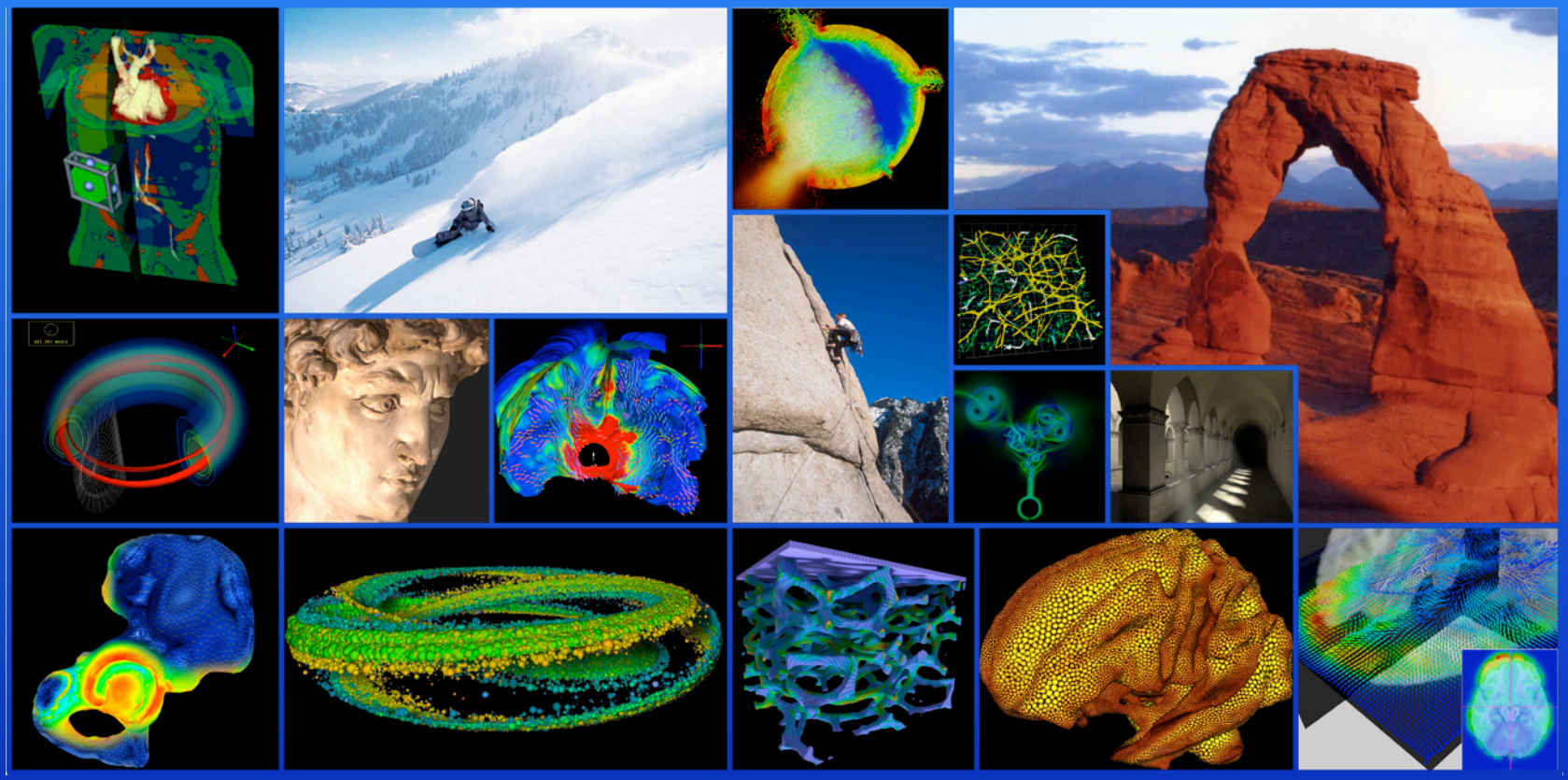
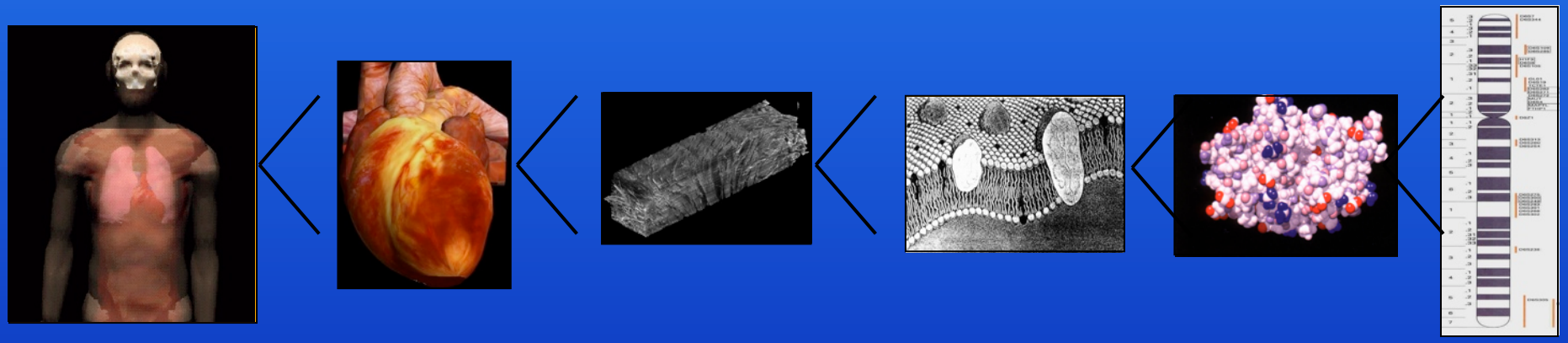
Computing and Visualizing the Future of Biomedicine



Chris Johnson
Scientific Computing and Imaging Institute
University of Utah

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

Biomedical Computing Challenges

The Paradox of Computational Biology*

- *"The success of computational biology is shown by the fact that computation has become integral and critical to modern biomedical research."*
- *"Because computation is integral to biomedical research, its deficiencies have become significant rate limiting factors in the rate of progress of biomedical research"*

The Knowledge Gap and the Culture Gap

- *"There are not sufficient personnel to meet the needs for creating better biological computing tools and user environments."*
- *There currently do not exist sufficient educational programs and resources to train the next generation of biomedical computing scientists*

*From the NIH Roadmap on Computing (Eric Jakobsson):

Biomedical Computing Pipeline

SCI INSTITUTE

Image & Data Acquisition

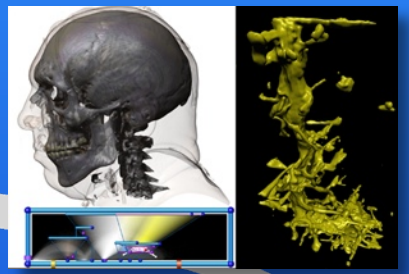
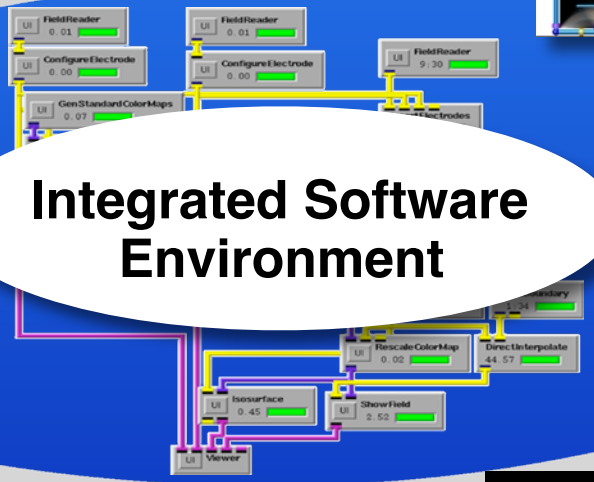


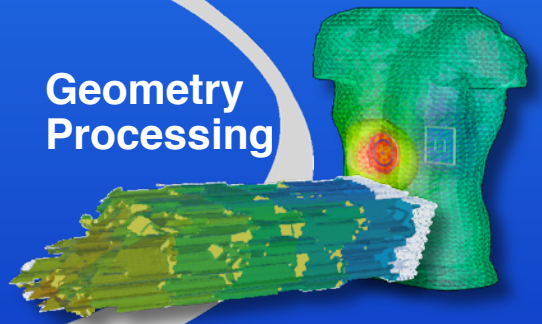
Image Processing

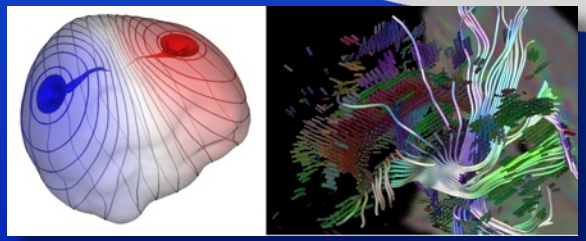
Validation



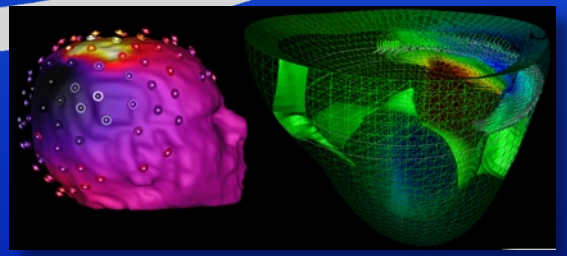
Integrated Software Environment

Geometry Processing





Visualization

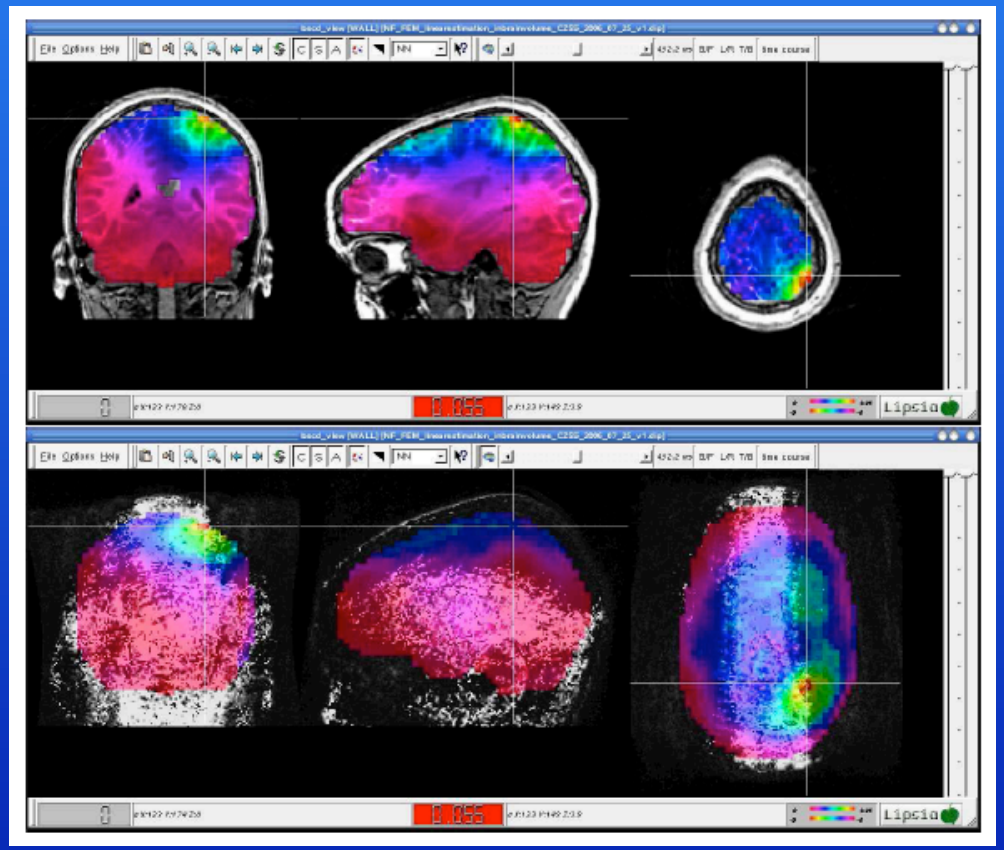


Mathematical Modeling & Simulation

EEG Acquisition for Epilepsy Localization

Epilepsy affects over 2.5 million Americans, and has an estimated health care total annual cost close to $12.5 billion per year

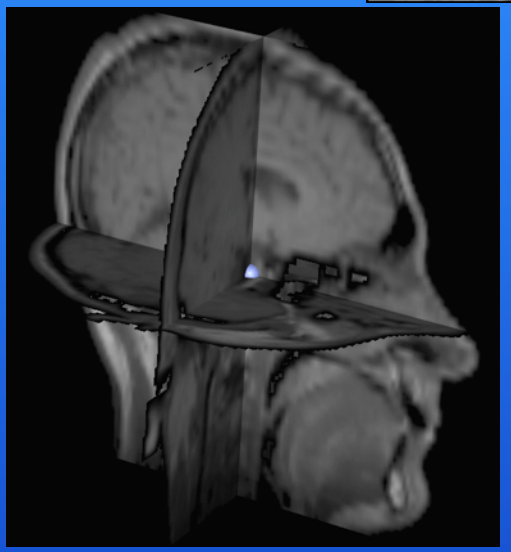
Illustration of 128 channel EEG acquisition carried out at Children's Hospital, Boston



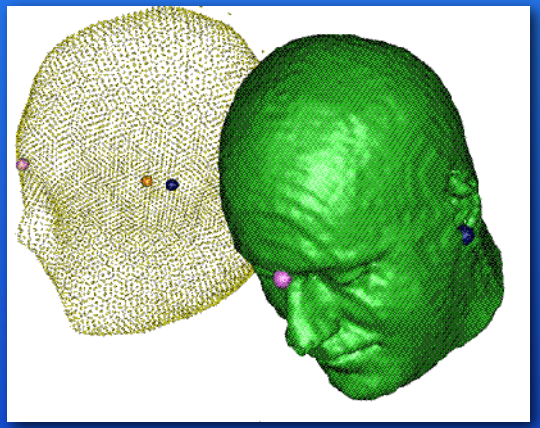
Images courtesy of Simon Warfield, Children's Hospital Boston

Geometric Modeling

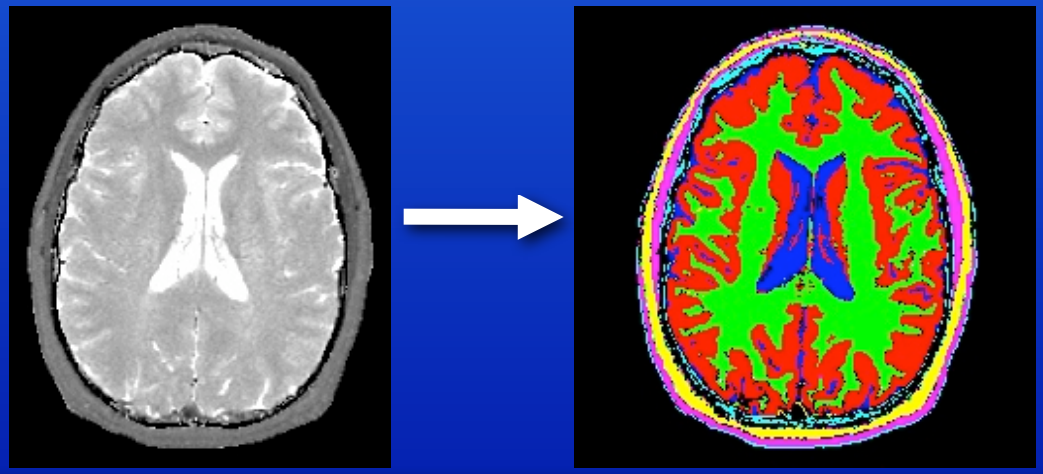
- Raw MRI and Digitized Points



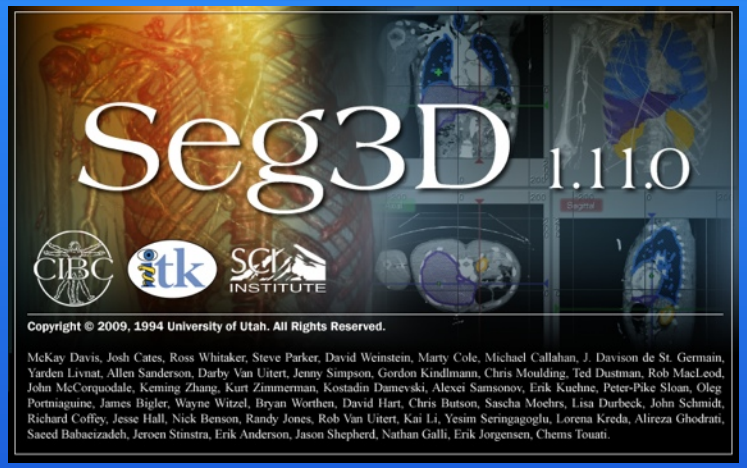
- Registration



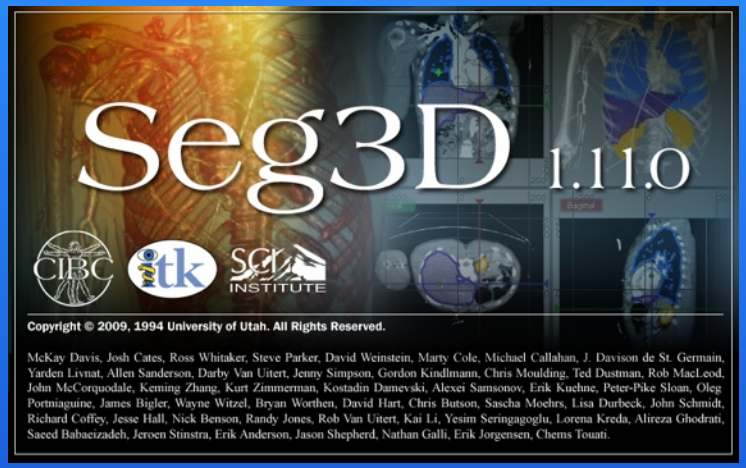
- Segmentation
  (aka classification)

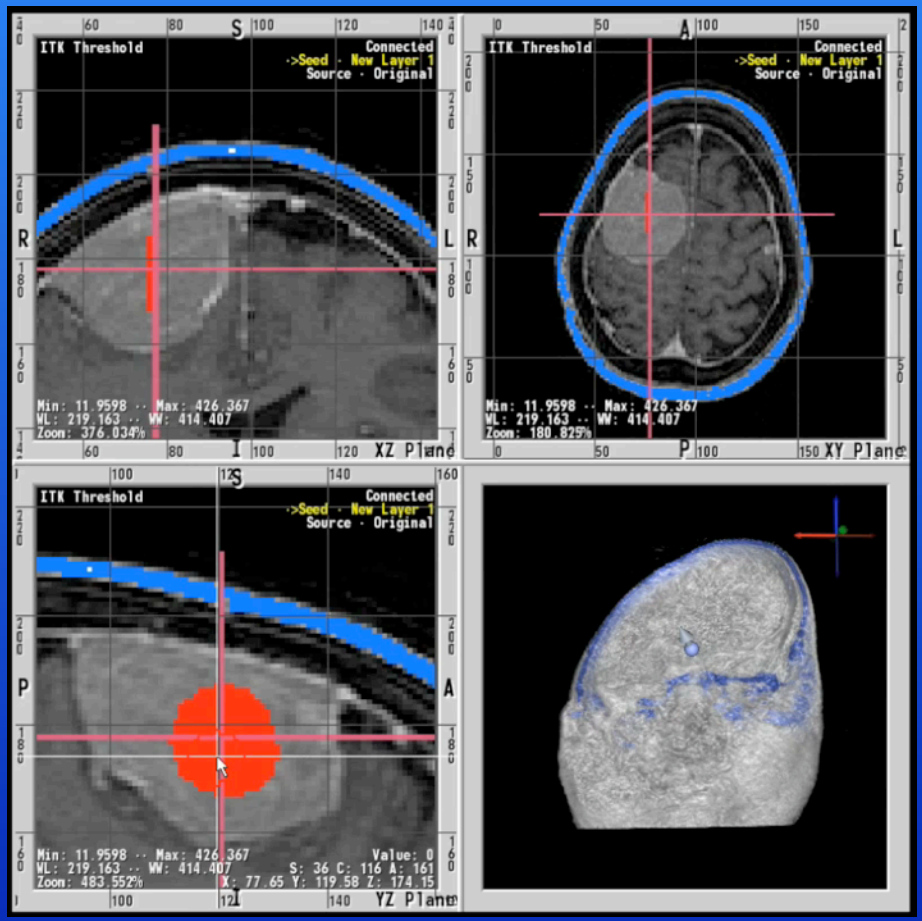


3D Image Segmentation

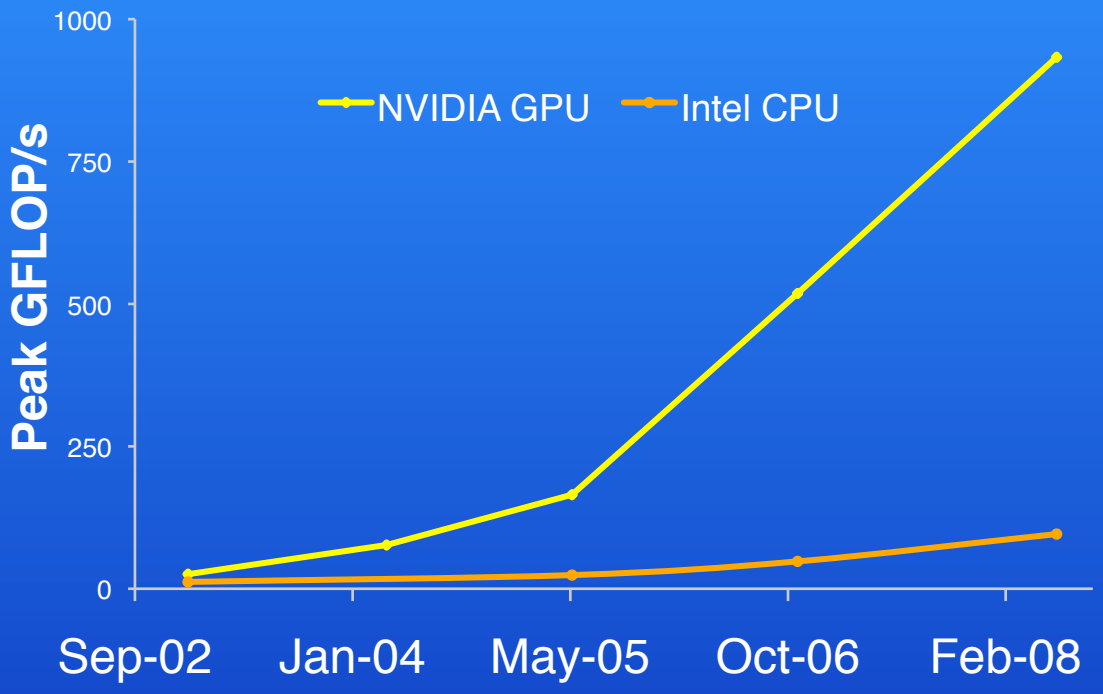


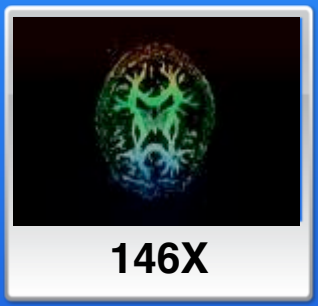
3D Image Segmentation





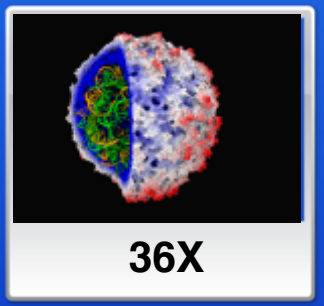
Simulation and Visualization with GPUs





146X

Medical Imaging
U of Utah



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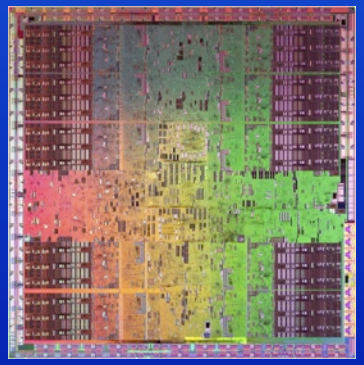
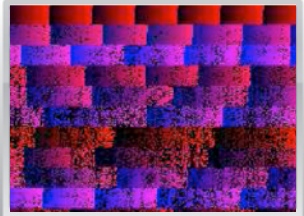
Molecular Dynamics
U of Illinois

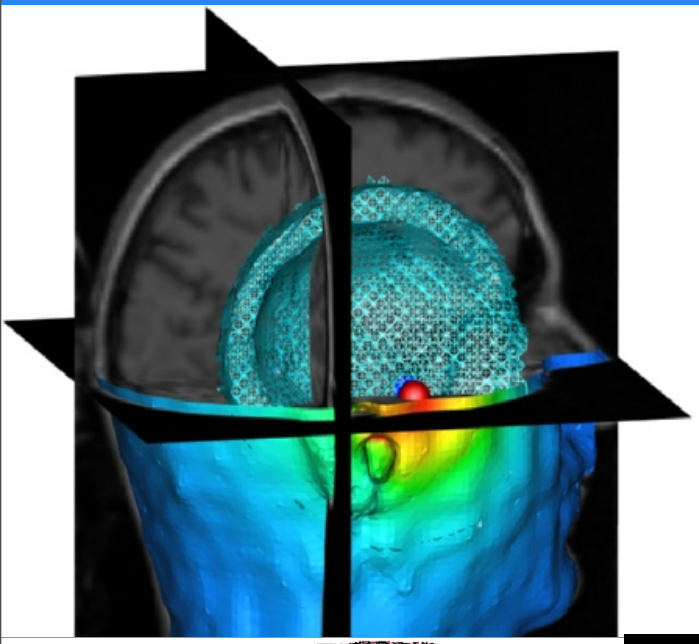


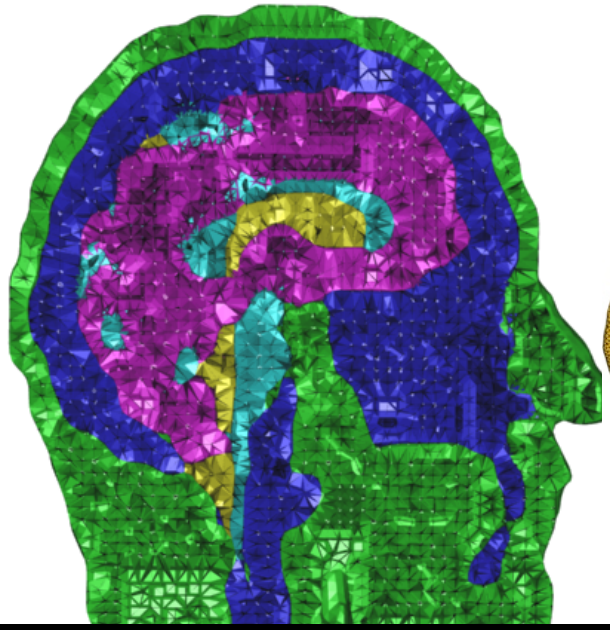


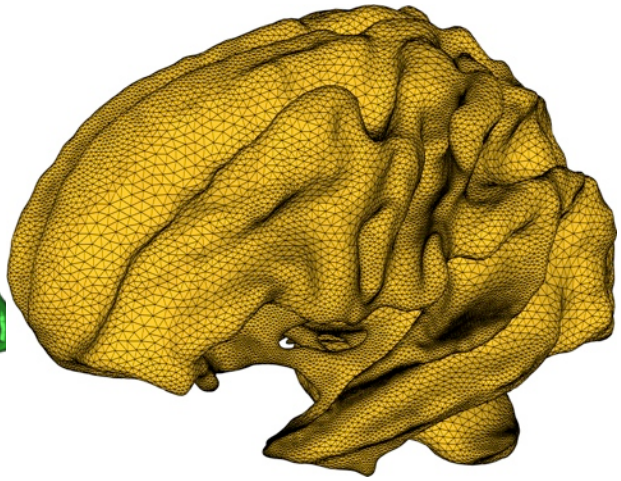
30X

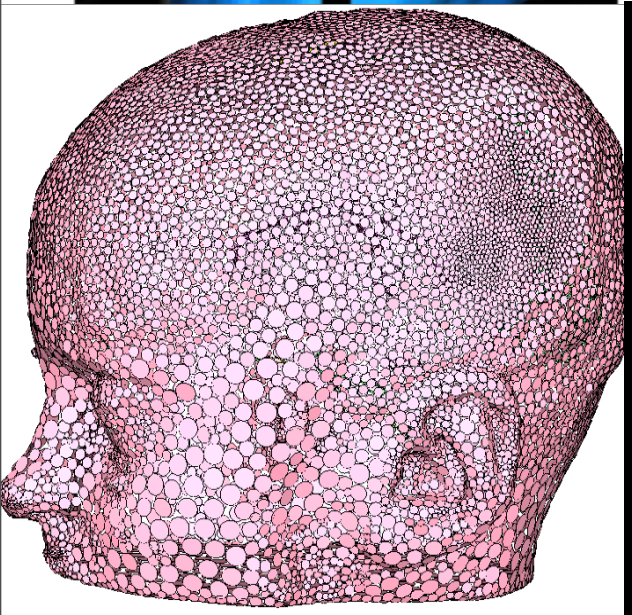
Gene Sequencing
U of Maryland

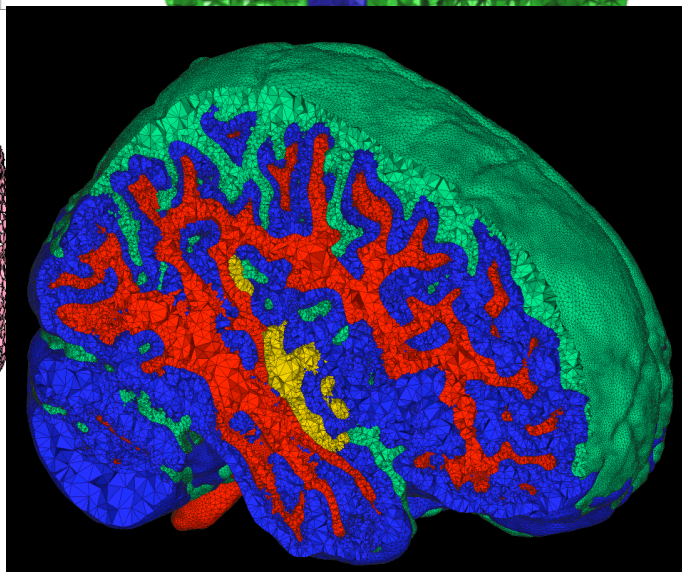
Mesh Generation - BioMesh3D

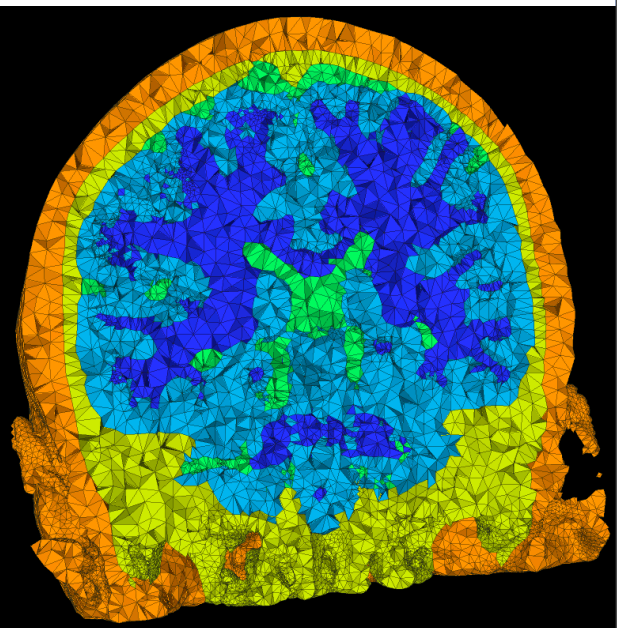








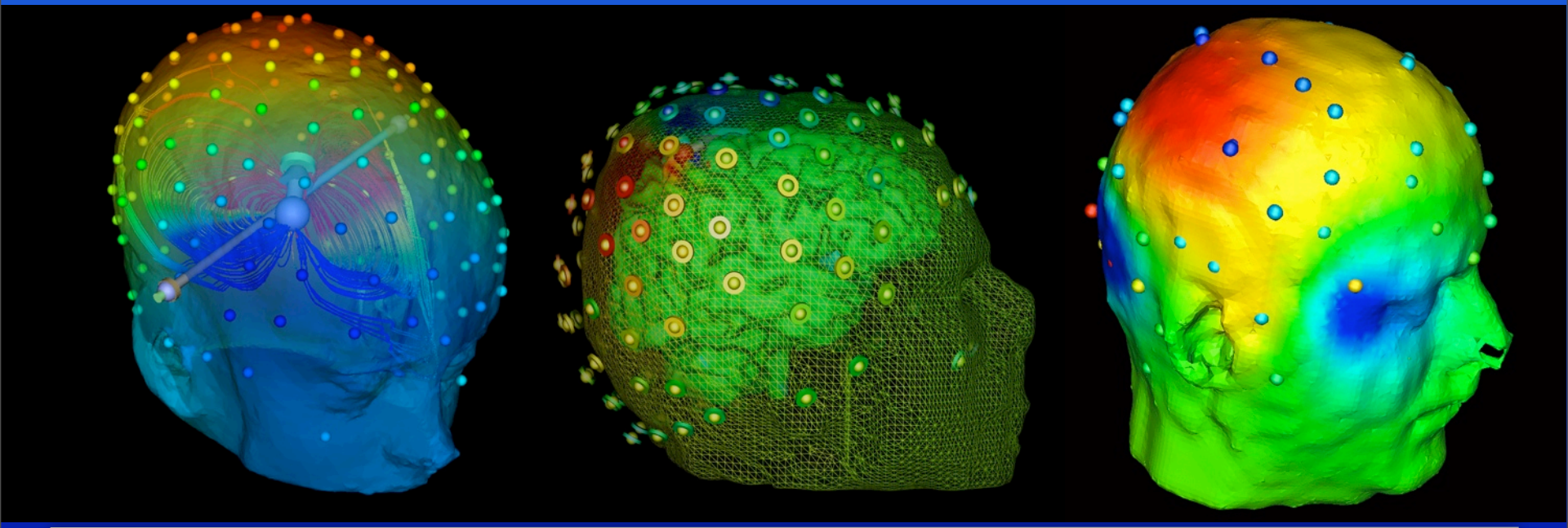




Epilepsy Source Localization

Optimization between data and computer simulation for given parameters

$$||\phi - \hat{\phi}|| = \sum_{k} \sum_{j=1}^{32} (\phi_j(t_k) - \hat{\phi}_j(t_k))^2$$



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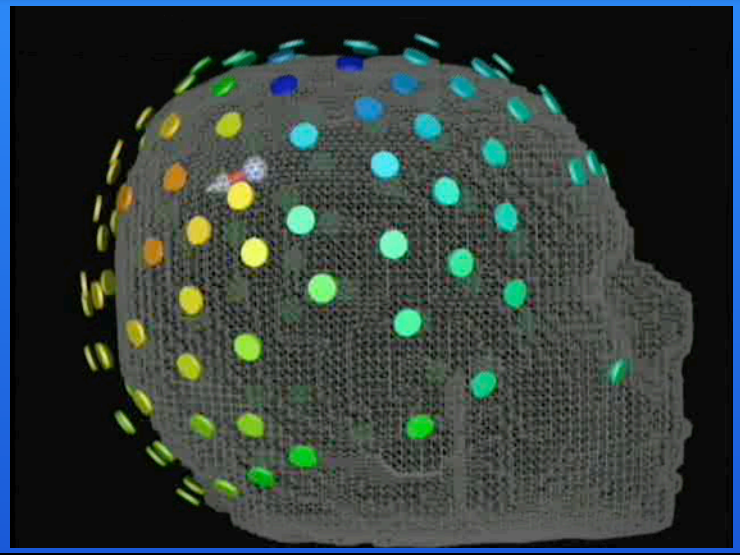
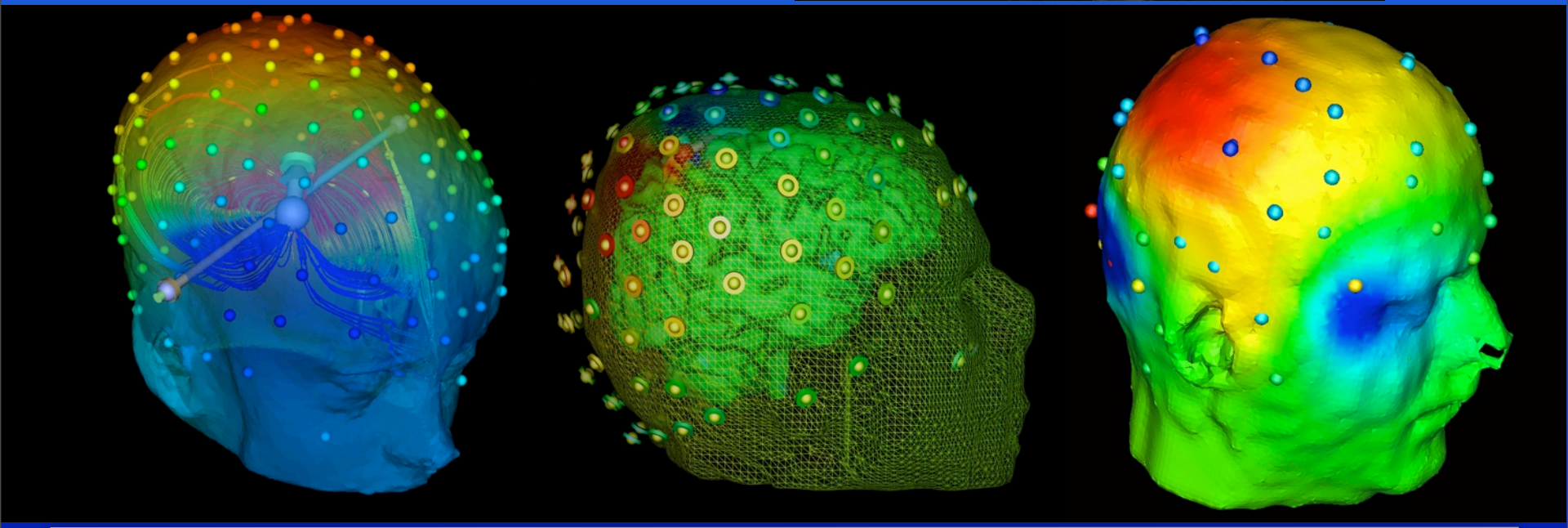
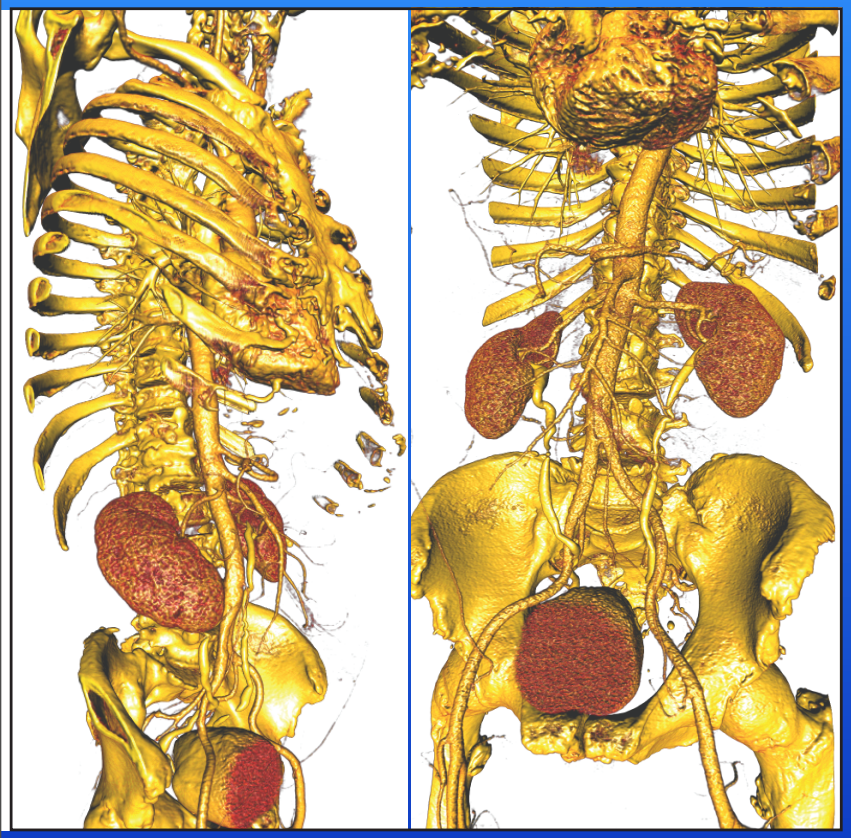
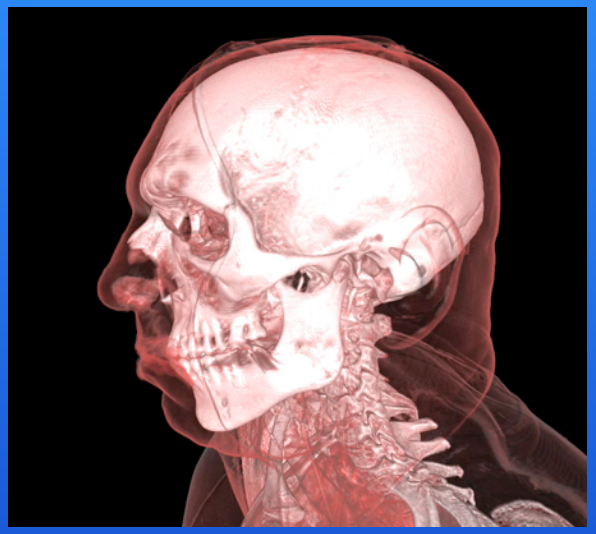
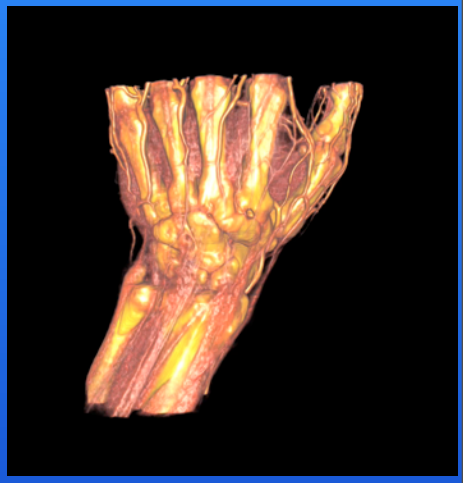


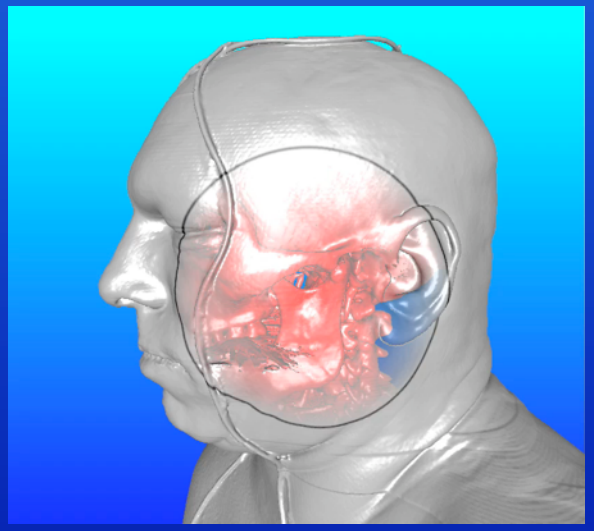


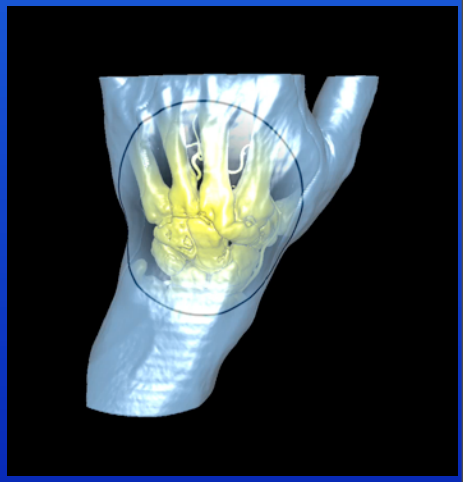
Biomedical Visualization





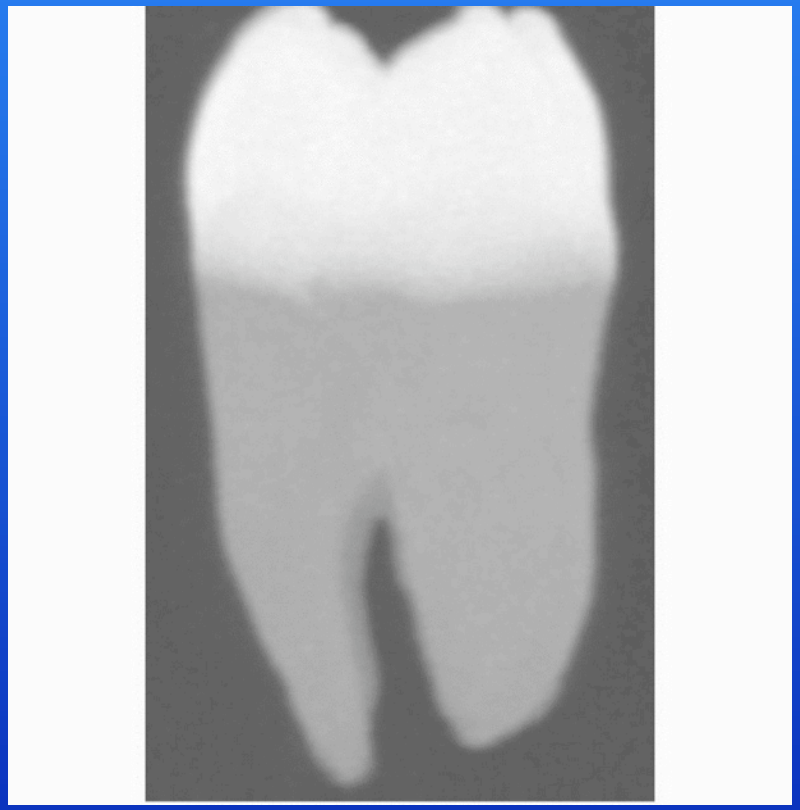






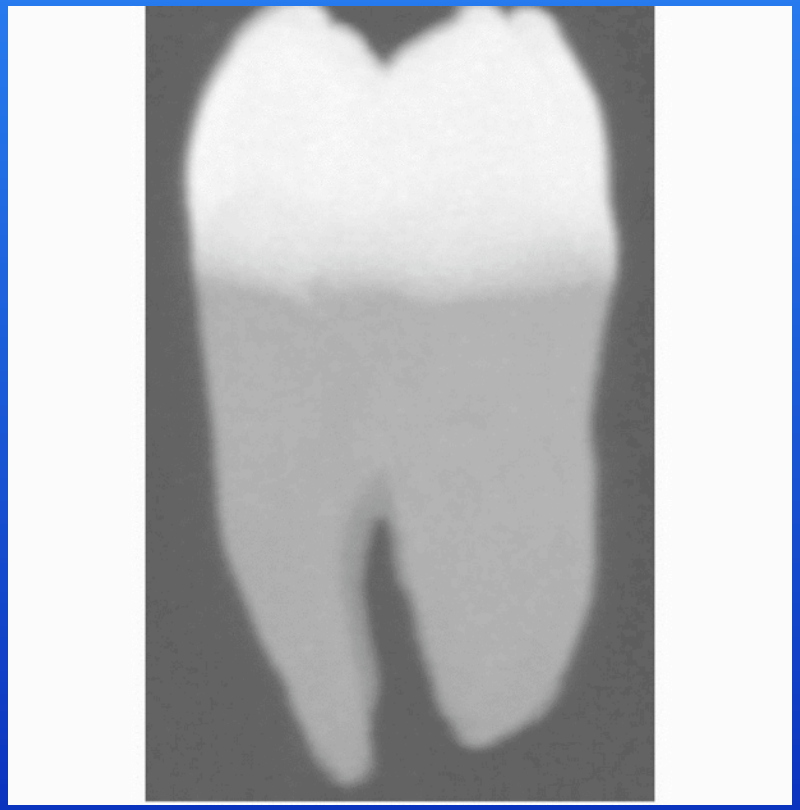
Biomedical Visualization

Biomedical Visualization



Maximum Intensity Projection (MIP)

Biomedical Visualization

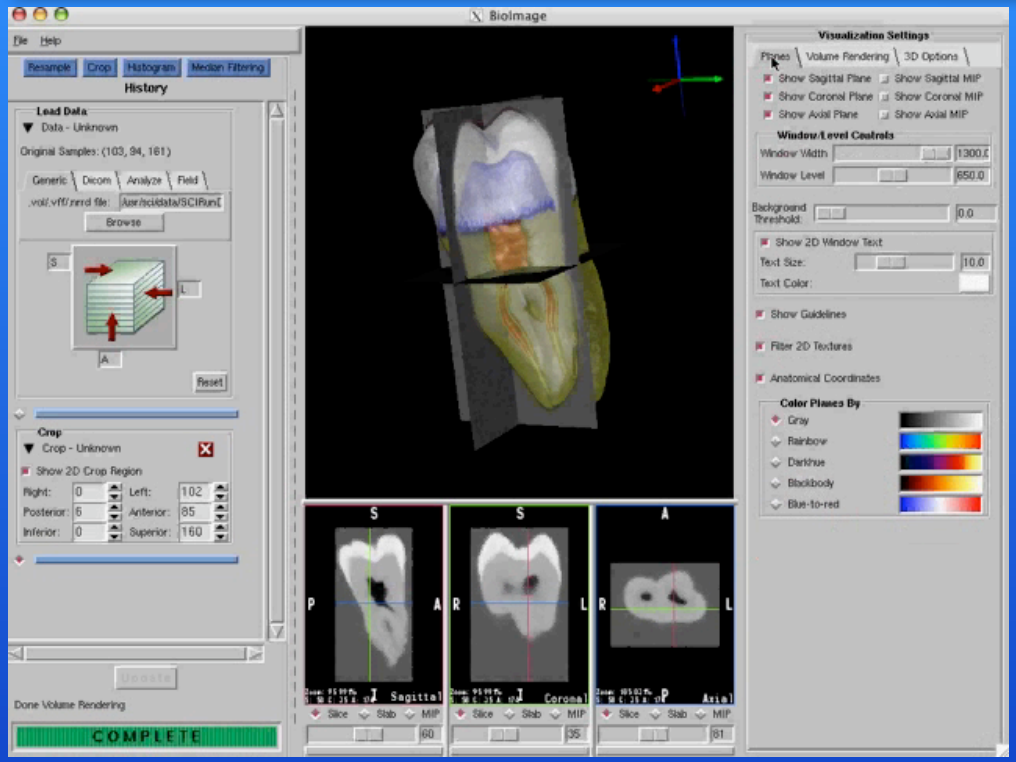


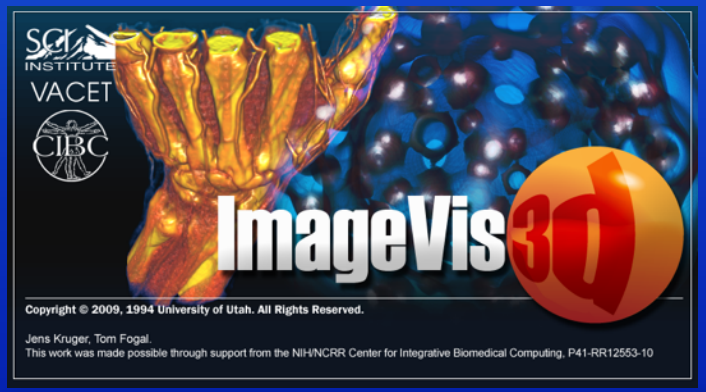
Maximum Intensity Projection (MIP)

Full Volume Rendering

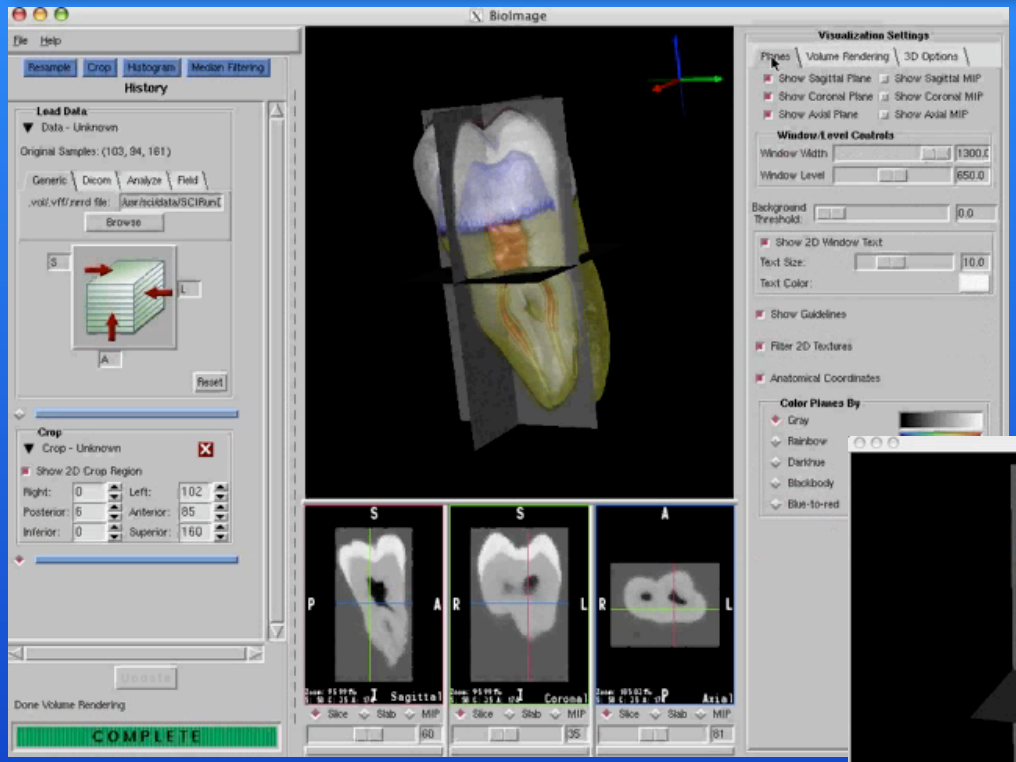
Biomedical Visualization Software

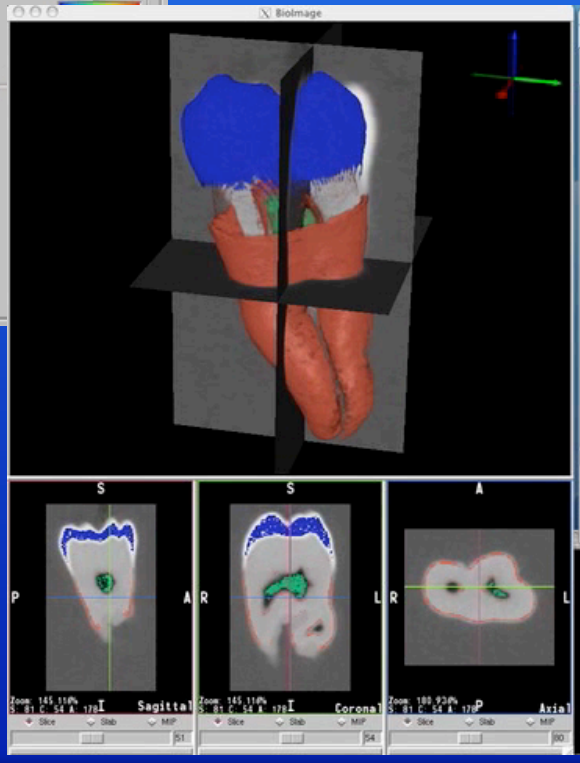
Biomedical Visualization Software

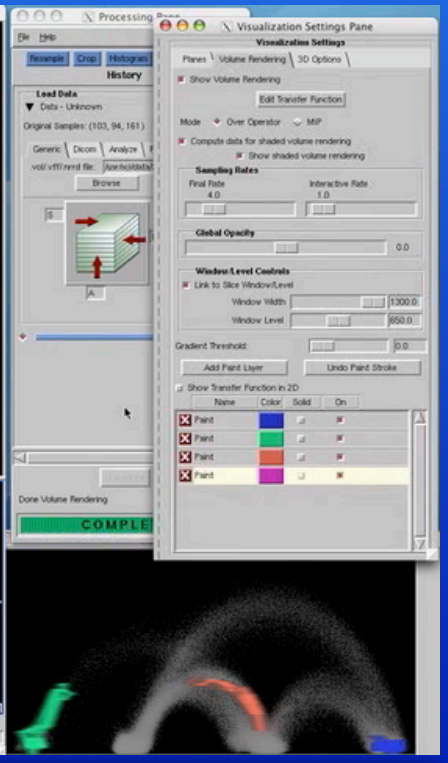


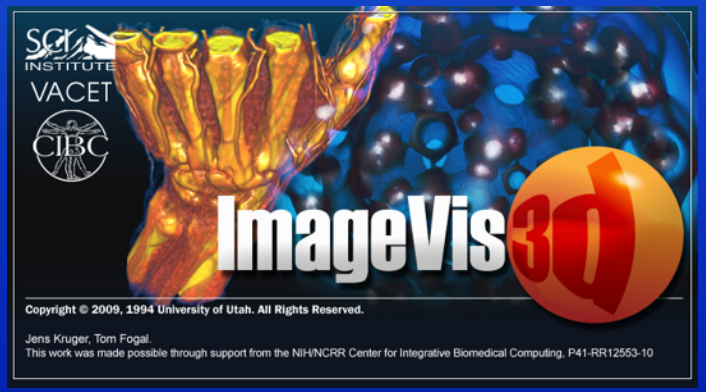


Biomedical Visualization Software

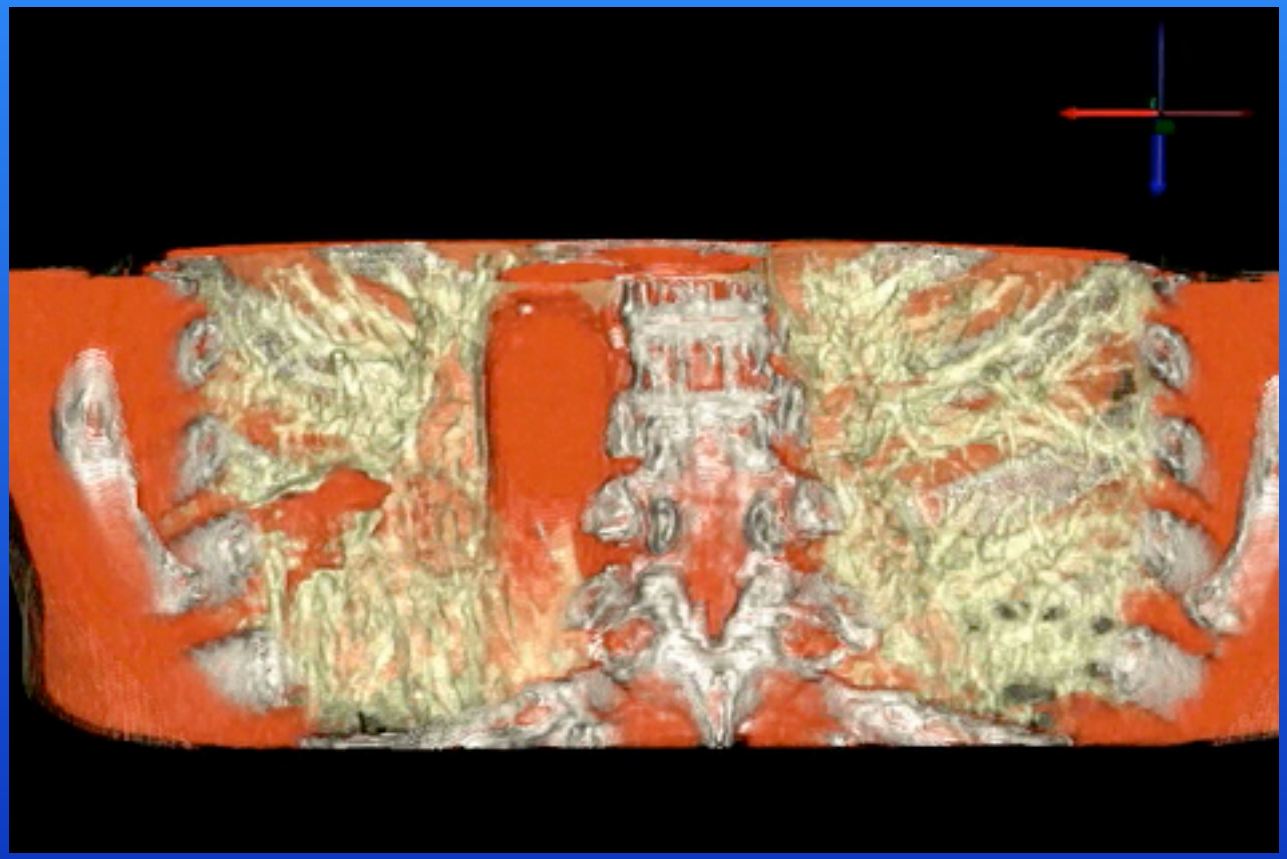






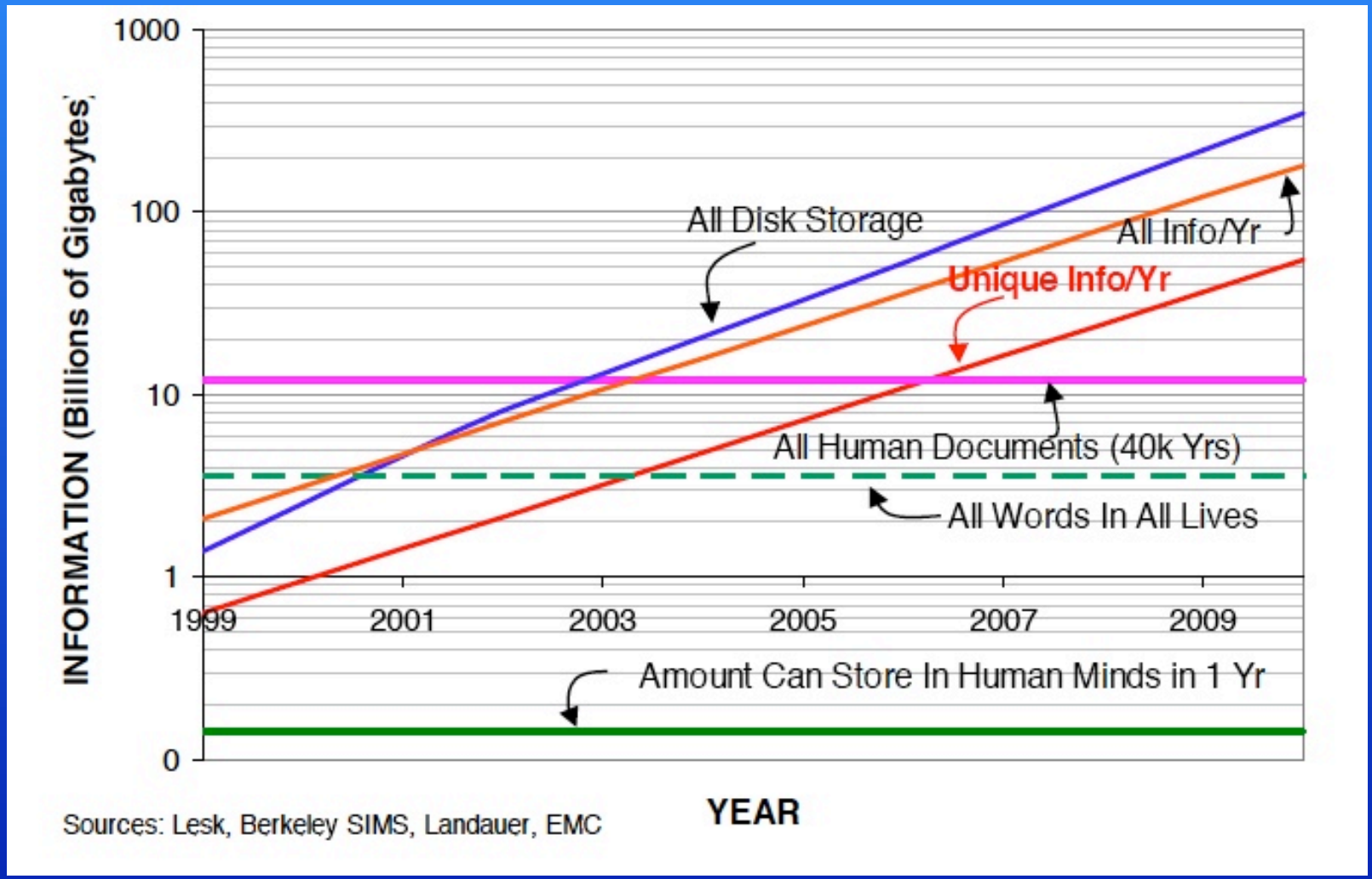


Time Dependent Visualization



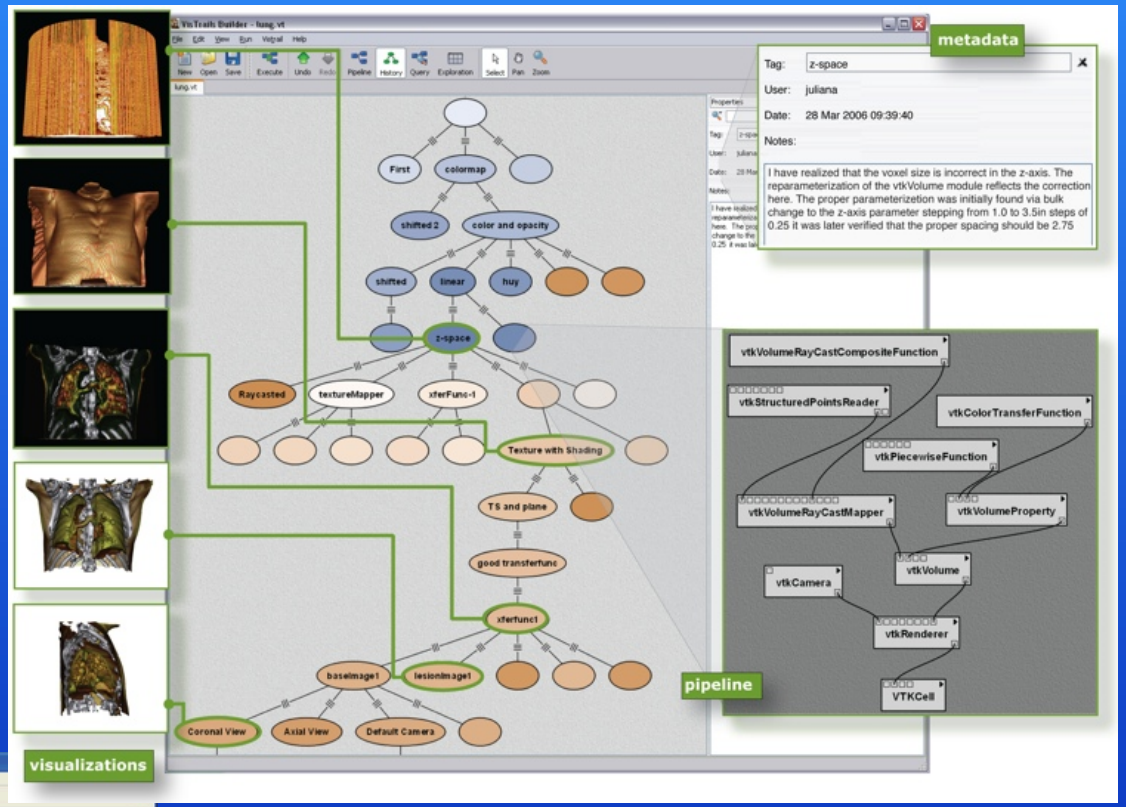
Time-dependent BioImage volume rendering of a 4D CT dataset. Interaction rate on a PC running Linux is approximately 10 frames per second. Data from collaborator George Chen (MGH).

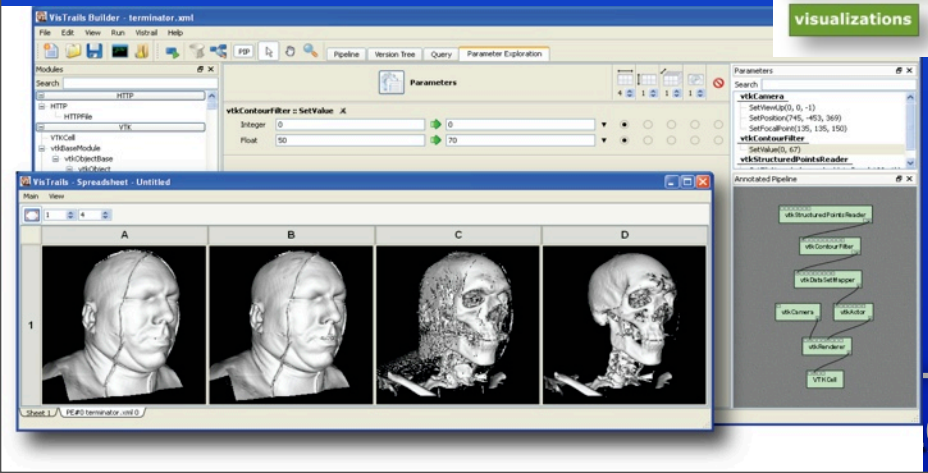
Information Big Bang



Workflow and Data Management

- Automatic Provenance Capture
- Task Creation by Analogy
- Intuitive Query Interfaces
- Support for Collaborative Exploration
- Extensibility





Scientific Computing and Visualization

Biomedical Computing Possibilities

The Bottom Line: Investing in biomedical computing will:

- Speed and broaden the scope of discovery in medicine
- Improve diagnosis and treatment of life-threatening diseases
- Leverage previous investments in both biomedicine and computing to create new life-saving technologies and make existing technologies more effective and cost efficient

Acknowledgements

NIH NCRR, NIBIB, NIHLB, NCBC, NLM

DOE ASCI and SciDAC

NSF

Utah Science and Technology Advanced Research (USTAR)

More Information

www.sci.utah.edu

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