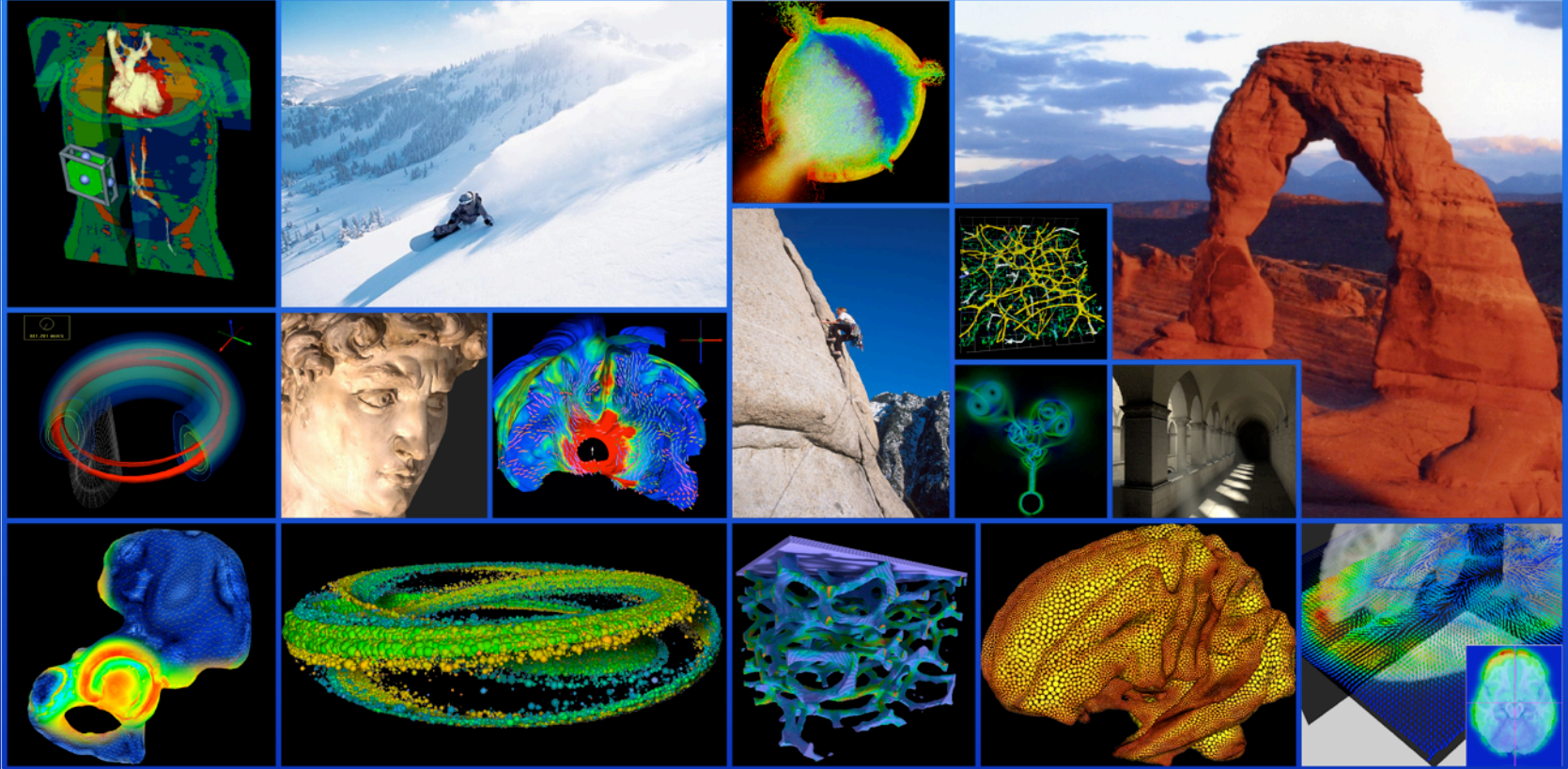


Computing and Visualizing the Future of Biomedicine



Chris Johnson
Scientific Computing and Imaging Institute
University of Utah

Biomedical Computing Across Scales



**Organism
& organ systems**

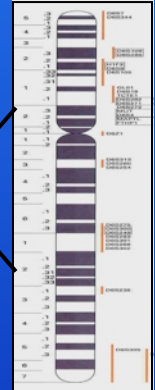
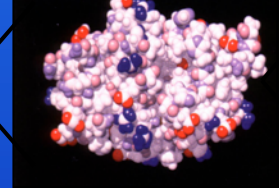
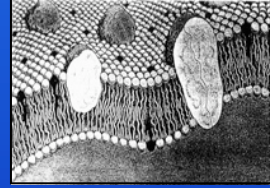
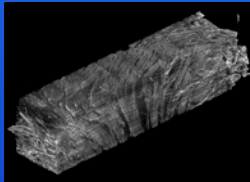
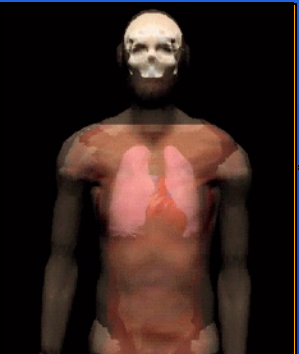
**Organ
(1m)**

**Tissue
(10⁻³m)**

**Cell
(10⁻⁶m)**

**Protein
(10⁻⁹m)**

**Atom
(10⁻¹²m)**



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

Scientific Computing and Imaging Institute, University of Utah

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):*

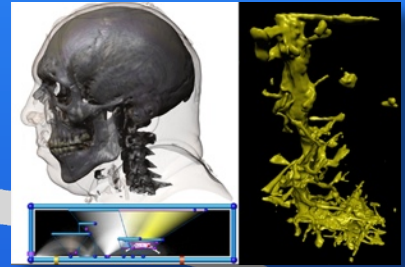
Biomedical Computing Pipeline



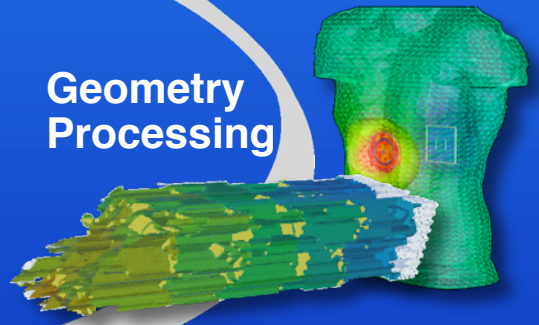
Image & Data Acquisition



Image Processing



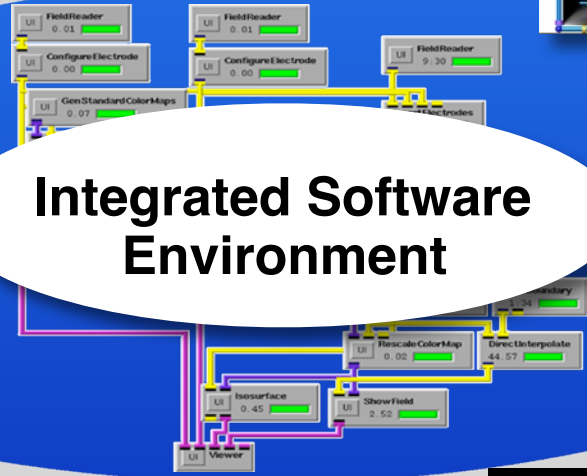
Geometry Processing



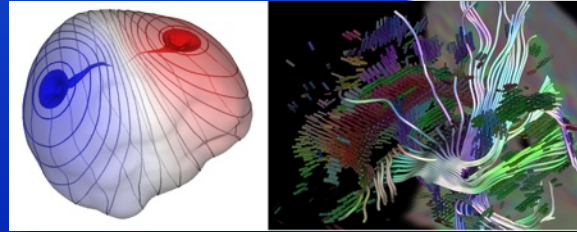
Validation



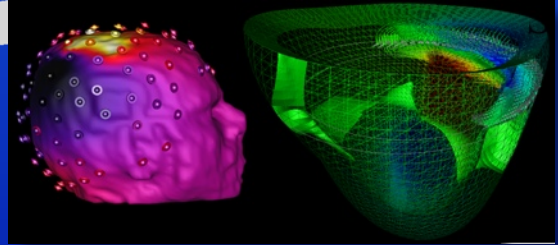
Integrated Software Environment



Visualization



Mathematical Modeling & Simulation



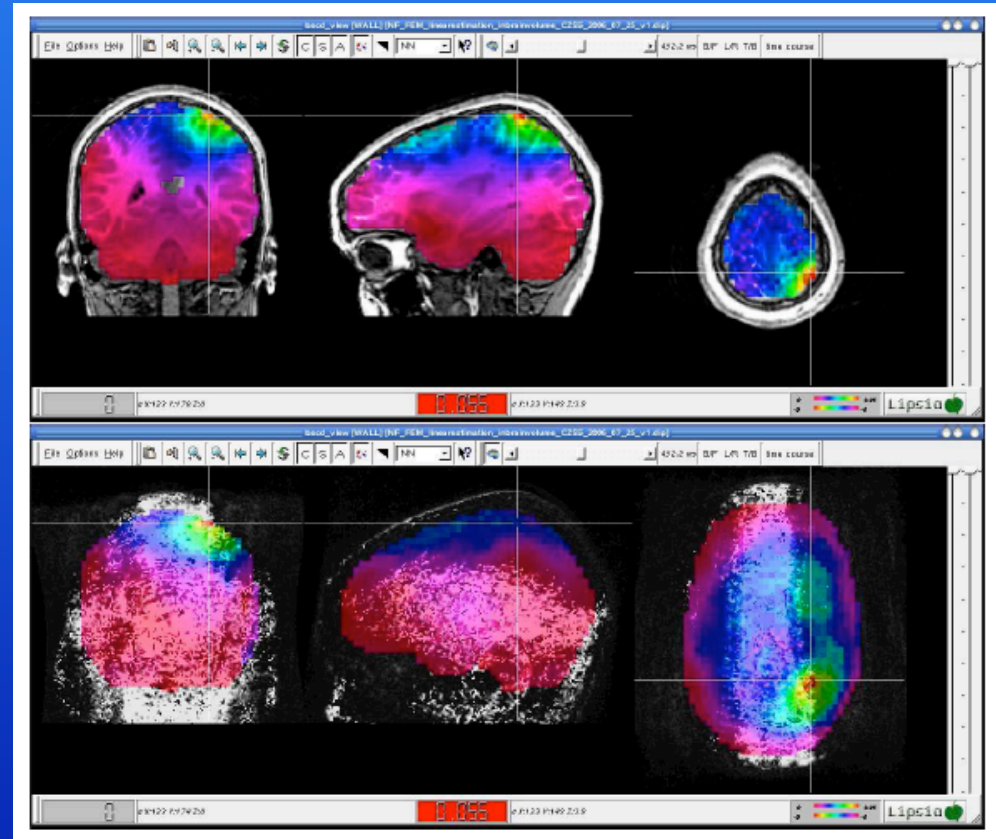
EEG Acquisition for Epilepsy Localization



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

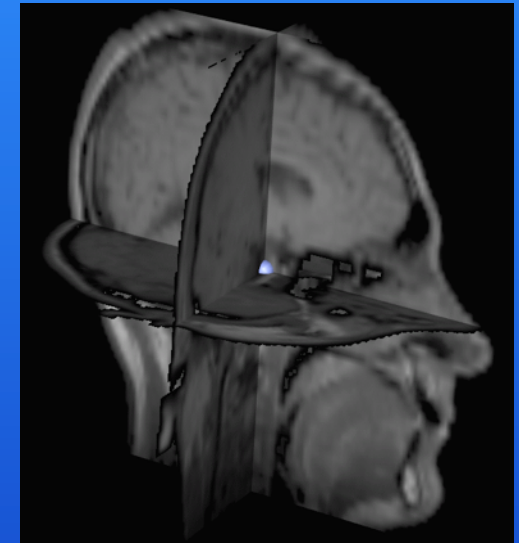


Images courtesy of Simon Warfield, Children's Hospital Boston

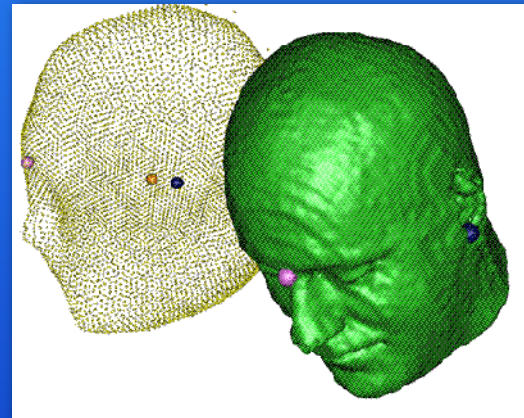
Scientific Computing and Imaging Institute, University of Utah

Geometric Modeling

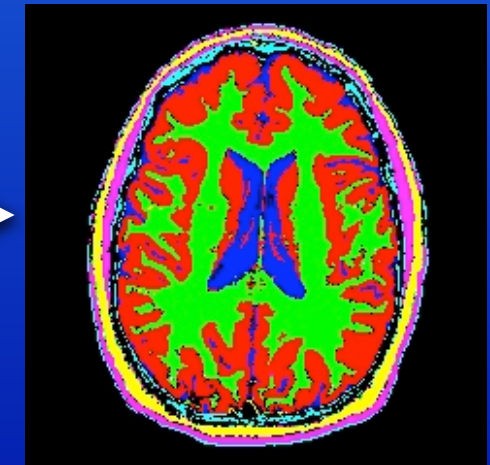
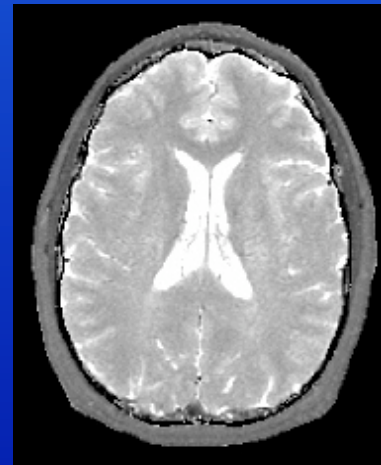
- Raw MRI and Digitized Points



- Registration



- Segmentation
(aka classification)



3D Image Segmentation

A screenshot of the Seg3D 1.11.0 software interface. The title "Seg3D 1.11.0" is prominently displayed in the center. Below the title are logos for CIBC, itk, and SCI INSTITUTE. The background shows a 3D anatomical model of a human torso with various organs segmented in different colors. The interface includes several panels and controls for image manipulation and segmentation.

Copyright © 2009, 1994 University of Utah. All Rights Reserved.

McKay Davis, Josh Cates, Ross Whitaker, Steve Parker, David Weinstein, Marty Cole, Michael Callahan, J. Davison de St. Germain, Yarden Livnat, Allen Sanderson, Darby Van Uitter, Jenny Simpson, Gordon Kindlmann, Chris Moulding, Ted Dustman, Rob MacLeod, John McCorquodale, Keming Zhang, Kurt Zimmerman, Kostadin Daneyvski, Alexei Samsonov, Erik Kuehne, Peter-Pike Sloan, Oleg Portniaguine, James Bigler, Wayne Witzel, Bryan Worthen, David Hart, Chris Butson, Sascha Mochrs, Lisa Durbeck, John Schmidt, Richard Coffey, Jesse Hall, Nick Benson, Randy Jones, Rob Van Uitter, Kai Li, Yesim Seringogoglu, Lorena Kreda, Alireza Ghodrati, Saeed Babaeizadeh, Jeroen Stijnstra, Erik Anderson, Jason Shepherd, Nathan Galli, Erik Jorgensen, Chems Touati.

3D Image Segmentation



Seg3D 1.11.0

CIBC itk SCI INSTITUTE

Copyright © 2009, 1994 University of Utah. All Rights Reserved.

McKay Davis, Josh Cates, Ross Whitaker, Steve Parker, David Weinstein, Marty Cole, Michiel Callahan, J. Davison de St. Germain, Yarden Livnat, Allen Sanderson, Darby Van Uitter, Jenny Simpson, Gordon Kindlmann, Chris Moulding, Ted Dustman, Rob MacLeod, John McCorquodale, Keming Zhang, Kurt Zimmerman, Kostadin Daneyvski, Alexei Samsonov, Erik Kuehne, Peter-Pike Sloan, Oleg Portniaguine, James Bigler, Wayne Witzel, Bryan Worthen, David Hart, Chris Butson, Sascha Mochers, Lisa Durbeck, John Schmidt, Richard Coffey, Jesse Hall, Nick Benson, Randy Jones, Rob Van Uitter, Kai Li, Yesim Seringogoglu, Lorena Kreda, Alireza Ghodrati, Saeed Babaeizadeh, Jeroen Stinstra, Erik Anderson, Jason Shepherd, Nathan Galli, Erik Jorgensen, Chems Touati.

ITK Threshold
->Seed - New Layer 1
Source - Original

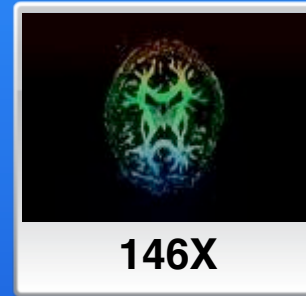
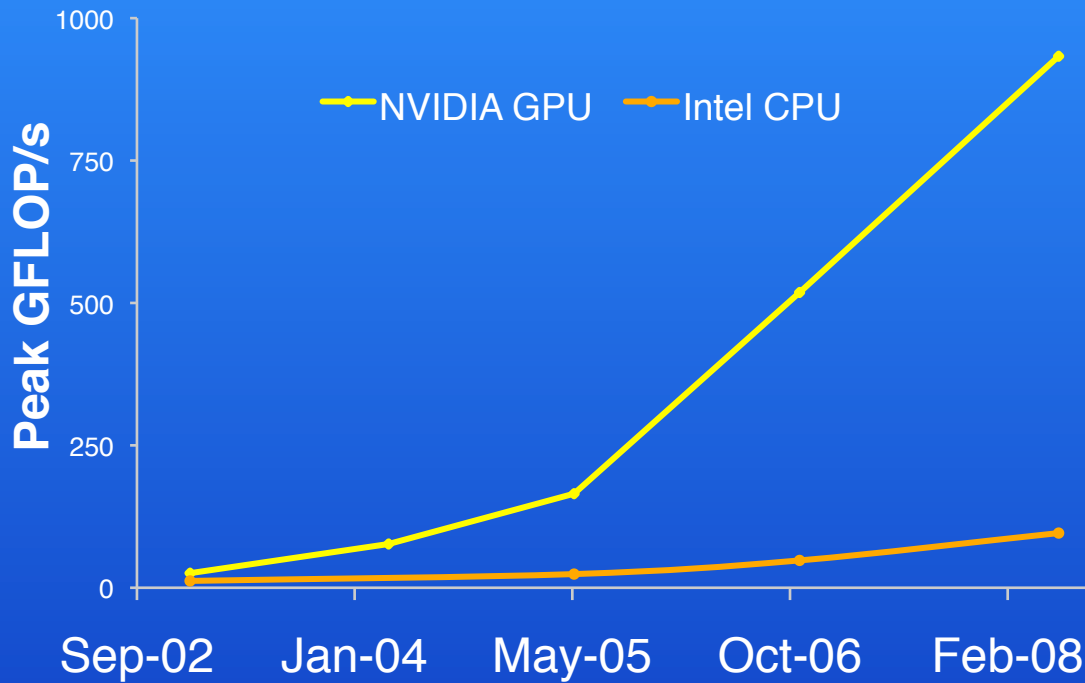
ITK Threshold
->Seed - New Layer 1
Source - Original

ITK Threshold
->Seed - New Layer 1
Source - Original

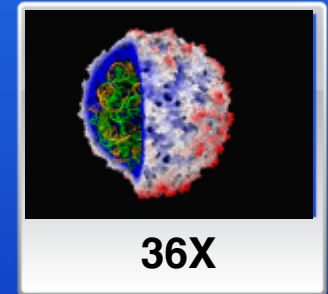
Value: 0



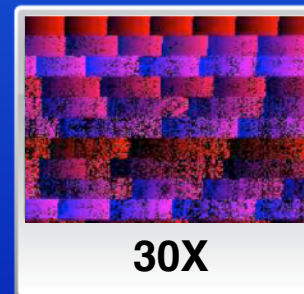
Simulation and Visualization with GPUs



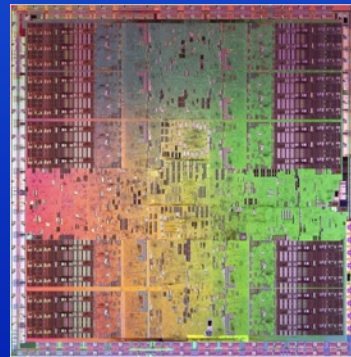
Medical Imaging
U of Utah



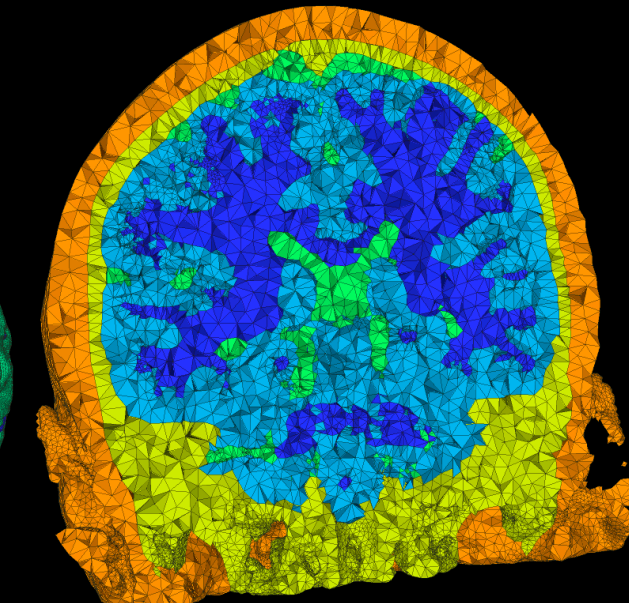
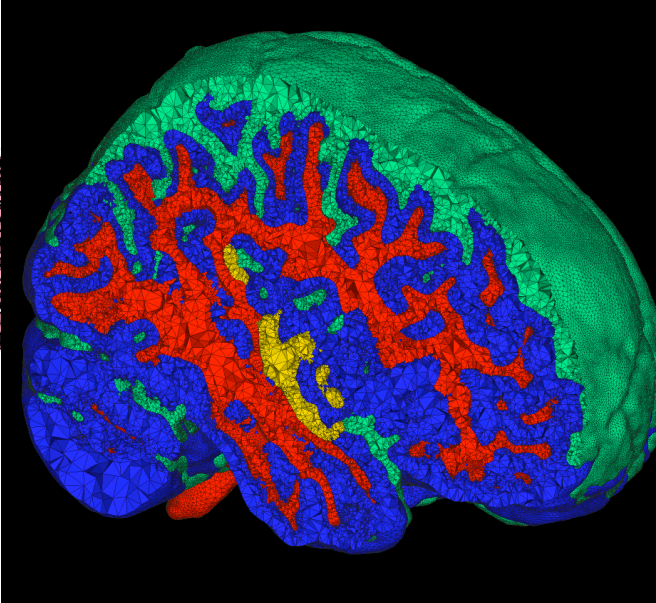
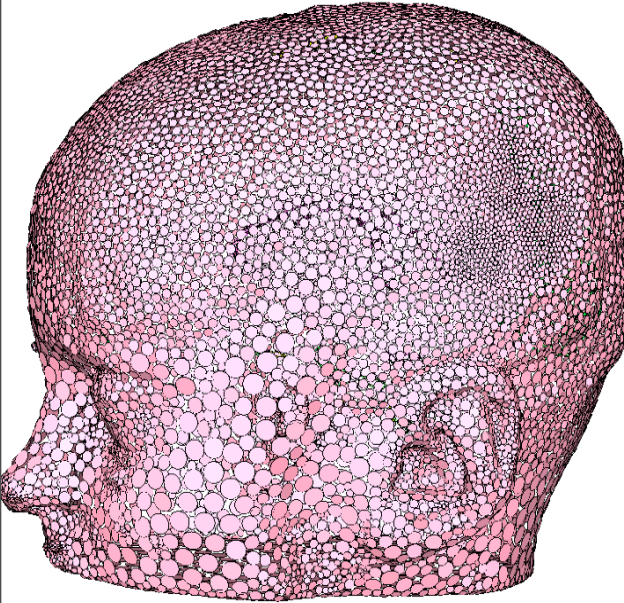
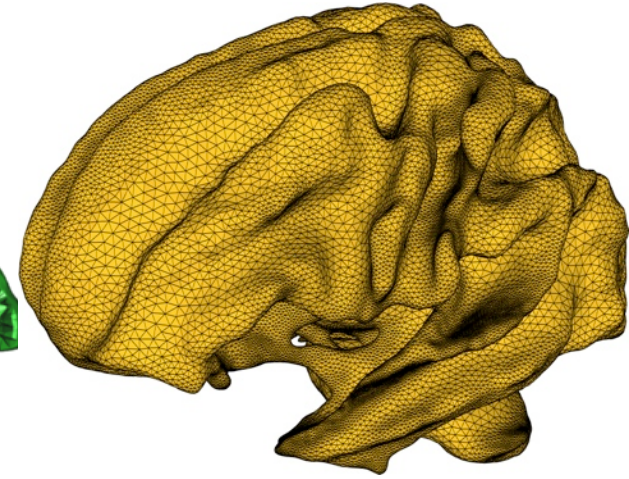
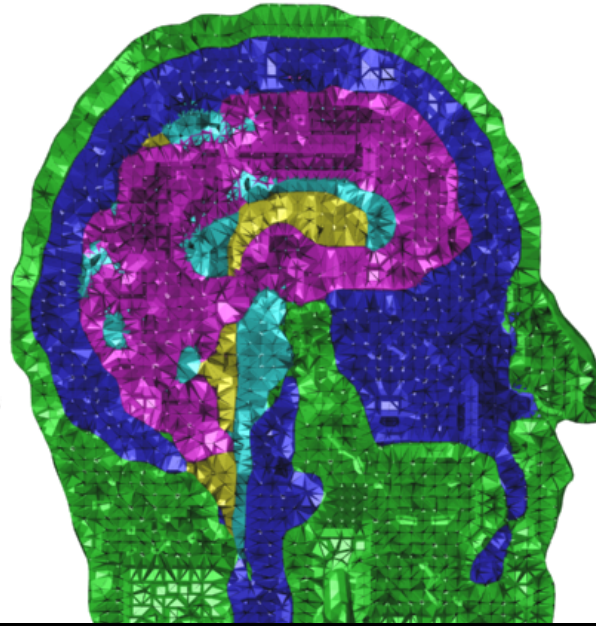
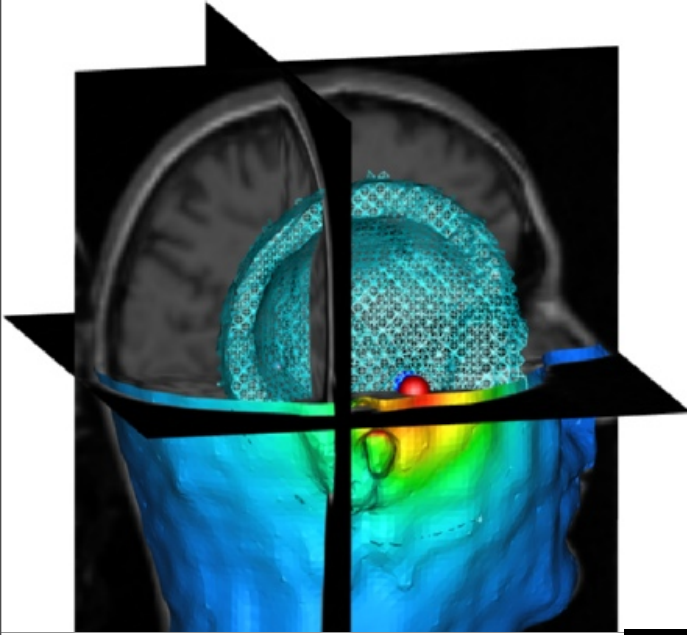
Molecular Dynamics
U of Illinois



Gene Sequencing
U of Maryland



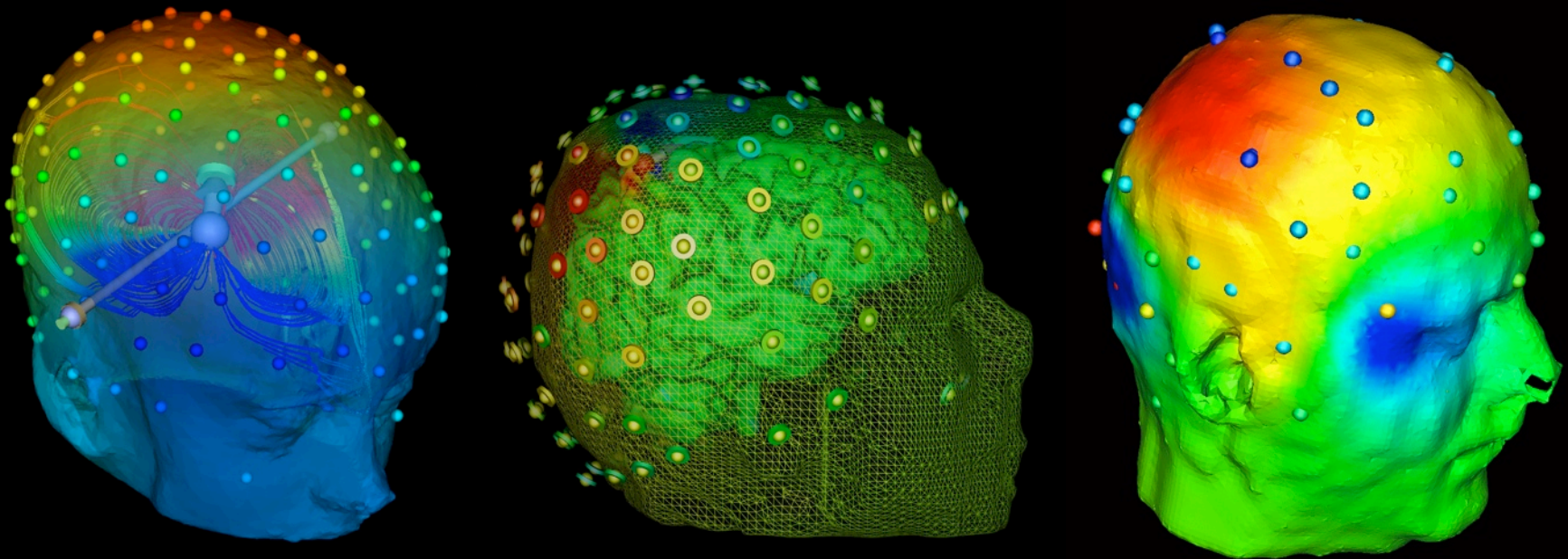
Mesh Generation - BioMesh3D



Epilepsy Source Localization

Optimization between
data and computer
simulation for given
parameters

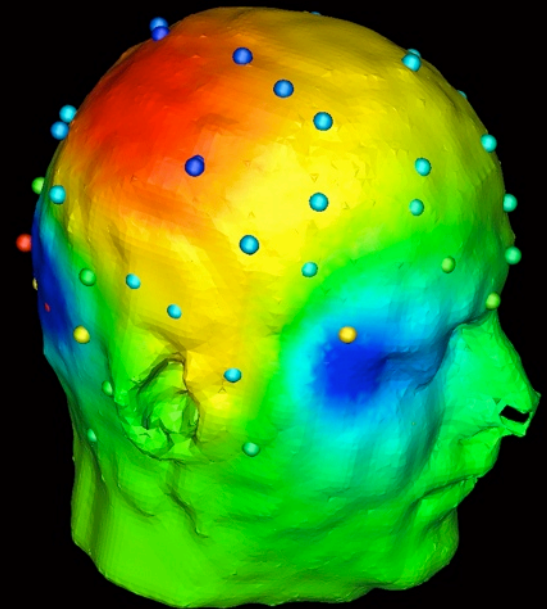
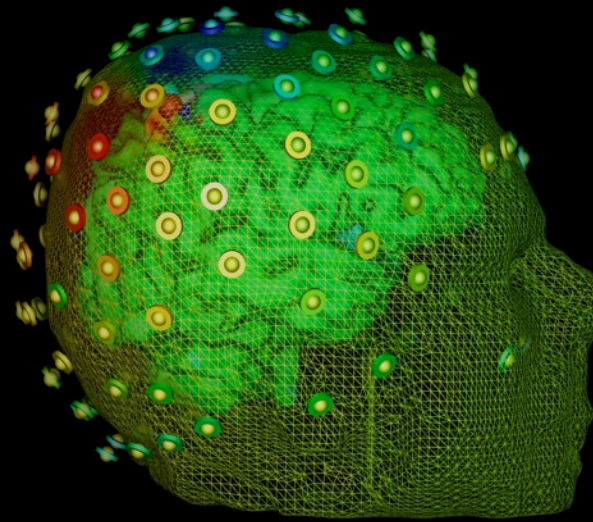
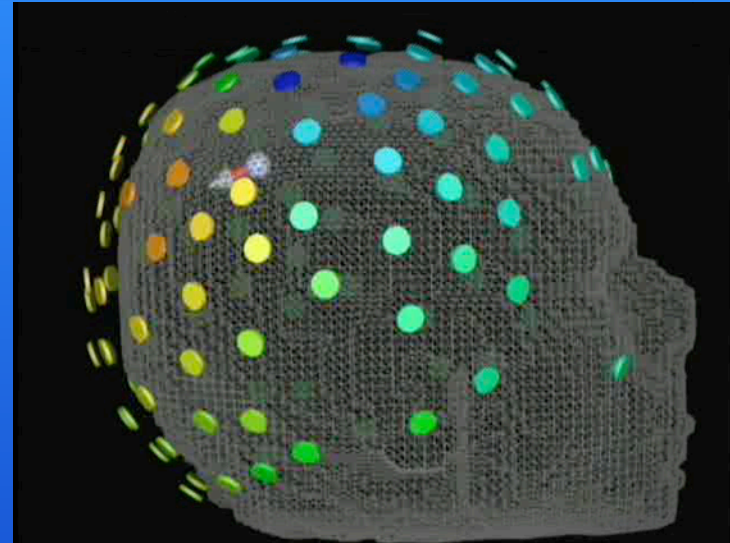
$$\|\phi - \hat{\phi}\| = \sum_k \sum_{j=1}^{32} (\phi_j(t_k) - \hat{\phi}_j(t_k))^2$$



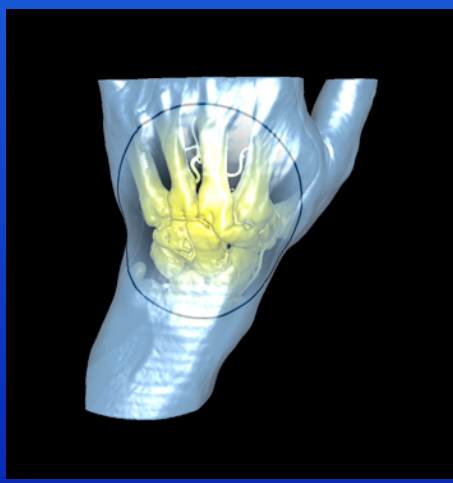
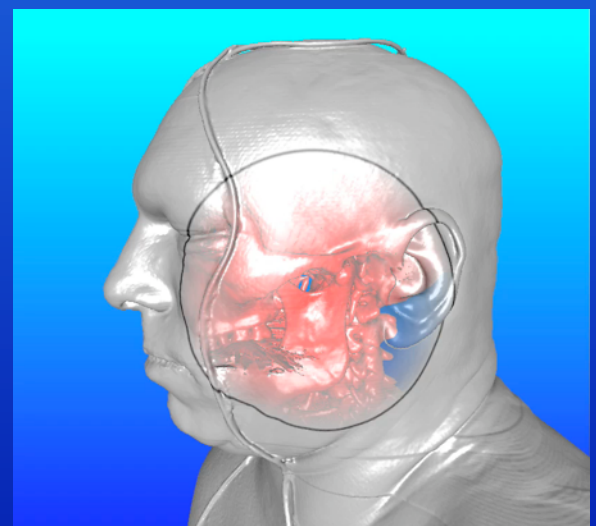
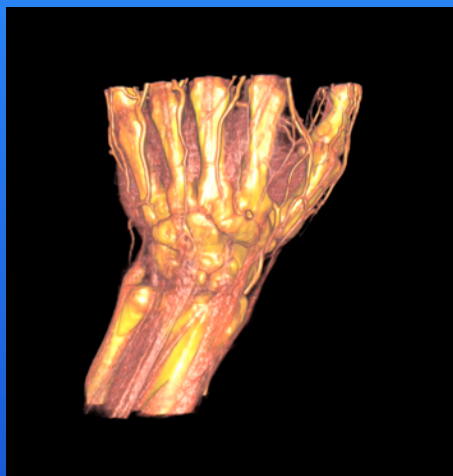
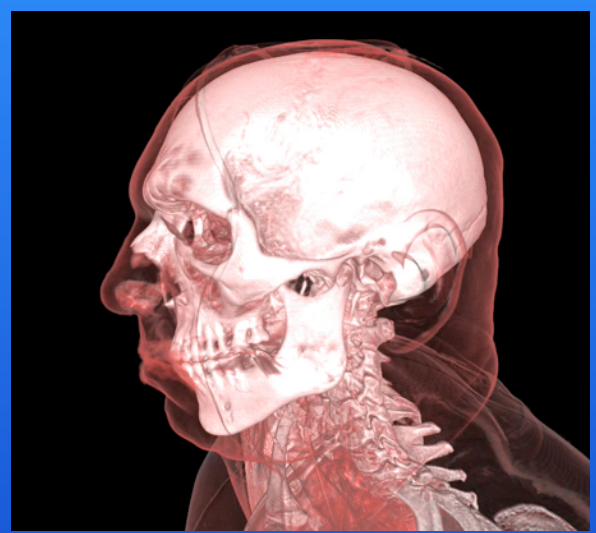
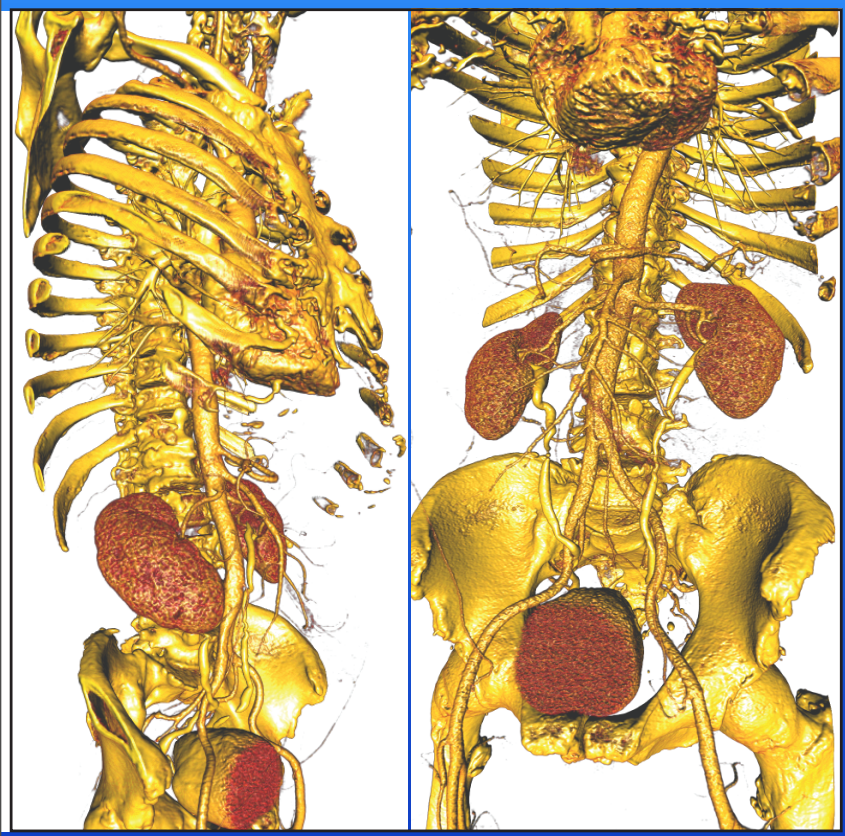
Epilepsy Source Localization

Optimization between
data and computer
simulation for given
parameters

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



Biomedical Visualization



SCI INSTITUTE
VACET
CIBC

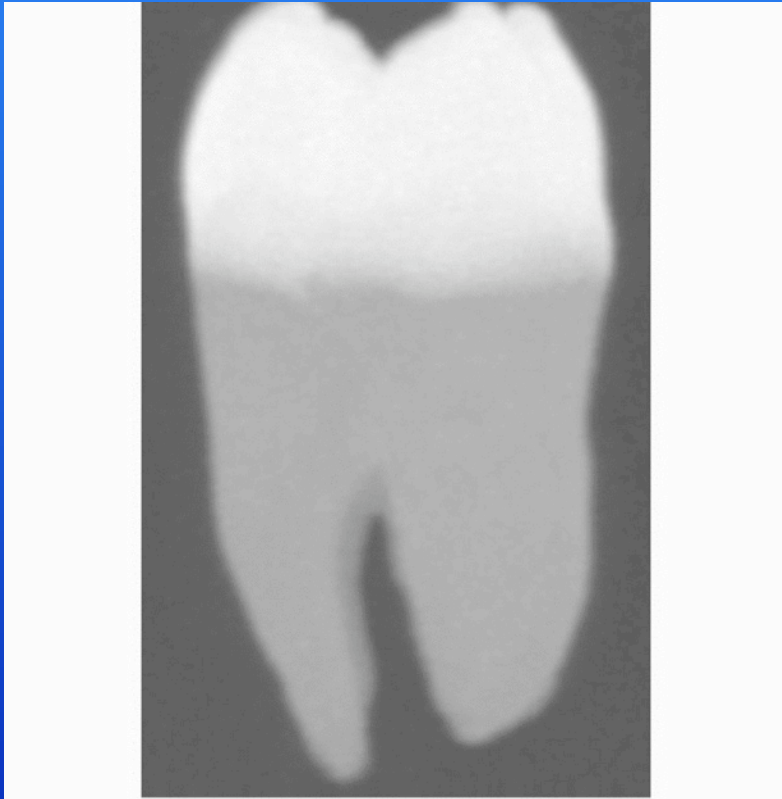
ImageVis 3D

Copyright © 2009, 1994 University of Utah. All Rights Reserved.
Jens Kruger, Tom Fogal
This work was made possible through support from the NIH-NICRR Center for Integrative Biomedical Computing, P41-RR12553-10

Biomedical Visualization

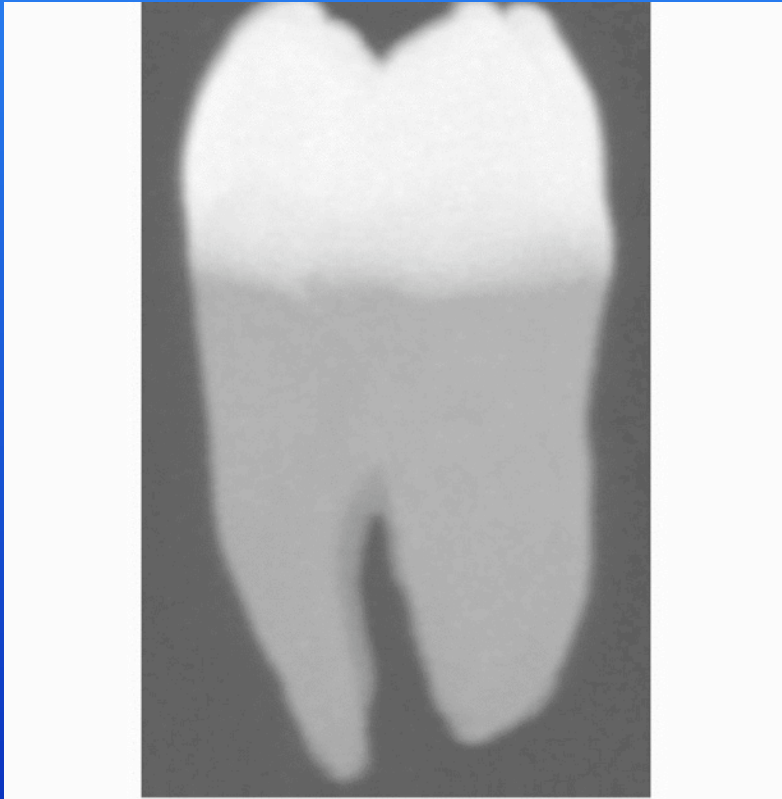


Biomedical Visualization



Maximum Intensity Projection (MIP)

Biomedical Visualization

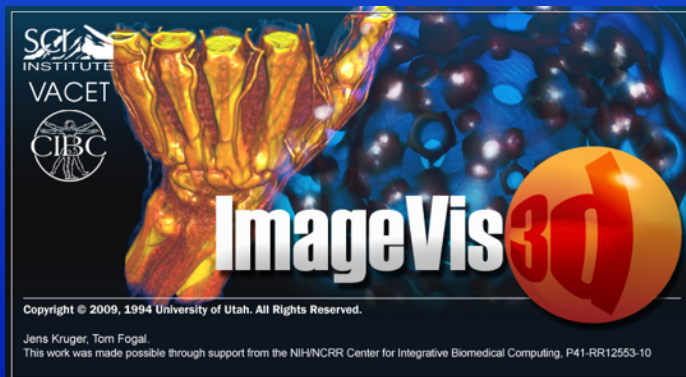


Maximum Intensity Projection (MIP)



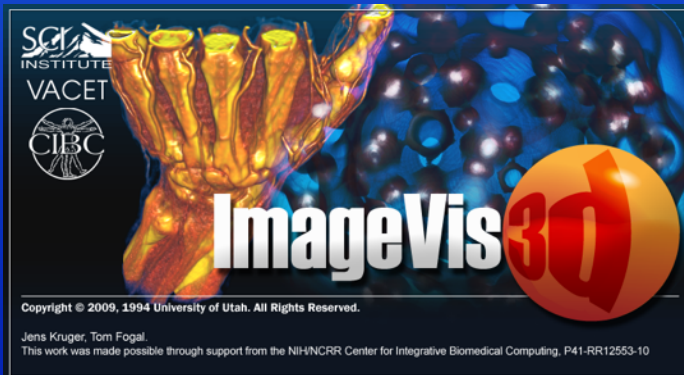
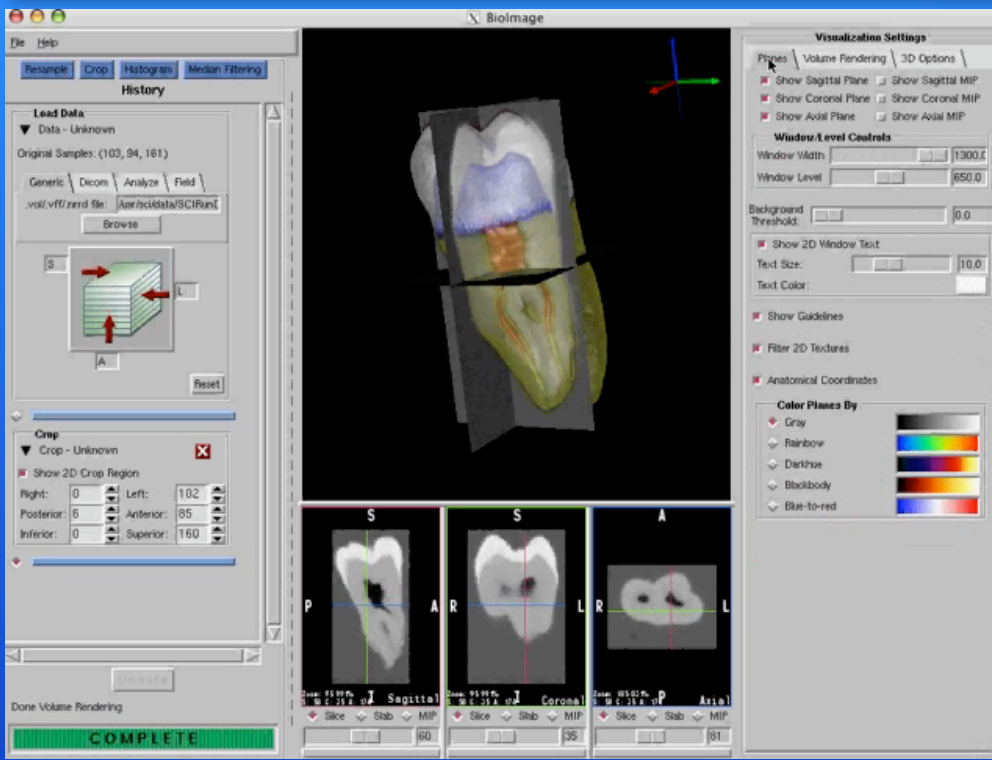
Full Volume Rendering

Biomedical Visualization Software

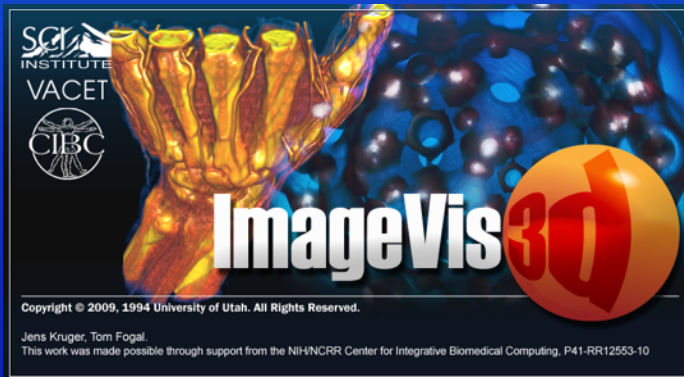
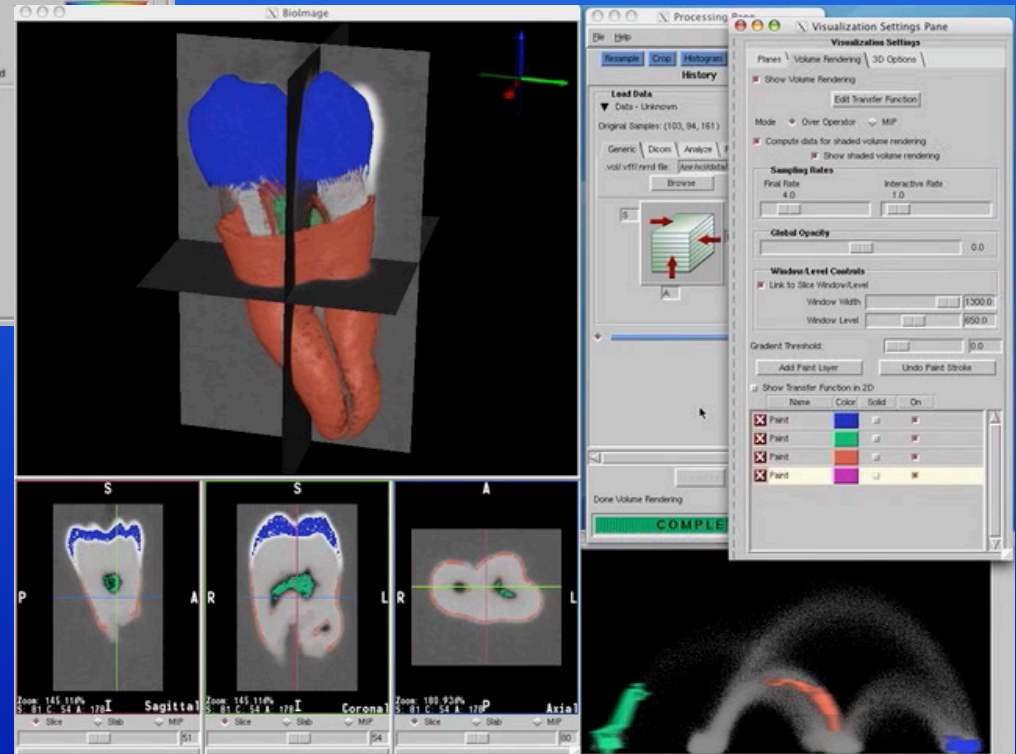
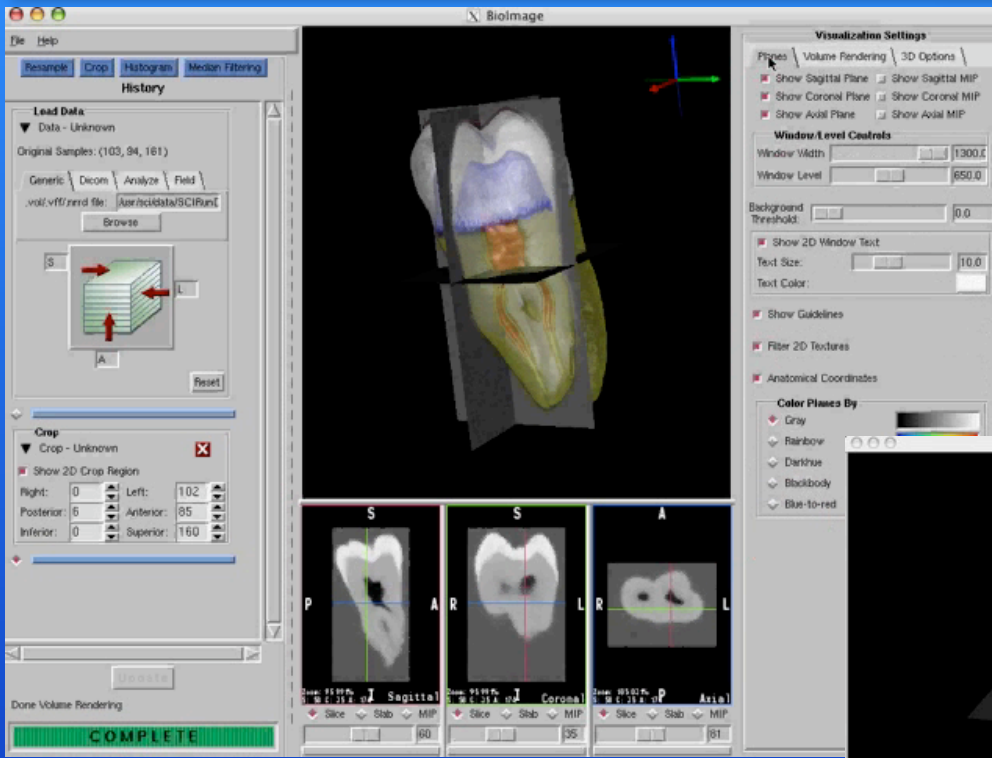


Scientific Computing and Imaging Institute, University of Utah

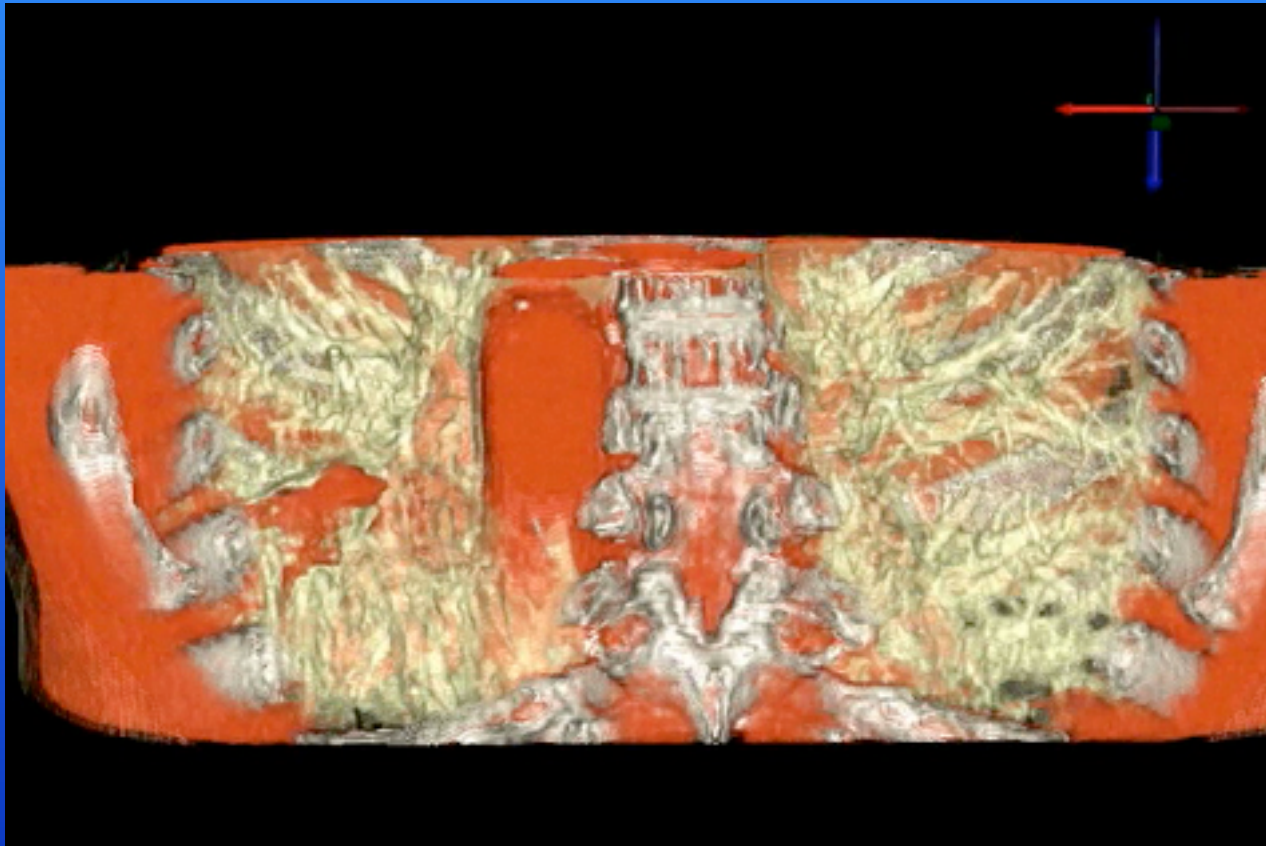
Biomedical Visualization Software



Biomedical Visualization Software

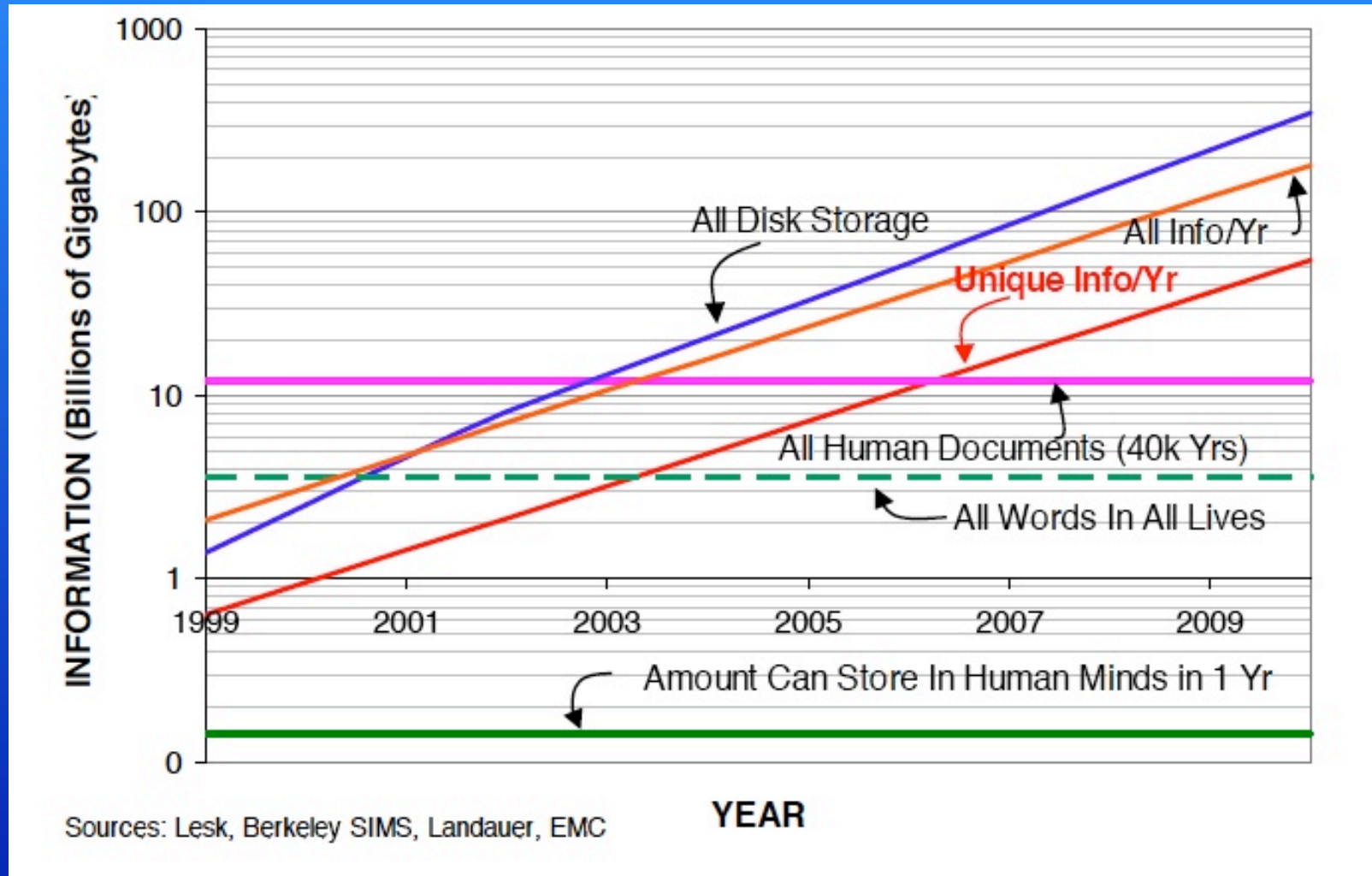


Time Dependent Visualization



Time-dependent BiImage 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



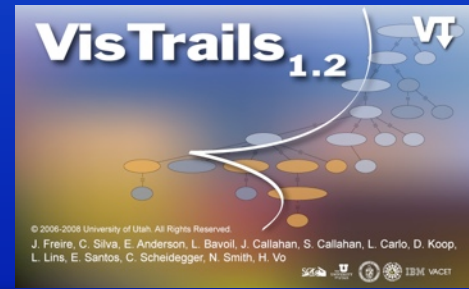
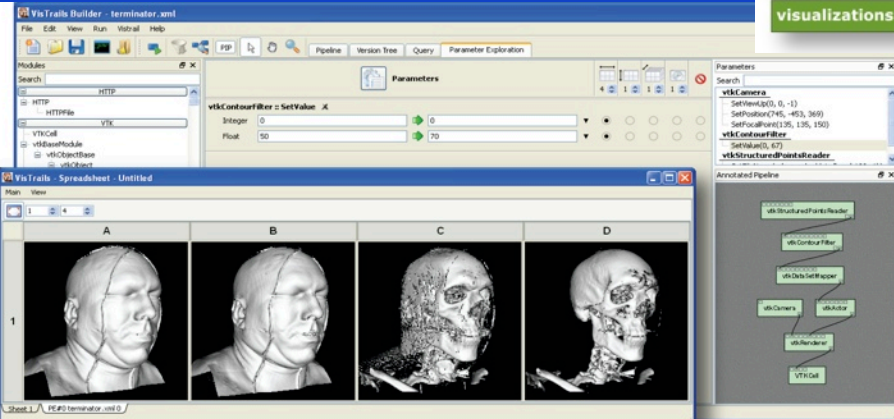
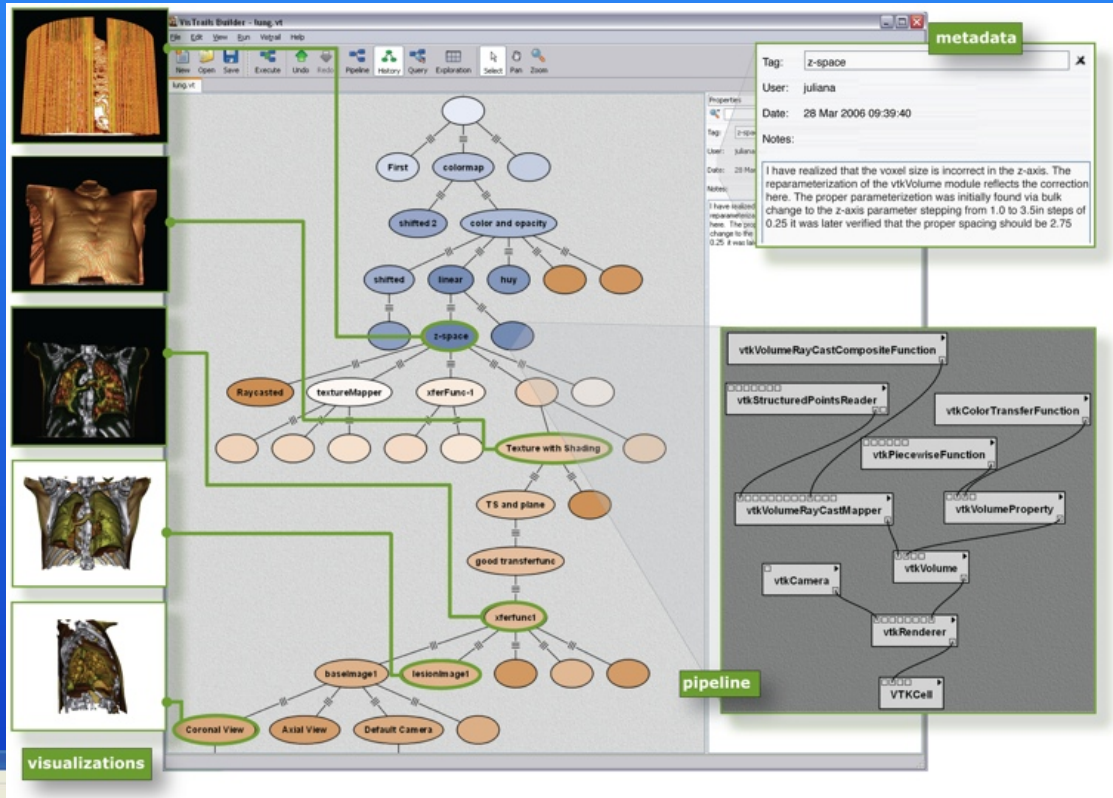
Automatic Provenance Capture

Task Creation by Analogy

Intuitive Query Interfaces

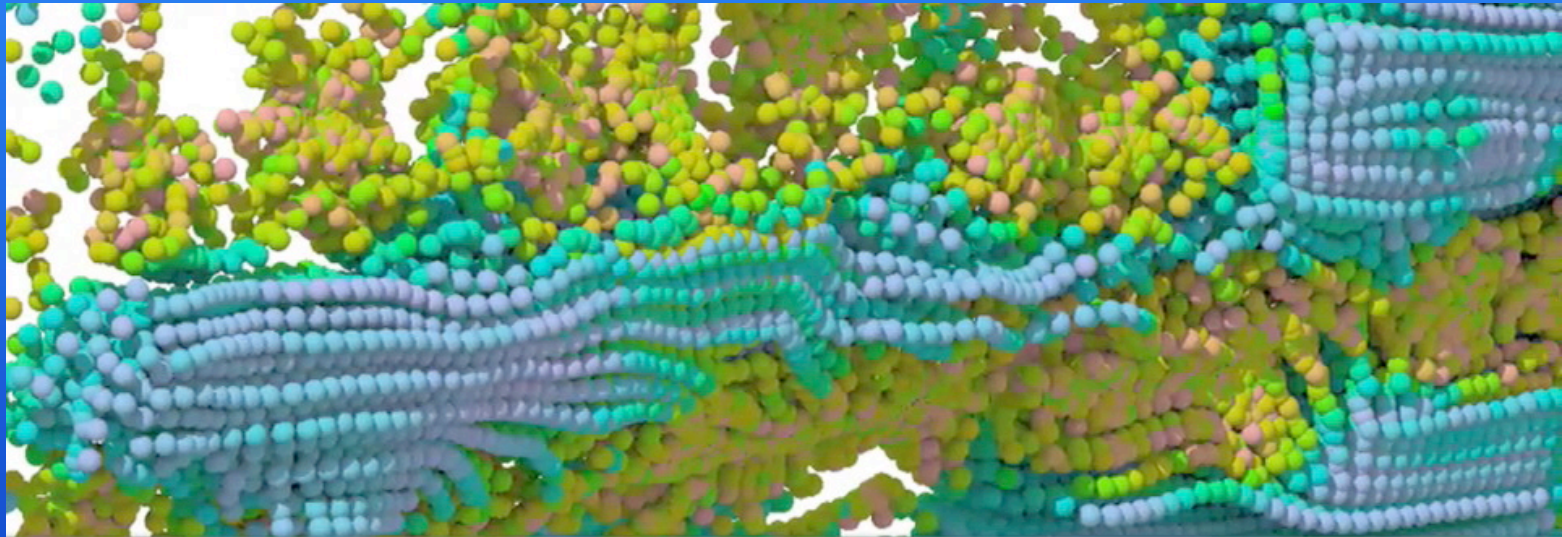
Support for Collaborative Exploration

Extensibility



ing Institute, University of Utah

Scientific Computing and Visualization



The Golden Age of Supercomputing



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

crj@sci.utah.edu