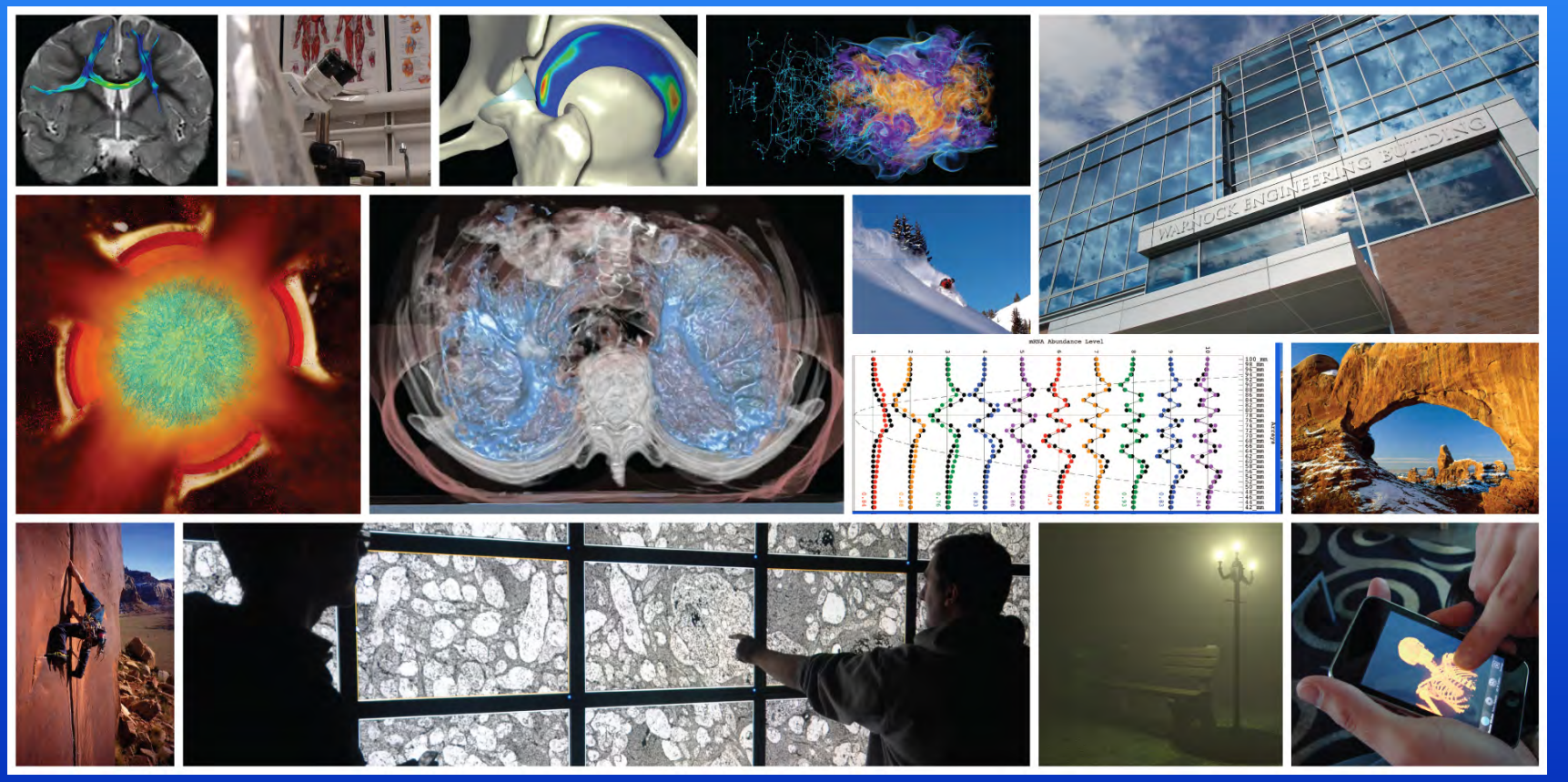
Large Scale Biomedical Visualization



Chris Johnson
Scientific Computing and Imaging Institute
University of Utah

SCI Institute Faculty

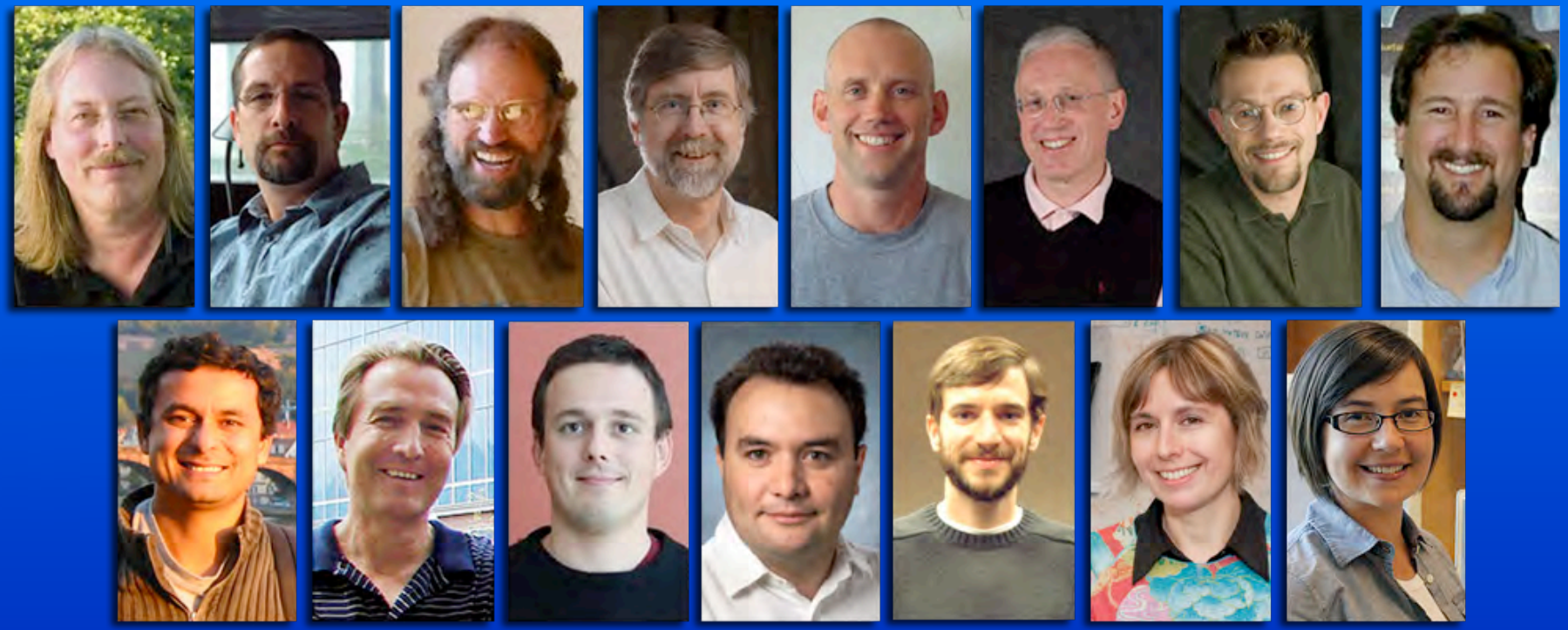


Image-Based Modeling, Simulation, and Visualization

Image & Data Acquisition

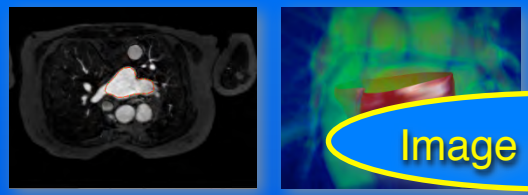
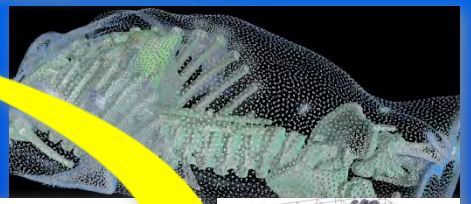
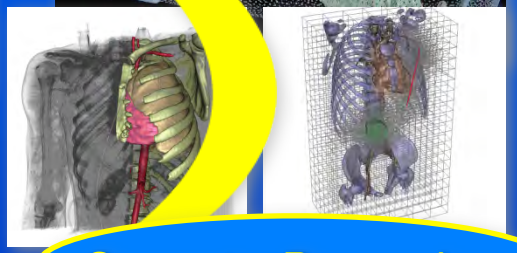


Image Processing

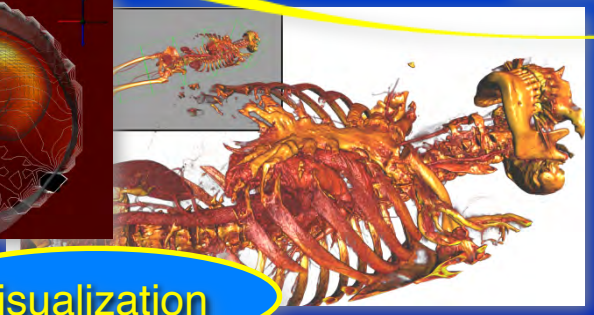
Lab/Clinic

Integrated Software Tools

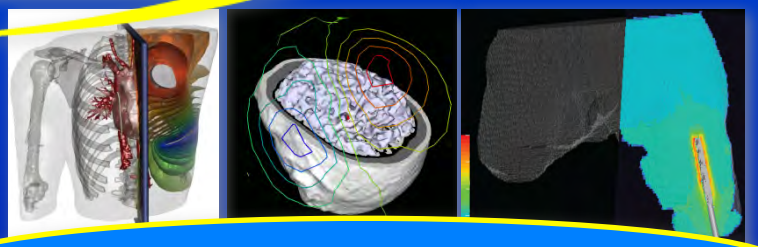




Geometry Processing



Visualization



Modeling, Simulation & Validation

CIBC Software Infrastructure

SCIRun is a modular dataflow programming Problem Solving Environment (PSE). SCIRun has a set of Modules that perform specific functions on a data stream. Each module reads data from its input ports, calculates the data, and sends new data from output ports.

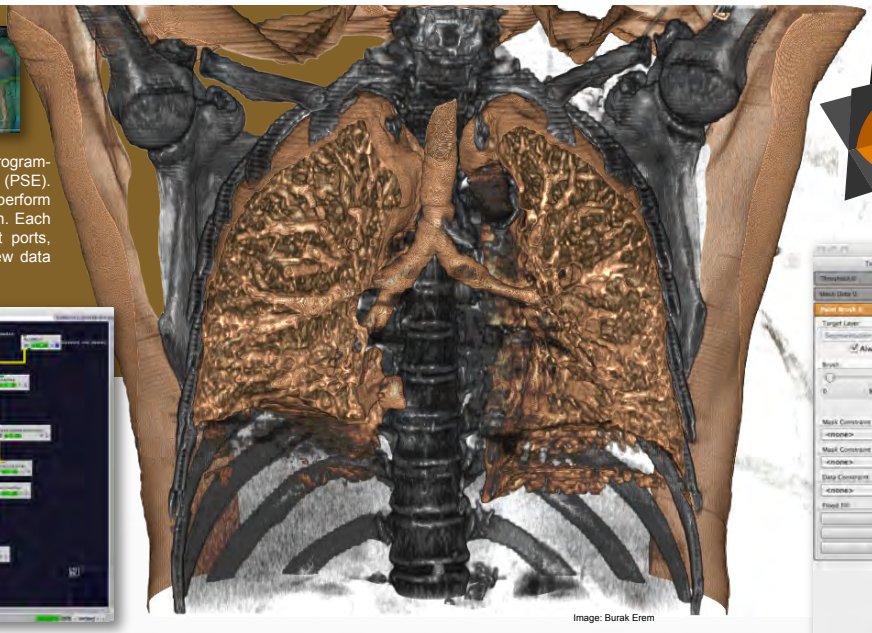
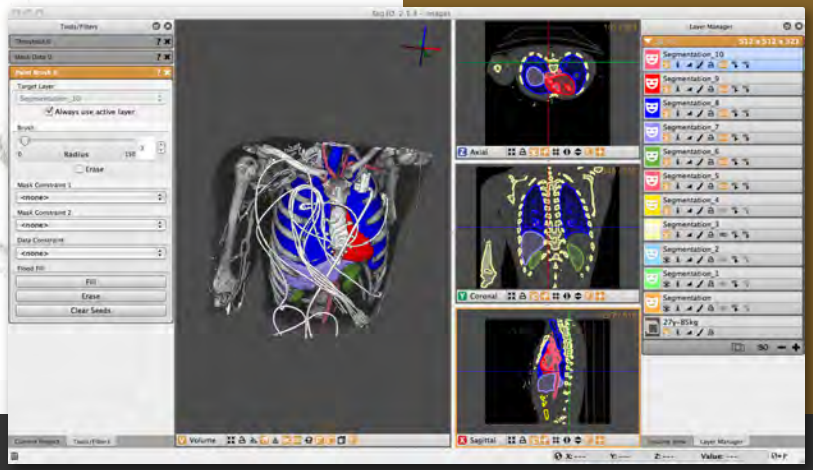
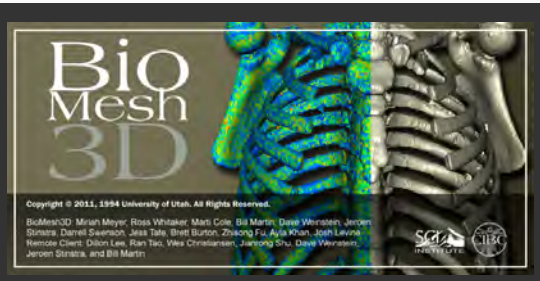


Image: Burak Erem

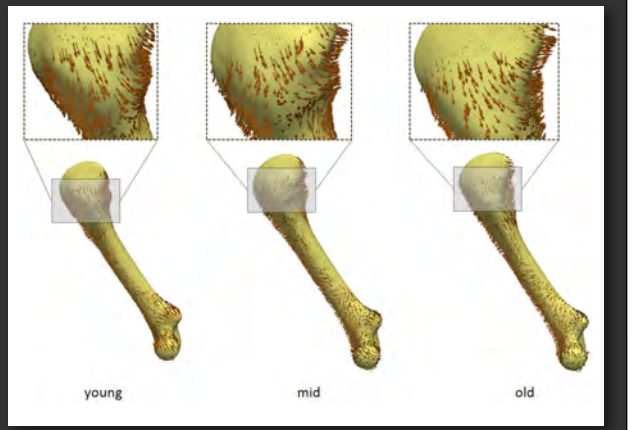
Seg3d2 is a recent redesigned volume segmentation and processing tool that combines a flexible manual segmentation interface with powerful higher-dimensional image processing and segmentation algorithms from the Insight Toolkit. Users can easily explore and label image volumes using volume rendering and orthogonal slice view windows.





BioMesh3D is a tetrahedral mesh generator for multi-material quality meshes out of segmented biomedical image data. The BioMesh3D program uses a particle system to distribute nodes on the separating surfaces that separate the different materials and then uses the TetGen software package to generate a full tetrahedral mesh. A client server interface is available to guide the user through the process of building a mesh. Because building a high quality mesh often requires a lot of computation, this application allows the user to connect to the SCI facility servers for computing their meshes.

The **ShapeWorks** software makes available a method for constructing compact statistical point-based models of ensembles of similar shapes that does not rely on any specific surface parameterization. The method requires very little preprocessing or parameter tuning, and is applicable to a wide range of shape analysis problems, including nonmanifold surfaces and objects of arbitrary topology. Tools are available for preprocessing data, computing pointbased shape models, and visualizing the results.

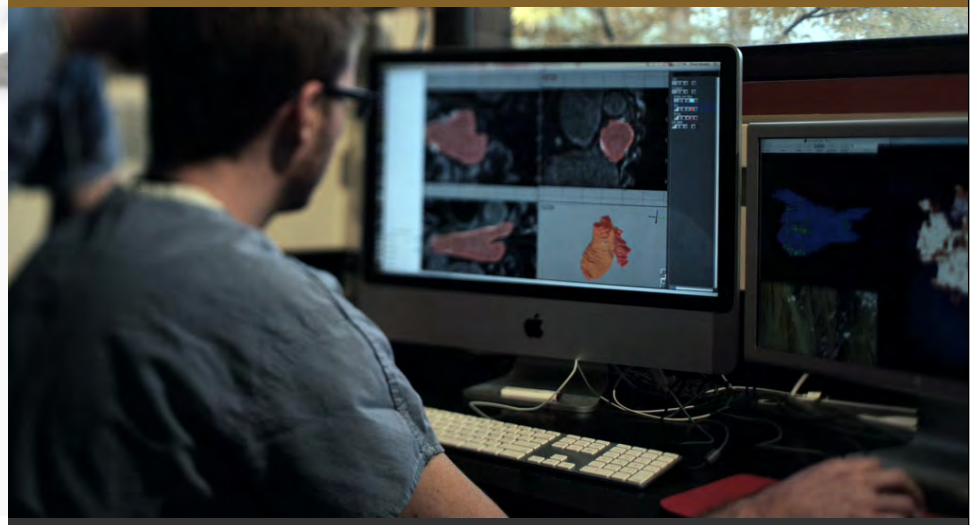


CIBC Software Infrastructure

Handheld devices have become a ubiquitous means of interacting with personal data. Expanding their use for interacting with complex rendered volume data means that scientists can now explore data with just their mobile device. Shown here, users interacting with the ImageVis3d volume renderer running on a large display wall using a tablet PC and iphone. The large visualization changes in real time based on interactions on the mobile device.

ImageVis3D is a new volume rendering program developed by the NIH/NCRR Center for Integrative Biomedical Computing (CIBC). The main design goals of ImageVis3D are: simplicity, scalability, and interactivity. Simplicity is achieved with a new user interface that gives an unprecedented level of flexibility (as shown in the images). Scalability and interactivity for ImageVis3D mean that both on a notebook computer as well as on a high end graphics workstation, the user can interactively explore terabyte sized data sets. Finally, the open source nature as well as the strict component-by-component design allow developers not only to extend ImageVis3D itself but also reuse parts of it, such as the rendering core. This rendering core for instance is planned to replace the volume rendering subsystems in many applications at the SCI Institute and with our collaborators.

Center for Integrative Biomedical Computing



Scientific Software Solutions

The Center for Integrative Biomedical Computing (CIBC) is dedicated to producing open-source software tools for biomedical image-based modeling, biomedical simulation and estimation, and the visualization of biomedical data. The Center works closely with software users and collaborators in a range of scientific domains to produce user-optimized tools and provides advice, technical support, workshops, and education to enhance user success. Biological projects and collaborations drive our development efforts, all with a single unifying vision: to develop the role of image-based modeling and analysis in biomedical science and clinical practice.

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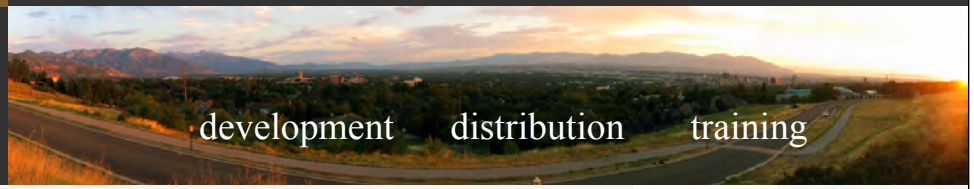
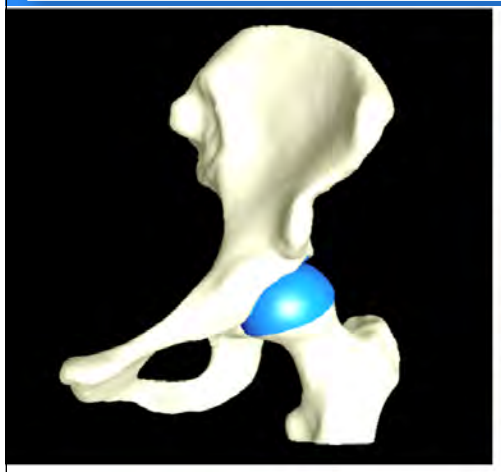
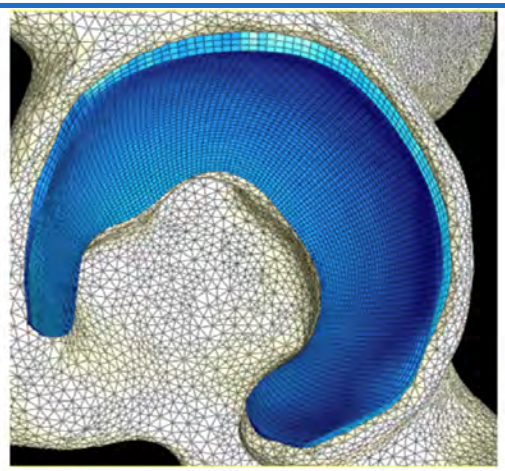
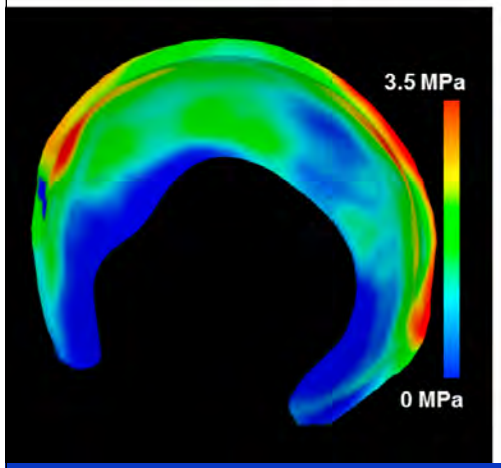
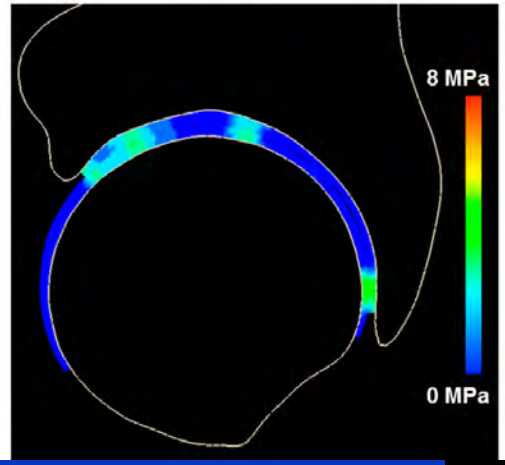


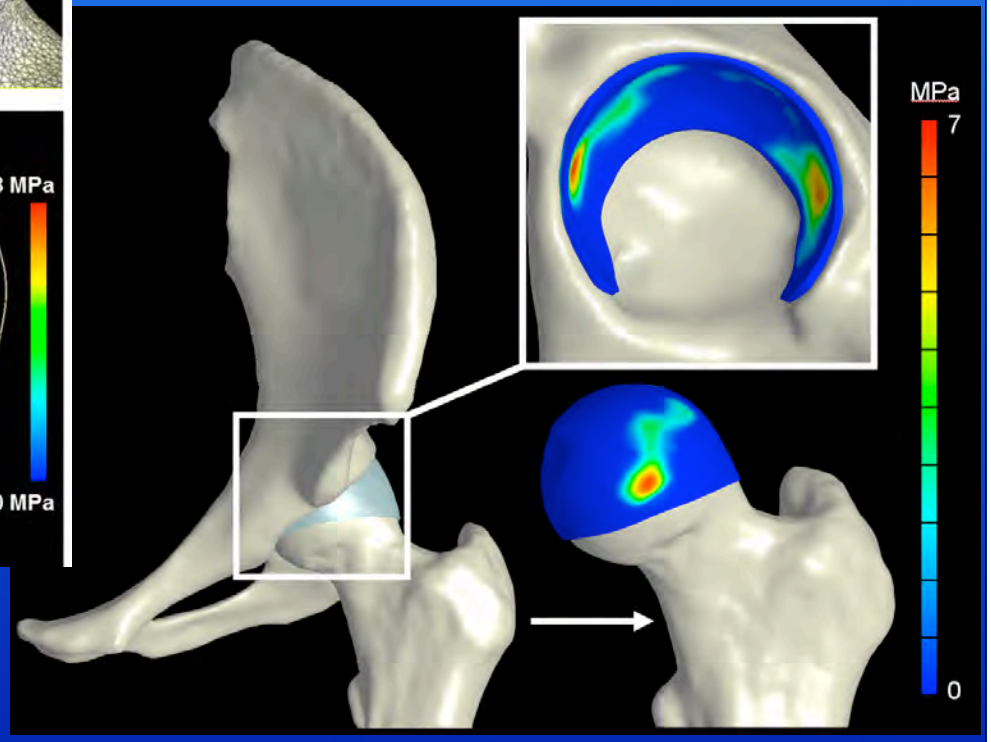
Simulate Stresses in the Articular Cartilage of Normal and Dysplastic Hips During Activities of Daily Living











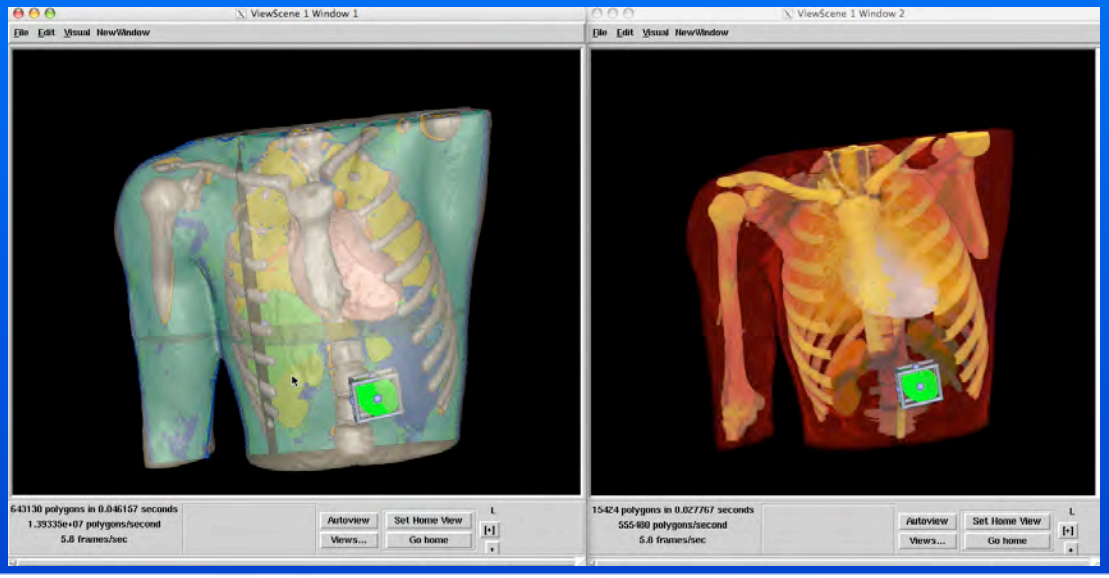
Hip Biomechanics Pipeline:

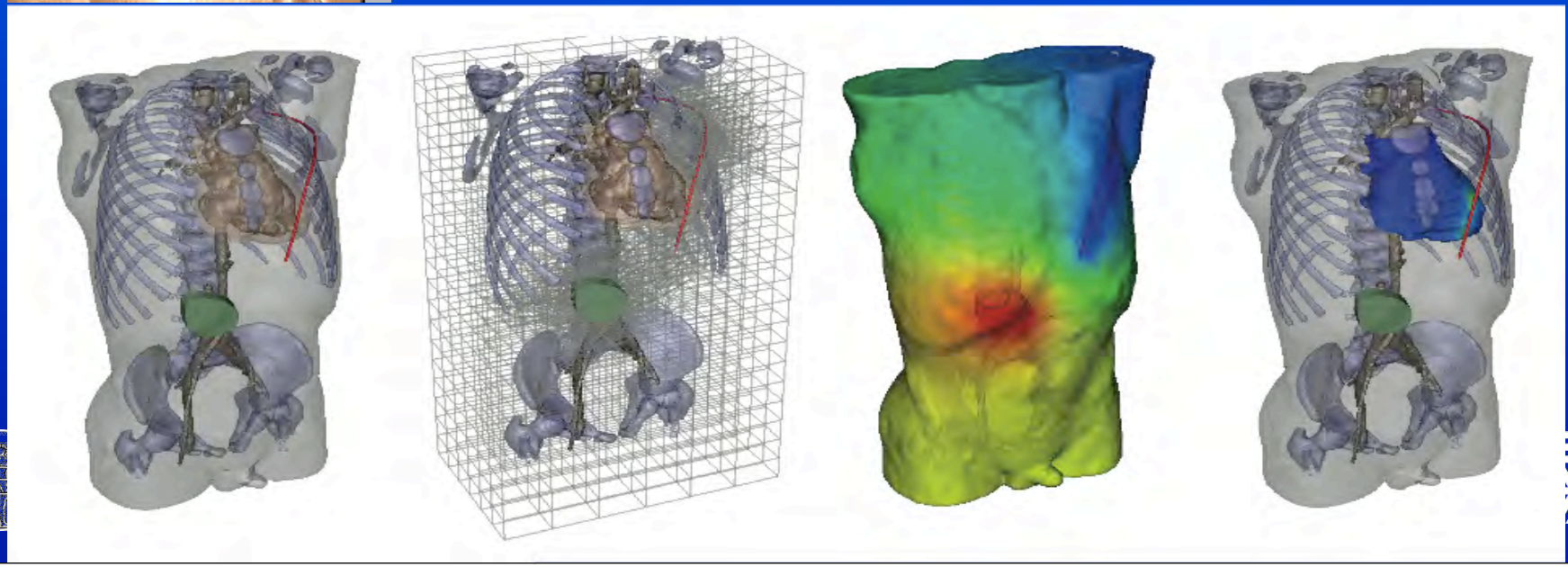
- CT Scan
- Segmentation
- Mesh Generation
- FE Simulation
- Visualization and Evaluation

Normal Hip Pressures due to Walking

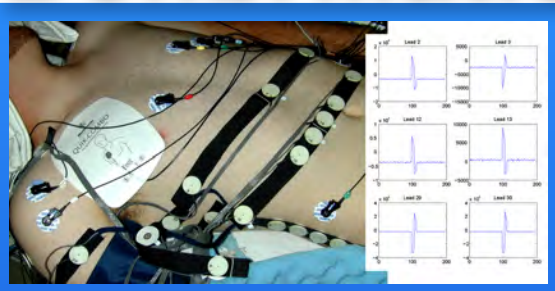
Personalized Medicine: Cardiac Defibrillation

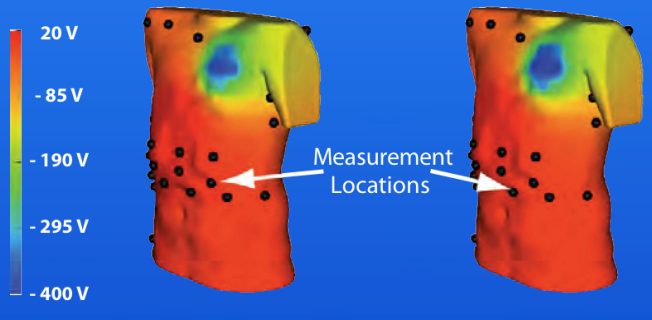
Image-Based Modeling, Simulation, and Visualization Pipeline





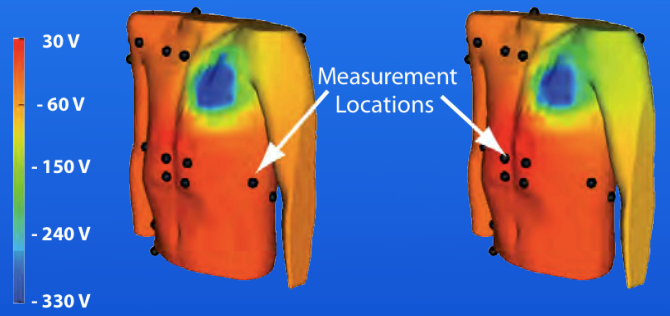
Defibrillation Simulation Results





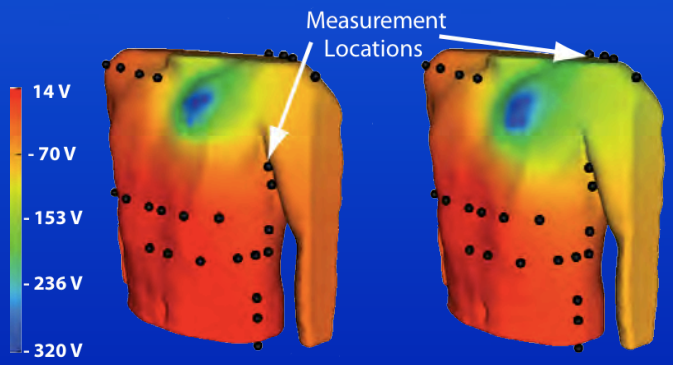
Measurement Reconstruction

Simulation



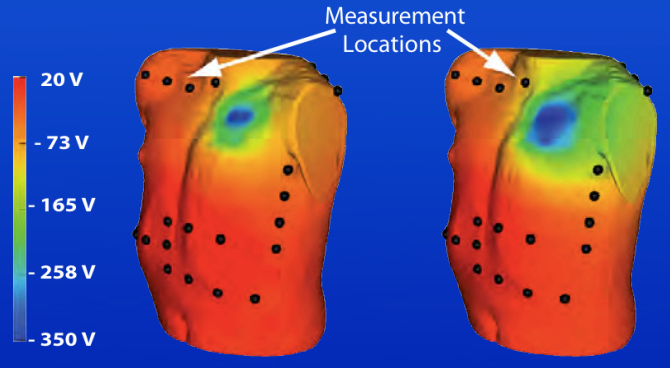
Measurement Reconstruction

Simulation



Measurement Reconstruction

Simulation



Measurement Reconstruction

Simulation

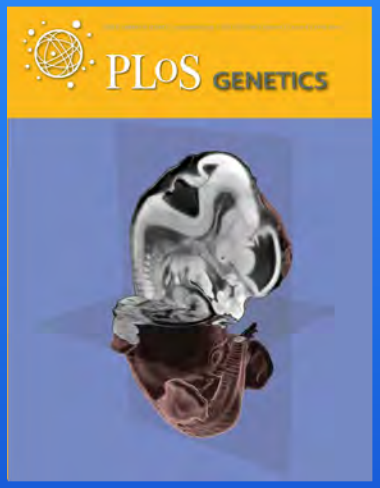
Atrial Fibrillation Ablation

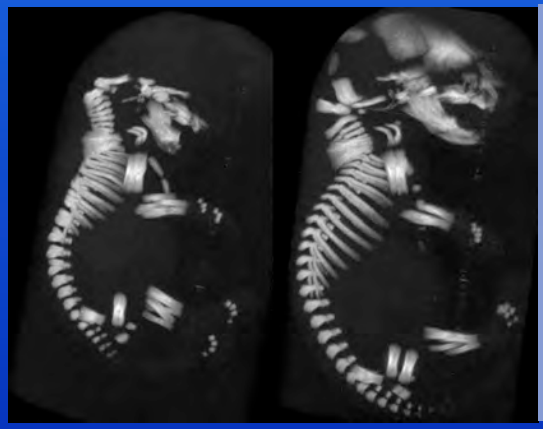
Nassir Marrouche, M.D.
Director, Comprehensive Arrhythmia Research and Management Center: CARMA

CIBC SCI www.sci.utah.edu THE UNIVERSITY OF UTAH NATIONAL INSTITUTES OF HEALTH

Genetics

Often, scientific breakthroughs stem from an enabling new technology

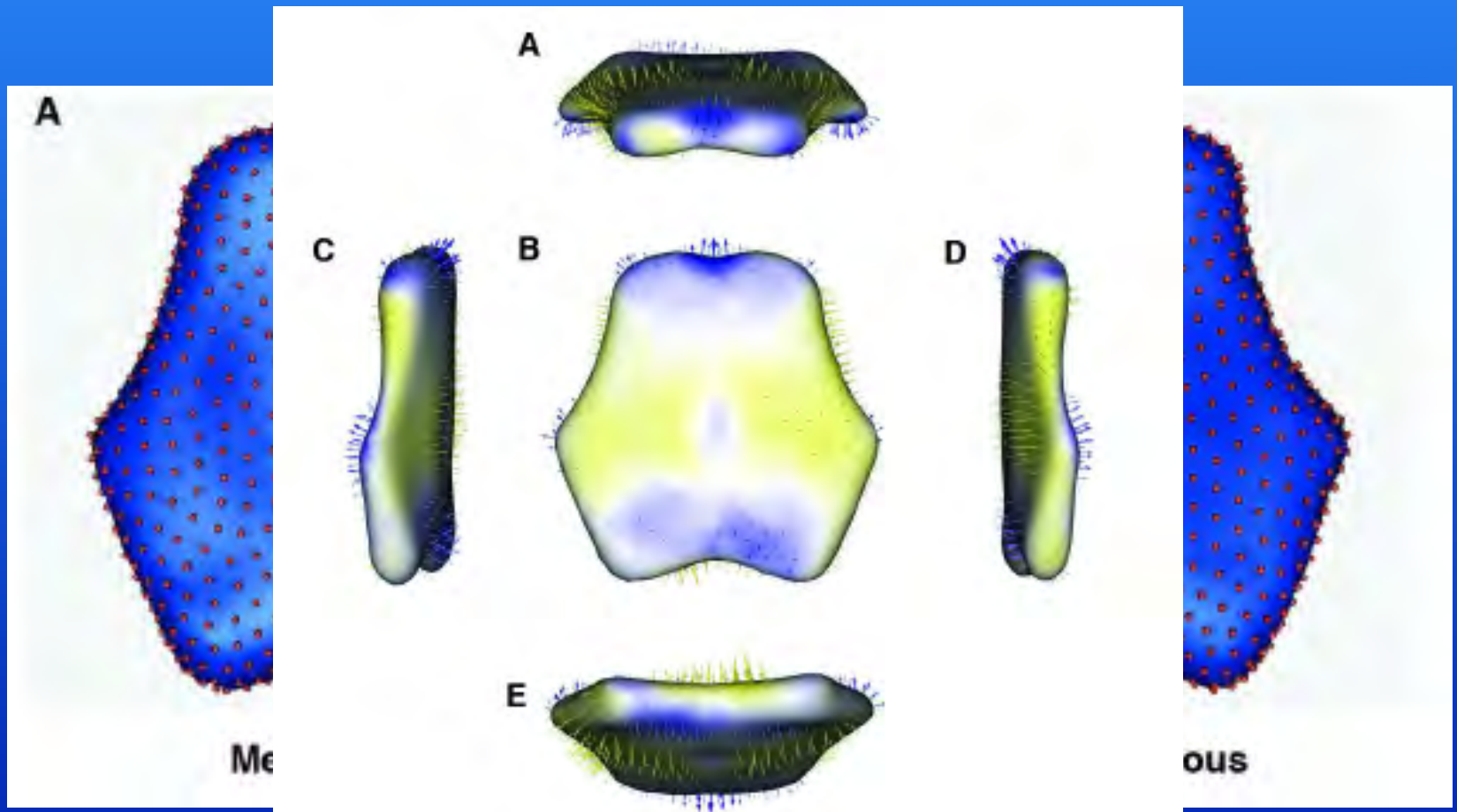




J.T. Johnson III, M.S. Hansen, I. Wu, L.J. Healy, C.R. Johnson, G.M. Jones, M.R. Capecchi, C. Keller.
"Virtual Histology of Transgenic Mouse Embryos for High-Throughput Phenotyping,"
In PLoS Genetics, Vol. 2, No. 1, pp. 471--477. April, 2006.

Shape, Genetics, and Evolution

Evolution of the Cranial Base



Shape, Genetics, and Cancer

Brain Tumor Progression

Shape Change: Preneoplastic, Invasion, Biomarker of Rx

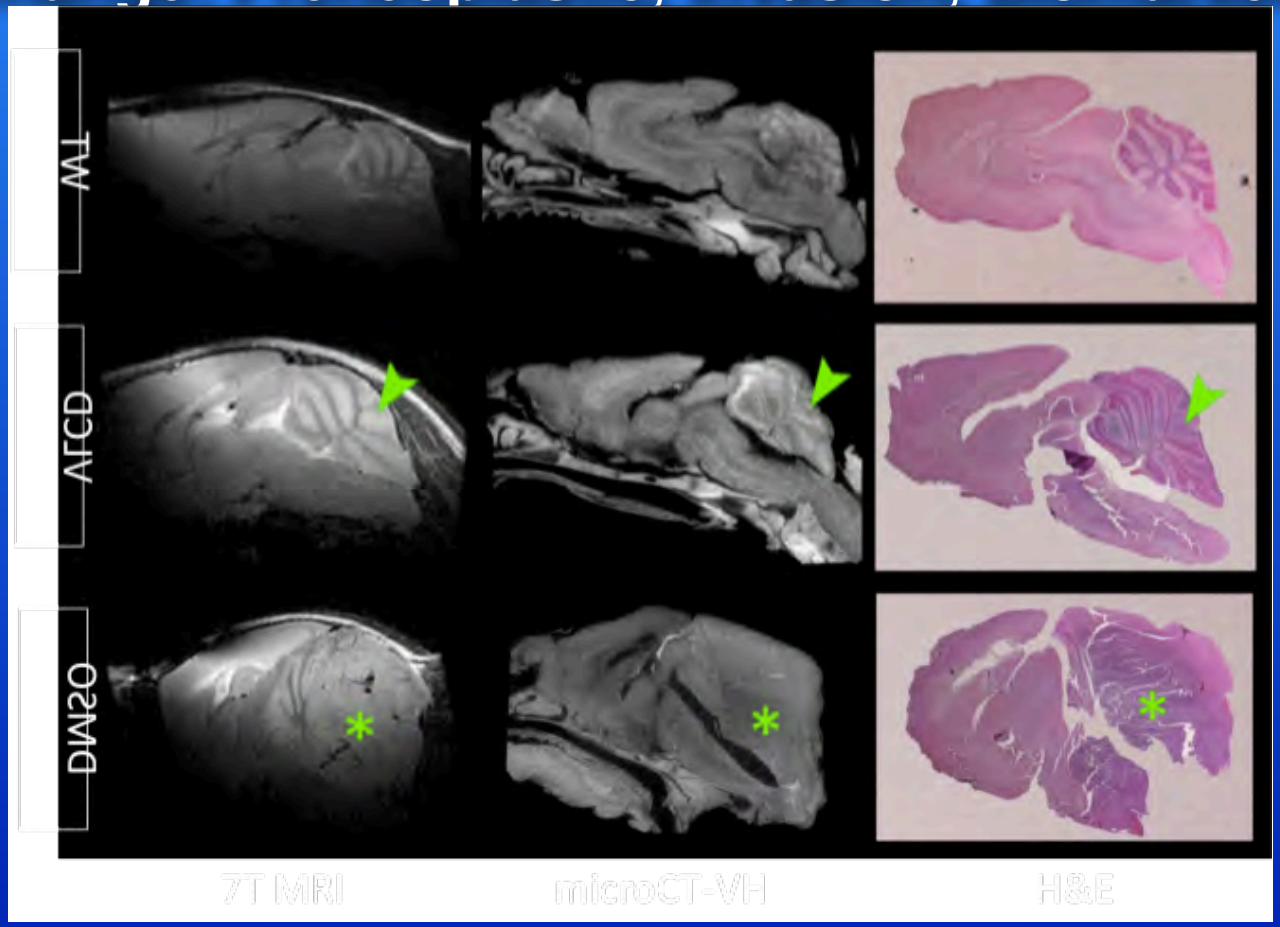


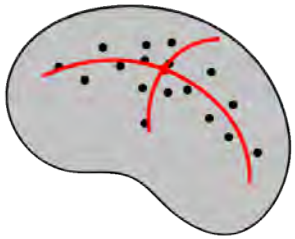
Image Courtesy of Charles Keller

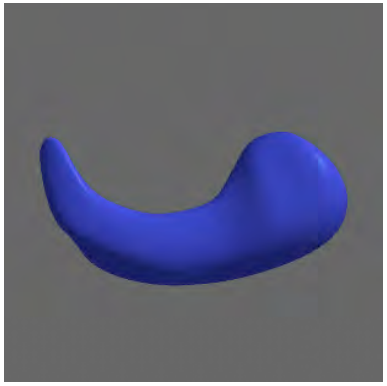
Relating Anatomical Shape to Neuropsychological Measures

- Given a Large collection of anatomical images of subjects with detailed Neuropsychological assessments how does one relate anatomical variation to Neuropsychological variables.
- Driving problem: The ADNI database currently has ~900 subjects each with detailed Neuropsychological evaluations.
- Extract and identify shape deformation patterns in brain anatomy that relate to observed clinical scores depicting cognitive abilities.

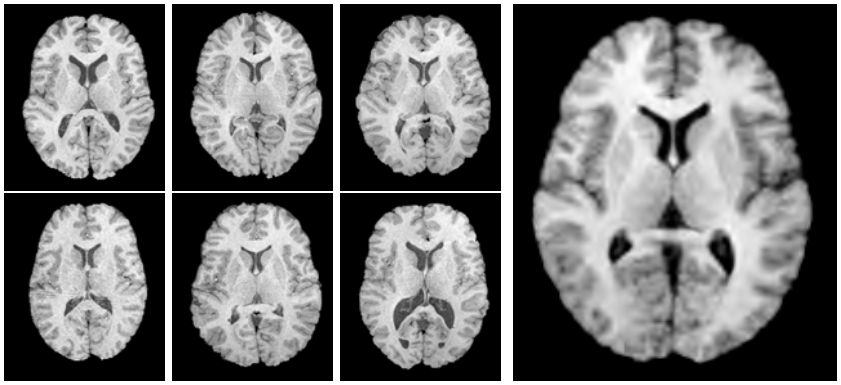
Changes in anatomy associated with cognitive decline in Mild Cognitive Impairment (MCI)

Statistics of Shape, Connectivity, and Function

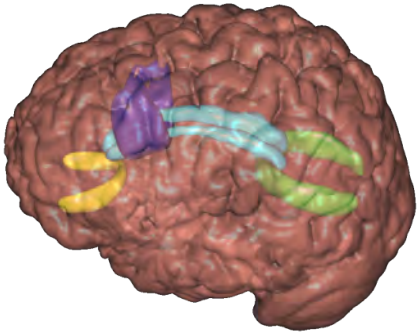


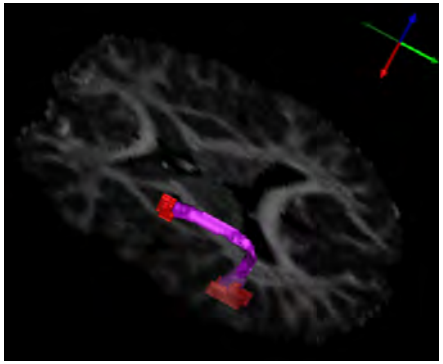


Computational Statistics in Nonlinear Spaces

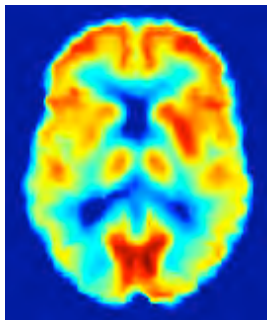


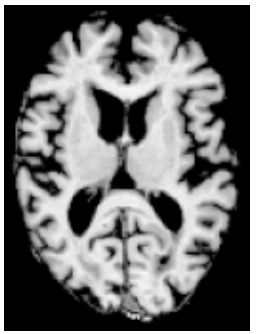
Anatomical shape averaging and variability





Diffusion Tensor Image Analysis Autism project





Combined PET + MRI analysis Alzheimer's disease project

SCI INSTITUTE

THE BRAIN INSTITUTE
THE UNIVERSITY OF UTAH

Seg3D - 3D Segmentation

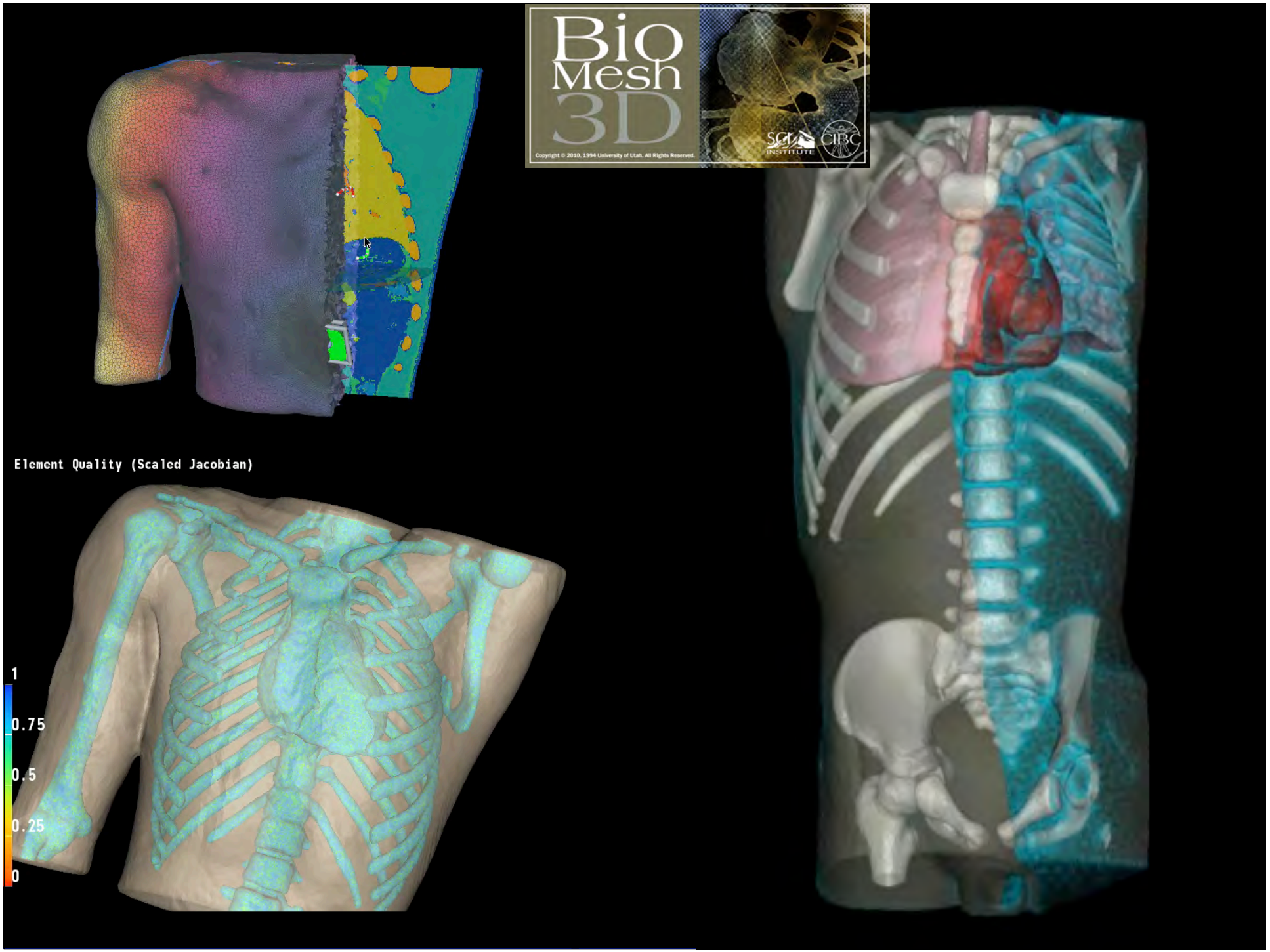
ITK-based

Layers (like Photoshop)

Light-weight

Open Source

software.sci.utah.edu


Bio
Mesh
3D
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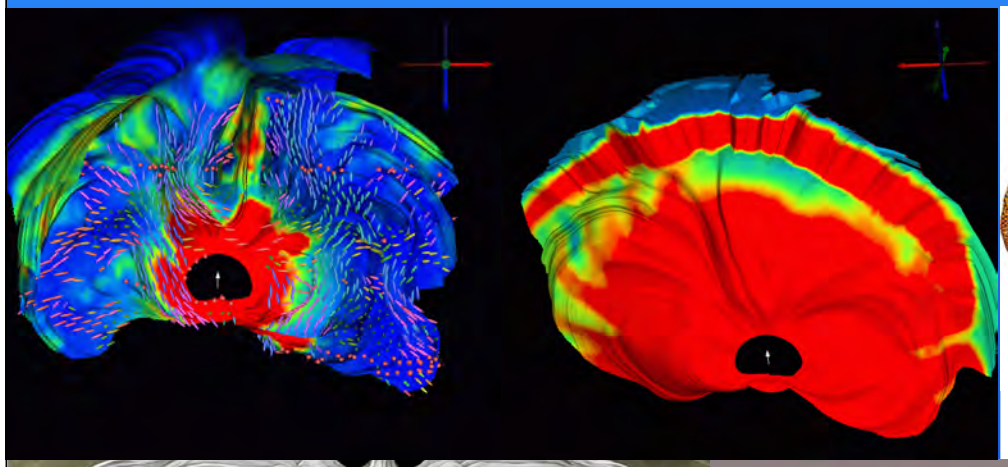
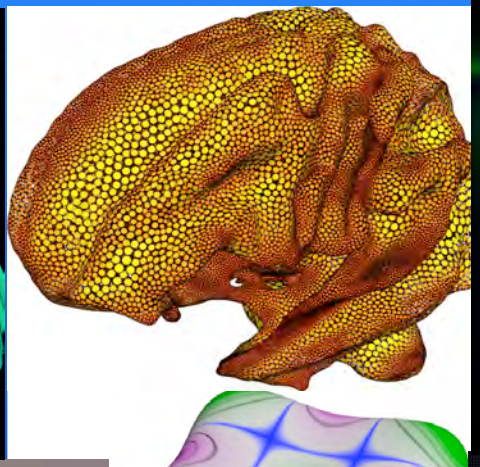
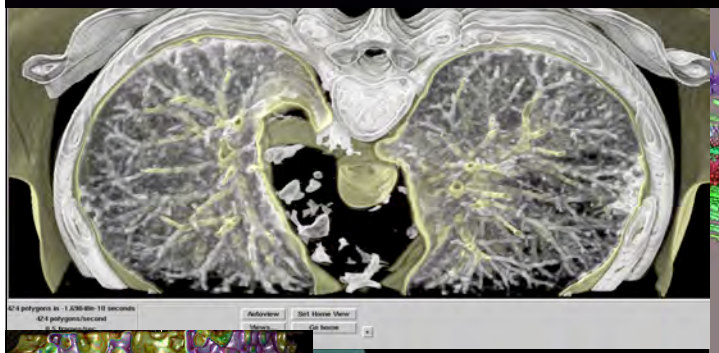
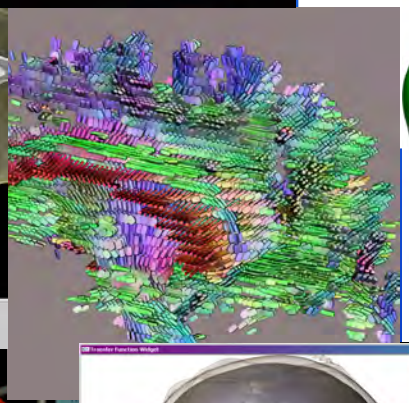
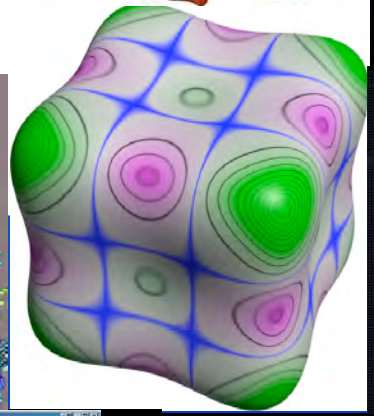
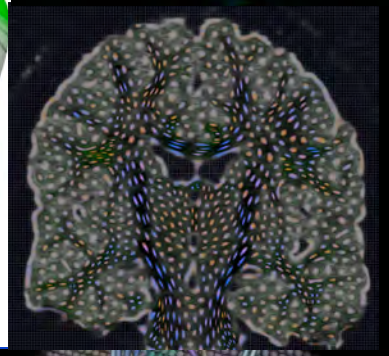
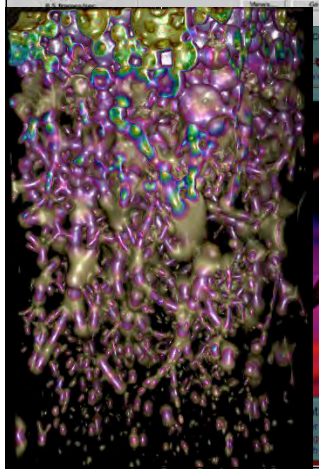
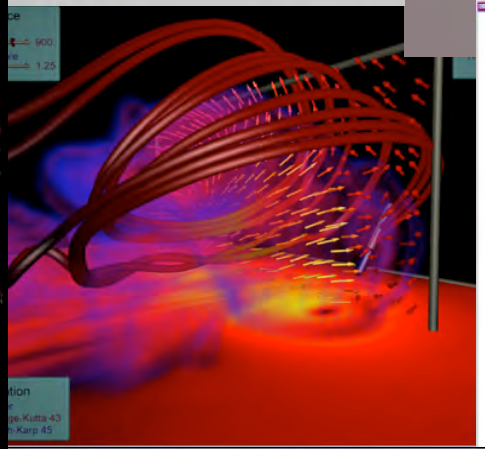
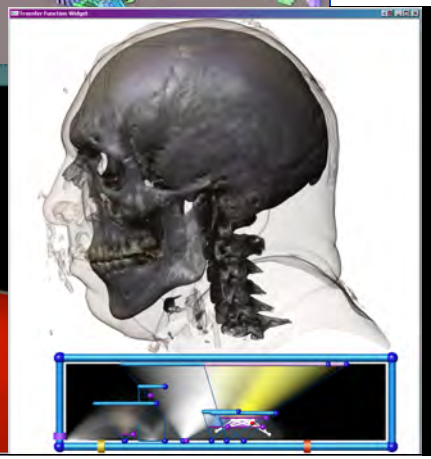
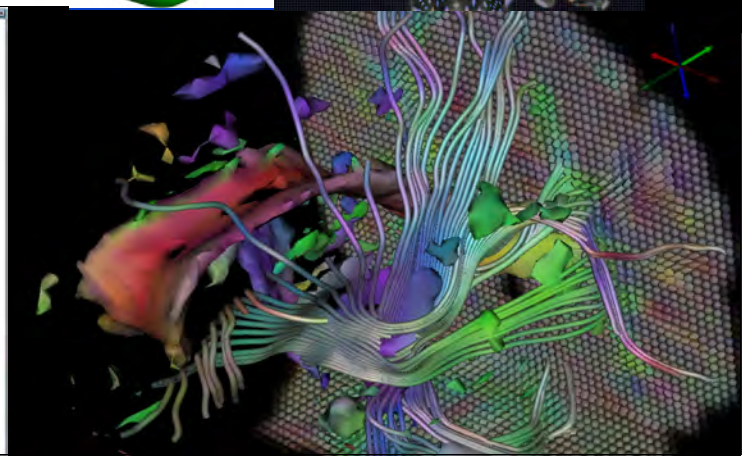
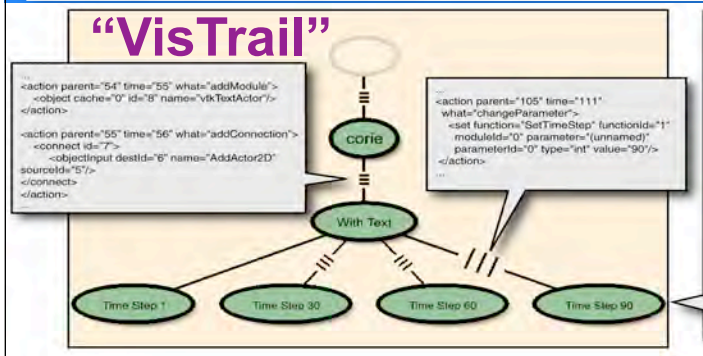
SCI INSTITUTE
CIBC
Element Quality (Scaled Jacobian)
1
0.75
0.5
0.25
0

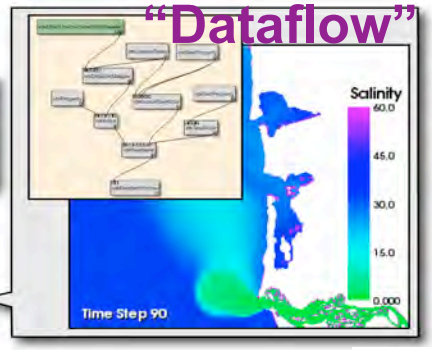
New Visualization Techniques

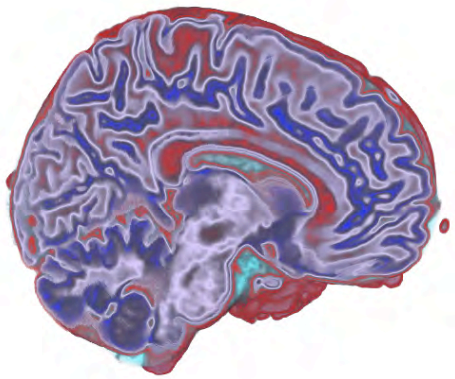



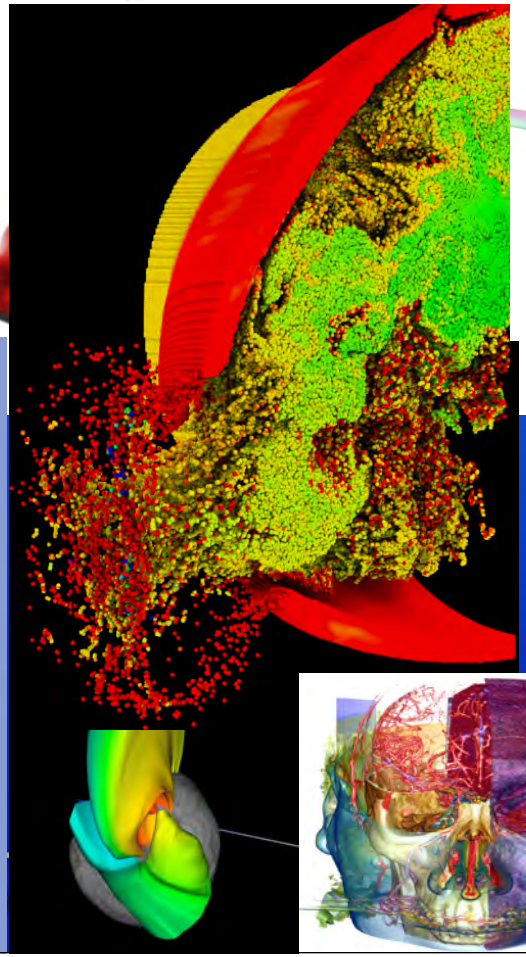









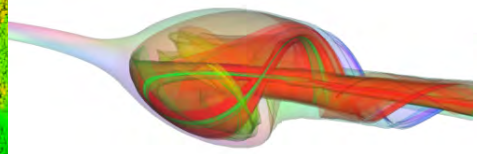
New Visualization Techniques

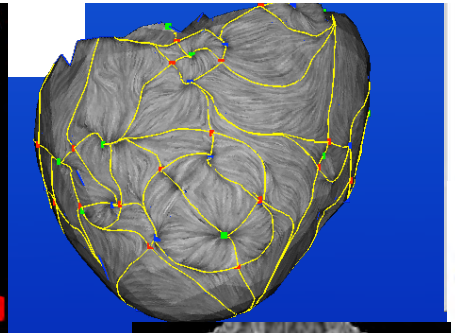


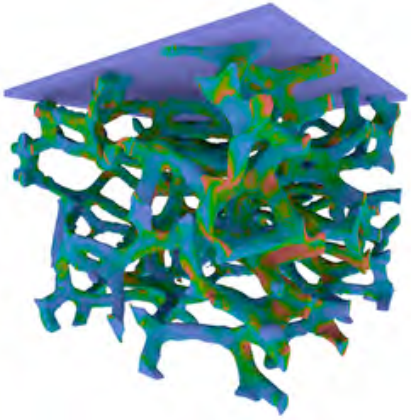


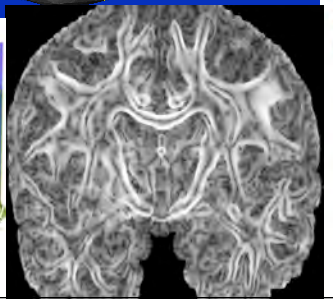












ImageVis3D and Tuvok

IO

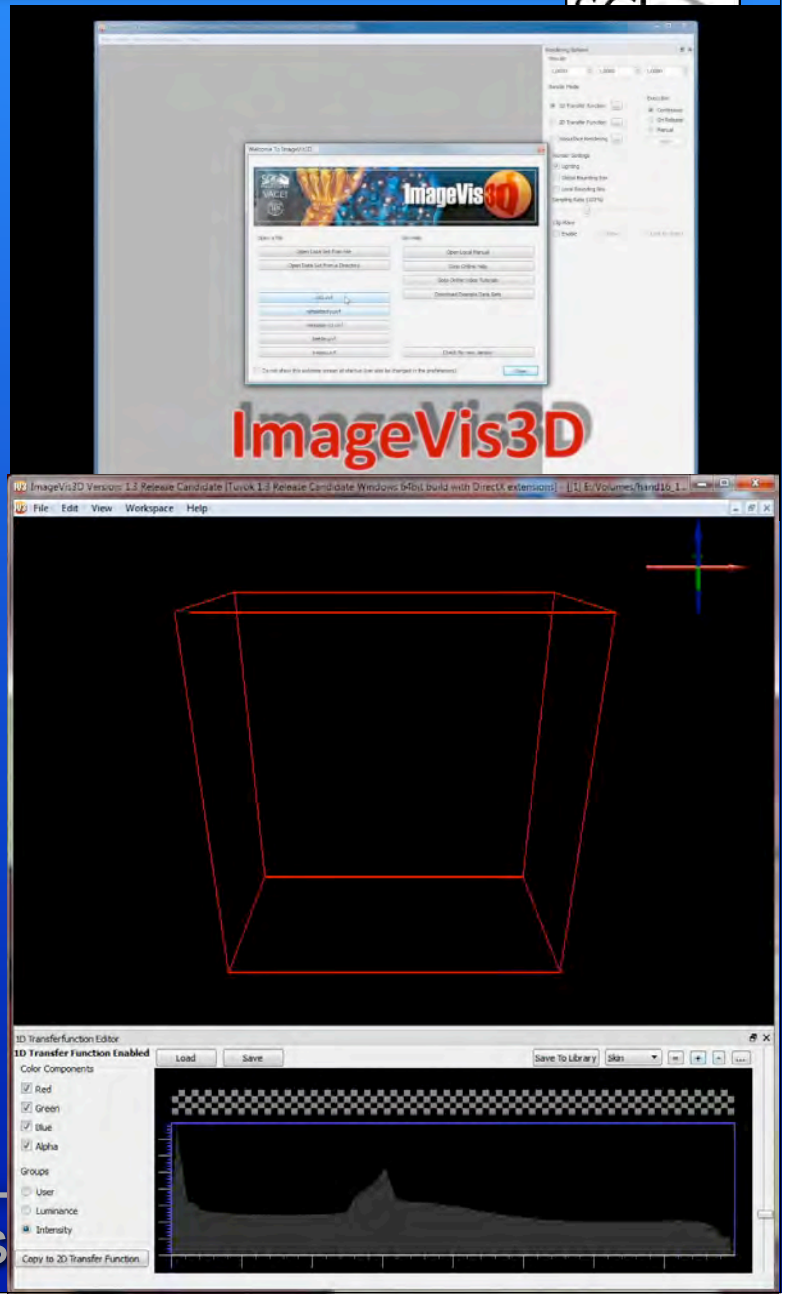
- Understands various file formats including DICOM
- Reads and handles data of up to 18 EB
- Provides Bricking and LoD computations

Renderer

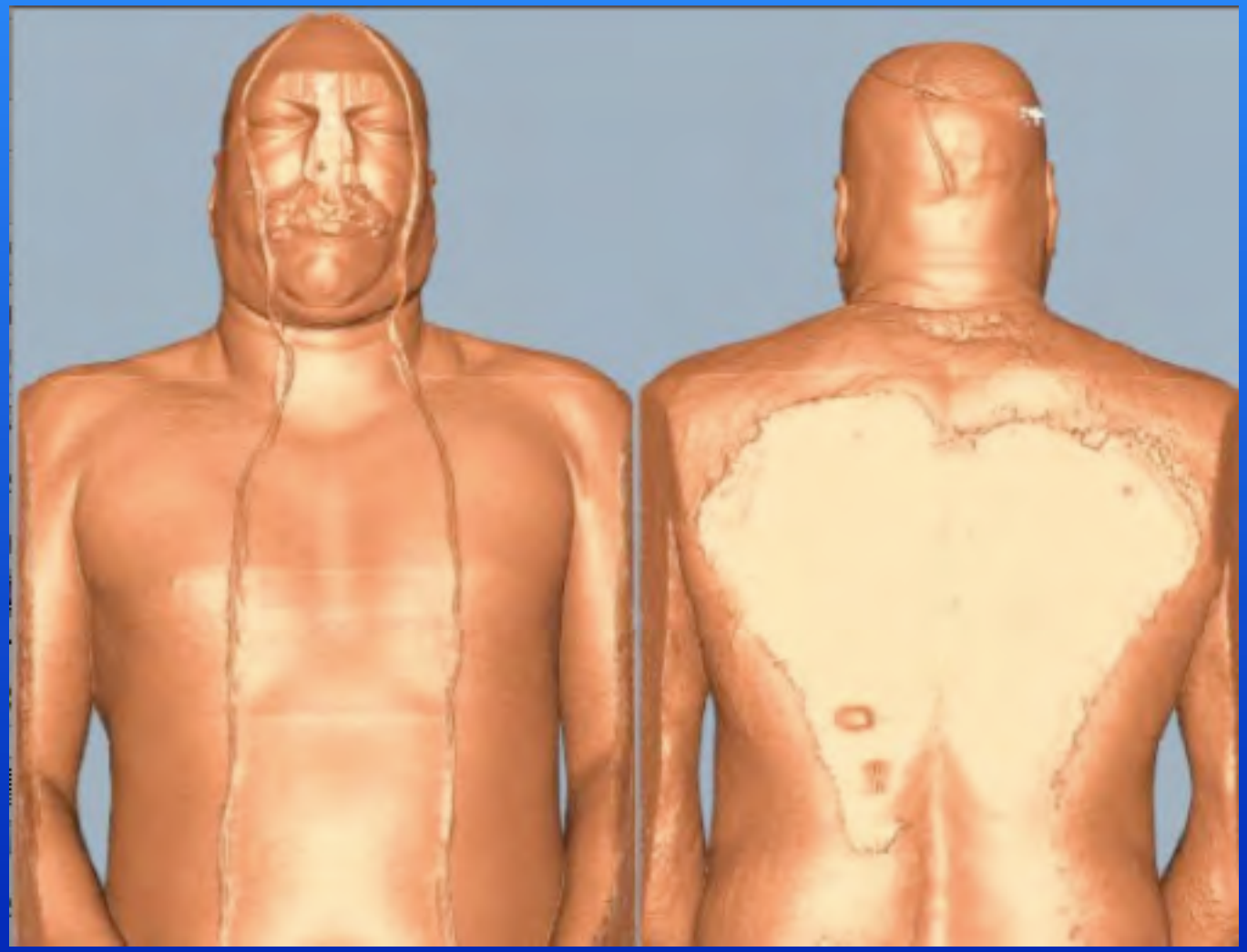
- Supports Raycasting and Slicing
- Supports 1D, 2D TFs, Isosurfacing, and ClearView
- Provides extensive support for older hardware

General

- Cross platform
- Intuitive and Configurable UI
- Supports multiple windows
- Open Source - MIT License

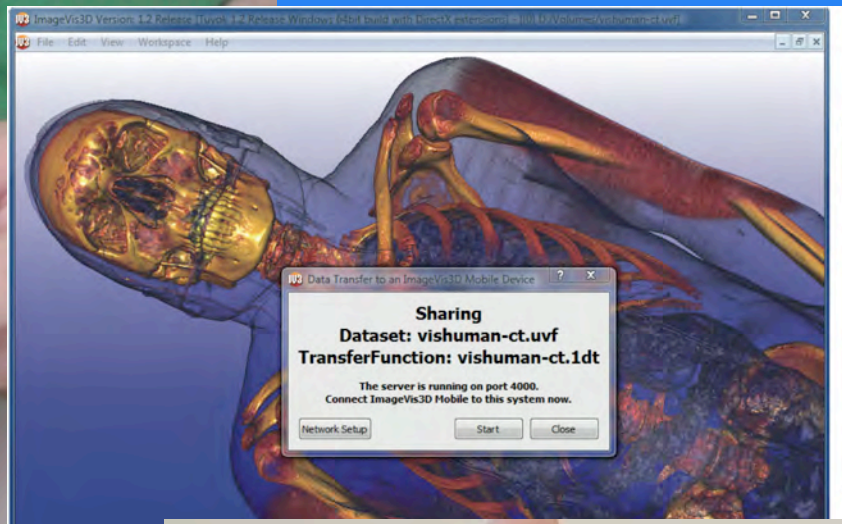


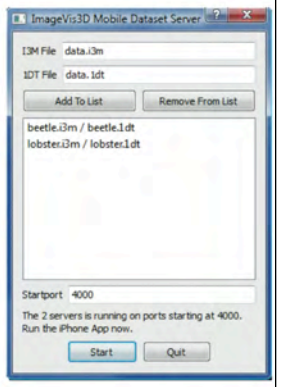
NIH Visible Male

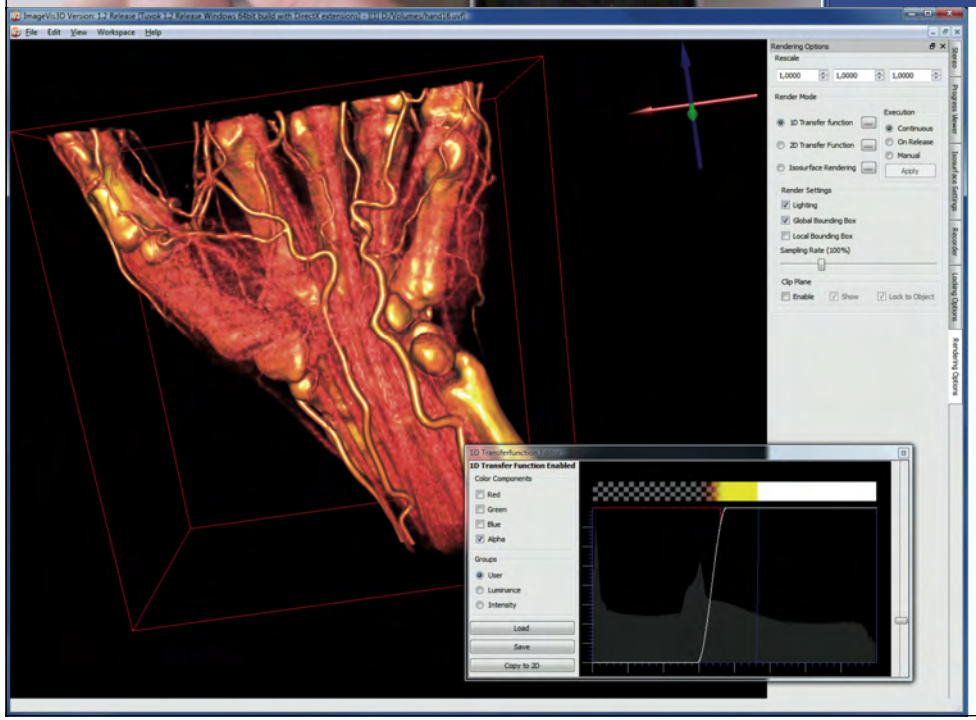


Visible Human - High Resolution

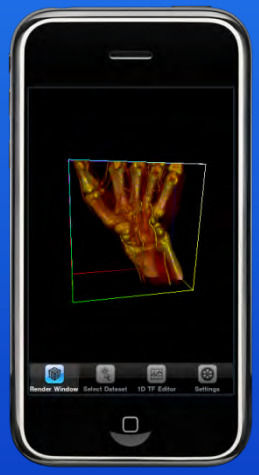
ImageVis3D - Mobile

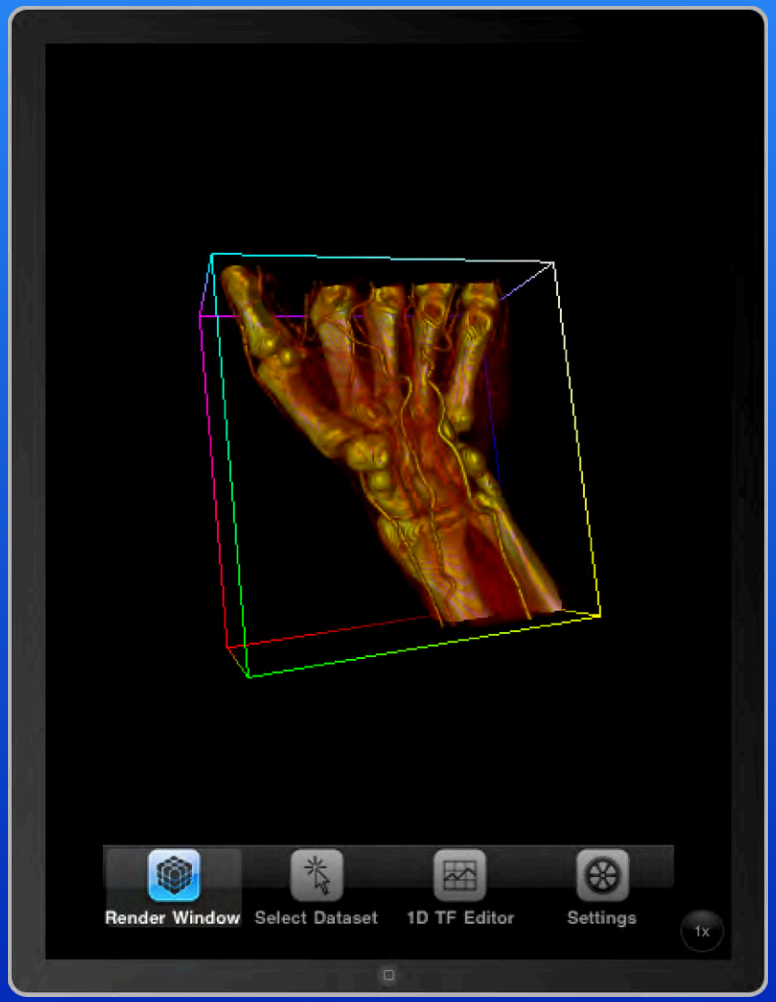




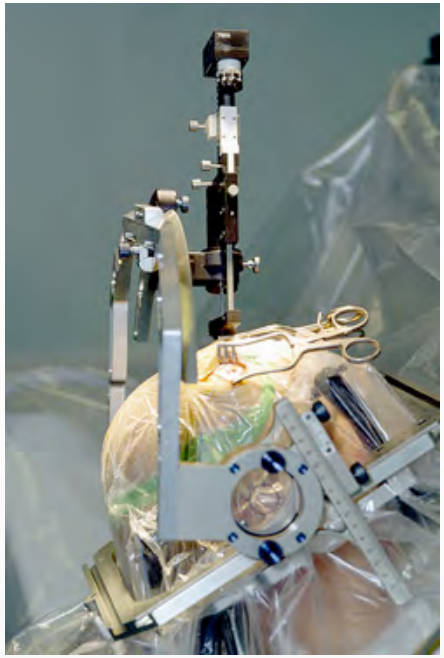


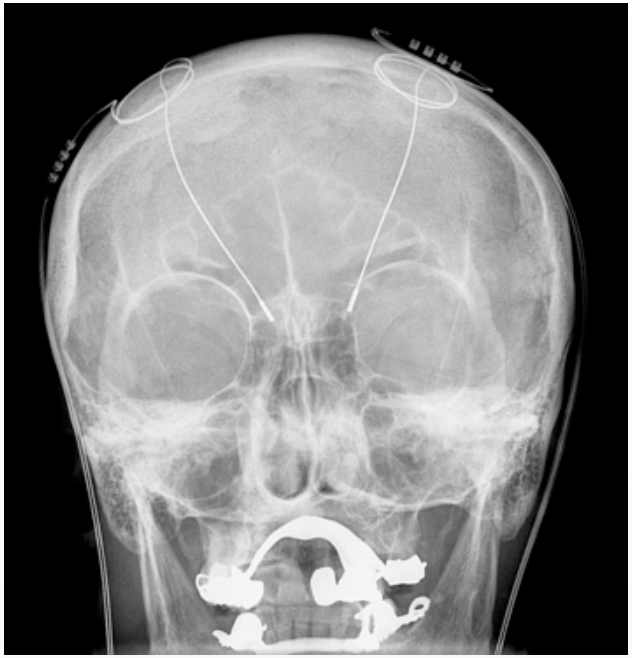
ImageVis3D Mobile



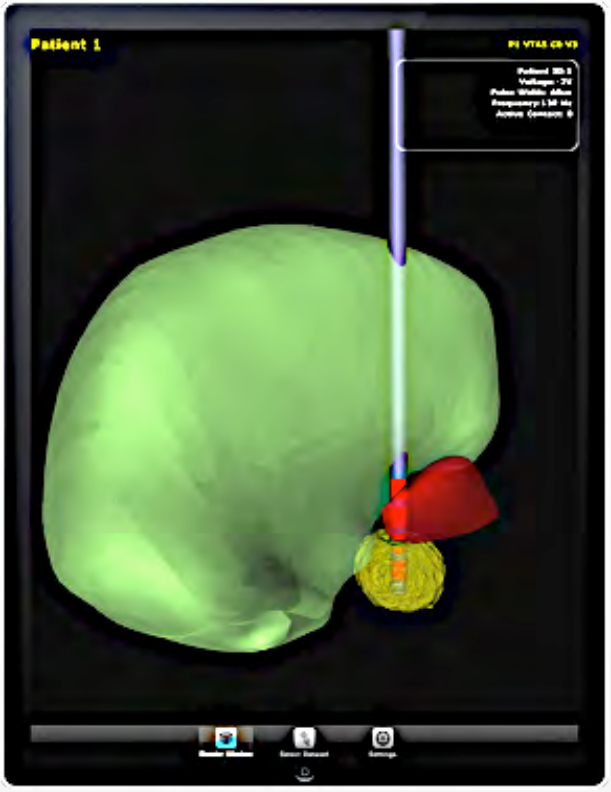


ImageVis3D Mobile DBS App



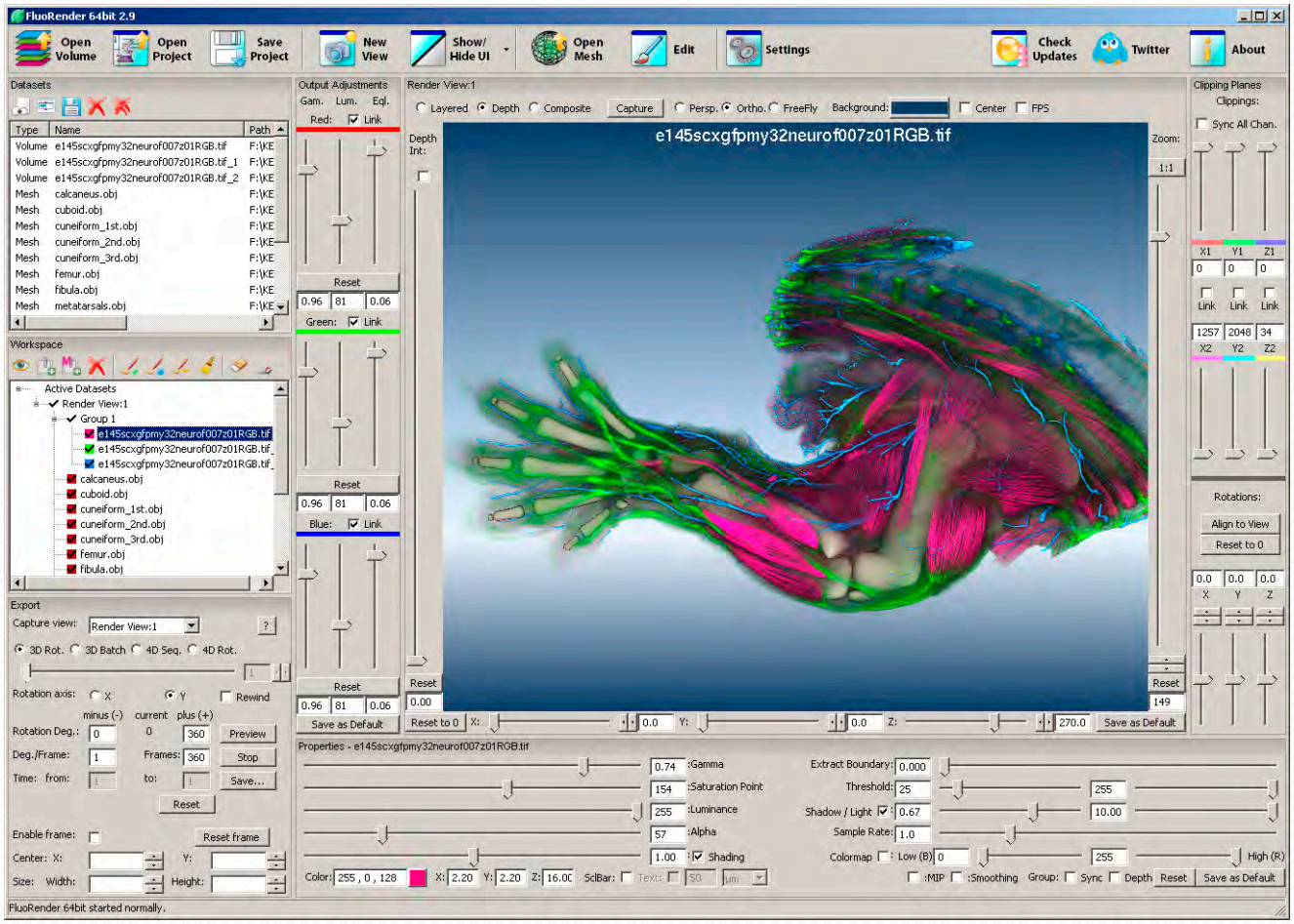


Deep Brain Stimulation
DBP: Chris Butson



C. Butson, G. Tamm, S. Jain, T. Fogal and J. Krüger "Evaluation of Interactive Visualization on Mobile Computing Platforms for Selection of Deep Brain Stimulation Parameters" *IEEE Transactions on Visualization and Computer Graphics, 2012 (in press).*

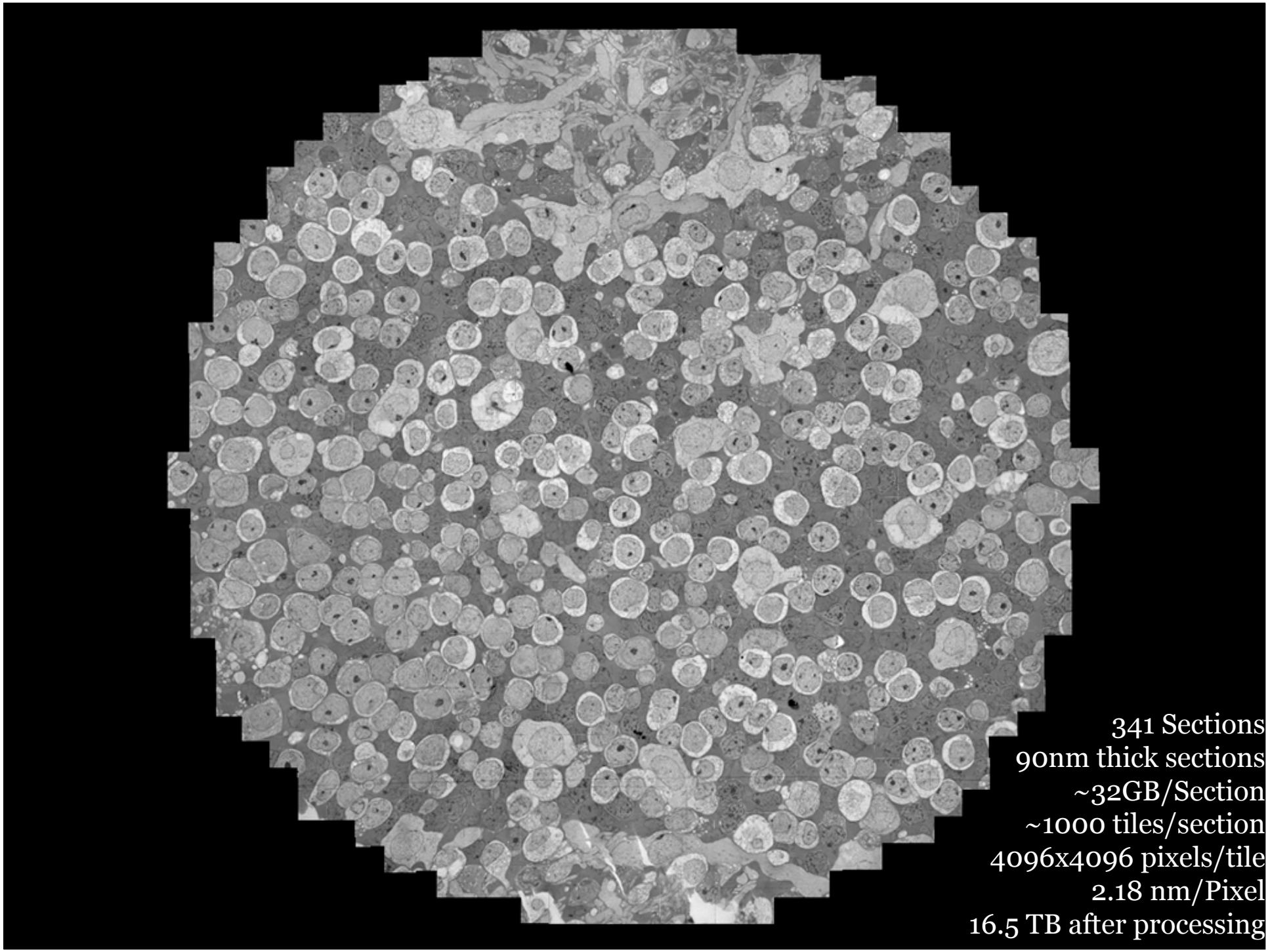
FluoRender Ver 2.9



Mouse hindLimb
A. Kelsey Lewis, Human Genetics, Univ. of Utah

UNIVERSITY OF UTAH SCHOOL OF MEDICINE
Department of Neurobiology and Anatomy

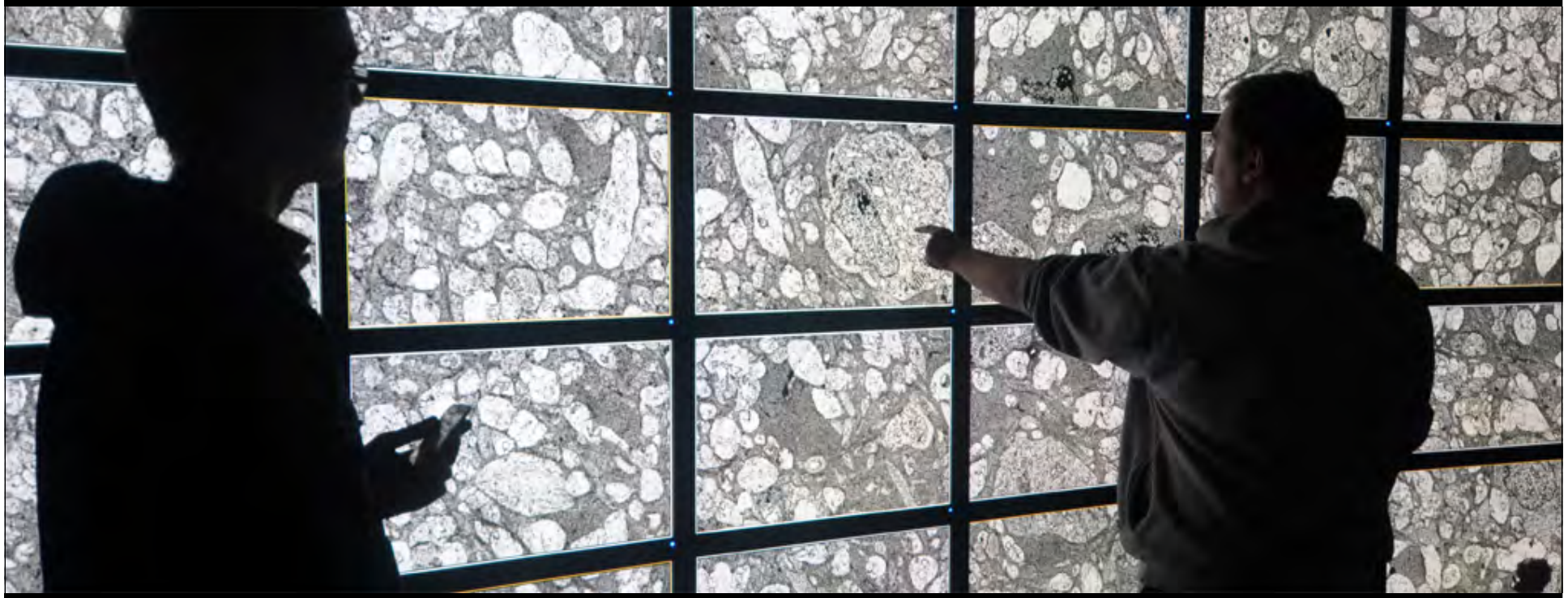
SCI INSTITUTE


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

Antony van Leeuwenhoek (1632-1723)

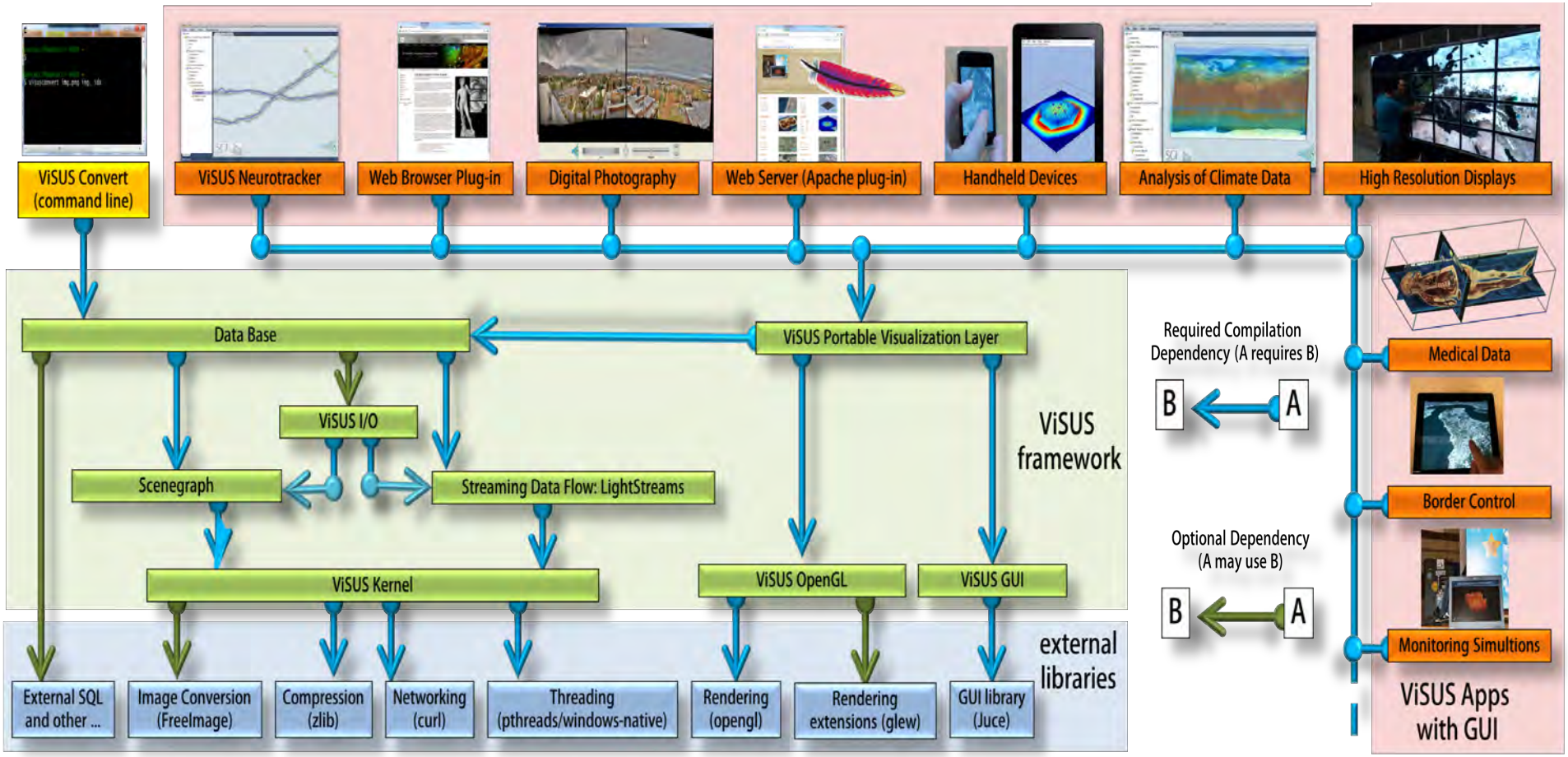
. . . my work, which I've done for a long time, was not pursued in order to gain the praise I now enjoy, but chiefly from a craving after knowledge, which I notice resides in me more than in most other men. And therewithal, whenever I found out anything remarkable, I have thought it my duty to put down my discovery on paper, so that all ingenious people might be informed thereof.

Antony van Leeuwenhoek. Letter of June 12, 1716

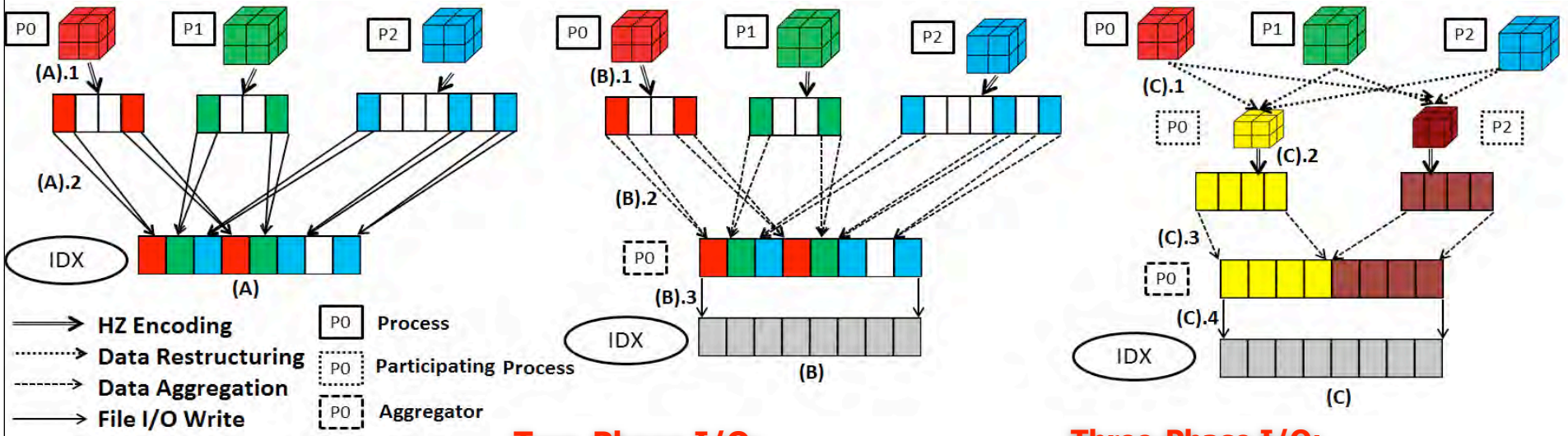


Michelangelos David

ViSUS Framework for Scalable Data



The ViSUS Parallel I/O Infrastructure (PIDX) Adopts a 3–Phase Data Transfer Model



One-Phase I/O:

(A).1 HZ encoding of irregular data set leads to sparse data buffers interleaved across processes.

(A).2 I/O writes to underlying IDX file by each process, leading to a large number of small accesses to each file.

Two-Phase I/O:

(B).1 HZ encoding of irregular data set leads to sparse data buffers interleaved across processes.

(B).2 Data transfer from in-memory HZ ordered data to an aggregation buffer involving large number of small sized data packets.

(B).3 Large sized aligned I/O writes from aggregation buffer to the IDX file.

Three-Phase I/O:

(C).1 Data restructuring among processes transforms irregular data blocks at processes P0, P1 and P2 to regular data blocks at processes P0 and P2.

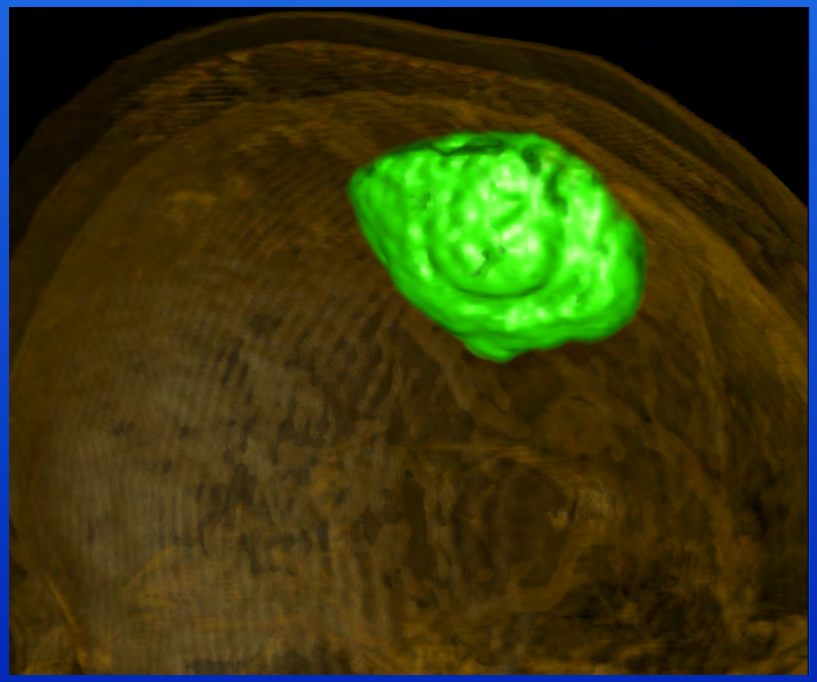
(C).2 HZ encoding of regular blocks leading to dense and non-overlapping data buffer.

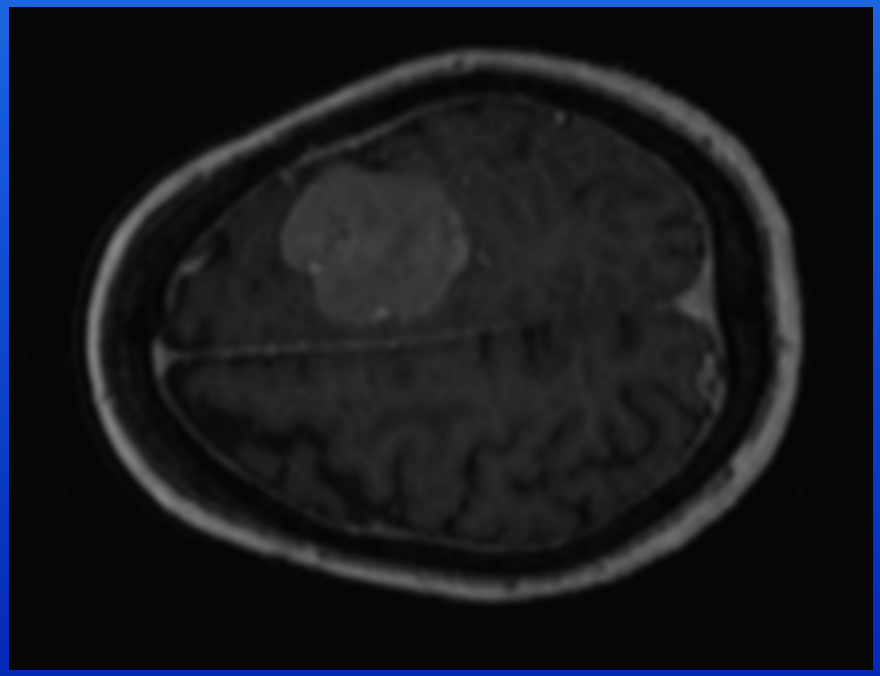
(C).3 Data transfer from in-memory HZ ordered data to an aggregation buffer involving fewer large sized data packets.

(C).4 I/O writes from aggregation buffer to a IDX file.

Uncertainty Visualization

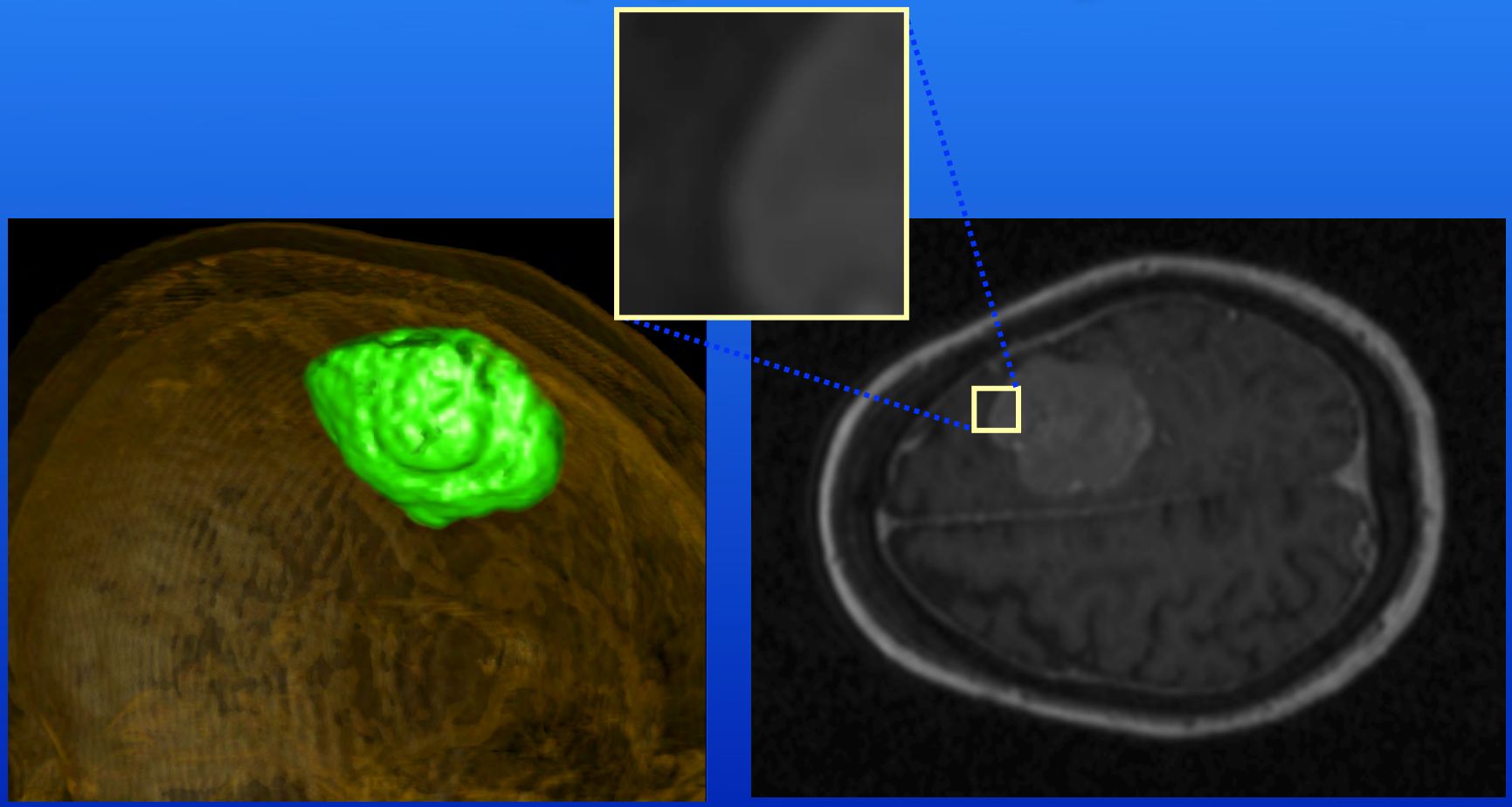
When is the last time you've seen an error bar in a 3D visualization?





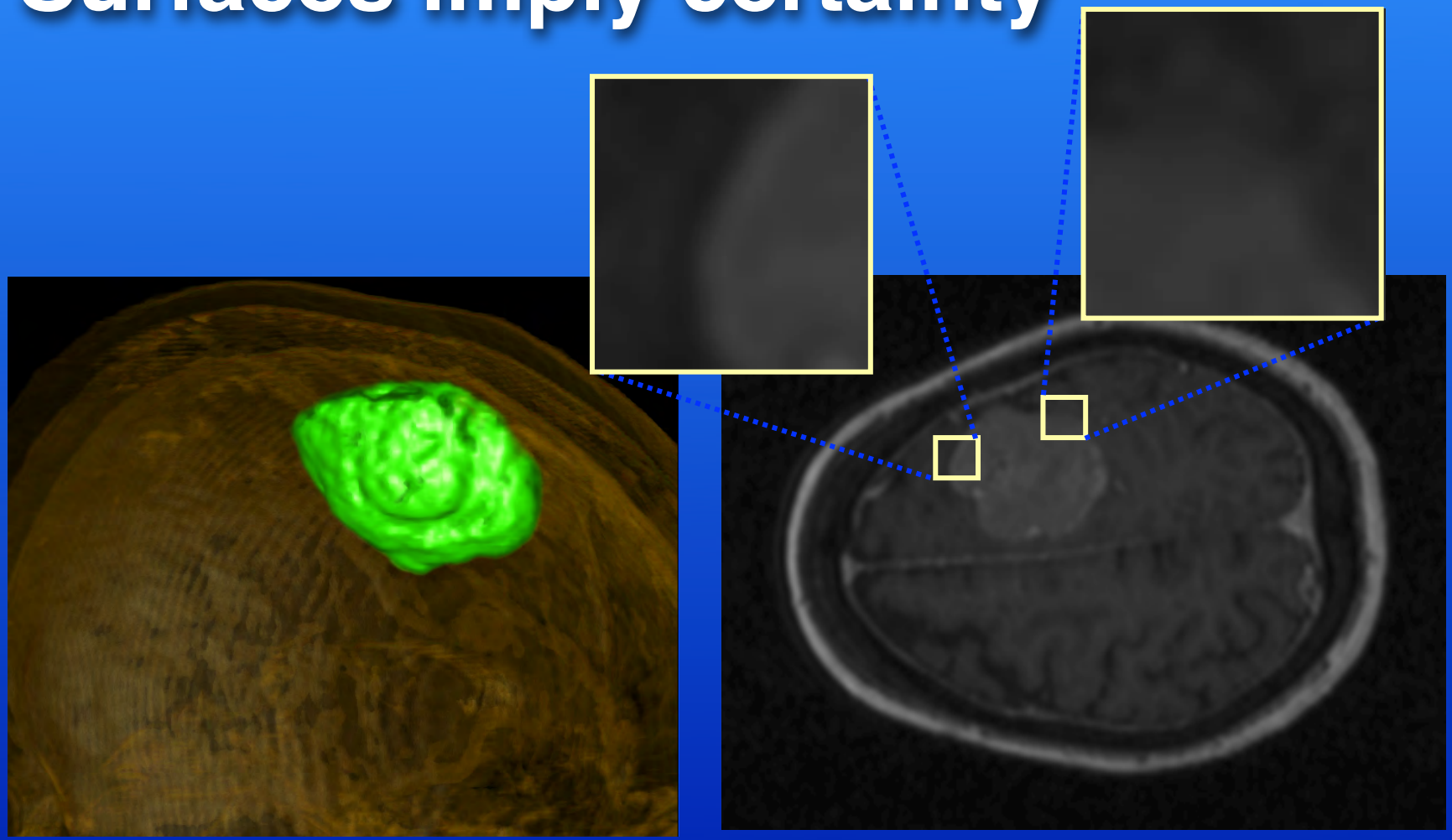
Uncertainty Visualization

Surfaces imply certainty



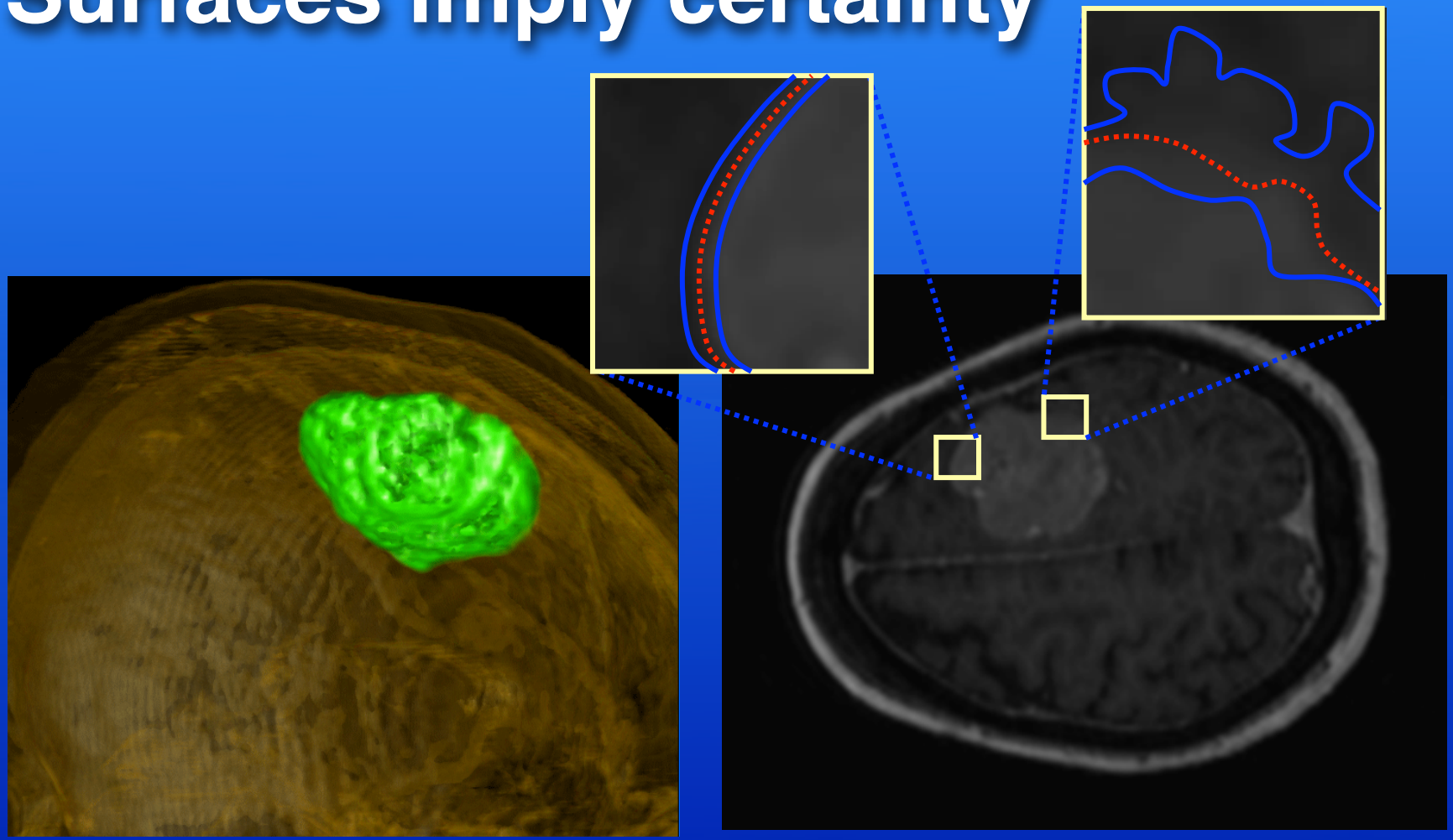
Uncertainty Visualization

Surfaces imply certainty

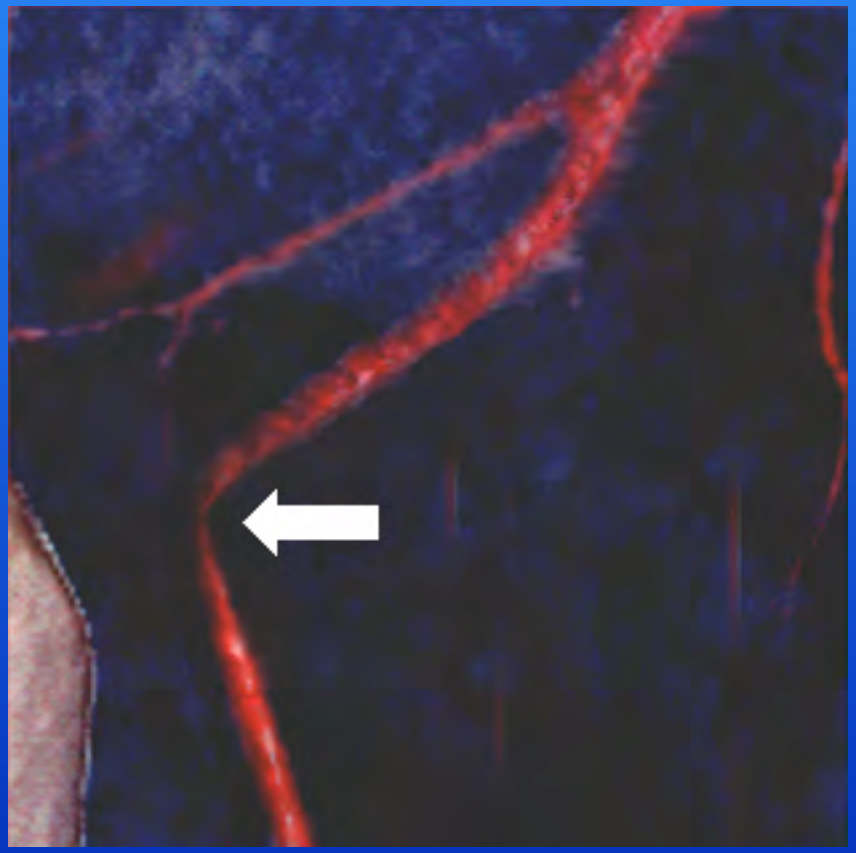


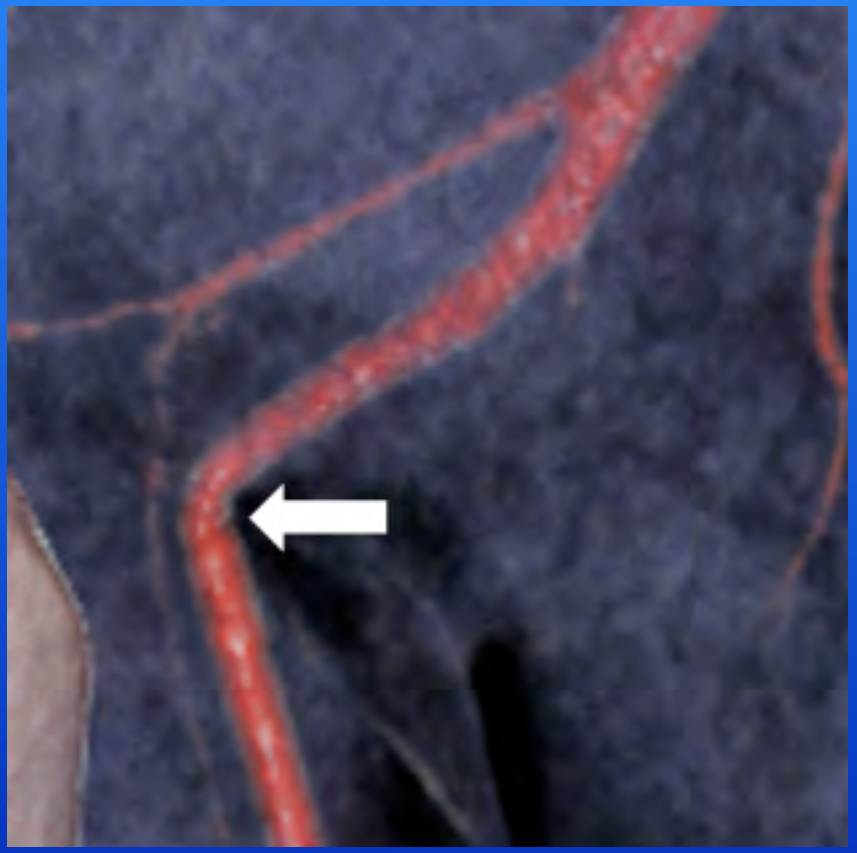
Uncertainty Visualization

Surfaces imply certainty



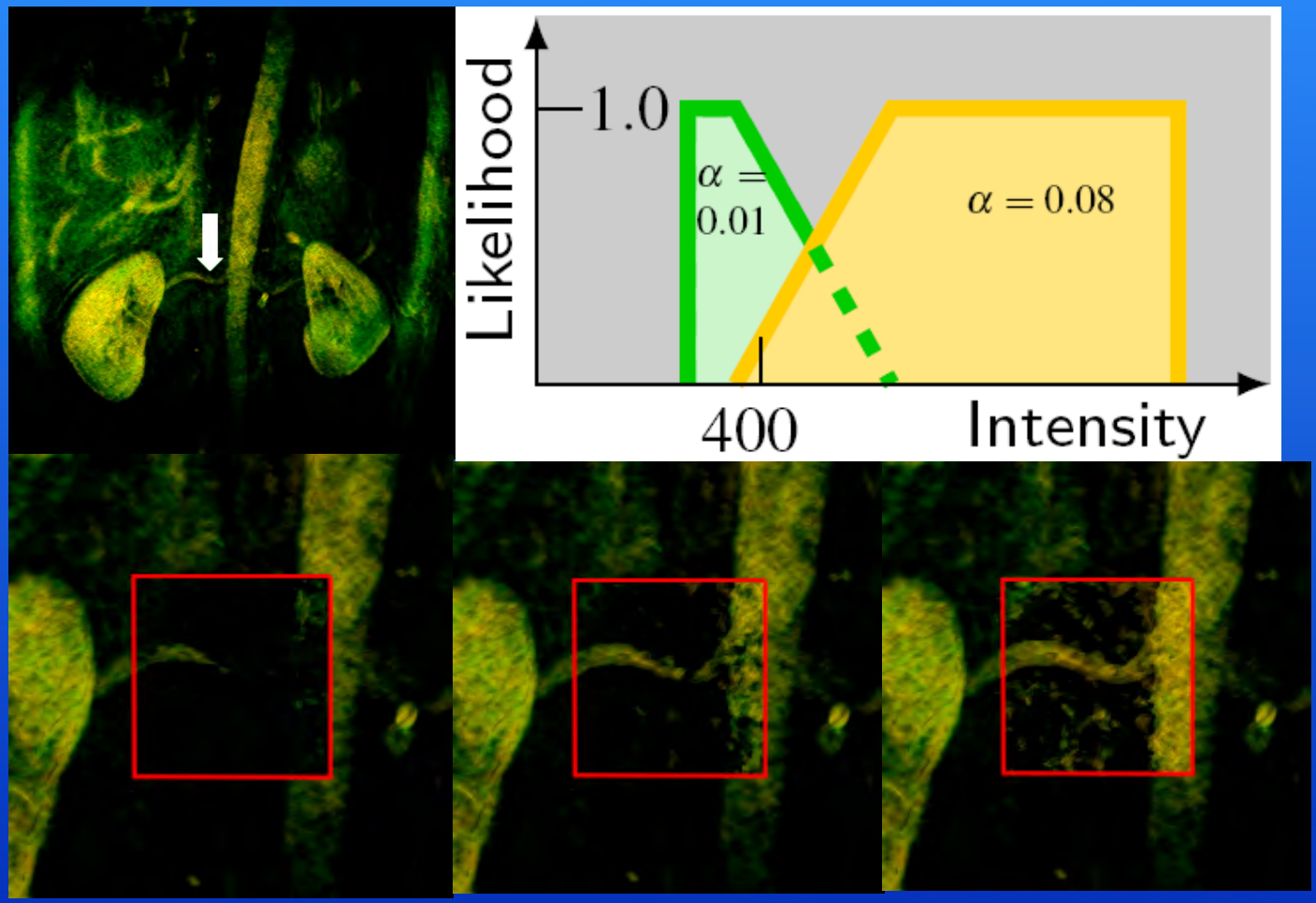
Uncertainty Visualization





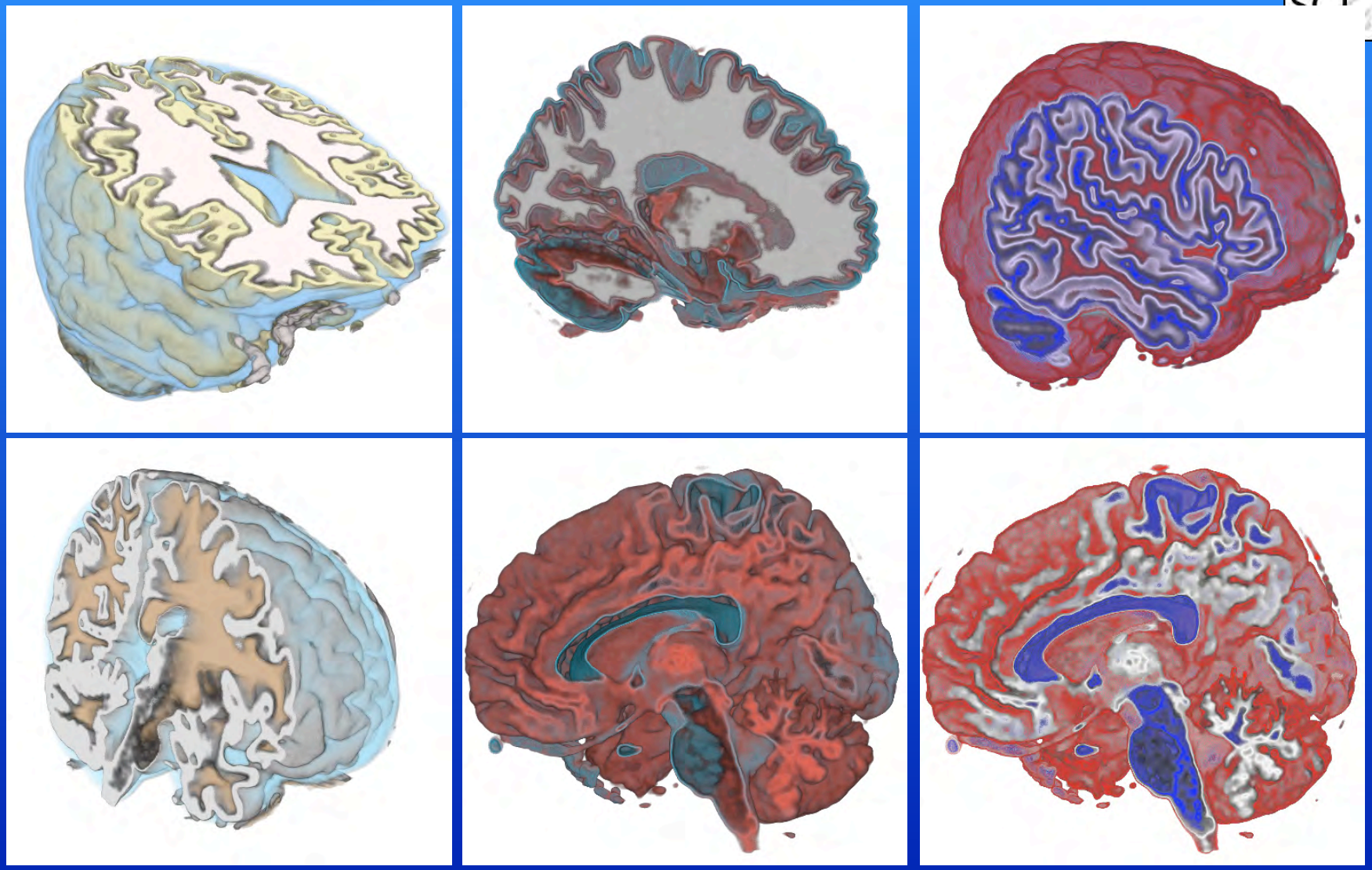
Images Courtesy of Claes Lundström, Patric Ljung, Anders Persson, Anders Ynnerman.

Uncertainty Visualization



Claes Lundström, Patric Ljung, Anders Persson, Anders Ynnerman. Uncertainty Visualization in Medical Volume Rendering Using Probabilistic Animation, IEEE Transactions on Visualization and Computer Graphics, 13(2007): no. 5

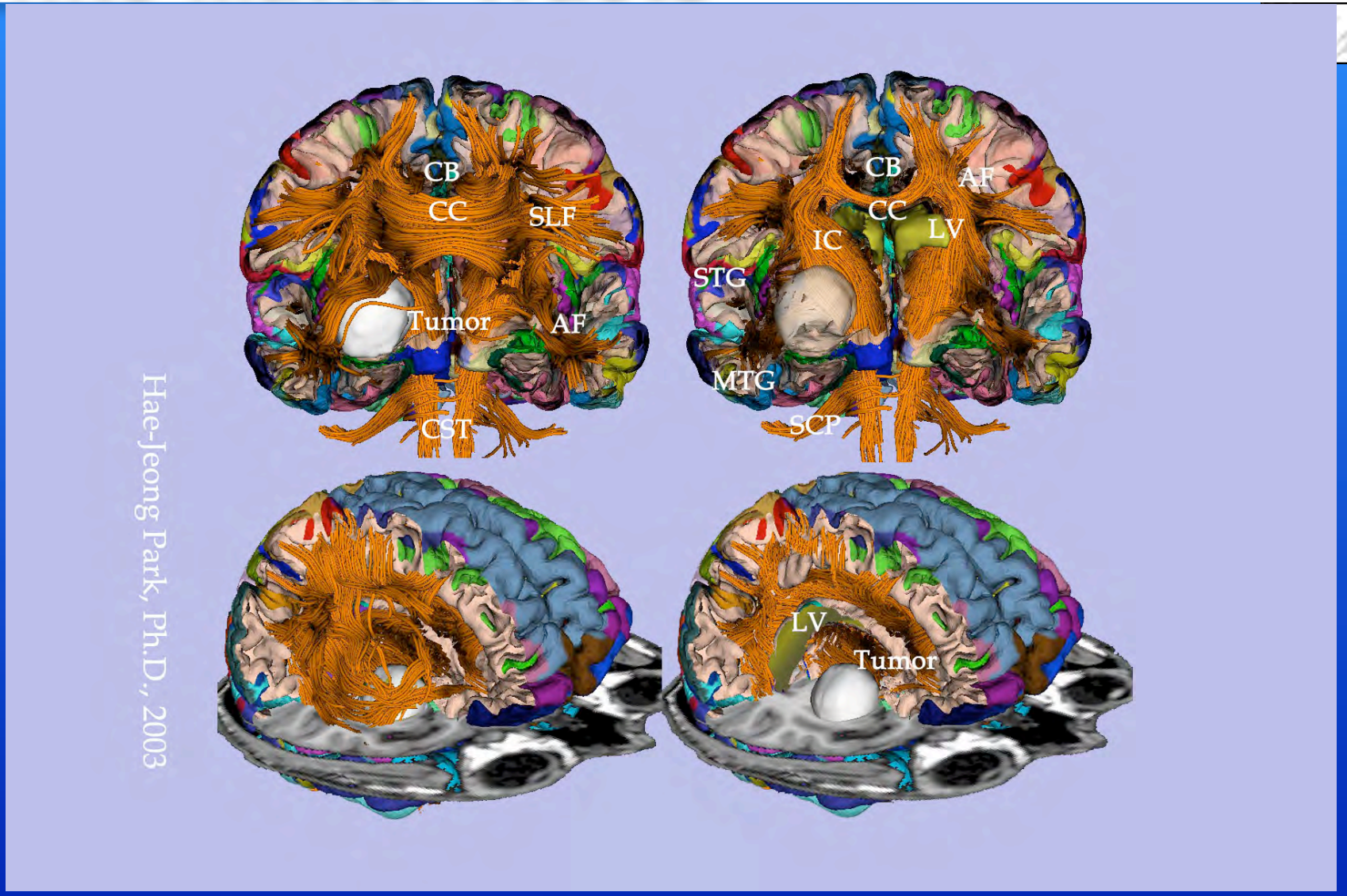
Visualizing Uncertainty



Fuzzy Sensitivity Confidence

Brain Structure - Fiber Tracks

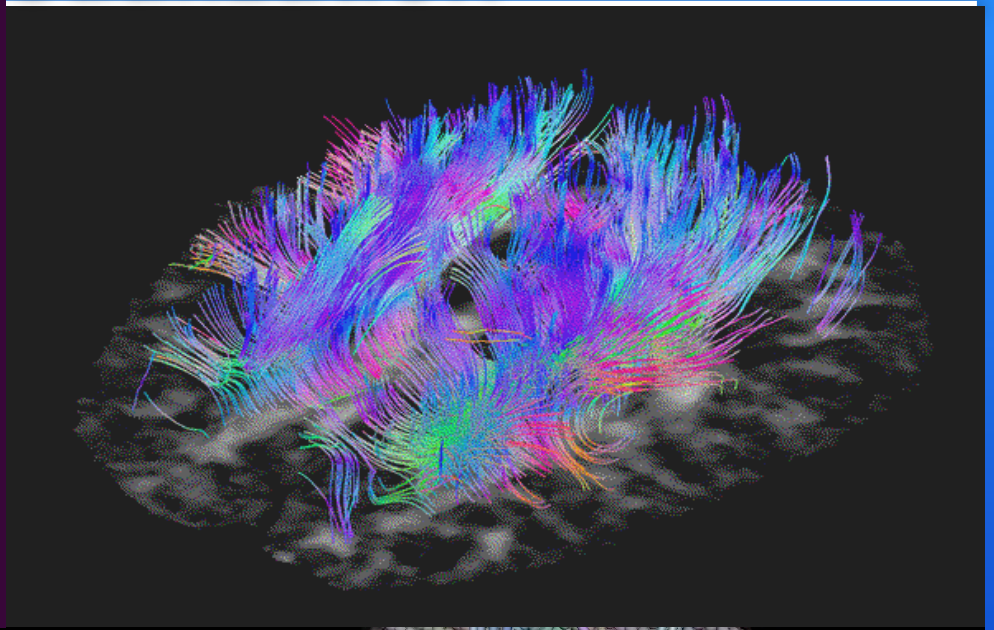
White Matter Tracts

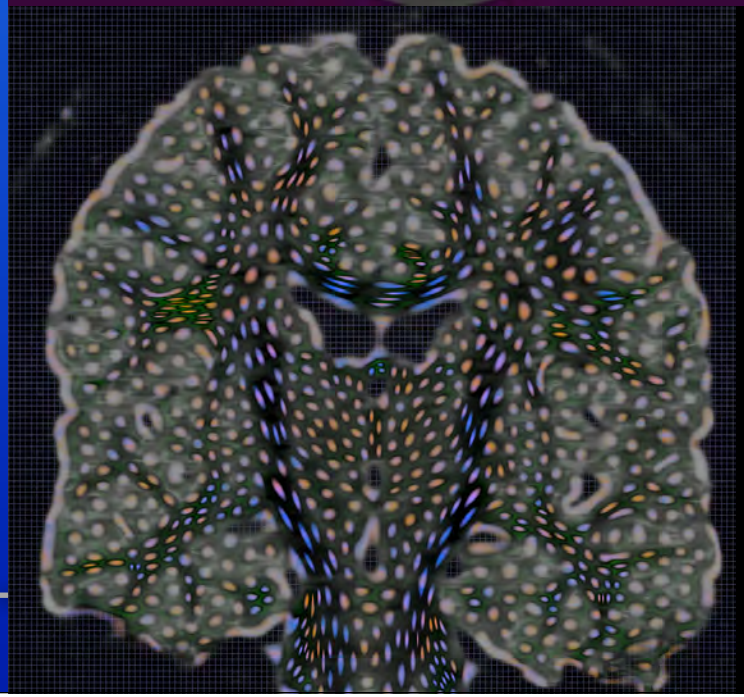


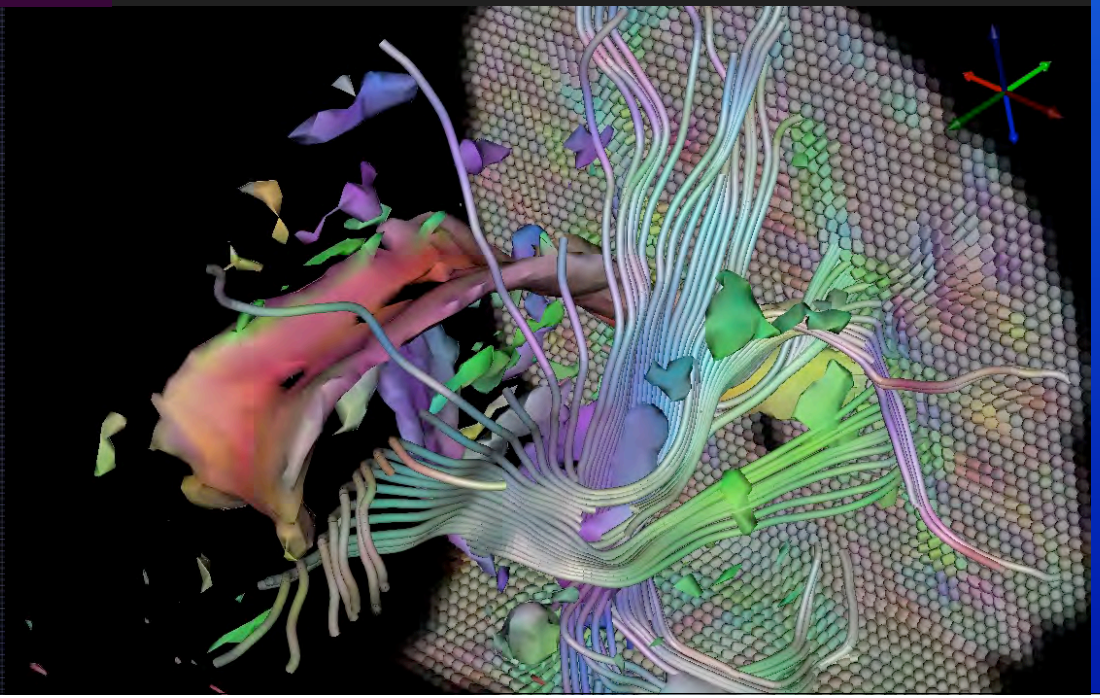
Park, Westin, and Kikinis, BWH, Harvard Medical School, 2003

Scientific Computing and Imaging Institute, University of Utah

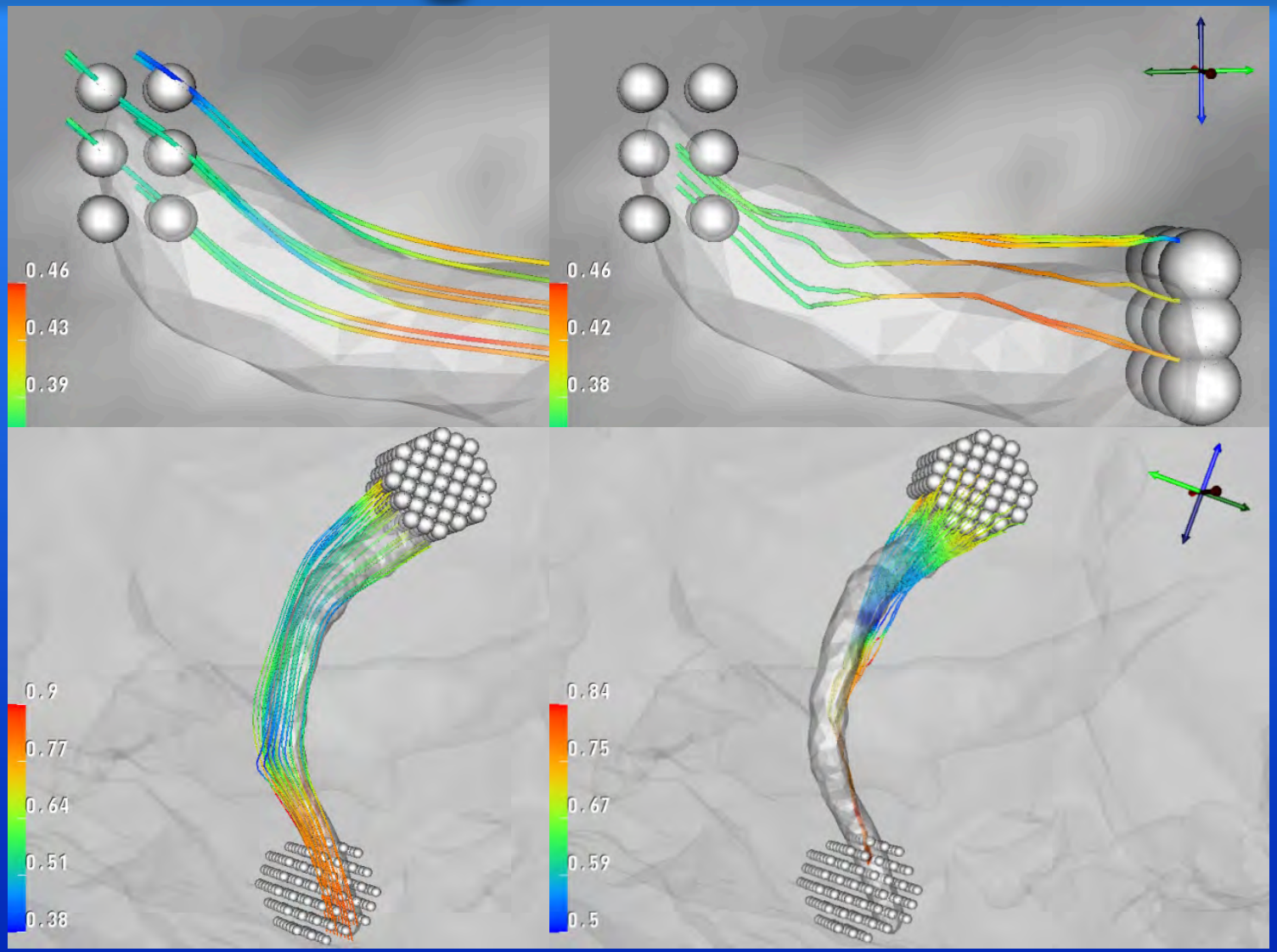
Diffusion Tensor Visualization





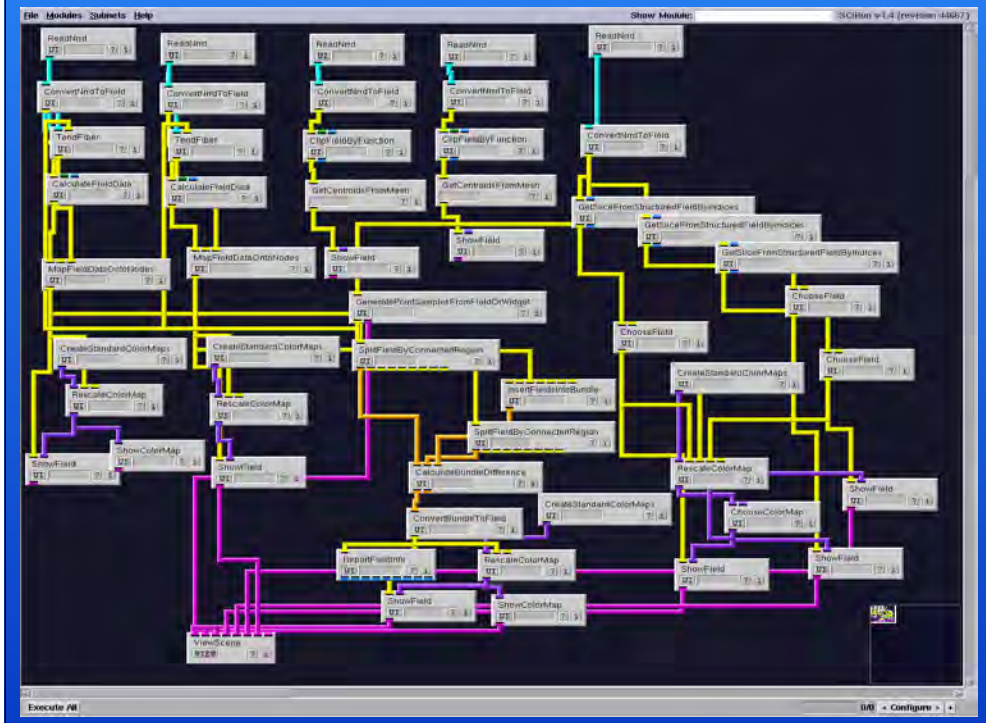


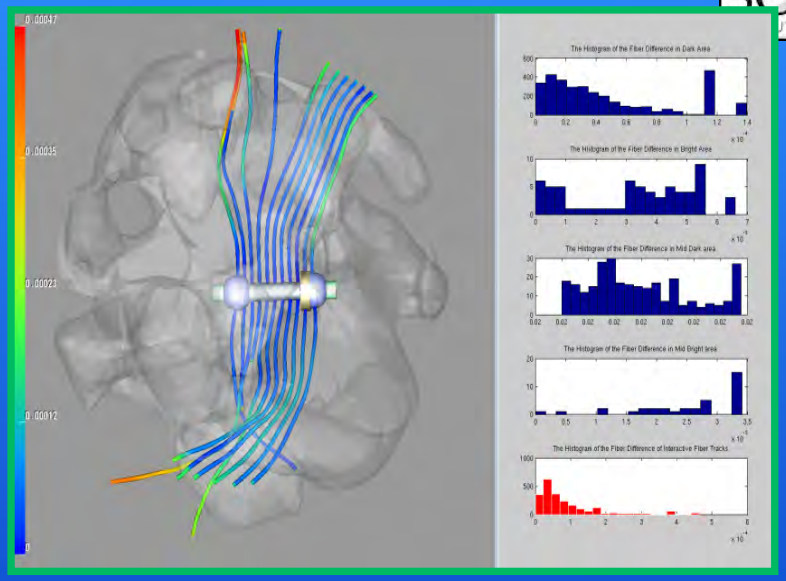
Fiber Tracking Results

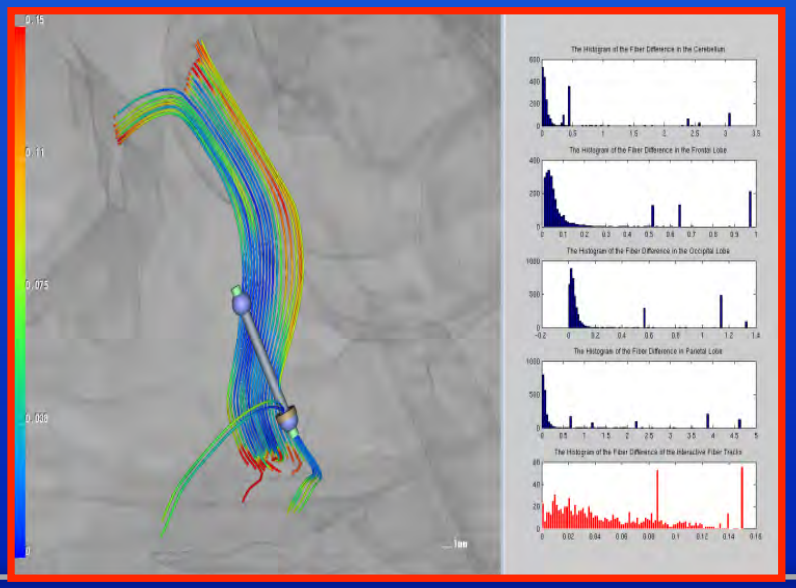


Streamline **Fast Marching**

iQuantVis



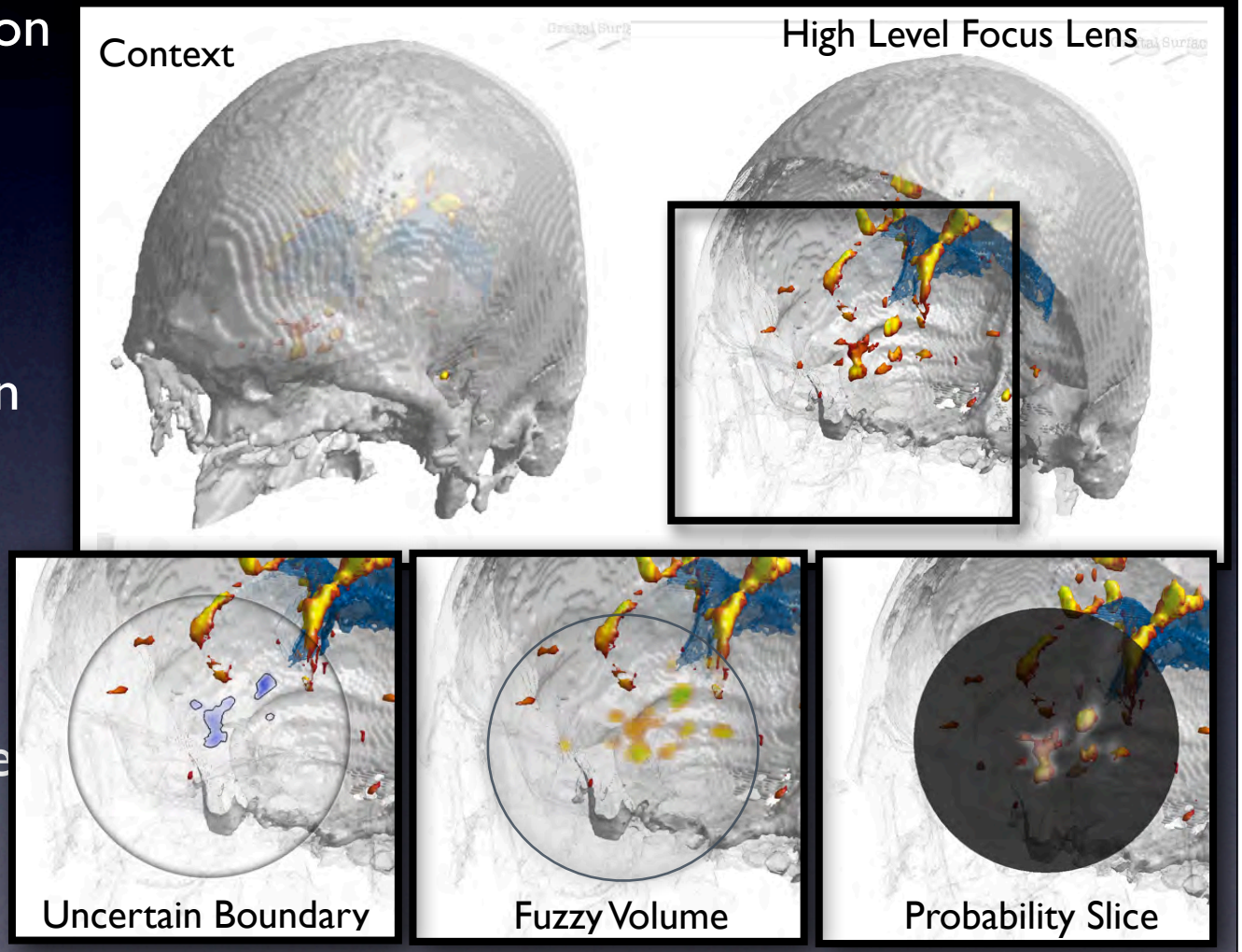




Scientific Computing and Imaging Institute, University of Utah

QuizLens: A Multi-lens approach for uncertainty exploration

- Global information important for qualitative evaluation & context
- Local information necessary for quantitative understanding
- Interchangeable lenses to explore various data characteristics

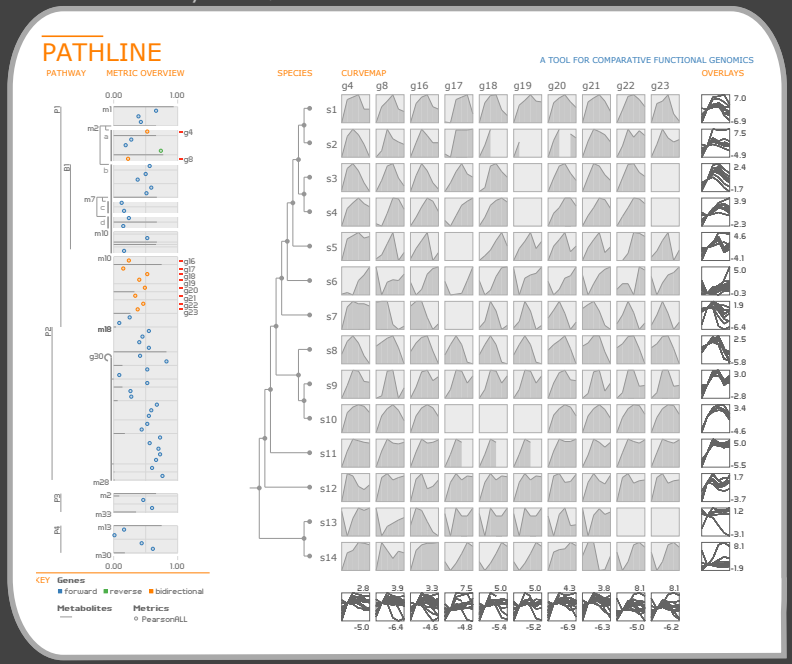


PROBLEM-DRIVEN VISUALIZATION RESEARCH *for biological data*

- target specific biological problems
- close collaboration with biologists
- rapid, iterative prototyping
- focus on genomic and molecular data

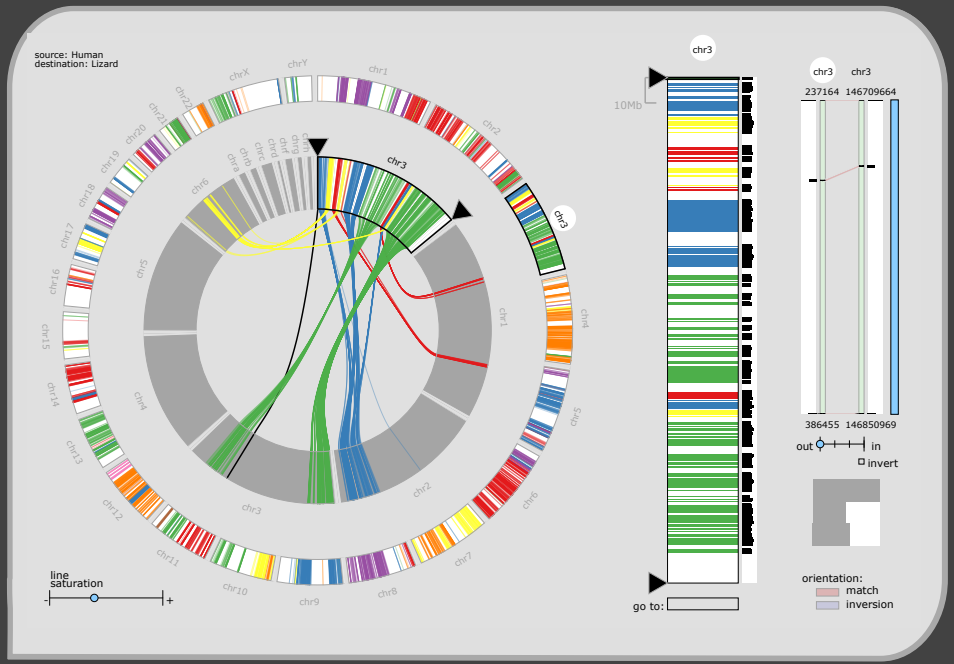
Pathline

M. Meyer et al., EuroVis 2010.

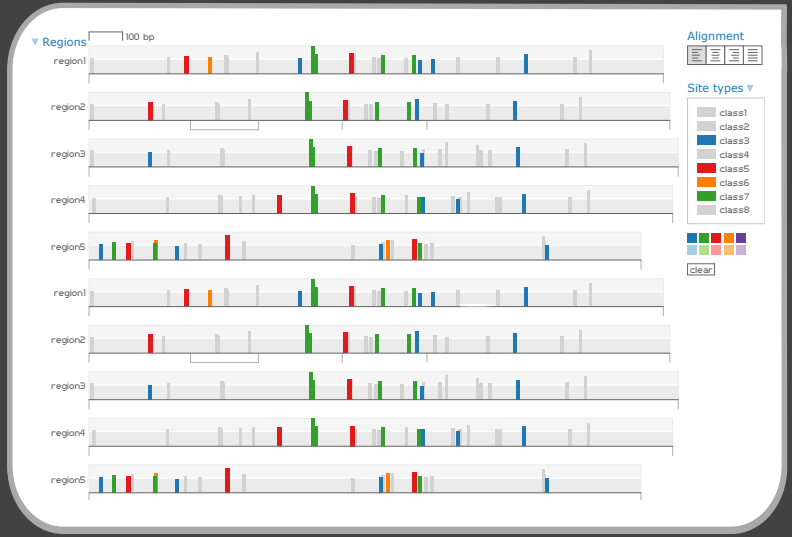


MizBee

M. Meyer et al., InfoVis 2009.

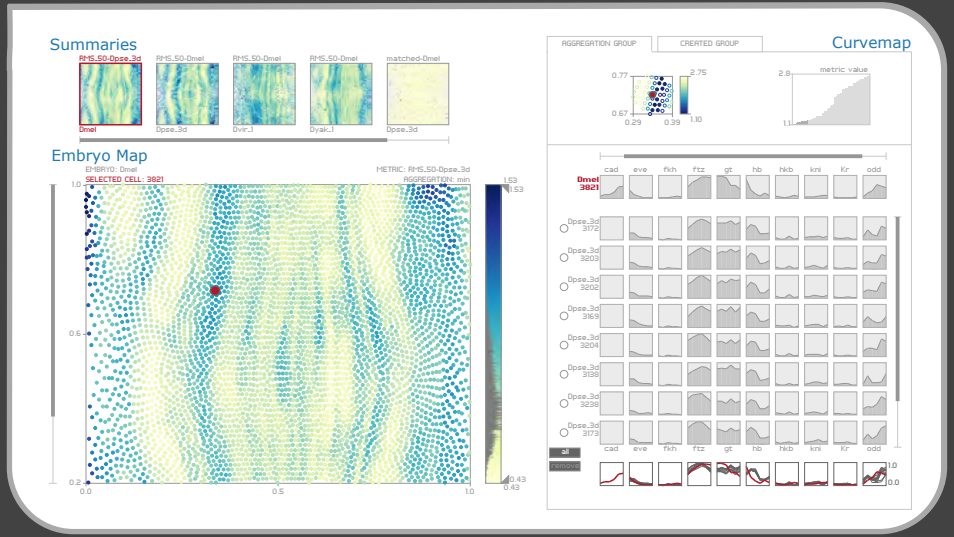


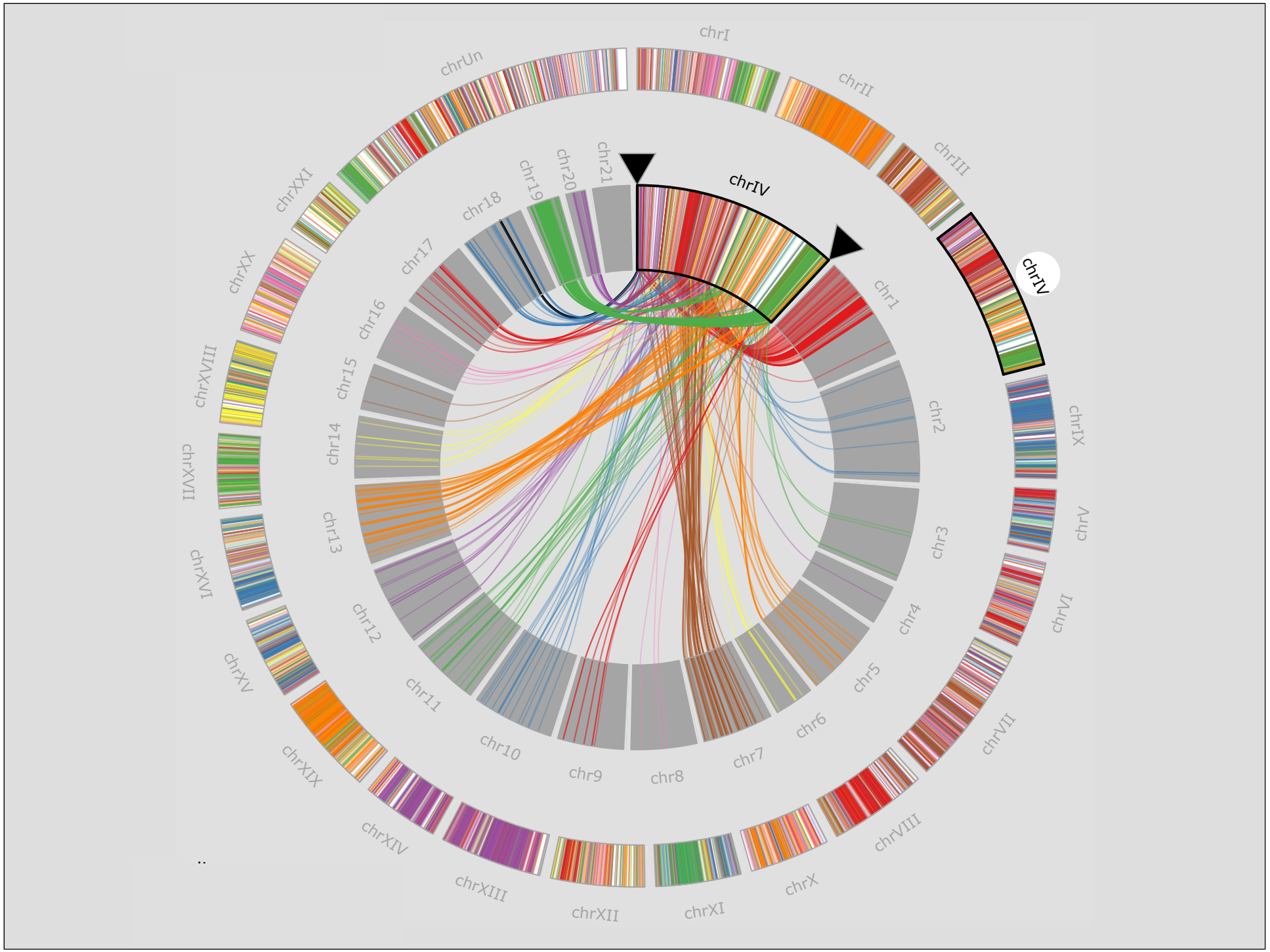
InSite



MulteeSum

M. Meyer et al., InfoVis 2010.

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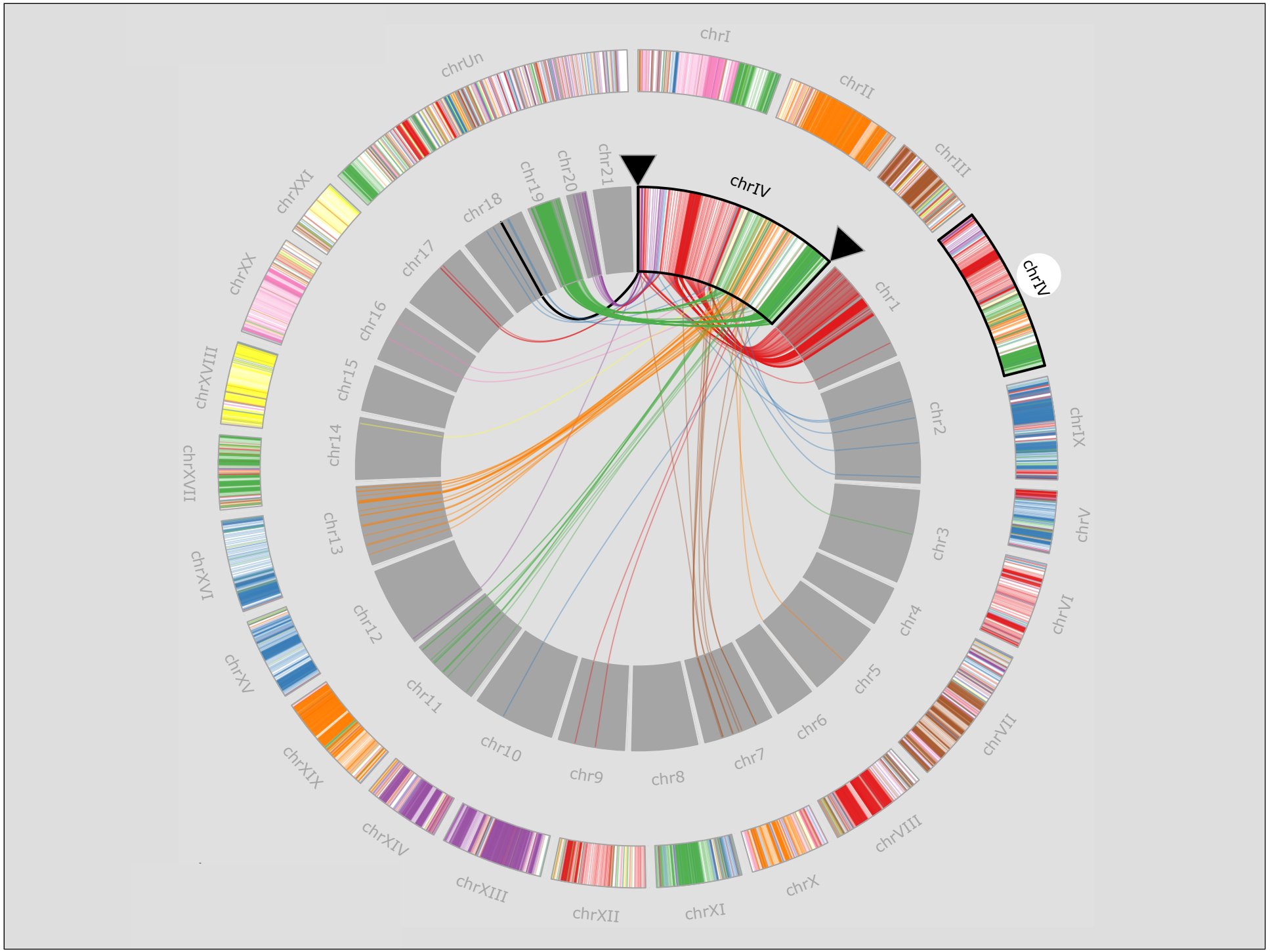
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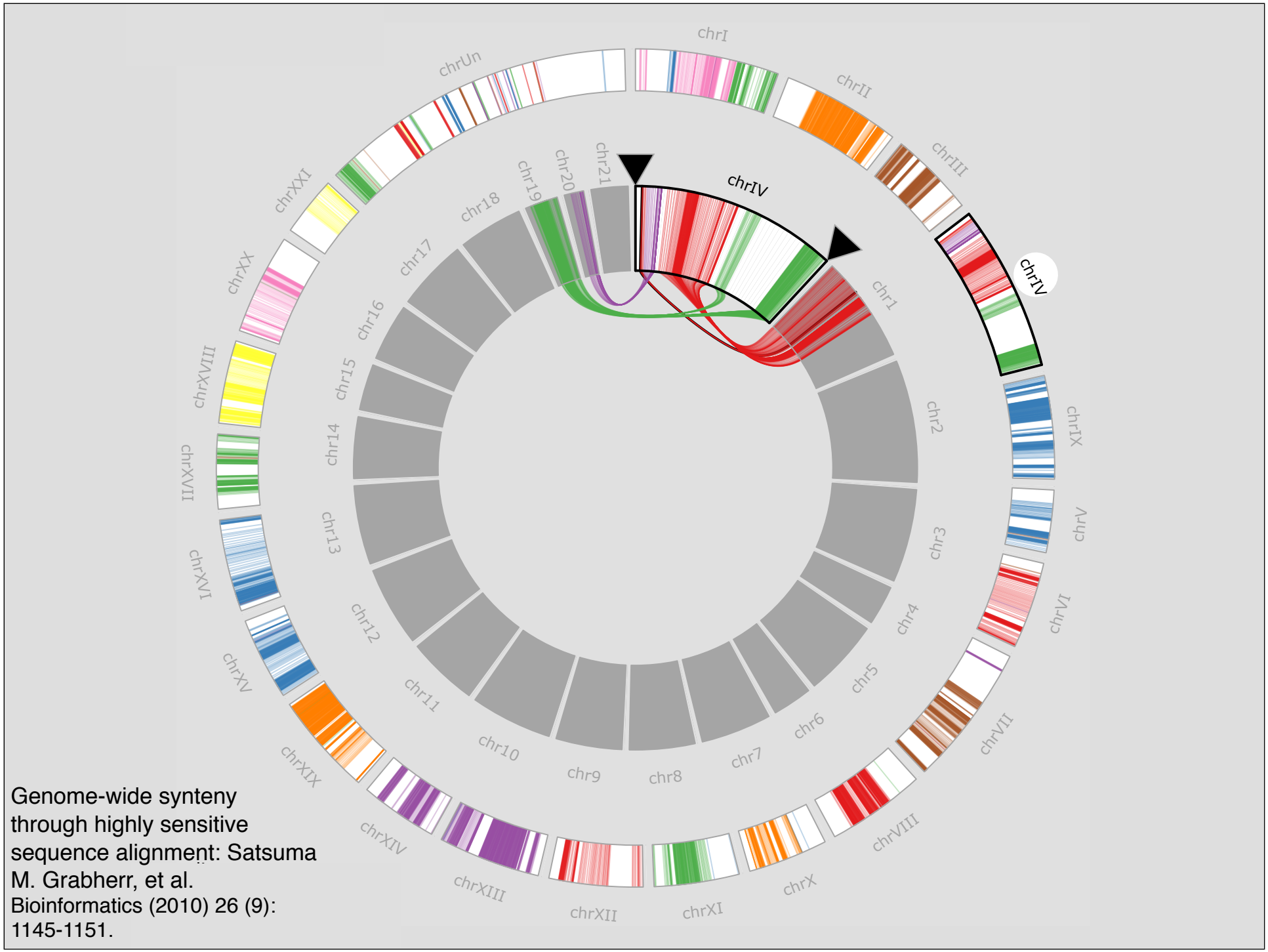

Genome-wide synteny through highly sensitive sequence alignment: Satsuma
M. Grabherr, et al.
Bioinformatics (2010) 26 (9): 1145-1151.

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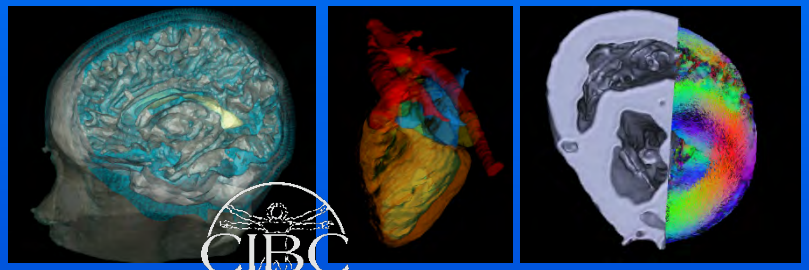
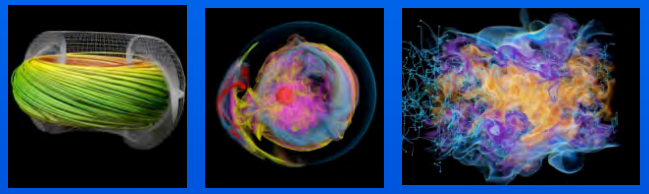
Acknowledgments

NIH/NIGMS Center for Integrative Biomedical Computing



SDAV

Scalable Data Management, Analysis and Visualization



Utah Center for Neuroimage Analysis

UTAH Center for Computational Earth Sciences

NIH NAMIC

Center for Extreme Data Management, Analysis, and Visualization

CEDMAV

KAUST

IAMCS
Institute for Applied Mathematics and Computational Science

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