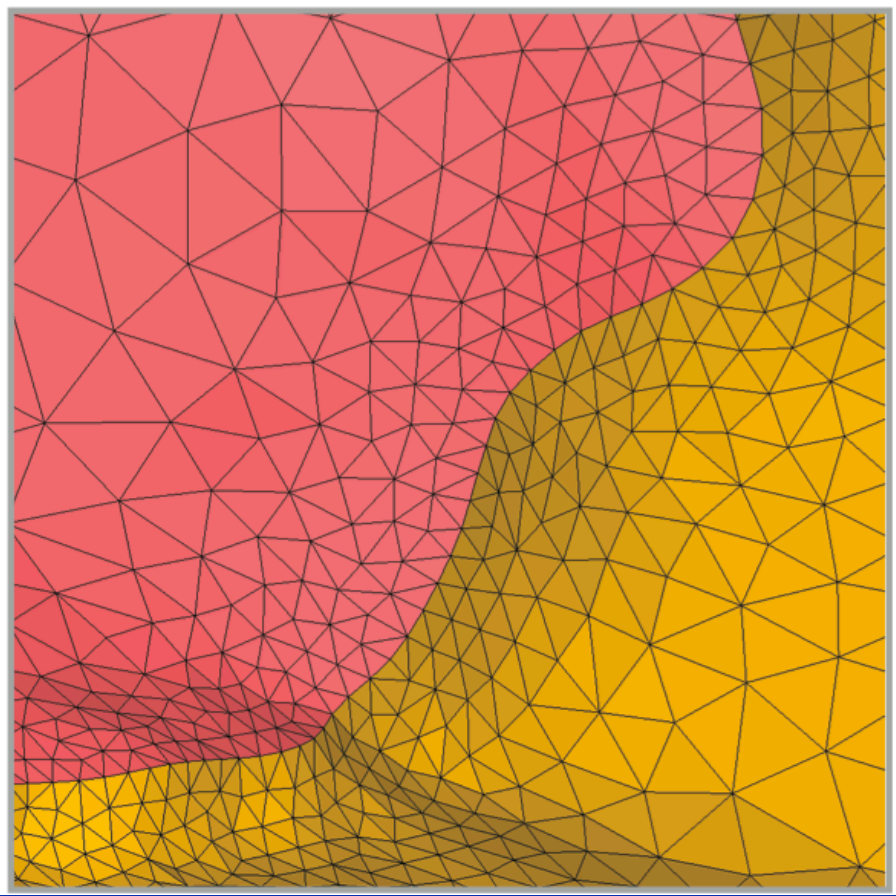


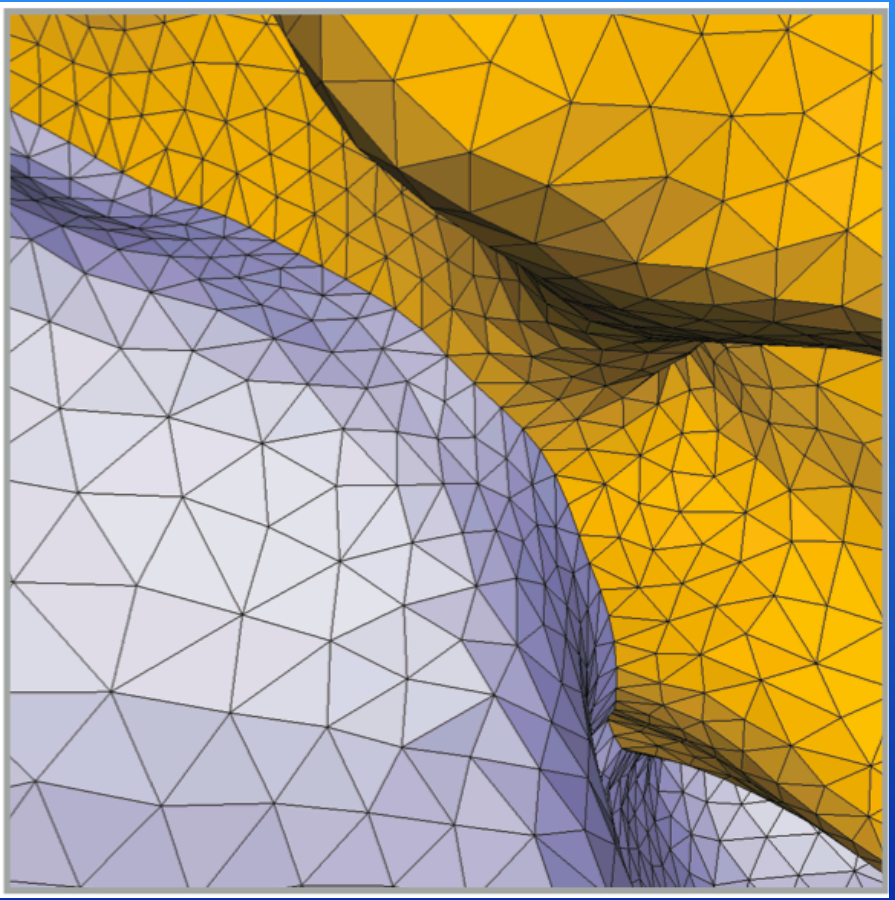


Topology, Accuracy, and Quality of Isosurface Meshes from Dynamic Particles, *Meyer et al., IEEE Visualization 2007.*

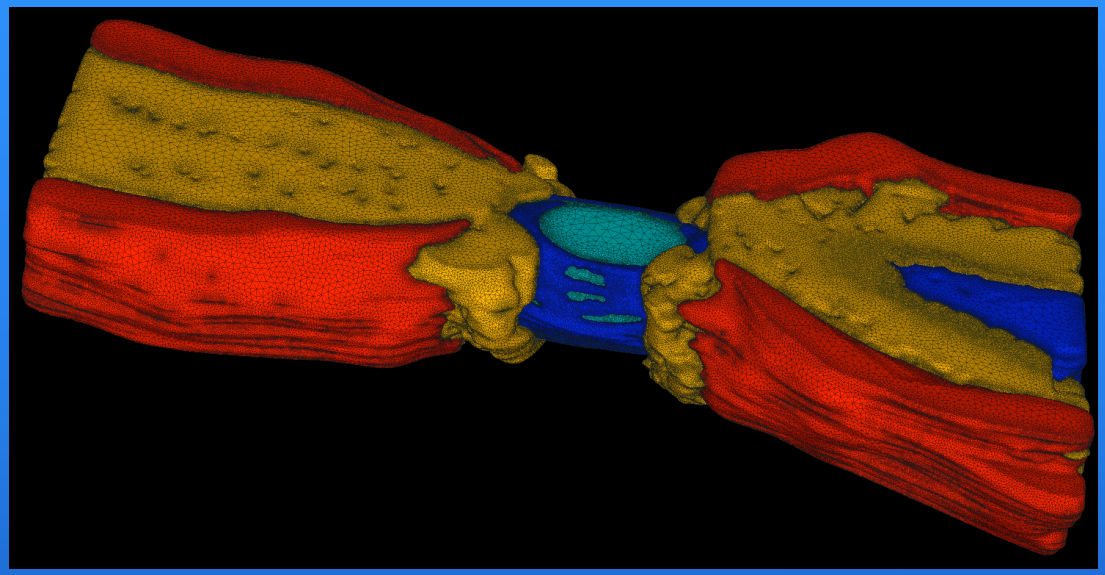


BioMesh3D: Multiple Materials



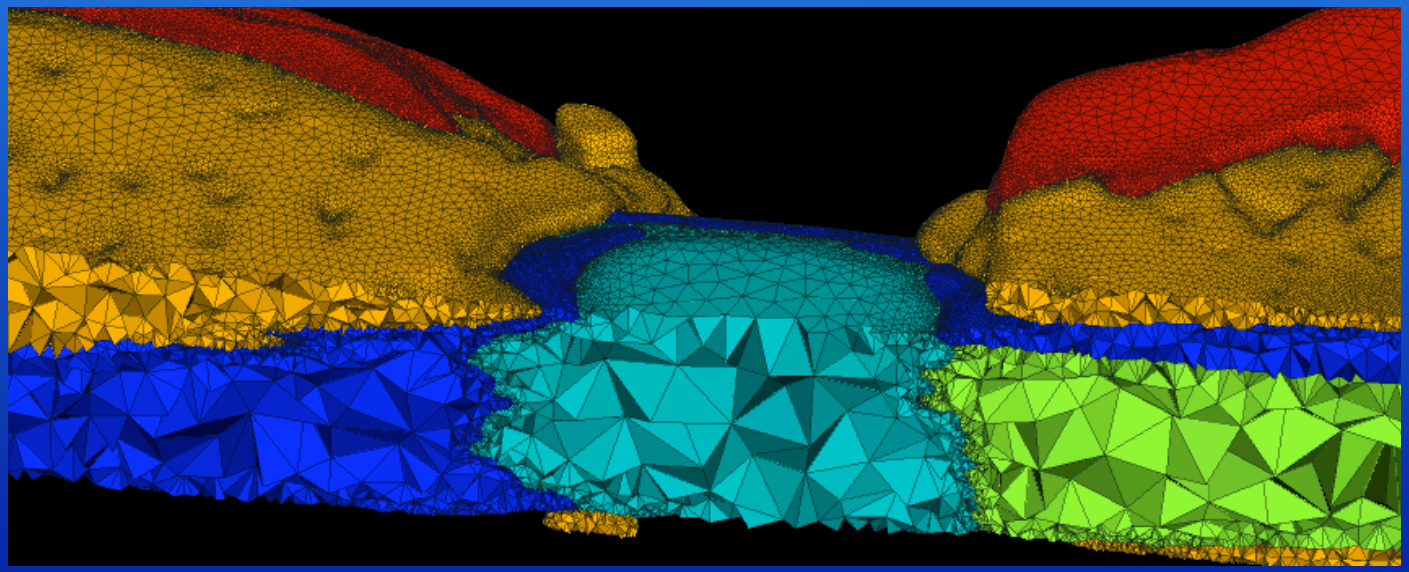


BioMesh3D Collaboration



EM of Nodes of Ranvier

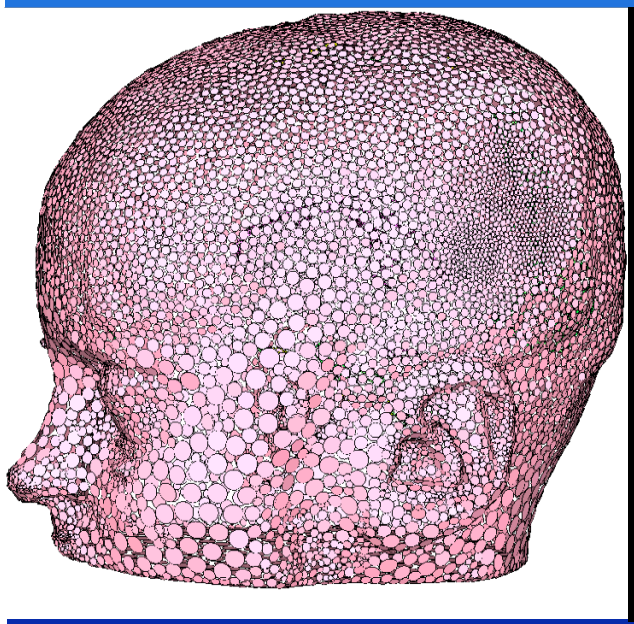
Mark Ellisman - NCMIR - UCSD

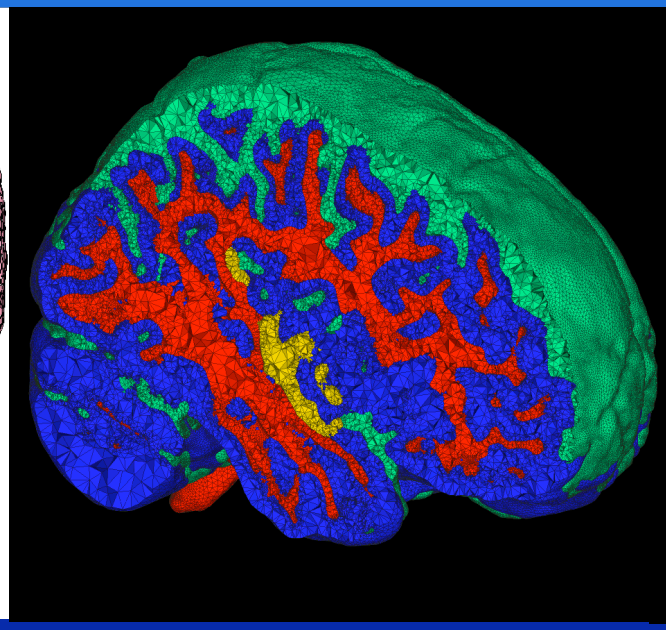


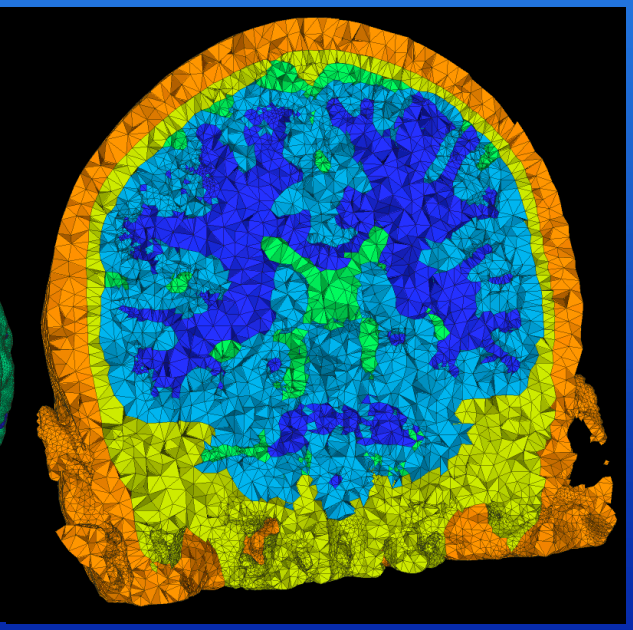
BioMesh3D Collaboration

Pediatric Epilepsy Localization

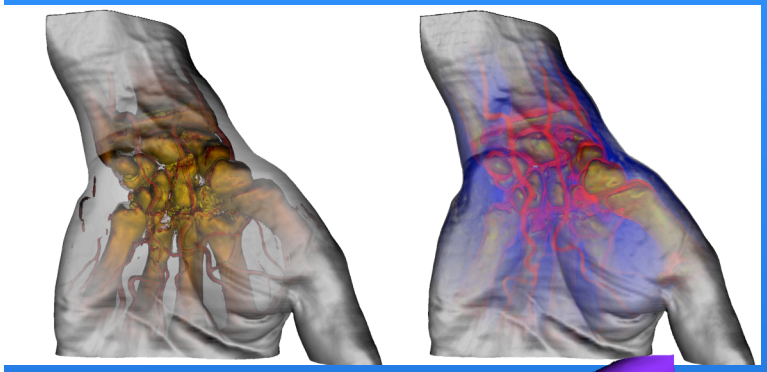
Simon Warfield – Boston Childrens Hospital

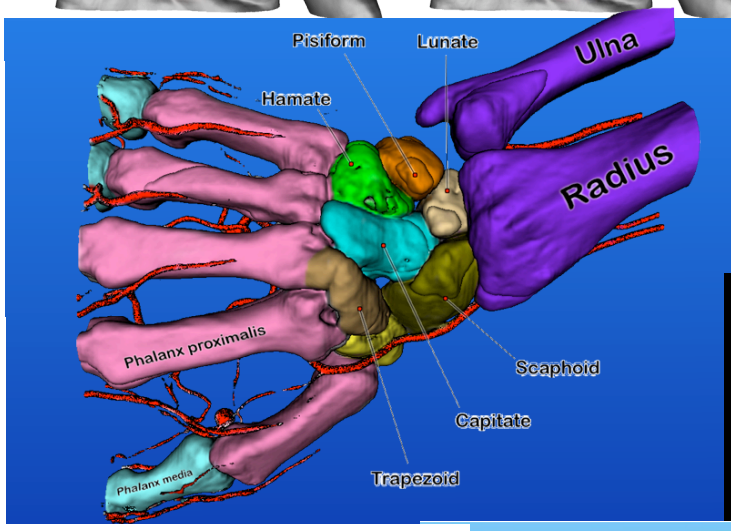


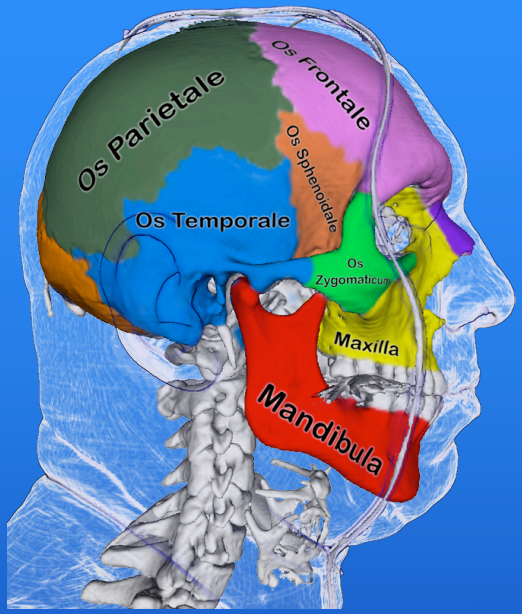


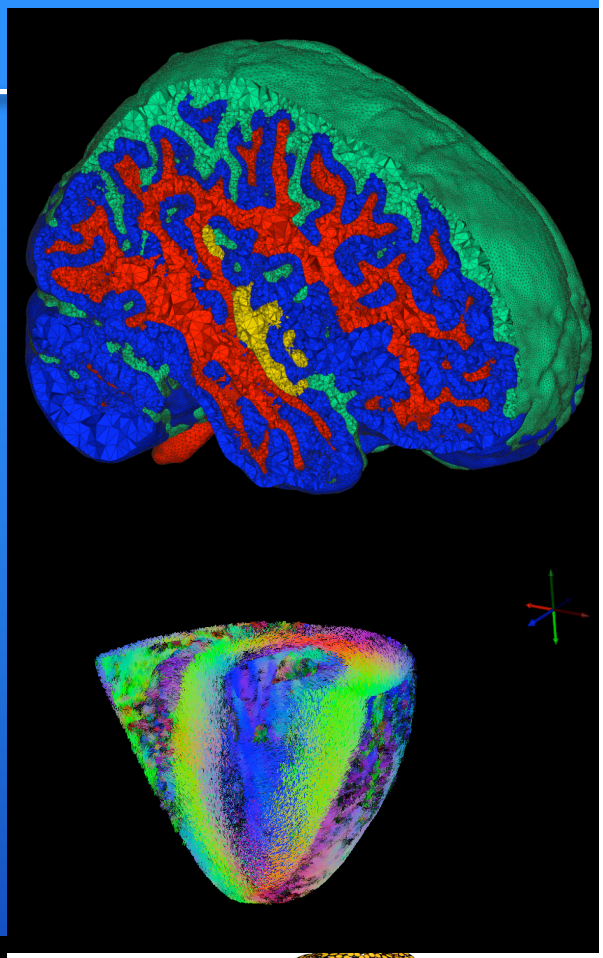


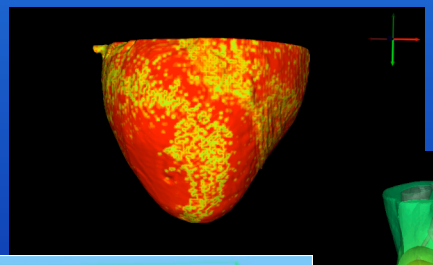
Visualization

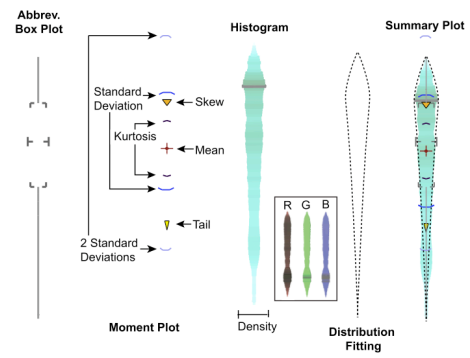


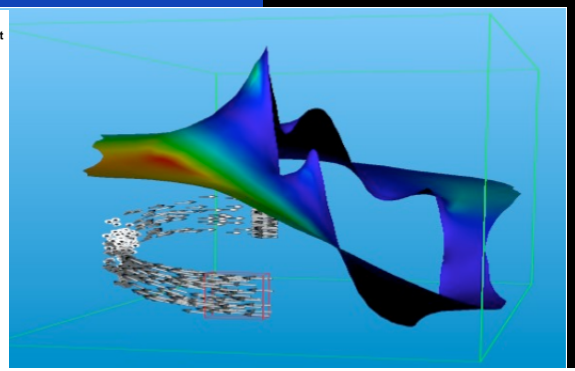


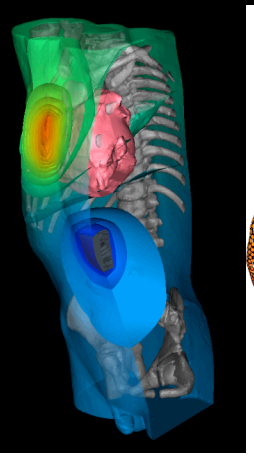


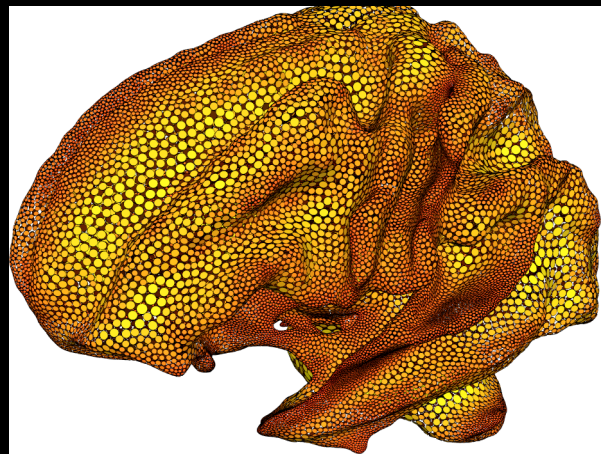




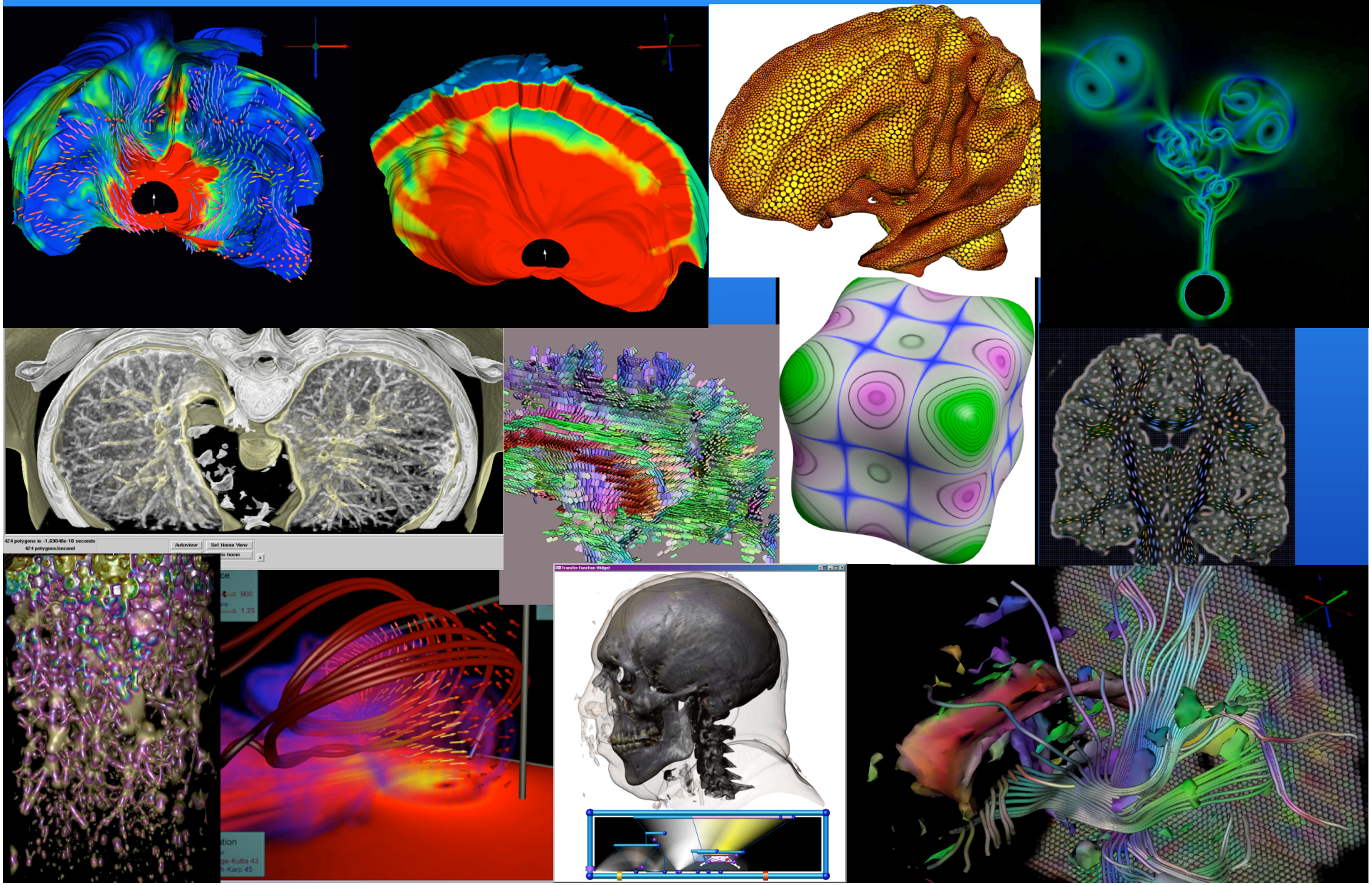




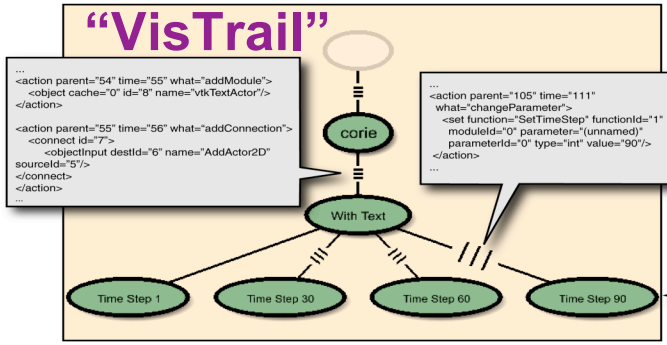


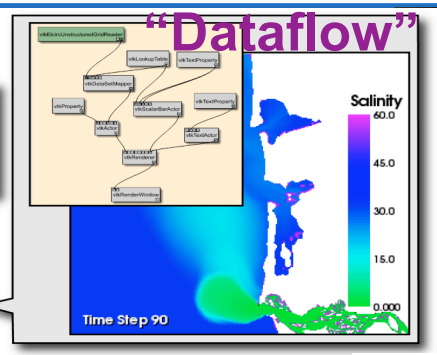


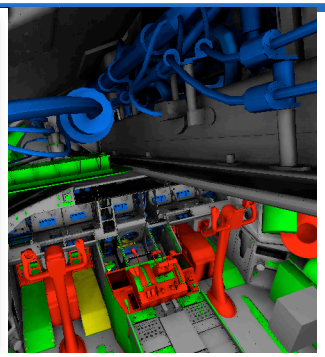
New Visualization Techniques

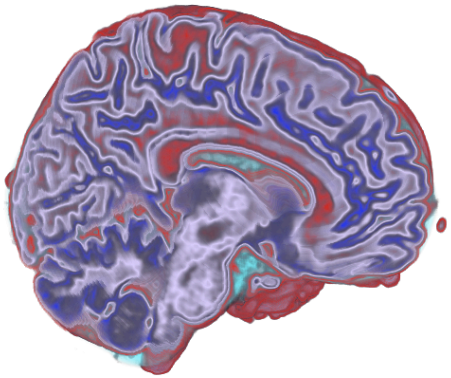


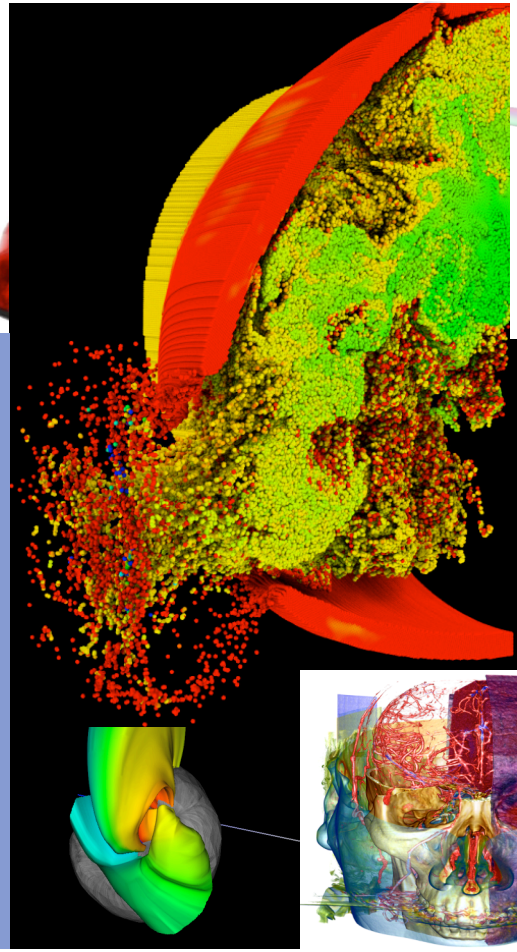
More New Visualization Techniques

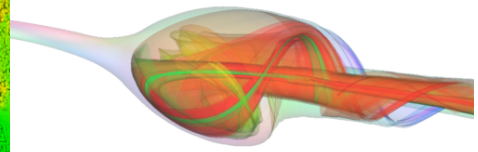


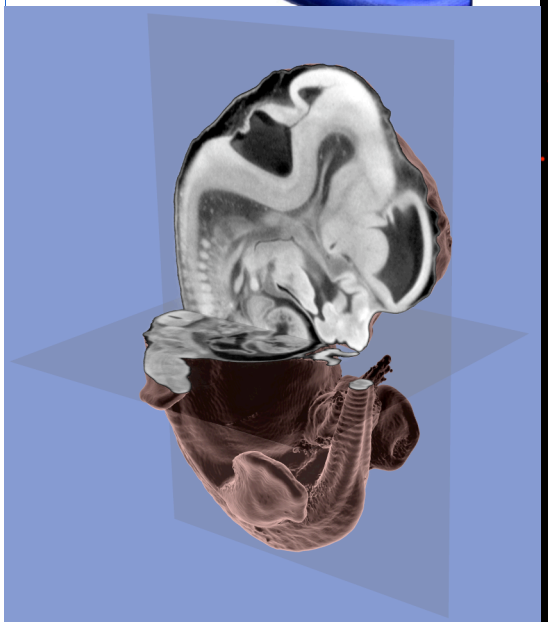


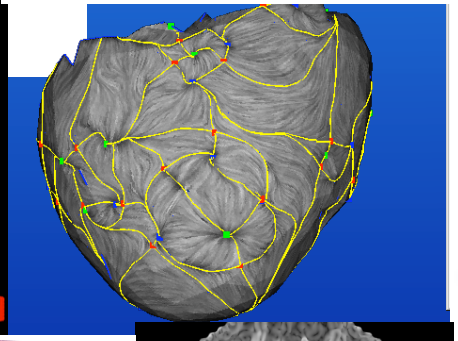


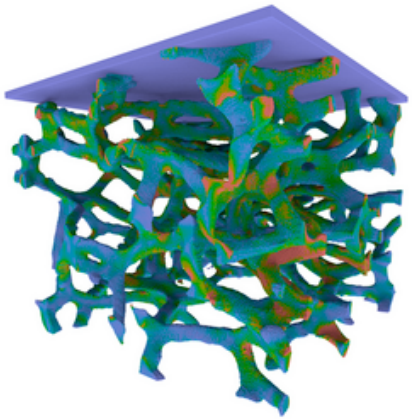


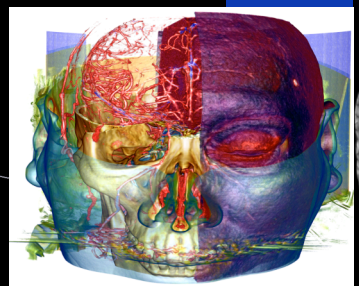


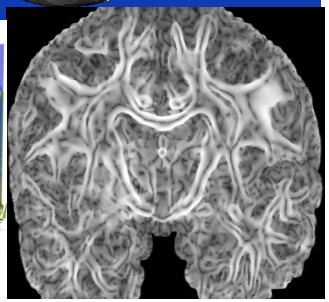




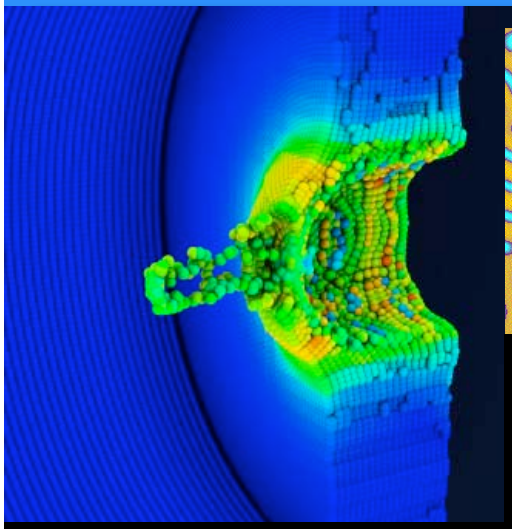


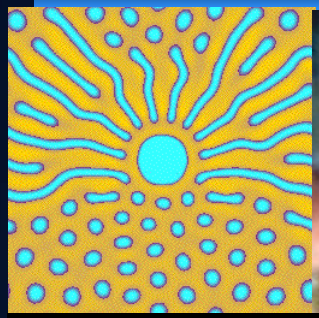


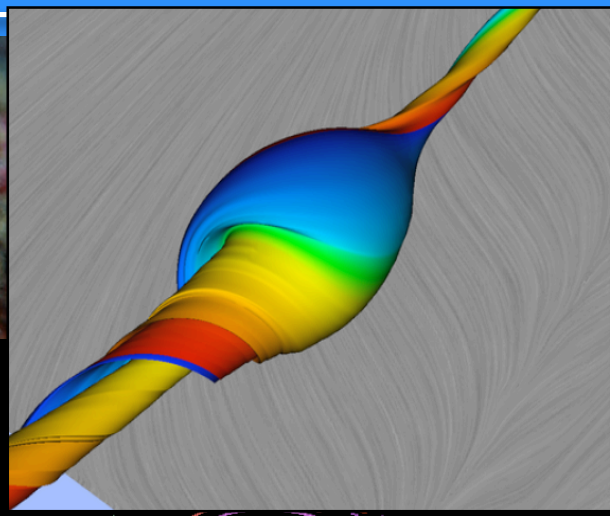


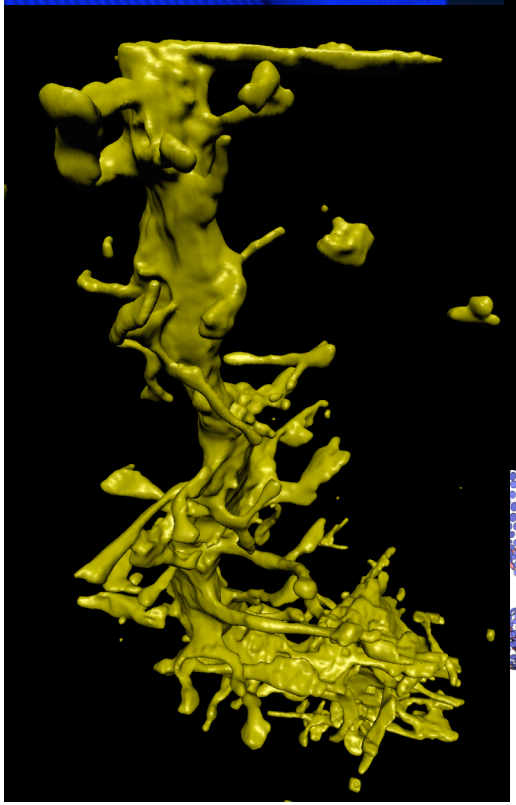


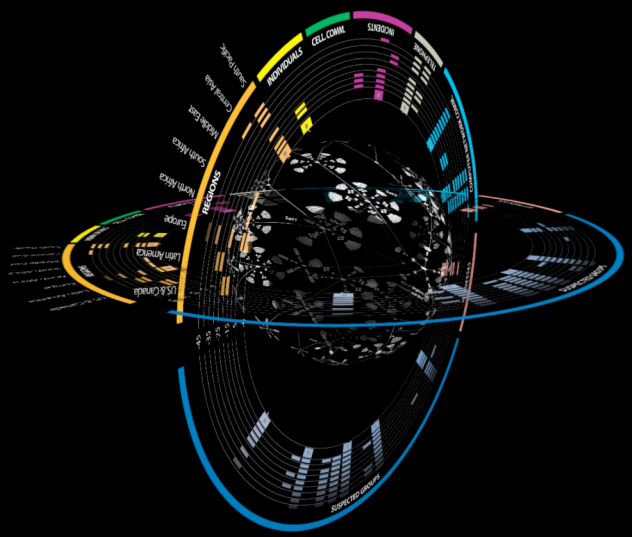
Even More New Visualization Techniques

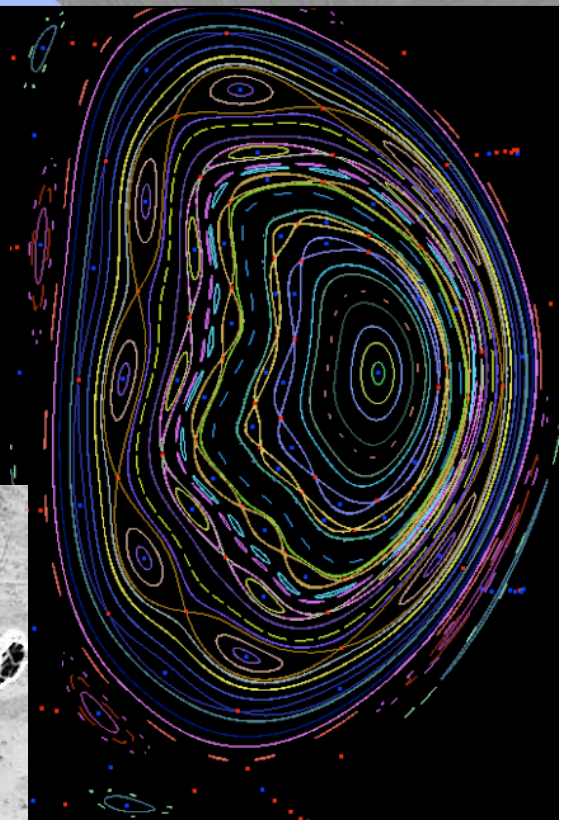


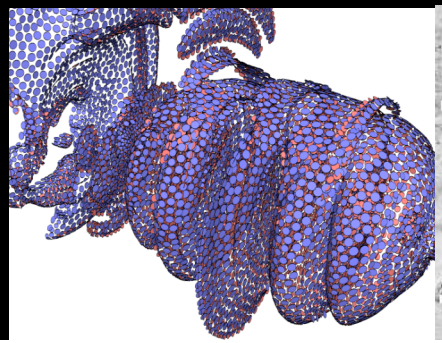


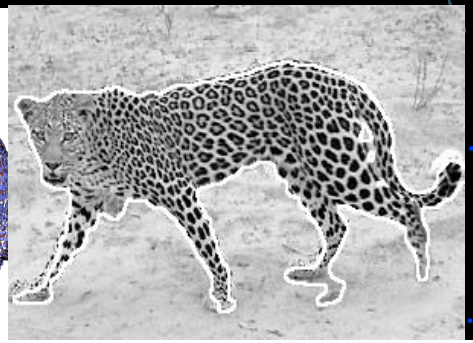


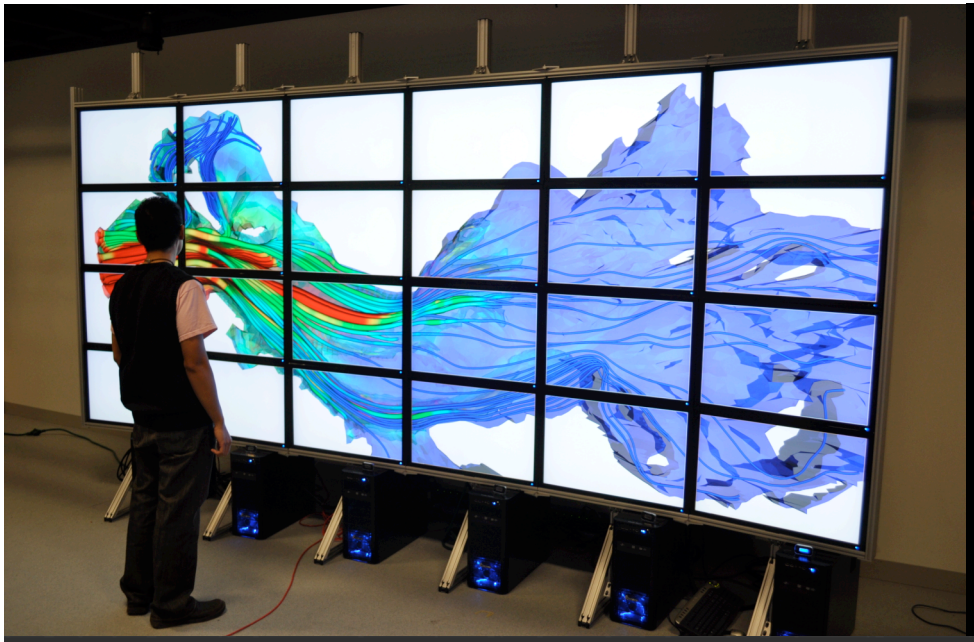


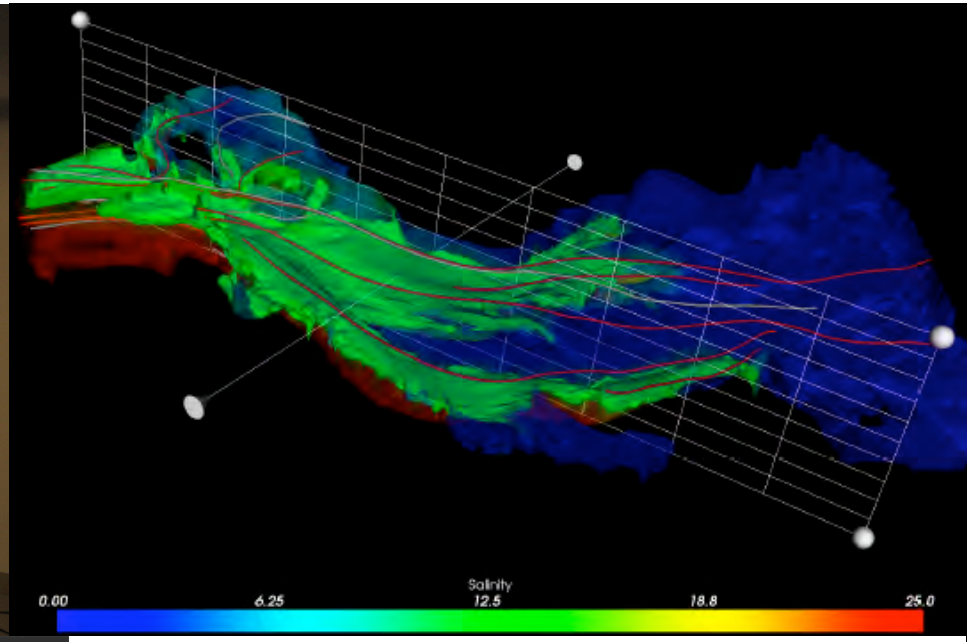


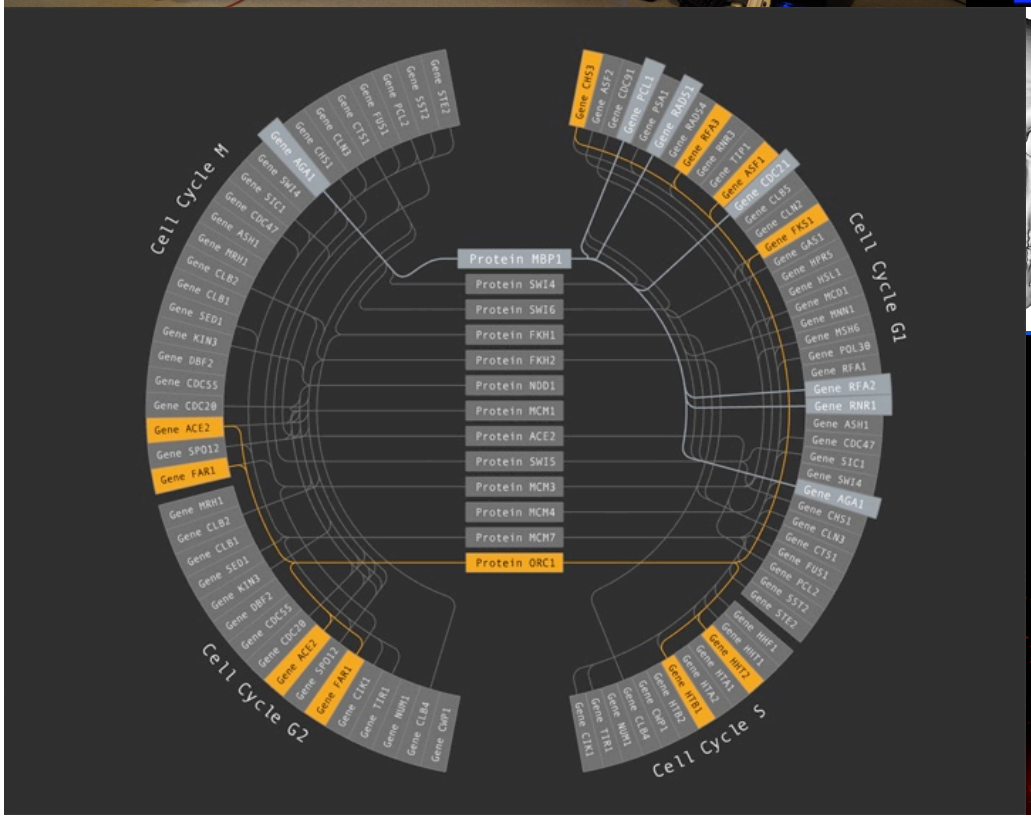


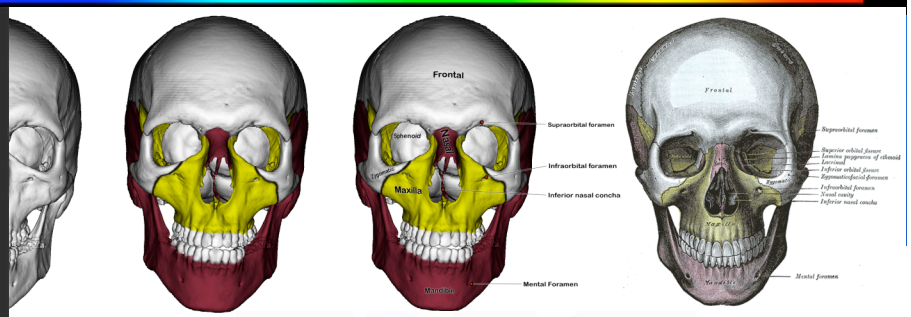


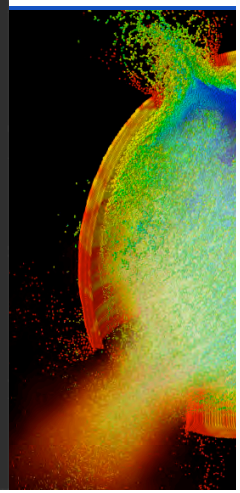


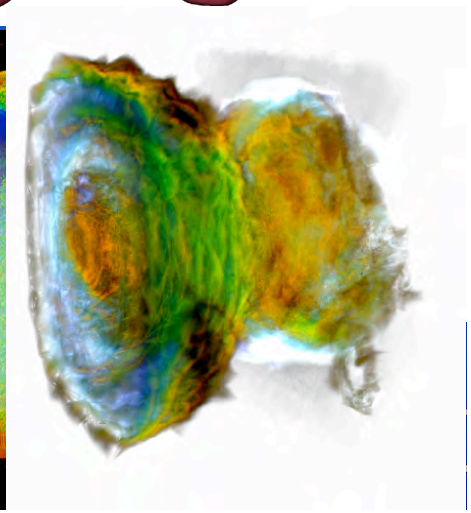


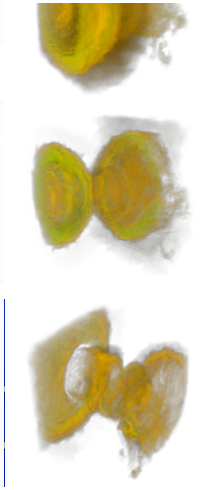

Salinity
0.00
6.25
12.5
18.8
25.0


Cell Cycle M
Cell Cycle G1
Cell Cycle S
Cell Cycle G2
Protein M8P1
Protein SWI4
Protein SWI6
Protein FKH1
Protein FKH2
Protein NDD1
Protein MCM1
Protein ACE2
Protein SWI5
Protein MCM3
Protein MCM4
Protein MCM7
Protein ORC1

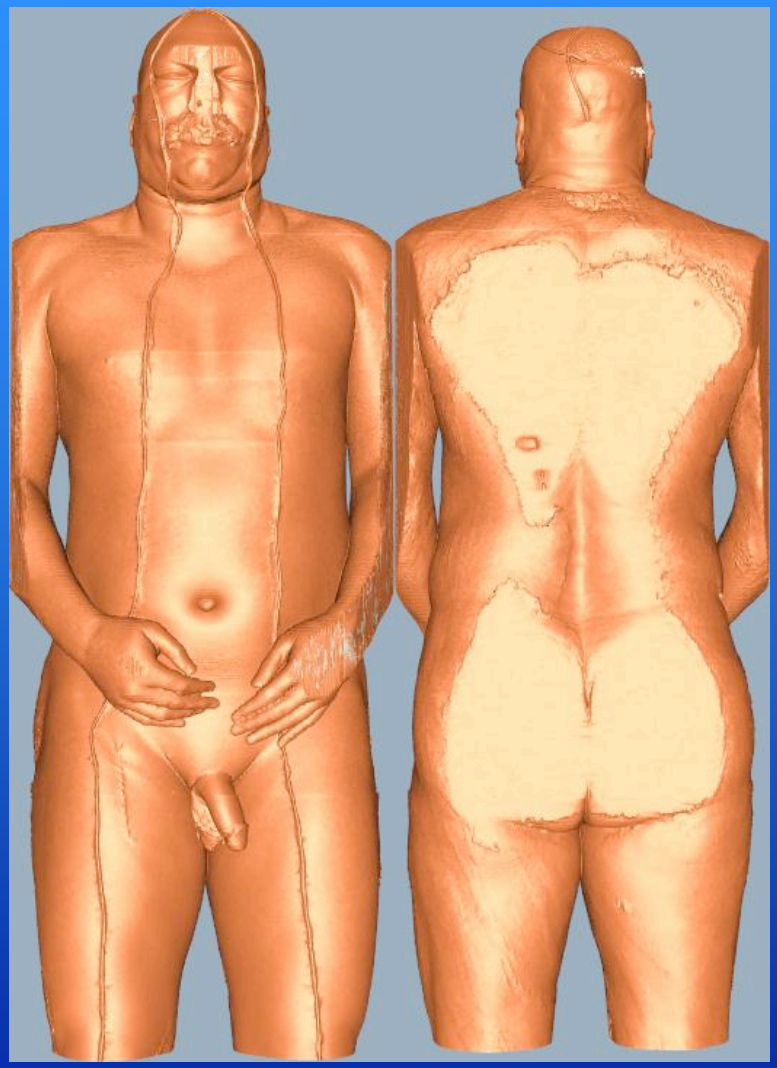

Frontal
Sphenoid
Maxilla
Mandible
Supraorbital foramen
Infraorbital foramen
Inferior nasal concha
Mental Foramen





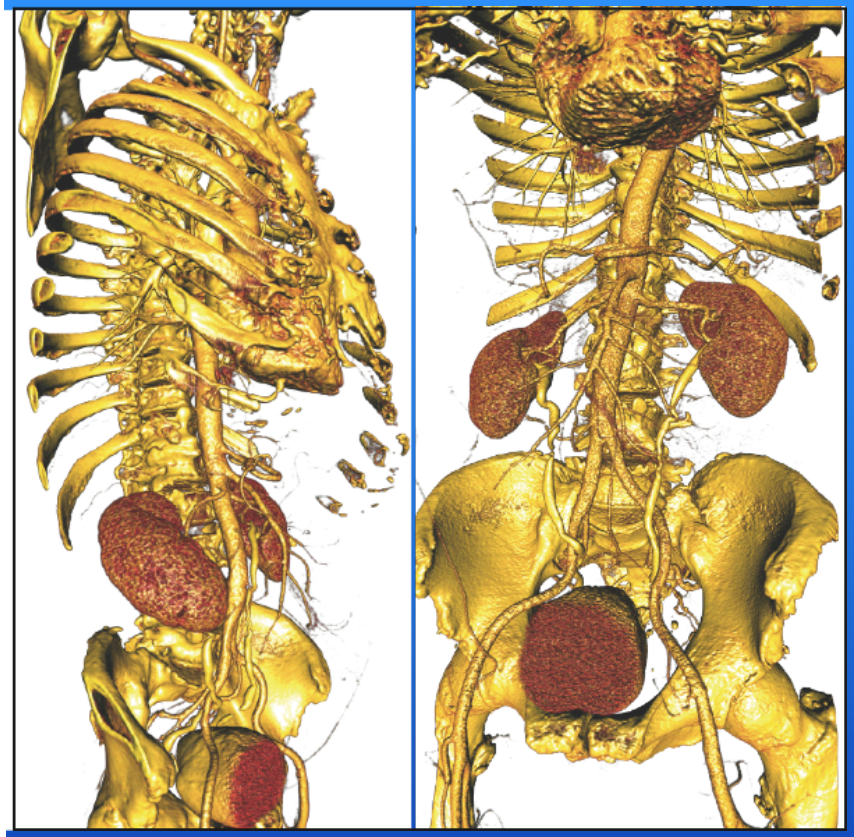


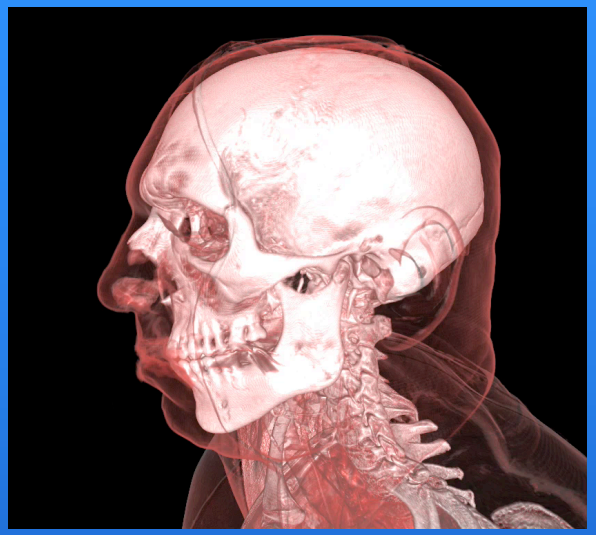
NIH Visible Male

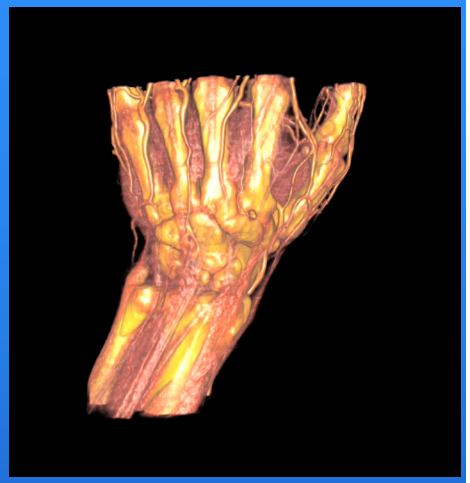


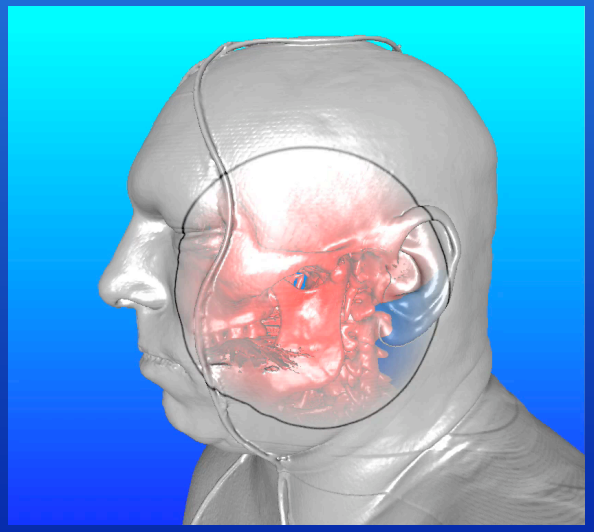
Visible Human - High Resolution

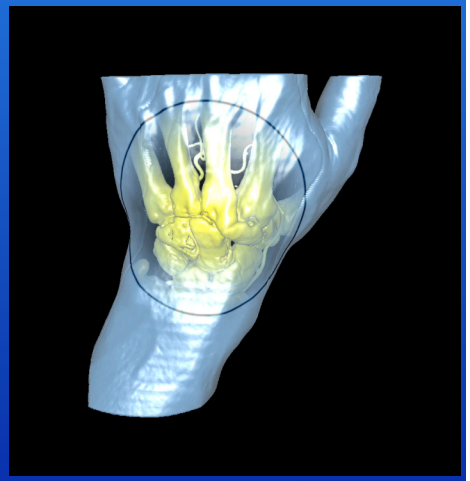
ImageVis3D





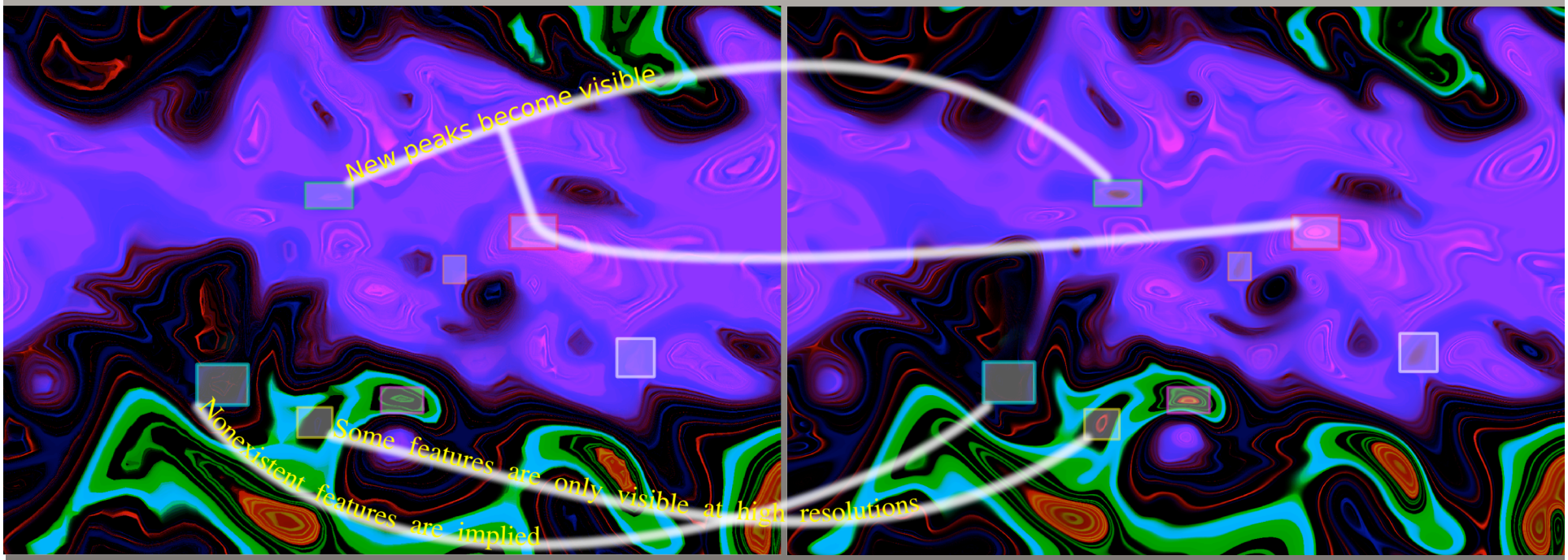






The Need for High Resolution Visualization

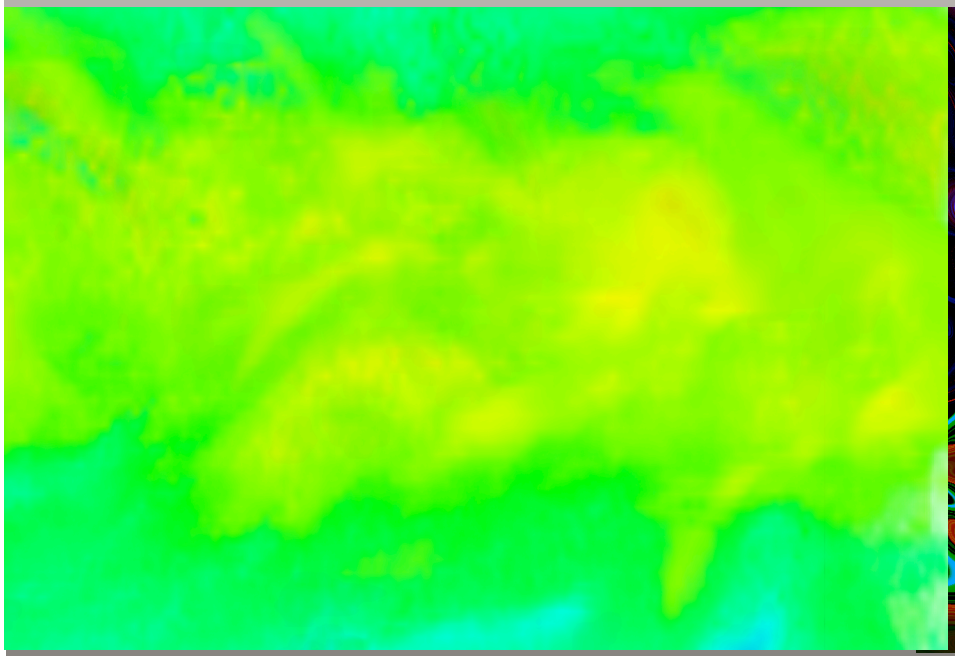
"…the data show for the first time how detailed transport and chemistry effects can influence the mixing of reactive scalars. It may be advantageous to incorporate these effects within molecular mixing models. It is worth noting that at present it is impossible to obtain this type of information any other way than by using the type of highly resolved simulation performed here."
Jacqueline Chen, Sandia National Laboratories



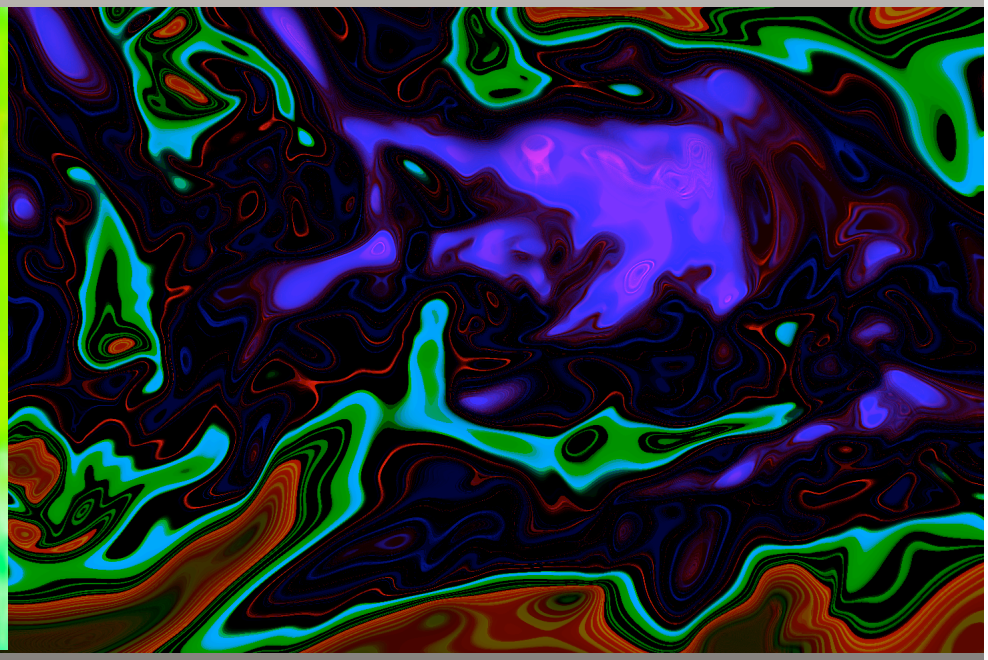
Lower Resolution

High Resolution

Tuvok Volume Rendering

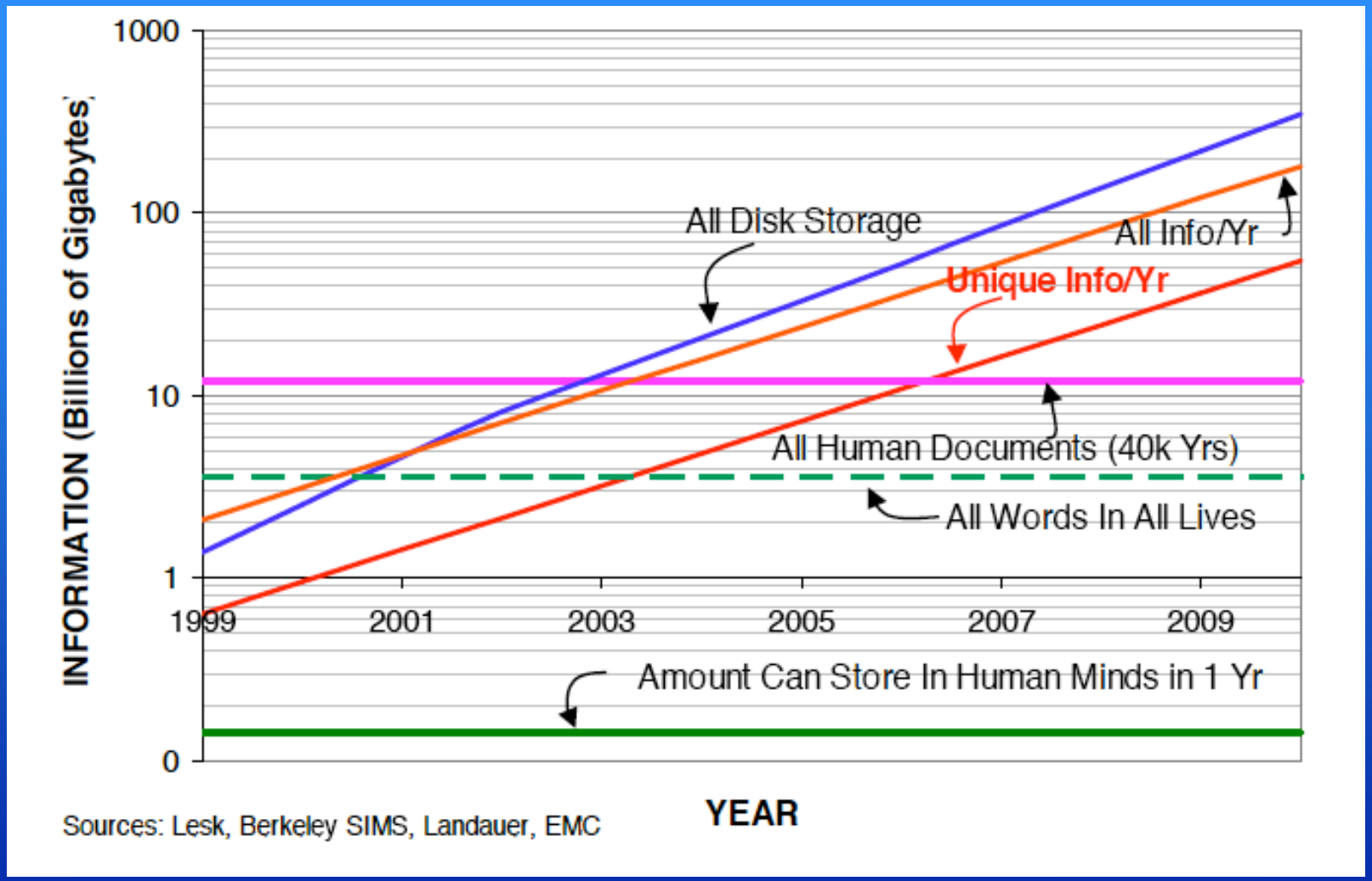


VisIt



Tuvok

Information Big Bang



VisTrails - www.vistrails.org

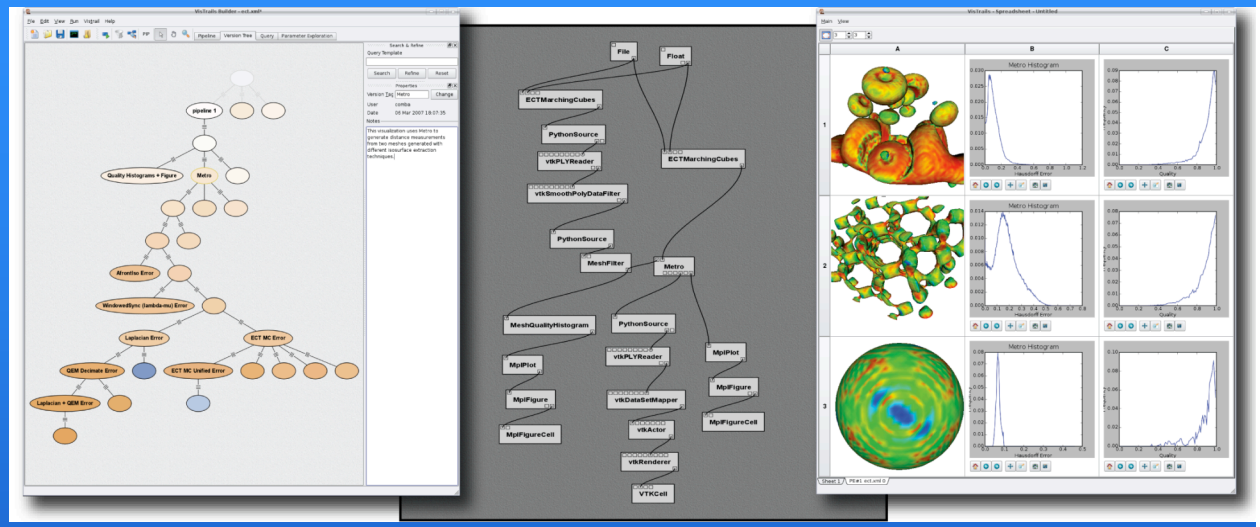
Automatic
Provenance Capture

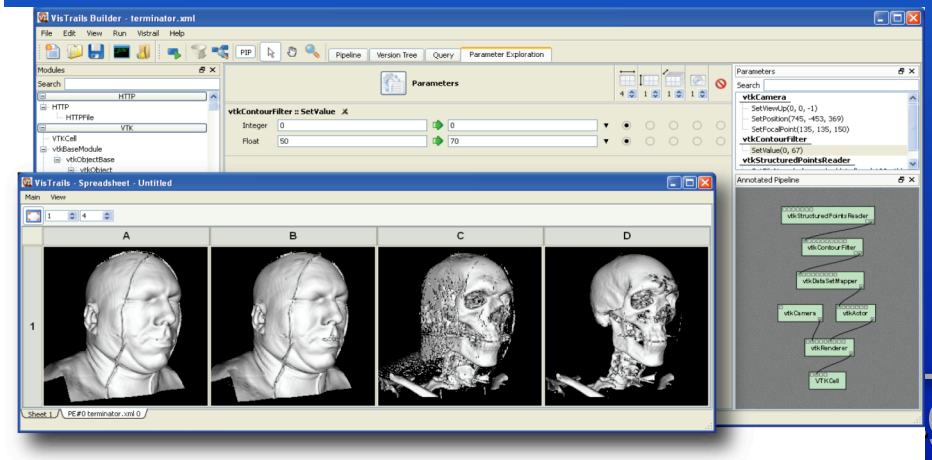
Task Creation
by Analogy

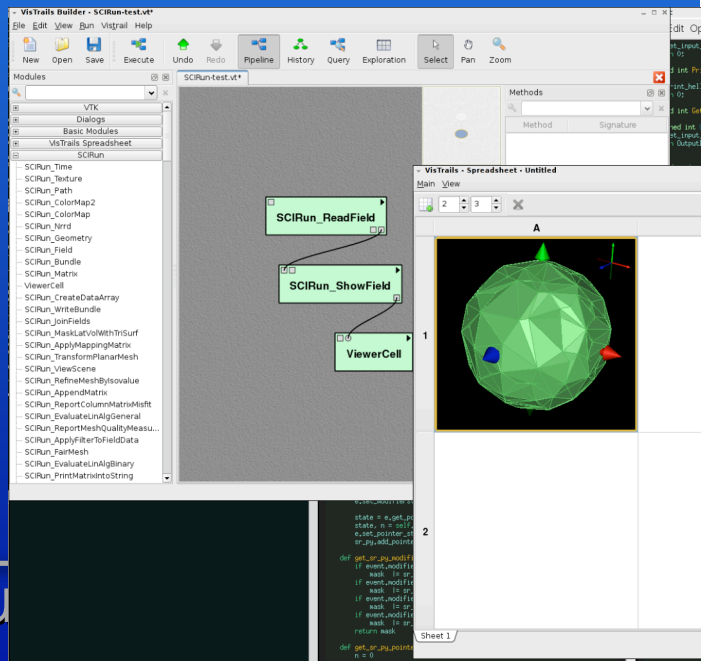
Intuitive Query
Interfaces

Support for
Collaborative Exploration

Extensibility







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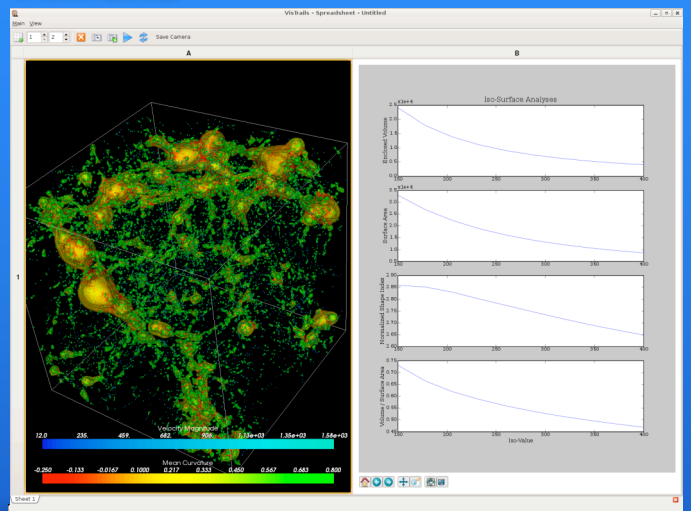
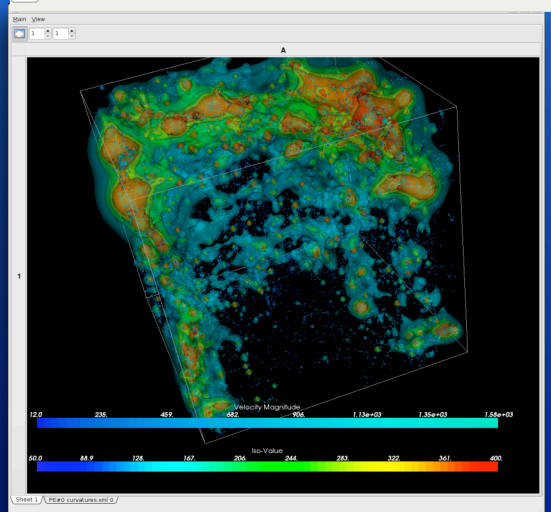
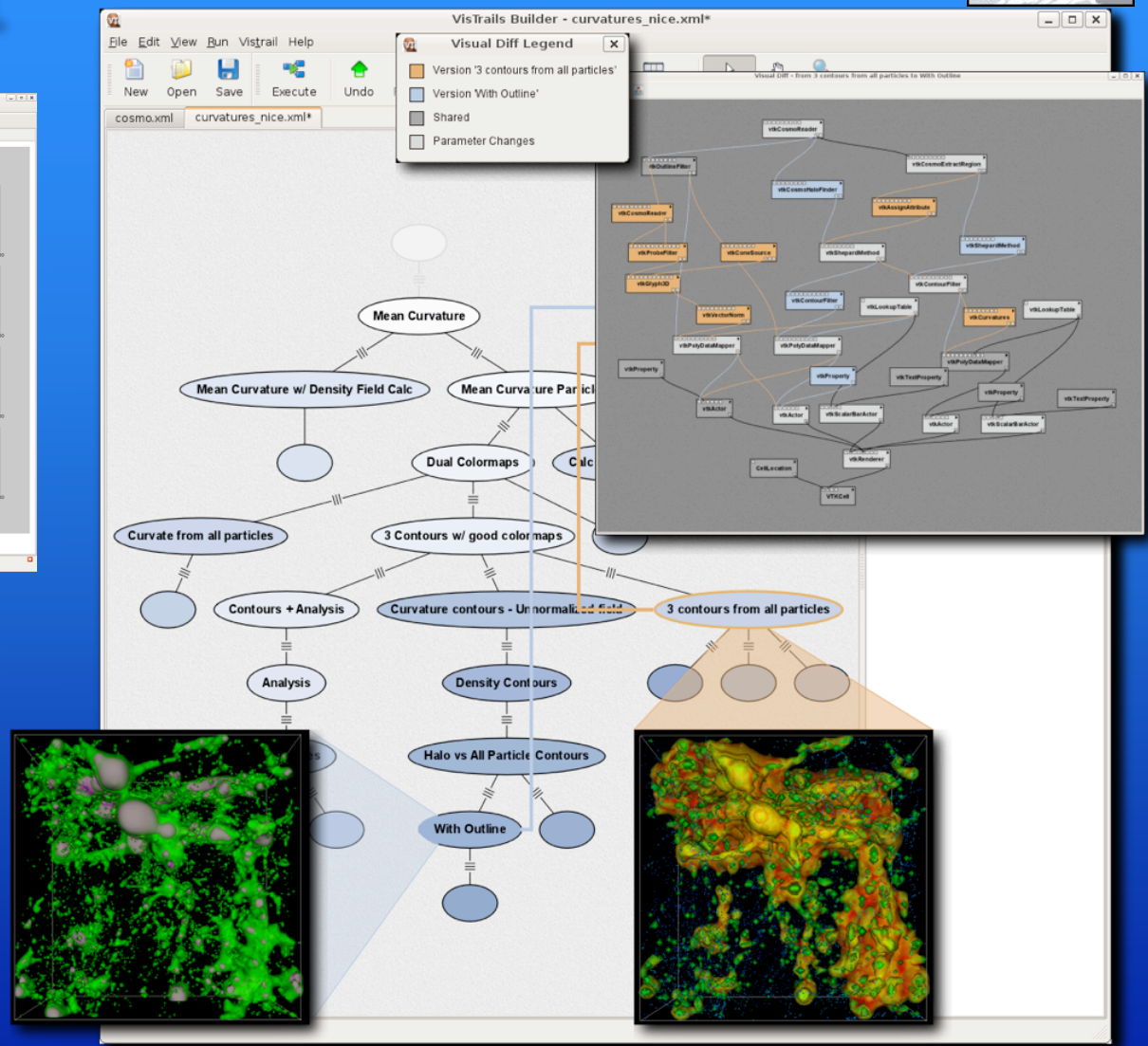
VisTrails and Scientific Applications

Cosmology at LANL, with J. Ahrens

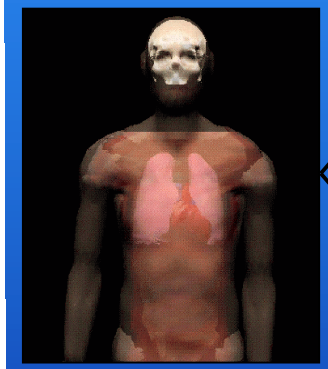


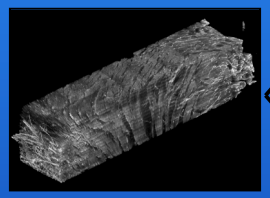


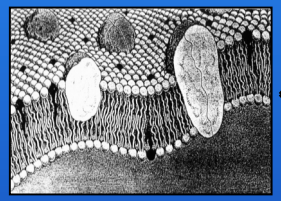


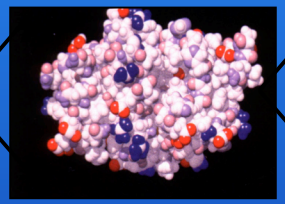
Biomedical Computing Across Scales

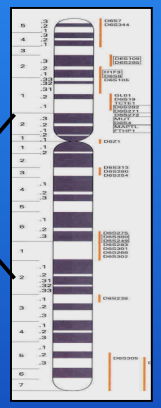
Organism & organ systems	Organ (1m)	Tissue (10^{-3}m)	Cell (10^{-6}m)	Protein (10^{-9}m)	Atom (10^{-12}m)











Systems models	Continuum models (PDEs)	ODEs	Stochastic models	Pathway models	Gene networks

Modeling, Simulation, and Visualization Algorithms; Software Frameworks; Databases; Networking

Courtesy: Peter Hunter, University of Auckland

The Scientific Computing and Imaging Institute

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NIH NCRR and BISTI

DOE ASCI and SciDAC

NSF

Utah Centers of Excellence

KAUST

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