SCIENTIFIC COMPUTING AND IMAGING INSTITUTE • UNIVERSITY OF UTAH

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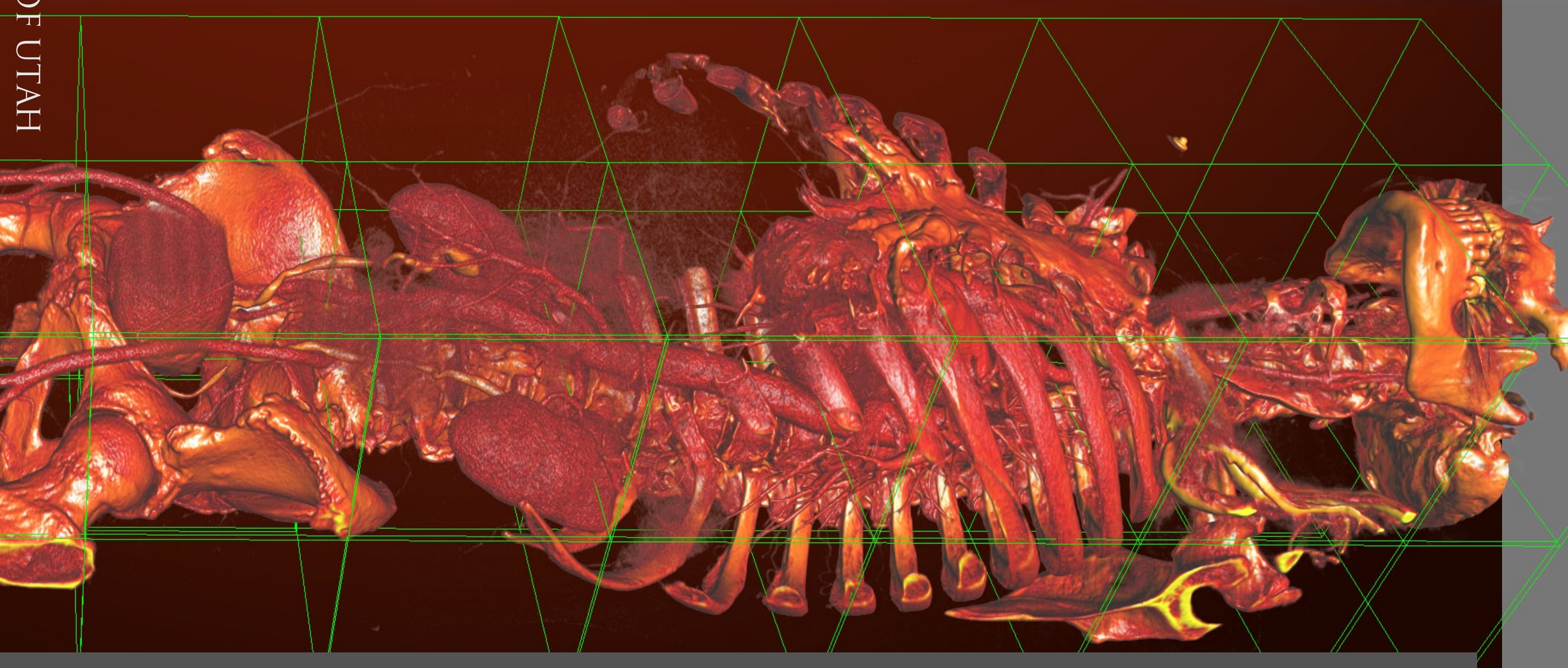

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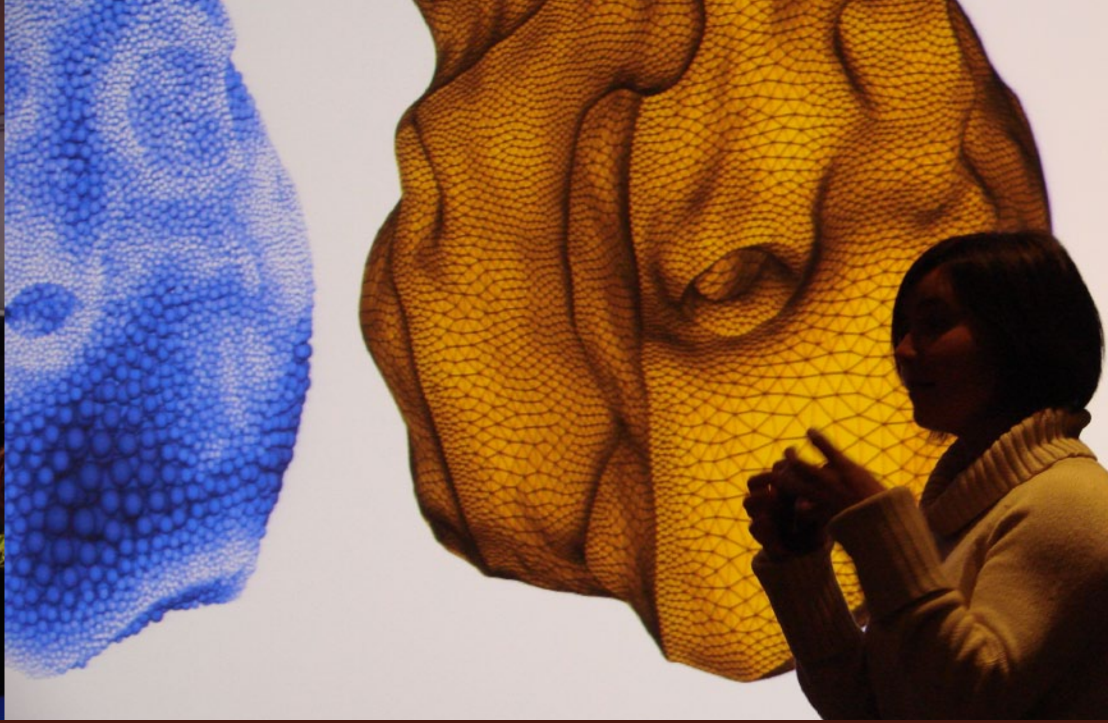
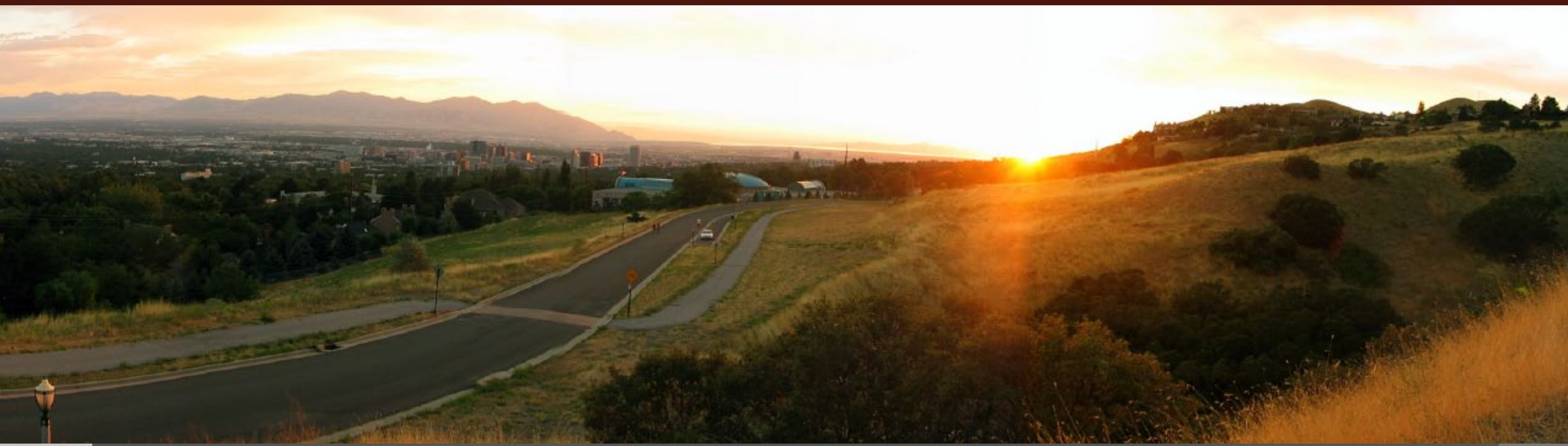


The Institute

The SCI research group was founded in 1994 by Drs. Chris Johnson and Rob MacLeod along with five graduate students. In 1996, we became the Center for Scientific Computing and Imaging and in 2000, the SCI Institute. The SCI Institute is now one of eight permanent research institutes at the University of Utah and home to nearly 200 faculty, students, and staff. The 15 tenure-track faculty are drawn primarily from the School of Computing, Department of Bioengineering, and Department of Electrical and Computer Engineering and virtually all faculty have adjunct appointments in other, largely medical, departments. Recent growth in the SCI Institute has come in part from the award in 2007 from the state of Utah of a USTAR (Utah Science and Technology Advanced Research) cluster in Imaging Technology. This allowed the Institute to recruit fournew faculty in image analysis: Professors Guido Gerig, Tom Fletcher, Tolga Tasdizen, and Orly Alter. During this same time period, we were also able to recruit Professor Valerio Pascucci in visualization and Professor Juliana Freire in scientific data management.

Over the past decade, the SCI Institute has established itself as an internationally recognized leader in visualization, scientific computing, and image analysis applied to a broad range of application domains. The overarching research objective is to conduct application-driven research in the creation of new scientific computing techniques, tools, and systems. An important application focus of the Institute continues to be biomedicine, however, SCI Institute researchers also address challenging computational problems in a variety of application domains such as manufacturing, defense, and energy. SCI Institute research interests generally fall into different areas: scientific visualization, scientific computing and numerics, image processing and analysis, and scientific software environments. SCI Institute researchers also apply many of the above computational techniques within their own particular scientific and engineering subspecialties, such as fluid dynamics, biomechanics, electrophysiology, bioelectric fields, parallel computing, inverse problems, and neuroimaging.

The SCI Institute either directs or is associated with several national research centers: the NIH Center for Integrative Biomedical Computing (CIBC), the DoE Visualization and Analytics Center for Enabling Technologies (VACET), the NIH National Alliance for Medical Image Computing (NA-MIC), the DoE Scientific Data Management Center, the NIH Center for Computational Biology, and the DoE Center for the Simulation of Accidental Fires and Explosions (C-SAFE). In July, 2008,

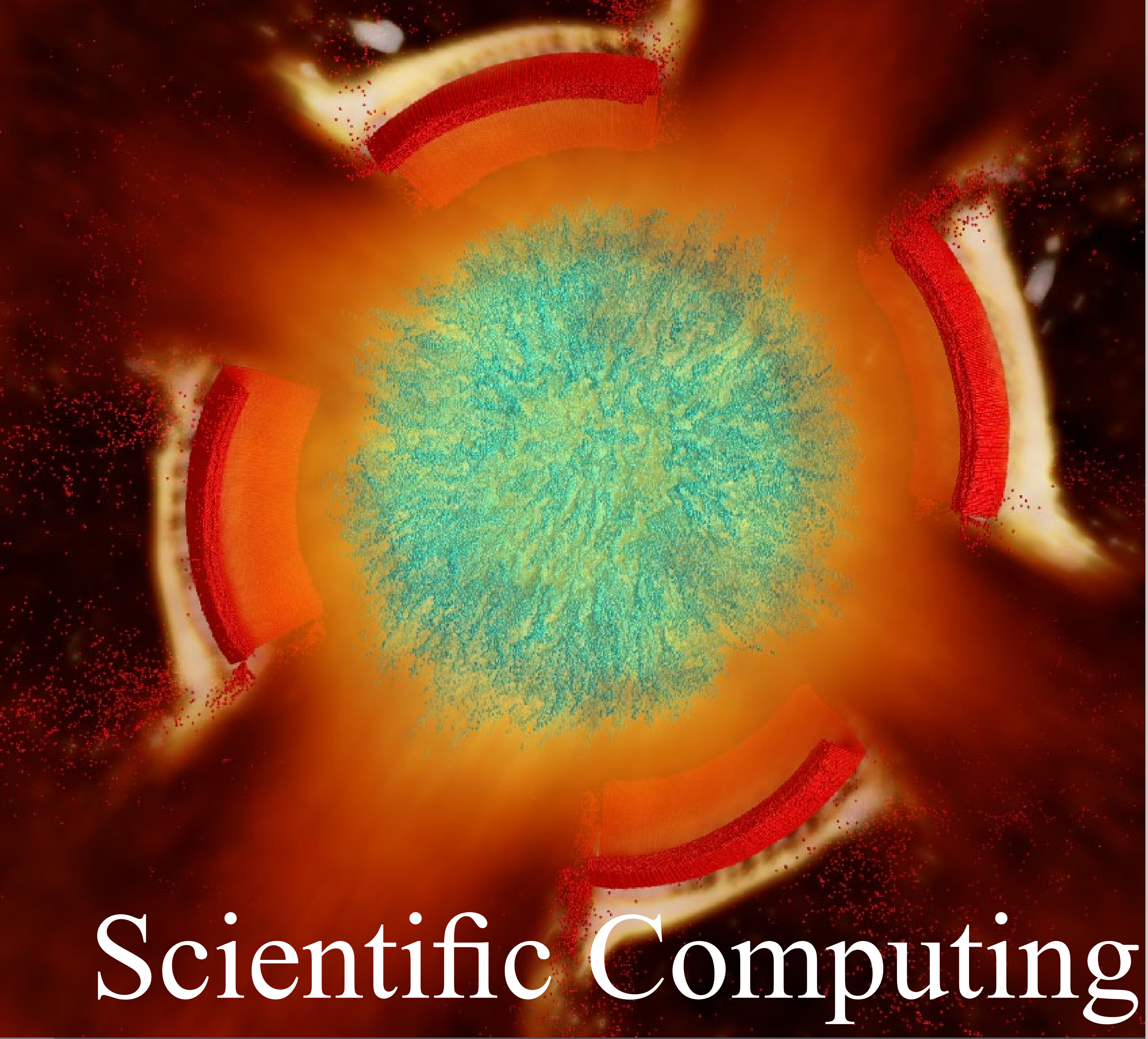


SCI was chosen as one of three NVIDIA Centers of Excellence in the U.S. (University of Illinois and Harvard University are the other two NVIDIA Centers).

A particular hallmark of SCI Institute research is the development of innovative and robust software packages, including the SCIRun scientific problem solving environment, Seg3D, ImageVis3D, VisTrails, and map3d. All these packages are broadly available to the scientific community under open source licensing and supported by web pages, documentation, and users groups.

The academic programs available for students are outstanding. The School of Computing has collaborated with faculty in the SCI Institute to create a graduate degree in Computing, which offers tracks in Scientific Computing and Graphics (Image Analysis is planned). The physical infrastructure is also outstanding with many large-scale computing facilities at the disposal of students and trainees, perhaps most exciting is the new NVIDIA computing cluster, which, along with a new graduate course in Parallel Programming for GPUs, provides opportunities for developing unique expertise in large-scale streaming architectures. SCI faculty also provide leadership in developing educational and research tracks in biomedical engineering through the Bioengineeeing Department. There are undergraduate and graduate tracks in computing and imaging, in part created and directed by SCI faculty. There is also a graduate track in cardiac electrophysiology and biophysics, directed by SCI faculty and supported through collaboration between SCI and the Cardiovascular Research and Training Institute (CVRTI).

Perhaps most encouraging is the general atmosphere provided by the SCI Institute and its nearly 200 members, all dedicated to some aspect of scientific computing. There is extensive expertise within the SCI Institute that covers all the topics required for simulation, modeling, and visualization including high performance computing, efficient numerical algorithms, large data management and storage, database management, and scientific visualization of all forms of scalar, vector, tensor, and volum data.



Scientific Computing

Scientific computing research at SCI focuses on constructing mathematical models and numerical solution techniques to analyze and solve scientific problems. In practical use, it is typically the application of computer simulation and other forms of computation to problems in various far reaching scientific disciplines.

Researchers at SCI develop programs that model systems being studied and run these programs with various sets of input parameters. Typically, these models require massive amounts of calculations and are often executed on supercomputers or distributed computing platforms. Numerical analysis is important for techniques used in scientific computing.

Scientific computing at SCI often models real-world changing conditions, such as the propagation of electrical currents within the heart or brain, air flow around a plane, an explosive device, or the interaction between fluids, etc. Such programs often create a ‘logical mesh’ in computer memory where each item corresponds to an area in space and contains information about that space relevant to the model. For example in cardiac models, each item might be a square millimeter; with tissue density, current strength, conductivity, diffusion properties, etc. The program would calculate the likely next state based on the current state, in simulated time steps, solving equations that describe how the system operates; and then repeat the process to calculate the next state.

Scientific computing research at SCI typically falls into the following areas: Forward and inverse methods in cardiology and neuroscience, computational fluid dynamics, computational geophysics, computational mathematics, computational biomechanics, computational physics, environmental simulation, high performance computing, and pattern recognition.

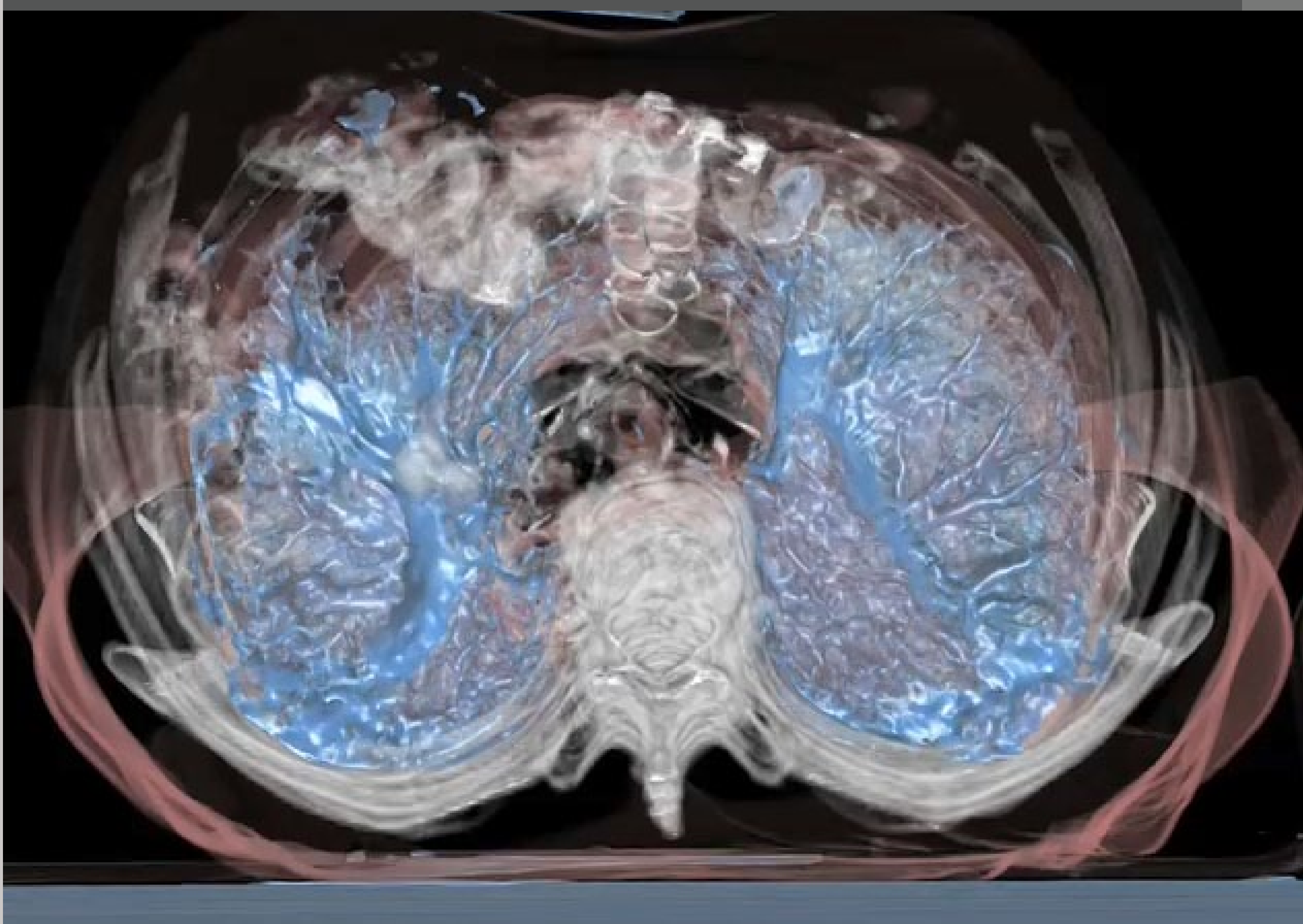
Scientific Visualization

The NIH-NSF Visualization Research Challenges report notes that one of the greatest scientific challenges of the 21st Century is to effectively understand and use the vast amounts of information being produced. In the past three decades, computational and acquisition technologies experienced unprecedented growth. This growth improved our ability to sense the physical world in precise detail and to model and simulate complex physical phenomenon.

As a field, visualization focuses on creating images that convey salient information about underlying data and processes. Visualization is crucial to our ability to comprehend such large and complex data. This data, in two, three, or more dimensions, conveys insight into diverse applications.

SCI provides cutting-edge visualization research and software to scientists, helping researchers gain insight into measured or simulated data. The visualization technology core develops and implements advanced high-performance algorithms and software for visualizing large, spatially distributed and/or time varying sets. The applications developed at the SCI place powerful visualization capabilities into the hands of researchers. These applications allow researchers to interactively explore and gain insight from large-scale image, experimental, and simulation data.

Scientific visualization research at SCI has a strong focus on applications spanning computational fluid dynamics, medical imaging and analysis, and fire and combustion simulations. Research involves novel algorithm development, simulation, information visualization, isosurface rendering, ray tracing, global illumination techniques, volume rendering, volume visualization, to building tools and systems that assist in the comprehension of massive amounts of scientific data. In helping researchers to comprehend spatial and temporal relationships between data, interactive techniques provide better cues than noninteractive techniques; therefore, much of scientific visualization research at SCI focuses on better methods for visualization and rendering at interactive rates.



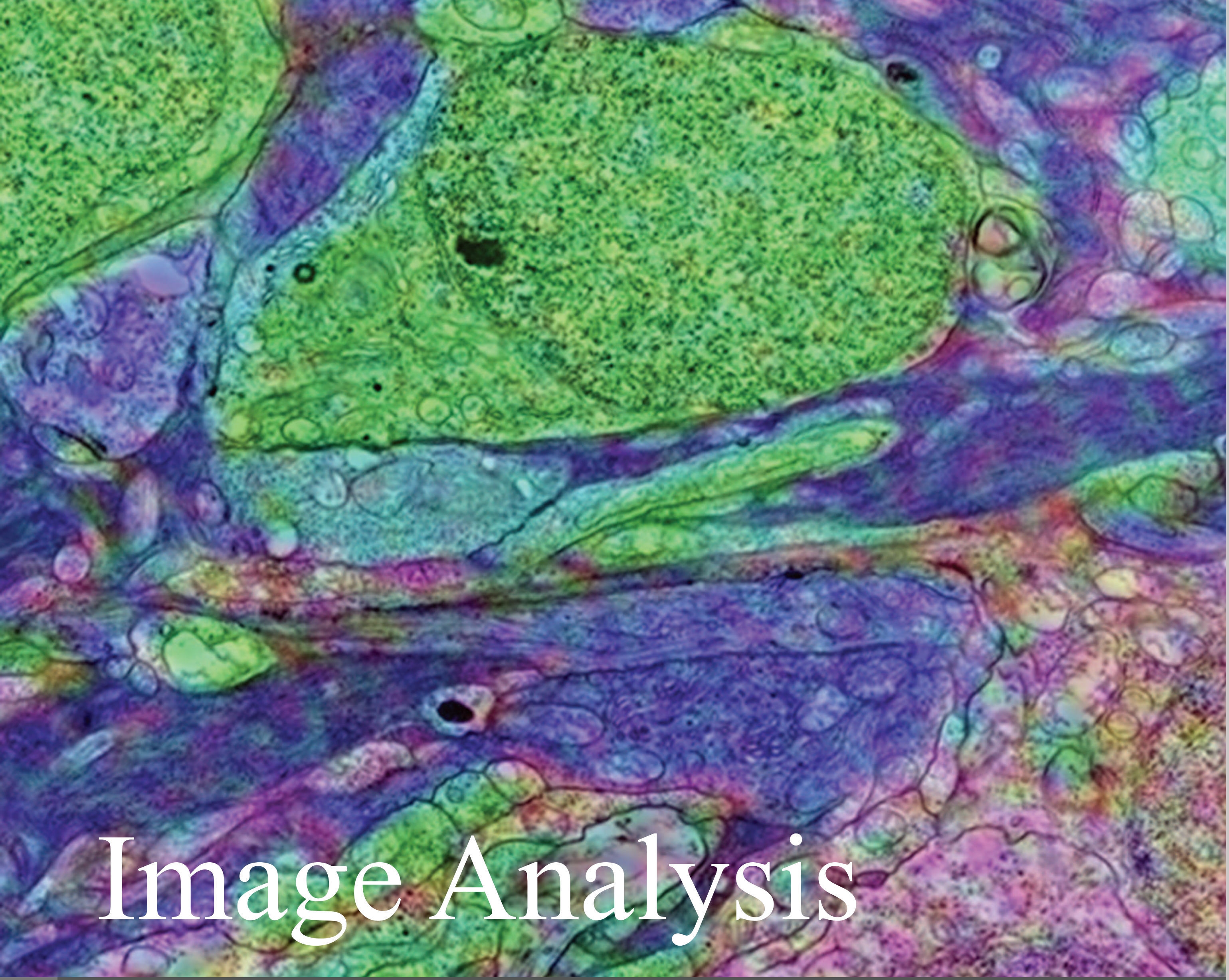


Image Analysis

SCI's imaging work addresses fundamental questions in 2D and 3D image processing, including filtering, segmentation, surface reconstruction, and shape analysis. In low-level image processing, this effort has produce new nonparametric methods for modeling image statistics, which have resulted in better algorithms for denoising and reconstruction. Work with particle systems has led to new methods for visualizing and analyzing 3D surfaces. Our work in image processing also includes applications of advanced computing to 3D images, which has resulted in new parallel algorithms and real-time implementations on graphics processing units (GPUs). Application areas include medical image analysis, biological image processing, defense, environmental monitoring, and oil and gas.

In biology and medicine, the problem of using images to derive geometric models is ubiquitous. Biomedical scientists need to quickly build geometric and statistical representations from collections of images. Geometric models are useful in a staggering range of biomedical applications, from patient-specific treatment decisions for orthopedic surgery and cardiology to basic scientific questions about blood flow and degenerative disease.

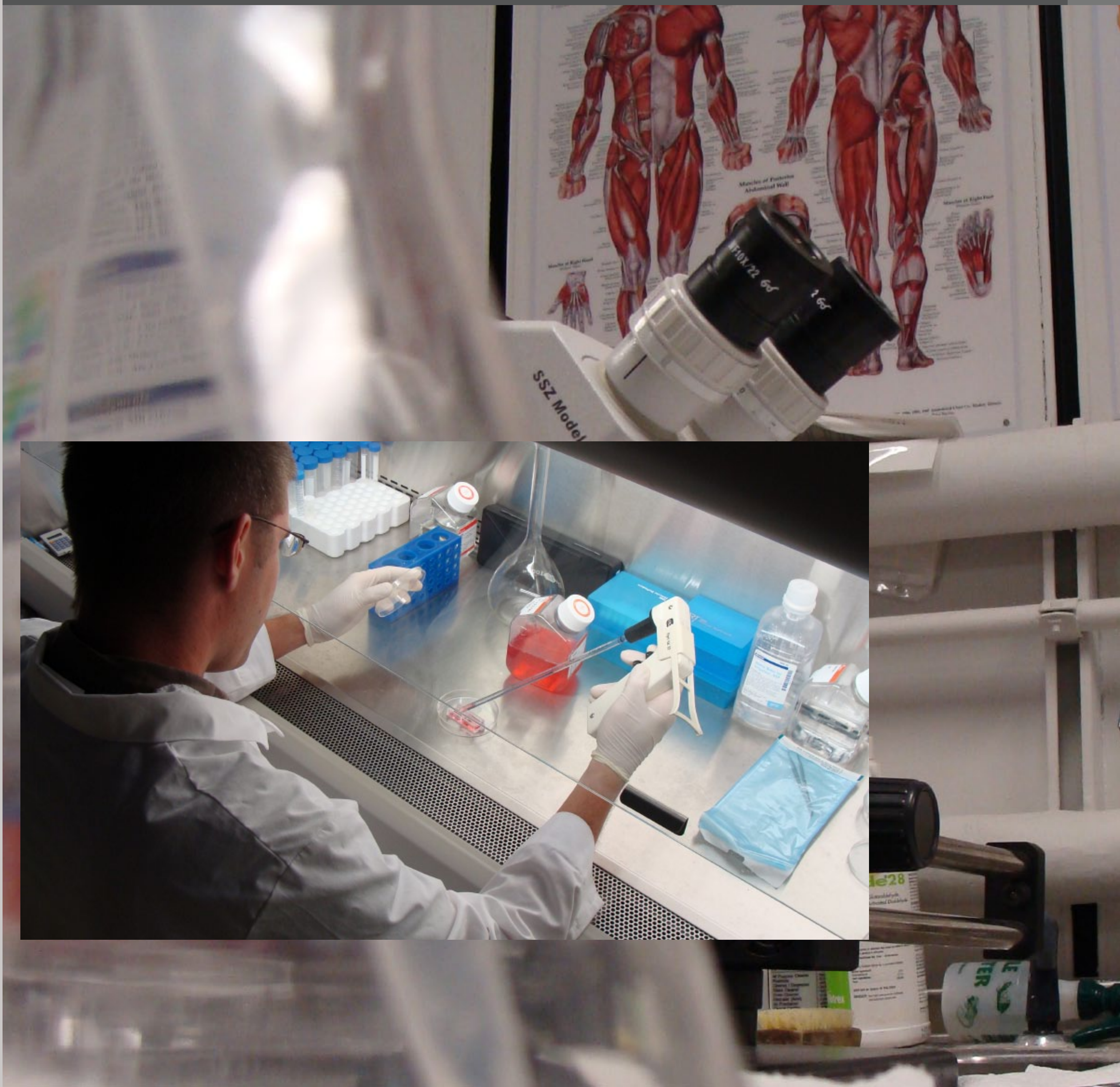
Generating discrete, geometric representations for subsequent analysis is one of the important challenges in image-based modeling. The image and geometry processing research core focuses on using image data to construct geometric models to be used for simulation, visualization, and quantitative analysis. Specifically, our focus is on tools for geometrically adaptive and conforming meshes, as well as statistical models of anatomical and biological shapes.

At SCI, the work of application scientists is tightly integrated with the research vision. Imaging and scientific computing advances allow for exciting opportunities to use simulation and visualization methods to improve clinical practice. SCI's developments focus on the robustness of imaging tools, in addition to open-source software which researchers may modify to better suit their needs. SCI strives to advance the state of the art through its strategies of image-based modeling, open-source tools, and application-driven development.

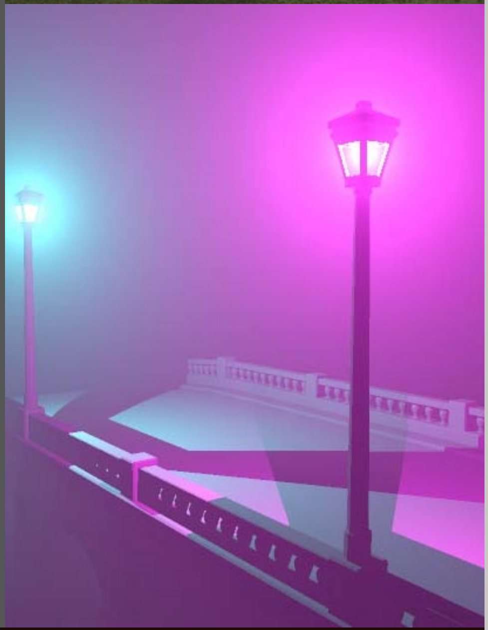
Computational Biomechanics

SCI Institute research in computational biomechanics focuses on the use of the finite element method to examine the mechanics of soft and hard tissues. We have developed techniques to build subject-specific finite element models of soft and hard tissues directly from medical image data such as CT, MRI, OCT or microscopy images.

We have also developed constitutitve models and finite element implementations that capture the nonlinear, anisotropic and viscoelastic properties of materials such as ligament, tendon, cartilage and meniscus. Our last focus has been on capturing boundary conditions in numerical simulations that are unique to biomechanics such as residual/initial stress and position-dependent anisotropy. The techniques have been applied to the study of knee mechanics, shoulder ligament mechanics, cartilage defects, and the hip.



Graphics



Graphics research at the SCI Institute is closely tied to our work in scientific visualization and information visualization. This research area focuses on algorithm development where graphics meets large scientific datasets. This area of research also involves the use of new platforms such as the iPad, iPhone, large storage systems such as isilon or the latest generation of graphics processing unit and the creation of tailored algorithms to those platforms. Current projects include the development and refinement of ray-tracing algorithms, light scatter algorithms, and efficient volume rendering packages such as Tuvok. Graphics research at SCI impacts nearly all of our other research areas.

GPU

Research in the area of the GPU is focused on harnessing the power of the GPU for visualization, simulation, image and information processing and analysis, and, of course, for graphics. As the speed and efficiency of graphical processing units (GPUs) grows at rates even faster than those of conventional central processing units (CPUs), there is a growing consensus that the streaming architecture embodied in most modern graphics processors has inherent advantages in scalability. Virtually all the contemporary developers of computer processing units are exploring opportunities for GPU improvement and there is an emerging set of standards and tools that can take advantage of these processors for more general purpose computing than graphics.

There has been considerable progress in implementing the hardware and the supporting infrastructure for GPU programming and streaming architectures. Extensions to the C language, such as CUDA, provide needed capability on standard C data structures, and there is an apparent convergence on open standards (e.g. OpenCL) for general purpose computing on the streaming architectures.

Such streaming architectures have significant implications for algorithm design, especially when applied to general purpose tasks beyond the graphics manipulations for which they were initially designed. They offer massively parallel single instruction multiple data (SIMD) processing of several dozen streams across multiple blocks, with fast access to shared memory and some restrictions of limited local memory size and relatively slow communication between blocks.

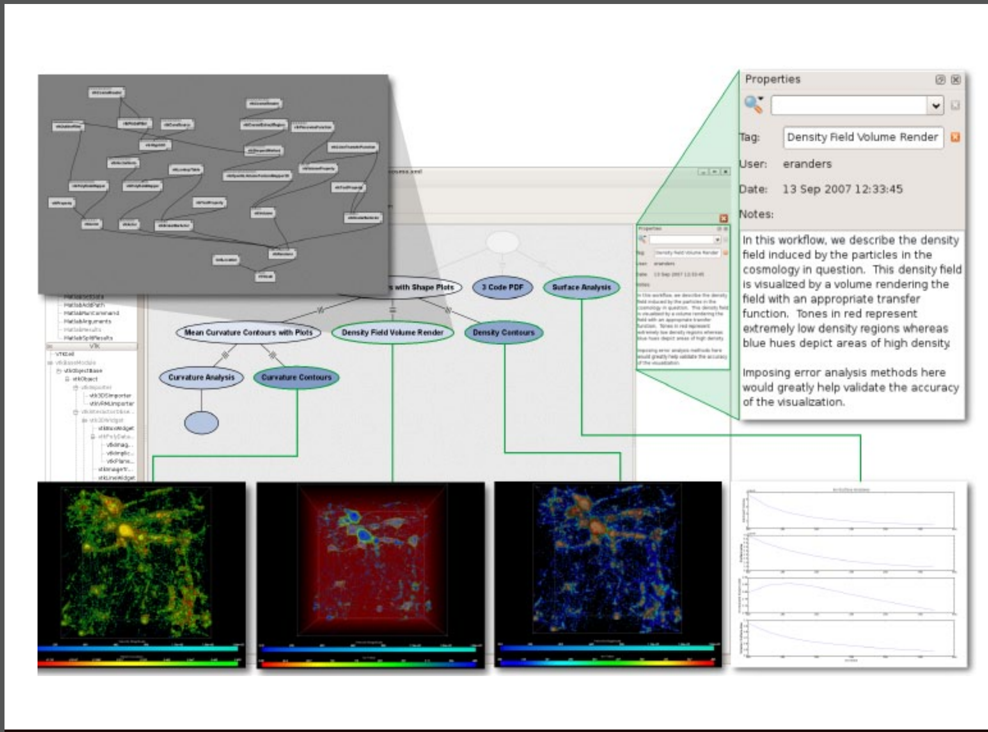
In the area of scientific computing the SCI Institute is actively pursuing streaming architectures that typically satisfy three criteria: i) not impose a particular update sequence on the solution, ii) rely primarily on synchronous updates, and iii) have a high computational density (amount of computation per unit of data) in the absence of global communication (e.g. to/from host or between blocks).

Scientific Data Management

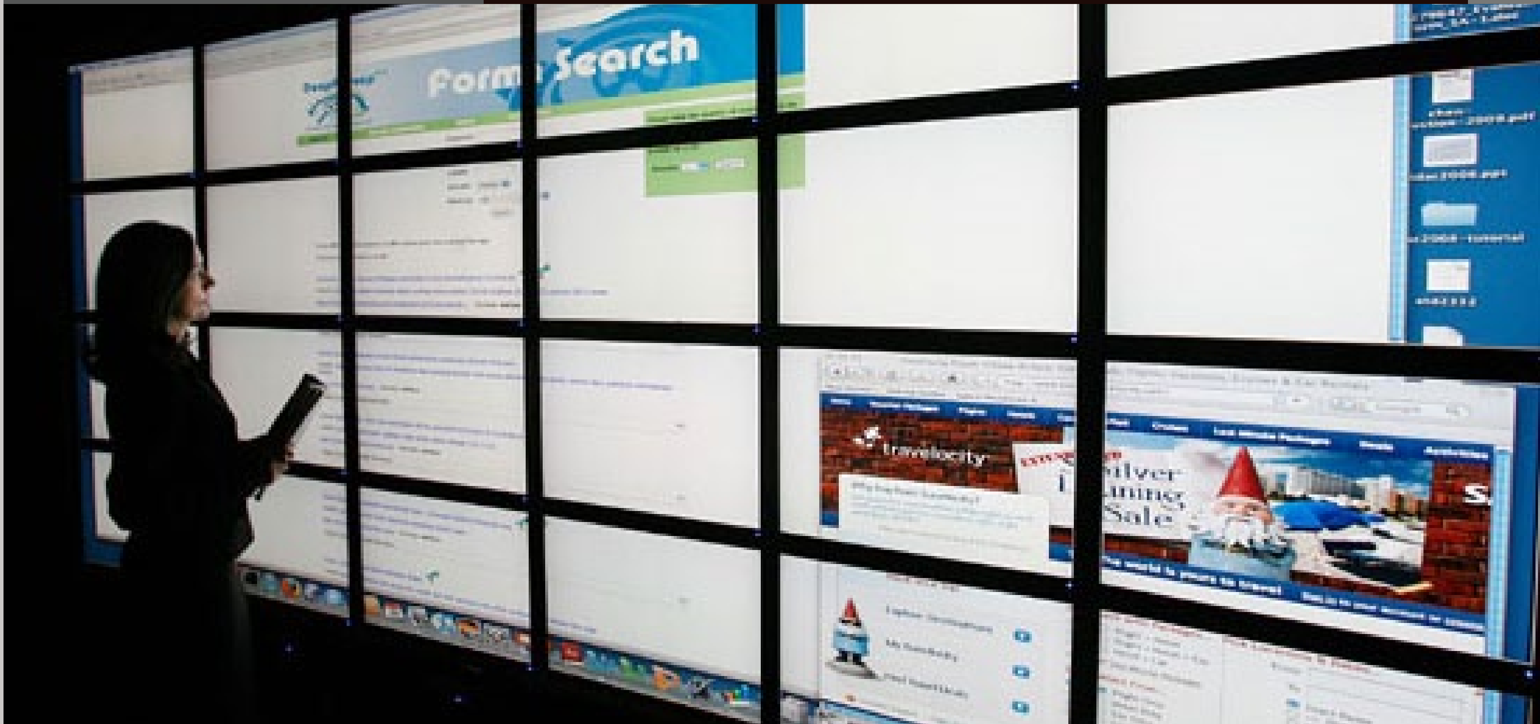
The Information Management group has been working on building new cyberinfrastructure that streamlines the creation, execution and sharing of complex visualizations, data mining and other large-scale data analysis applications. We developed VisTrails (www.vistrails.org), a new open source, scientific workflow and provenance management system that was designed to manage rapidly evolving workflows common in exploratory applications. VisTrails provides novel mechanisms for capturing and interacting with provenance that greatly simplify the data exploration process. The system has been downloaded over 8,000 times since its beta release in January, 2007. VisTrails has been adopted as part of the cyberinfrastructure in large scientific projects, as well as a teaching and learning tool in graduate and undergraduate courses, both in the U.S. and abroad.

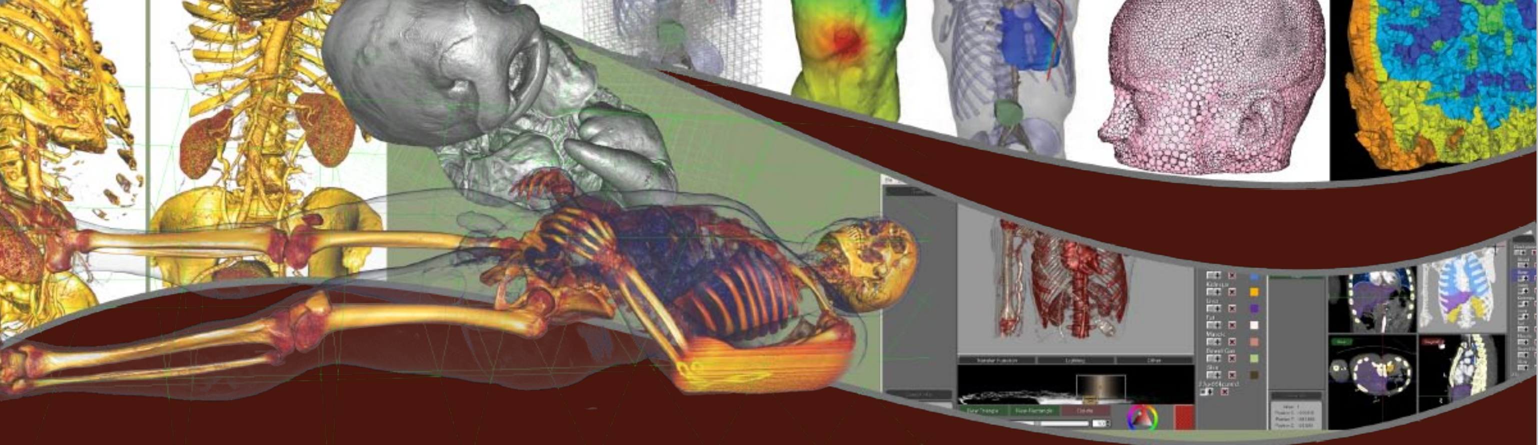
There has been an explosive growth in the volume of structured information on the Web. This information often resides in the hidden (or deep) Web, stored in databases and exposed only through queries over Web forms. A recent study by Google estimates that there are several millions of such form interfaces. However, the high quality information in online databases can be hard to find: it is out of reach for traditional search engines, whose index include only content in the surface Web.

Our group is combining techniques from machine learning, information retrieval and databases to build infrastructure that automates, to a large extent, the process of discovering and organizing hidden-Web data sources, a necessary step to large-scale retrieval and integration of Web information. This infrastructure will enable people and applications to more easily find the right databases and consequently, the hidden information they are seeking on the Web. We have used our hidden-Web infrastructure to build DeepPeep (www.deeppeep.org), a new search engine for Web forms.



An example of an exploratory visualization for studying celestial structures derived from cosmological simulations using VisTrails. Complete provenance of the exploration process is displayed as a "vistrail." Detailed metadata are also stored, including free-text notes made by the scientist, the date and time the workflow was created or modified, optional descriptive tags, and the name of the person who created it.





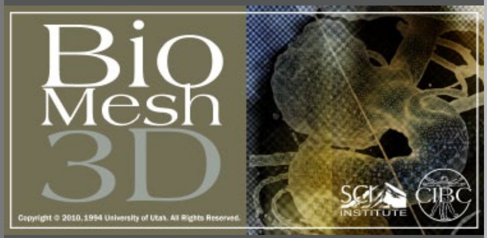
Scientific Software Development

SCIRun

SCIRun is a Problem Solving Environment (PSE), for modeling, simulation and visualization of scientific problems. SCIRun now includes the biomedical components formally released as BioPSE, as well as BioMesh3D.

BioMesh3D

BioMesh3D is a tetrahedral mesh generator, that is capable of generating 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. BioMesh3D is currently integrated with SCIRun and uses the SCIRun system to visualize the intermediate results.

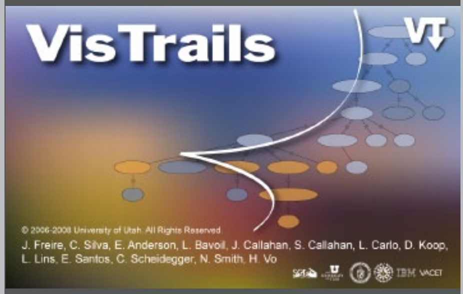


Seg3D

Seg3D is a free volume segmentation and processing tool developed by the NIH Center for Integrative Biomedical Computing at the University of Utah Scientific Computing and Imaging (SCI) Institute. Seg3D combines a flexible manual segmentation interface with powerful higher-dimensional image processing and segmentation algorithms from the Insight Toolkit. Users can explore and label image volumes using volume rendering and orthogonal slice view windows.

VisTrails

VisTrails is a new scientific workflow management system developed at the University of Utah that provides support for data exploration and visualization.

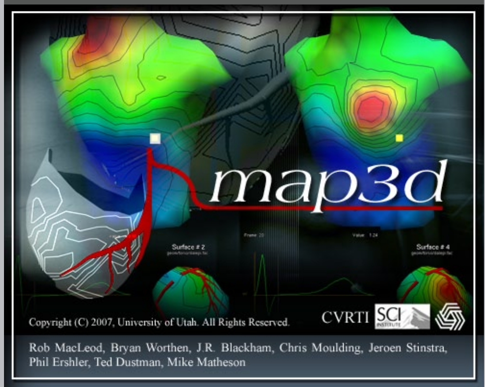


ImageVis3D

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.

map3d

map3d is a scientific visualization application written to display and edit complex, three-dimensional geometric models and scalar, time-based data associated with those models. [map3d License] (Linux, Mac OSX, SGI, Windows)



FluoRender

FluoRender is an interactive rendering tool for confocal microscopy data visualization. It combines the renderings of multi-channel volume data and polygon mesh data, where the properties of each dataset can be adjusted independently and quickly. The tool is designed especially for neurobiologists, and it helps them better visualize the fluorescent-stained confocal samples.

ShapeWorks

The ShapeWorks software is an open-source distribution of a new 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. The proposed correspondence point optimization uses an entropy-based minimization that balances the simplicity of the model (compactness) with the accuracy of the surface representations. The ShapeWorks software includes tools for preprocessing data, computing point-based shape models, and visualizing the results.

FEBio

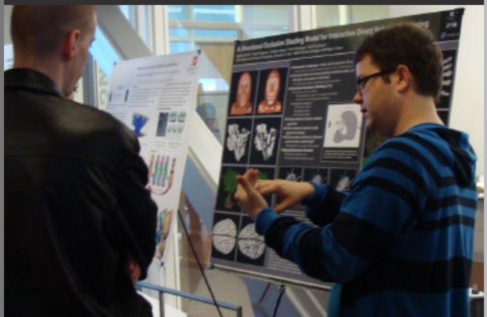
FEBio is a nonlinear finite element solver that is specifically designed for biomechanical applications. It offers modeling scenarios, constitutive models and boundary conditions that are relevant to many research areas in biomechanics. All features can be used together seamlessly, giving the user a powerful tool for solving 3D problems in computational biomechanics. The software is open-source, and pre-compiled executables for Windows, OS-X and Linux platforms are available.

PreView is a Finite Element (FE) preprocessor that has been designed specifically to set up FE problems for FEBio. It allows the user to specify the boundary conditions and material properties in a user-friendly graphical environment.

PostView is a finite element post-processor that is designed to post-process the results from FEBio. It offers the user a graphical user interface to visualize and analyze the FE model.

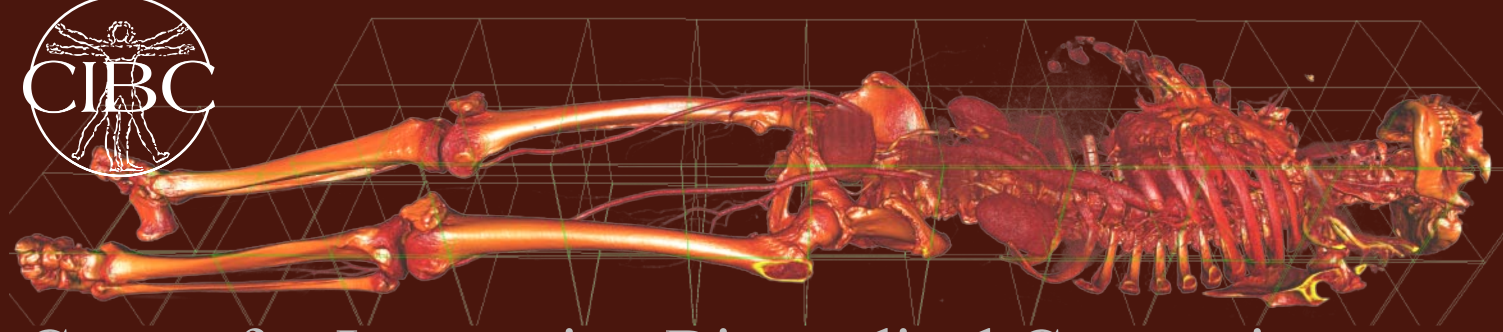
Collaborative Impact

Effective and meaningful collaborations are the life blood of the SCI Institute. SCI Institute research is a result of bringing world class computer science and bioengineering into cutting-edge projects in fields ranging from neuroimaging to forest fire simulation. In the vast majority of our collaborations the SCI Institute expertise and work is made available to whole communities via open source software releases. This enables the fundamental idea of gaining the largest impact possible from SCI research.



SCI Institute research collaborators

- Lawrence Livermore National Laboratories
- Lawrence Berkeley National Laboratories
- Sandia National Laboratories
- Oak Ridge National Laboratory
- Pacific Northwest National Laboratories
- Los Alamos National Laboratories
- Argonne National Lab
- University of California San Francisco
- University of California Los Angeles
- Texas A&M University
- North Eastern University
- University of North Carolina
- University of Texas Austin
- University of Oregon
- Yale University
- Harvard University
- Duke University
- University of Chicago
- Brown University
- Medical College of Wisconsin
- John's Hopkins University
- Children's Hospital Boston
- Mayo Clinic
- Brigham & Womens Hospital
- Princeton Plasma Physics Laboratory
- Smithsonian Institute
- National Center for Microscopy and Imaging Research
- National Biomedical Computation Resource
- Neuroimaging Informatics Tools and Resources Clearinghouse
- Center for Coastal Margin Observation & Prediction
- Imperial College London
- King Abdullah University of Science and Technology
- University of Kaiserslautern
- Technical University of Munich
- University of Münster
- University of Aukland
- National Institute for Research in Computer Science and Control (Inria)
- Center of Advanced European Studies And Research (CAESAR), Bonn University of Stuttgart
- Canadian Meteorological Center
- Kitware
- VisTrails.org
- General Electric Research Labs
- General Atomics
- Electrical Geodesics Inc
- SGI



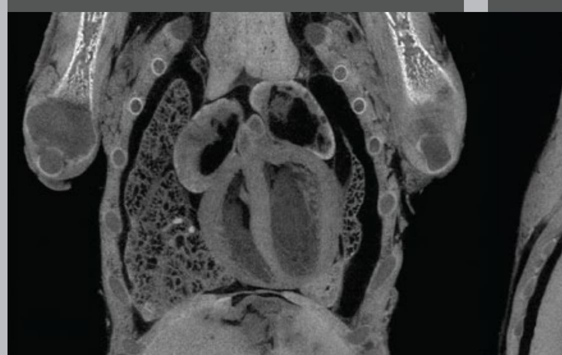
Center for Integrative Biomedical Computing

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 CIBC works closely with software users and collaborators in a range of scientific domains to produce user-optimized tools. The Center also provides advice, technical support, workshops, and education to enhance user success with the provided tools. 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. The overarching goal of the CIBC is to advance the state of practice in biomedical computing and its applications both to biomedical science and to the translation of this science to clinical practice.

Image-Based Small-Animal Phenotyping
Charles Keller, MD - University of Texas Health Science Center at San Antonio

The Center is working aggressively in collaboration with the Charles Keller Laboratory to develop an advanced treatment protocol for the most common form of brain tumor affecting children, Medulloblastoma. These brain tumors form as a result of overgrowths of infant neuronal stem cells of the cerebellum. Nearly all children with medulloblastoma are treated with surgery, chemotherapy, and radiation. Radiation treatment is especially harsh on children under three years of age, for whom it often results in serious cognitive impairment. Unfortunately, in this young population, treatment, surgery and chemotherapy with no radiation typically has only a 34% survival rate. Better radiation-sparing treatments in younger patients are needed. Fortunately, promising research indicates the possibility to develop therapies based on targeting key cell growth factors and signaling molecules involved in the cancerous cell growth of medulloblastoma. The Center works closely with Dr. Keller and his team to provide the computational tools required to develop better treatment strategies that address the underlying biological causes of the disease and avoid the harsh side effects of current treatments.

The Keller Laboratory has developed a strain of laboratory mouse with a specific genetic flaw that results in the development of brain tumors precisely resembling medulloblastoma. These mice allow researchers to investigate the development of brain tumor cells and to test the effectiveness of treatments. The neuroscientists need a method to quantifiably measure the differences between normal brains and those affected by medulloblastoma, as well as those exposed to treatment. The proposed approach relies on 3D CT images of subject mice and the application of CIBC software tools, such as Seg3D, ShapeWorks, and ImageVis3D, for volumetric data analysis.



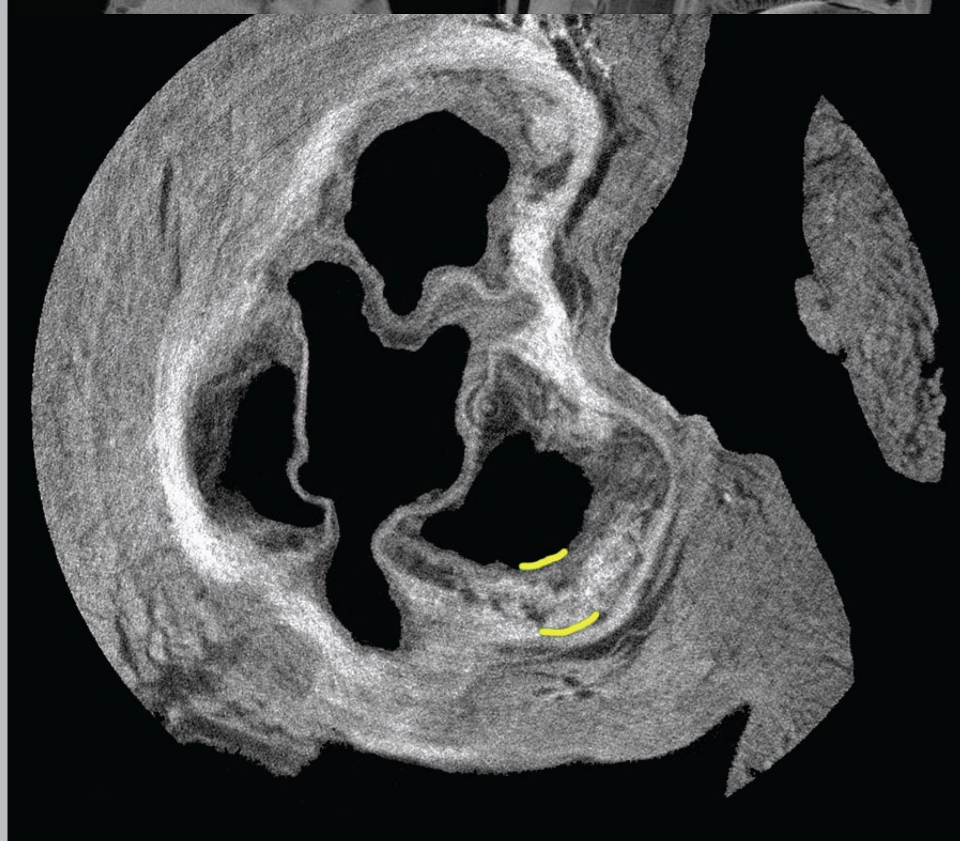


Image-based Management of Atrial Fibrillation
Nassir Marrouche MD, Chris McGann MD - University of Utah

The CIBC Center continues to work in close collaboration with Dr. Nassir Marrouche and his team at the Comprehensive Arrhythmia Research and Management (CARMA) Center to advance the state of technology used for the monitoring and treatment of Atrial Fibrillation (AF). AF is an electrophysiological rhythm disorder that causes the upper chambers of the heart to beat in an desynchronized, chaotic fashion that results in reduced pumping efficiency in the heart. This condition represents the most frequent type of cardiac rhythm disorder, one that significantly increases the risk of stroke, increases the chance of death, and diminishes quality of life. This problem already affects some 4 million Americans and the incidence is increasing within the aging populations of the world.

The only truly curative treatment for AF is a procedure known as ablation. In ablation, a catheter is inserted through the veins into the heart and some form of energy is applied to the inner surface of the heart (the endocardium) to electrically isolate the pulmonary veins. These pulmonary veins flow from the lungs into the left atrium and are considered the dominant site of the stimulus for AF so that electrically isolating them by means of tissue burns reduces or eliminates the stimulus for AF. Ablation is gaining popularity because, unlike pharmacological treatments, it represents a true cure that carries virtually no side effects. However, the treatment has not been successful for all patients for reasons that are not fully understood, but may be associated with pre-existing fibrosis in the left atrium. MRI provides a means to observe and evaluate this fibrosis and, with measurements of the extent of fibrosis, a means of predicting outcome and a basis for treatment guidance.

Seg3D is currently being used by researchers and clinicians at the Comprehensive Arrhythmia Research and Management (CARMA) Center.

Dr. Nassir Mourrouche, Director, Comprehensive Arrhythmia Research and Management Center: CARMA, performing an atrial fibrillation oblation using our Seg3D software within a new 3T MRI system.

Magnetic resonance imaging (MRI) visualization has the potential to reveal important data about the condition of cardiac tissues, such as the presence and location of fibrosis in the left atrium pre-ablation or the distribution of post-ablation scar formation. This information could be critical in planning the application of ablation therapy and guiding the ablation process. Using MRI during ablation would allow physicians to see the extent of ablation lesions as they form and provide a possible means of guiding the placement, energy level, and duration of each ablation to achieve optimal results.

High-Resolution Source Imaging From EEG
Don Tucker - Electrical Geodesics Inc. and University of Oregon

The CIBC, in close collaboration with Dr. Don Tucker, is seeking to improve EEG-based source localization through new computational methods and tools. In both research and clinical practice, EEG is a cost-effective tool for understanding brain activity. Although functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) provide high spatial resolution, their temporal resolution is limited. They are also both based on indirect measures of neurophysiological activity such as metabolic changes. EEG is directly sensitive to the underlying neural sources. Its temporal resolution is limited only by the sampling rate; however its spatial resolution is assumed to be poor, even compared to PET. In fact, the spatial resolution of the human EEG remains unknown because the limits of electrical source reconstruction have not been tested with adequate measurement technology.

Advances in EEG technology now include fast, robust, dense (256-channel) arrays, exact sensor position measurement, and EEG source localization methods. These advances have significantly improved the spatial resolution of source estimates with EEG and may promise accurate monitoring of cortical activity in both space and time. By itself, high-resolution EEG would be affordable even for small hospitals in remote locations and could be easily managed by technicians in the field.

We are working with Dr. Tucker to improve near-term translational uses of EEG-based source localization, moving closer to determining the true resolution possible with EEG, and improving the capabilities of our other neuroscience collaborators.

Top: Dense array EEG (dEEG) captures important detail on normal brain function (language) and pathology (seizure onset). Bottom: Cortical surface extraction from MRI and dipole source model tessellation.

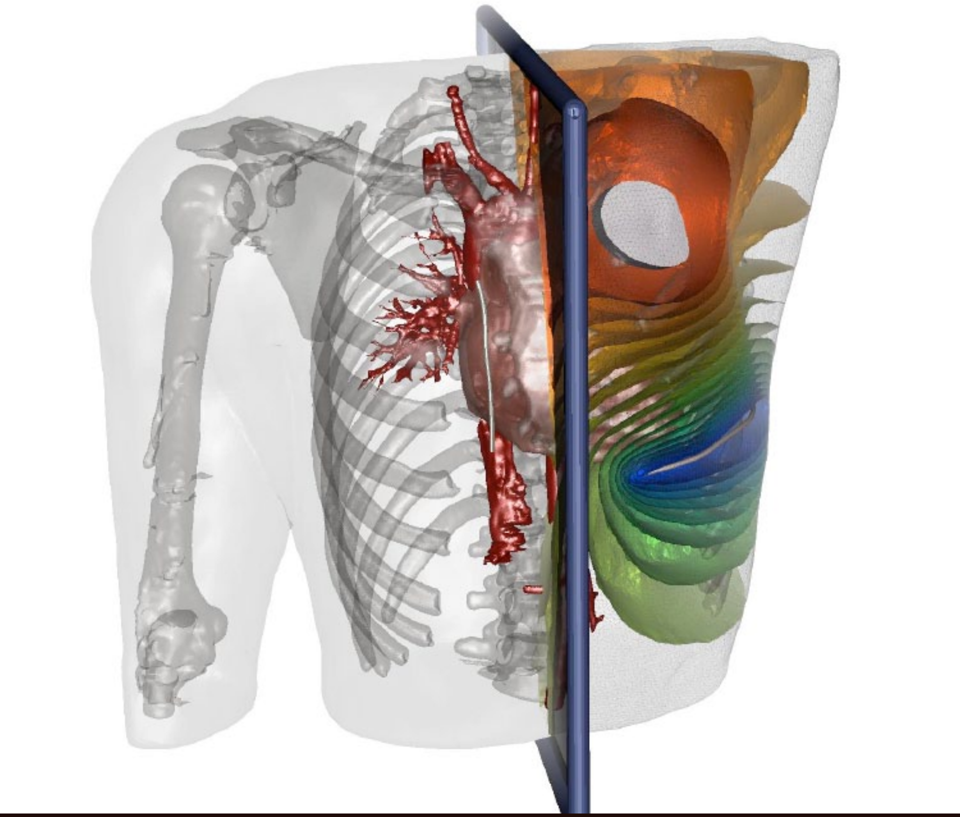
Simulation of Cardiac Defibrillation

John Triedman, MD, Children's Hospital Boston
Matt Jolley, MD, Stanford University
Natalia Trayanova, John's Hopkins University
Tom Pilcher, University of Utah

The CIBC has a longstanding collaboration with Drs. Triedman, Jolley, Trayanova, and Pilcher to improve the design and efficacy of implantable cardioverter-defibrillators (ICDs) through improved computational modeling and new simulation tools. ICDs are now a standard tool of modern interventional cardiology, providing an effective, lifesaving technology. Over 110,000 devices were implanted in patients in the U.S in 2004 alone. However, the growing size and diversity of the population with ICDs have exposed some of the limitations of this technology. To minimize the risk of fatal events, ICDs are usually designed and implanted with standardized safety factors, with little tailoring to an individual subject. ICDs are designed to provide electrical shocks higher than many patients need in order to accommodate the 17-24% of patients who require more energetic shocks. Additionally, current ICD design is suboptimal for many patients, specifically children, patients of small body size, and patients with congenital heart disease, resulting in unnecessary pain, unsuccessful shock, and diminished quality of life.

Unique difficulties exist for these groups, including high rates of lead failure frequently inappropriate therapy, mismatch of lead device and lead size to the patient's body, and the effects of somatic growth and long life expectancy. Lead failure, in particular, can result in substantial risks. These data indicate that tuning ICD parameters to patient-specific factors is critical to further developing ICD technology. The potential for adverse effects coupled with the increasing use of these devices has spurred renewed interest in reexamining the standard design approaches.

Current ICD design is suboptimal for many patients, specifically children, patients of small body size, and patients with congenital heart disease.



Visualization of a patient-based three-dimensional finite element model. First, a segmentation was done using Seg3D. Second, a three-dimensional geometric mesh was created from the segmented volume. Third, a large-scale finite element simulation was performed using BioPSE. Finally, the model and simulation results were visualized using SCIRun.

In previous studies with Drs. Triedman and Jolley, the CIBC created a series of detailed torso models, which form the basis of the simulations, as well as interactive software tools to place the ICD device and electrodes at any locations within the torso model. We have used SCIRun software to generate a database of over 400 different electrode lead configurations placed inside four different computational anatomical models. We continue to develop and improve these models, using a suite of tools including SCIRun, ImageVis3D, Seg3D and BioMesh3D.

Expanding the scope of the research occurs on several fronts. We have begun clinical validation of the simulation models through a collaboration with physicians at the Primary Childrens' Hospital at the University of Utah. In these experiments, we create patient specific models of a cohort of children and young adults with congenital heart abnormalities who require ICD implants. During the implant surgery, which includes testing the ICD in situ, we record body surface ECGs from up to 32 sites placed at specific locations on the thorax. By capturing the electrical signals during the testing of the device, we obtain patient specific torso surface potentials from the shock, which we then compare to simulations of the same shock using the torso geometry and actual device location.

A second new direction of the research seeks to use detailed simulations of fibrillation and defibrillation in high resolution models of human hearts. For this collaboration with Dr. Natalia Trayanova, we perform MRI scans of explanted or autopsied human hearts using the small animal MRI facilities at the University of Utah. These scans include diffusion weighted MRI, which yields information on local fiber structure of the heart as scales well below 1mm. Such detailed, realistic models of the heart will provide the substrate necessary to address fundamental questions about the role of heart anatomy and fiber structure on the propensity of the heart for fibrillation as well as the mechanisms of successful and unsuccessful defibrillation shock. We will then combine findings from the heart simulations with the torso models and develop complete, whole body models of fibrillation and defibrillation.

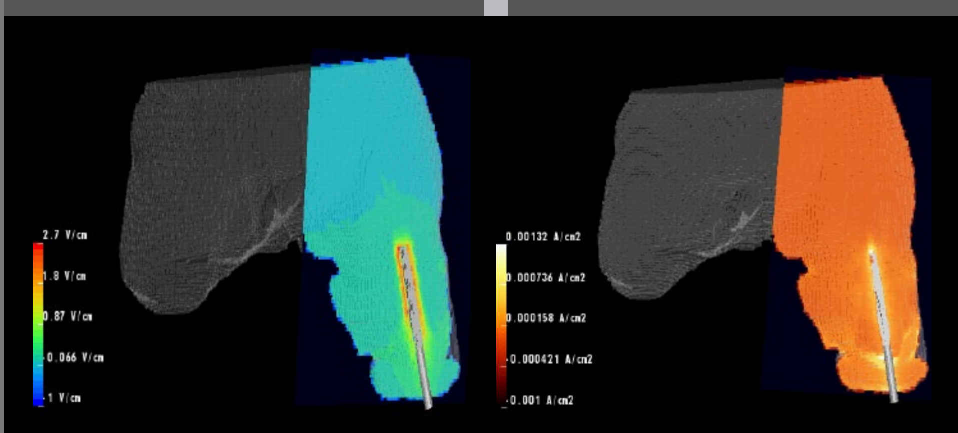
Simulation of Electric Stimulation for Bone Growth

Roy Bloebaum, Brad Isaacson - University of Utah

The Center is working closely with scientists at the VA Bone and Joint Research Lab to improve the success of prosthetic limb implants for injured combat veterans. For surgeons installing artificial metal implants that connect directly to bone, a major challenge is achieving good osseointegration (the bond between the living bone and the surface of the load bearing implant). Osseointegration is achieved by encouraging the bone to grow into the artificial material, creating a strong skeletal interlock. This form of prosthetic attachment has major advantages over traditional stump and socket, especially in the population of combat veterans who have lost limbs from explosive devices and typically have little residual limb length left to attach the prosthesis. Control of bone growth, or osseogenesis, at the interface site is essential for achieving rapid and successful osseointegration.

Current methods for promoting osseointegration involve placing a load on the prosthesis for extended periods of time, which encourages osseogenesis at the implant interface. However, this method is not always successful and osseointegration remains a challenge. The Center collaborates with Professor Roy Bloebaum and his team at the VA Bone and Joint Research Lab to develop new methods for promoting osseogenesis using electrical stimulation and to improve the technology for achieving rapid, quality osseointegration in veterans with combat related injuries.

The goal of this project is to develop an Osseointegrated Intelligent Implant Design (OIID) system (a comprehensive and validated computational infrastructure that will support the creation of patient specific models of the residual limbs of amputees to assist in the evaluation and treatment by means of osseointegration). The Center provides specially adapted software required for many aspects of this system including image based modeling, visualization, simulation, and estimation. Seg3D, for example, identifies from CT scans the tissues that make up the residual limb. Then with BioMesh3D, investigators can generate patient specific geometric models that will be the basis for simulations of electric field from selected stimulating electrode configurations using the SCIRun problem solving environment. Comparison of simulated results to measured results in patients will provide validation and allow further refinement of the simulation. This research will result in a system for quickly assessing optimal electrode placement for electrically enhanced osseointegrated implants. Development of the OIID system will be of great benefit to our injured combat veterans and will likely lead to other applications that require osseointegration.



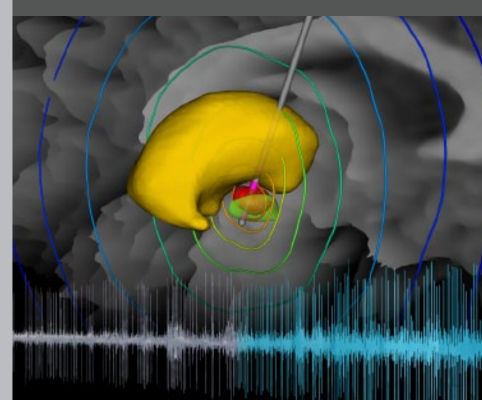
Electric Field (top) and Current Density (bottom) distributions at the bone-implant interface.

Simulation of Deep Brain Stimulation

Christopher R. Butson, Ph.D. - Medical College of Wisconsin

The CIBC is working with neuroscientist Dr. Chris Butson at the Medical College of Wisconsin to develop new computational tools and methods for planning neurostimulation system implantation surgery as a treatment for Parkinson's Disease. Parkinson's disease (PD) is a significant health problem for the aging population of the U.S. There are a 1.5 million PD patients in the United States. Despite the success of pharmaco-based treatment for PD, many patients develop disabling motor side effects over time. One alternative for these patients is deep brain stimulation (DBS). DBS is a therapy in which a neurostimulation system is implanted in the brain during stereotactic surgery. The effectiveness of DBS is well established, but DBS is not without side effects. The primary side effects are neuropsychological. The problem of DBS treatment is additionally complicated by two factors. First, DBS is a complicated procedure with many free parameters and is heavily dependent on the skill of the clinician. Second, no atlas exists for clinicians to share therapeutic or side effect outcomes for DBS patients.

The CIBC is focused on solving two general computing problems to assist Dr. Butson and his team: 1) the ability to generate large, complex, multi-resolution finite element models and 2) visualization of the model results. This project will help provide a knowledge base of correlations between stimulation-induced activation of particular brain regions and neuropsychological outcomes. The project will also result in an activation atlas that expresses the knowledge base in an interactive, 3D viewer, using the Center's SCIRun software. The overall goal is to better manage patient outcomes through use of the knowledge base the project will create, in addition to the potential to predict neuropsychological outcomes in DBS patients.



Bayesian Source Imaging of Pediatric Epilepsy

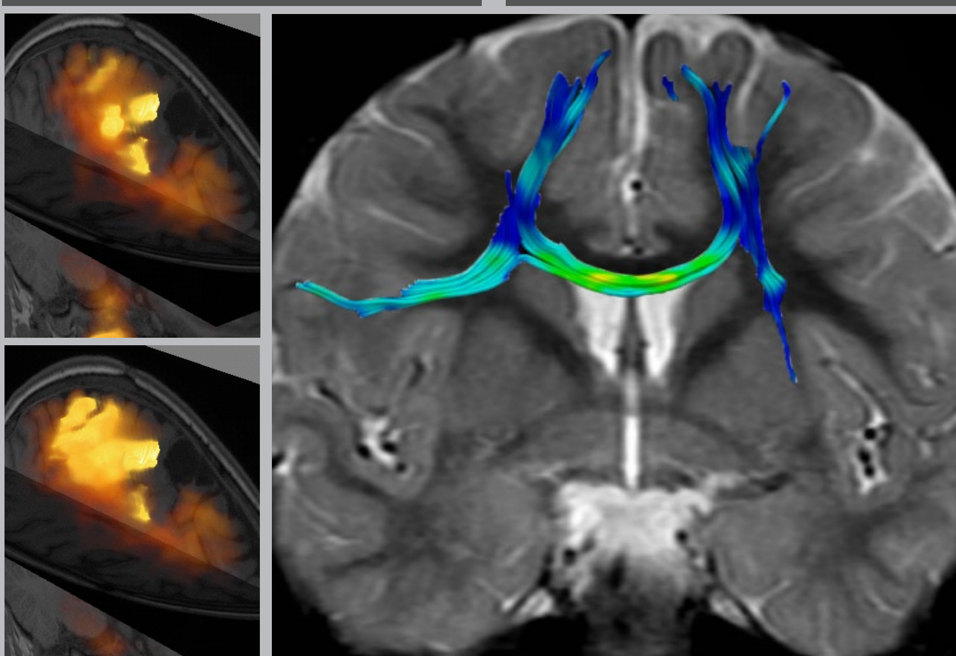
Simon Warfield, Computational Radiology Laboratory (CRL) - Department of Radiology at Children's Hospital Boston

Working with Dr. Simon Warfield, the CIBC is developing computational tools to improve the localization of lesions in epileptic patients. Epilepsy is a chronic neurological disorder caused by disturbances in the normal electro-chemical function of the brain. Epilepsy affects over 2.5 million Americans and has an estimated total annual health care cost close to $12.5 billion per year. Medications for epilepsy often have significant side effects and currently medications fail to halt seizures in up to 20% of patients. These patients are candidates for surgical intervention. Approximately 75 % of epilepsy patients have their first seizure in childhood. Many become candidates for surgical intervention only after a long period of partially effective medication that can have debilitating educational and sociological side effects.

Many epileptic seizures are due to lesions. Accurate identification and localization of lesions is critical to improved surgical intervention. Current state-of-the-art surgical interventions are limited by the risks and difficulty of identifying lesions prior to surgery. Existing efforts to localize lesions rely upon scalp EEG, as well as the more

accurate but invasive intra-dural EEG source localization, and the qualitative review of a range of imaging techniques such as MRI, MR spectroscopy, CT, PET, and fMRI. Technological innovations offer the prospect of improving foci localization and thereby dramatically improving patient outcomes. The development of a highly accurate non-invasive localization of epileptogenic foci would also extend surgical intervention to patients previously deemed inoperable. In current practice, the assessment of imaging data is carried out for each modality independently. In this study, we seek to show that the interpretation of data from these imaging modalities benefits from the integration and simultaneous assessment of those images at the same time.

The overall goal of this project is to develop quantitative analysis algorithms to dramatically improve the capacity to detect and localize epileptogenic foci, in order to enable curative surgery for a significantly increased number of patients.



Left: Spatio Temporal patient data of an 18 year old female epilepsy patient with relapse of symptoms after previous surgical resection. Right: Diffusion MRI and tractography indicated asymmetrical, atypical white matter tracts, concordant with increased atypical spectral coherence on EEG. The patient has a white matter abnormality, adjacent to a focal cortical dysplasia, that is clearly visible on both conventional MRI and on diffusion MRI.

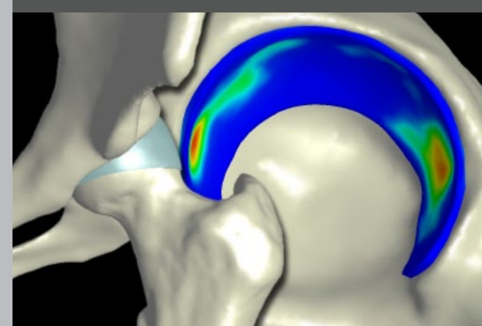
Statistical and Biomechanical Analysis of Hip Dysplasia

Dr. Jeffrey Weiss, Dr. Andrew Anderson - University of Utah

Hip dysplasia is a misalignment in the hip joint that causes abnormal stress and wear to tissues in and around the joint. It may be the leading cause of premature osteoarthritis of the hip. The biomechanics of this condition and the process of joint degeneration that results are still poorly understood.

In this study, 3D models of hip joints are produced based on CT scans from three populations, subjects with no hip dysplasia, those suffering traditional hip dysplasia, and those with retroverted hip dysplasia. The data is then segmented and meshed into accurate 3D models using Seg3D and BioMesh3D. The models are then imported into a simulation environment that will put the virtual joints through normal activities such as walking, or climbing and descending stairs, and allow researchers to visualize where abnormal stress loads occur. Many models from each population are statistically combined to create single models that represent the average in morphology for each population. These models will serve as a baseline average example against which any given patient specific model can be quantifiably compared.

Development of the tools and methods needed for rapidly generating patient specific simulation models of dysplastic hips will not only improve our understanding of the disease itself, it will also greatly improve the quality of treatment and allow early detection of the disease. Early treatment may not require surgery and is much more likely to result in complete recovery.



Applied research at the MRL is focused on helping patients with dysplastic hips. By analyzing subject-specific models of dysplastic and normal hips, we can compare the cartilage stresses in these hips during activities of normal daily living.

DOE SciDAC VACET

Visualization and Analytics Center for Enabling Technologies

The SciDAC Visualization and Analytics Center for Enabling Technologies (VACET) focuses on leveraging scientific visualization and analytics software technology as an enabling technology for increasing scientific productivity and insight. Our mission is to foster scientific insight through creating and deploying effective data understanding technology that is truly responsive to the needs of our stakeholders in the scientific research community who are “awash in data.” It is widely accepted that one of the bottlenecks in contemporary science is the need to gain insight from vast collections of complex data.

The vision for our Center is to respond directly to this challenge by adapting, extending, creating when necessary and deploying visualization and data understanding technologies for our science stakeholders. Organized as a Center for Enabling Technologies, we are well positioned to be responsive to the needs of a diverse set of scientific stakeholders in a coordinated fashion using a range of visualization, mathematics, statistics, computer and computational science and data management technologies.

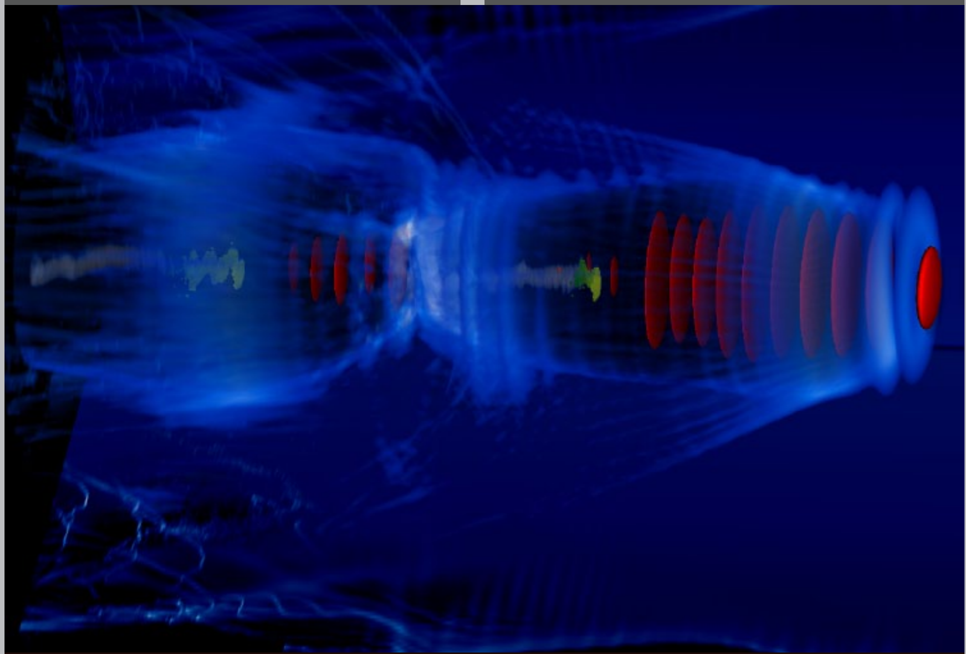
Accelerator Modeling - Beam Analysis

The Problem. Traditionally, physicists perform a manual classification of “particle bunches” through visual inspection of large amounts of simulation output data. The objective is to find those particles that are undergoing acceleration in a laser wakefield. Such manual inspection is time consuming. One main goal of this project is reduce the time for detection and analysis of particle beams.

Currently, particle bunches are classified based on a single reference timestep. The project aims to use the complete temporal history of the particles to enable more accurate beam classification. The large sizes (TBs) of current datasets presents challenges for the analysis of the complete time series. Development of efficient methods for data analysis and data management methods (such as FastBit) is, therefore, a central part of this project. Simulations have largely varying temporal and spatial resolution which analysis methods need to reliably handle.

The Solution. First, we address the manual search problem by developing new algorithms that perform automatic particle beam detection by locating particles undergoing acceleration in large, time-varying accelerator simulation results. We solve the temporal analysis problem with new algorithms that perform automatic detection across time. Our solutions rely on new algorithms for computing 3D histograms in FastBit1 These methods provide us with information about the histogram counts as well with bitvectors allowing us to quickly access particles associated with a set of histogram bins. This functionality is essential to enable efficient implementation of the beam path analysis algorithm.

The Impact. Automating the detection of particle beams significantly reduces the time required for manual inspection of the data. This step is essential to enable analysis large collections of simulation data. By considering information from the complete time series we enable more accurate classification and analysis of particle beams. Analysis of the temporal evolution of particle bunches is essential for the understanding of how particles are accelerated in a laser wakefield accelerator. In the long run, this capability will certainly help accelerator scientist to accelerate data understanding. We are also planning to integrate this method with other Visualization/Analysis tools (VisIt) as part of a broad set of high-performance tools for scientific knowledge discovery.



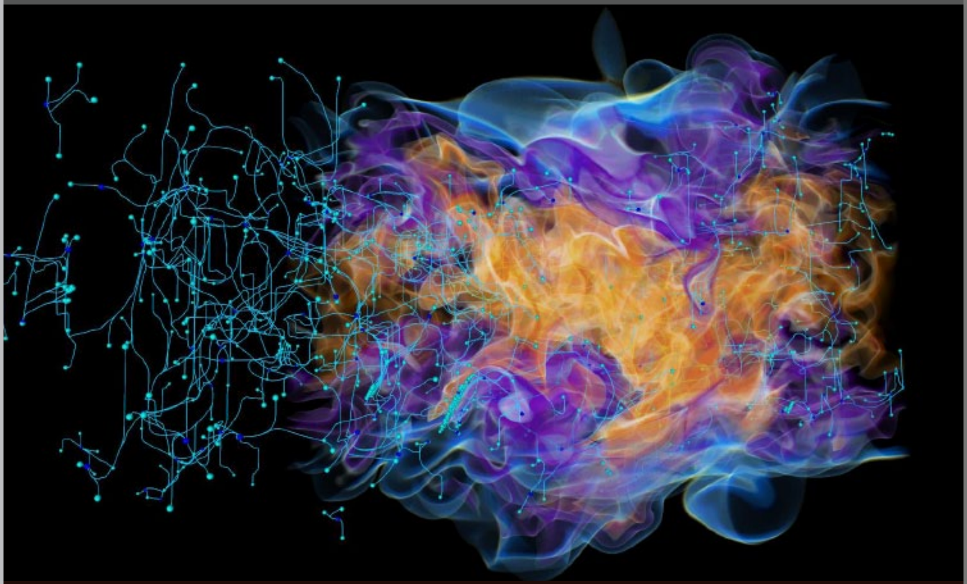
Three-dimensional simulations model the self-consistent evolution of laser pulse and wake, as well as the acceleration of particles. Shown here is a volume rendering of the laser pulse (red), wake (blue), and particle bunch (green low energy, yellow high energy).

Compared to conventional particle accelerators, plasmas can sustain accelerating fields that are thousands of times higher. To exploit this ability, massively parallel SciDAC particle simulations provide physical insight into the development of next-generation accelerators that use laser-driven plasma waves. These plasma-based accelerators offer a path to more compact, ultra-fast particle and radiation sources for probing the subatomic world, for studying new materials and new technologies, and for medical applications.

Combustion - Topological Analysis of DNS Simulation Results

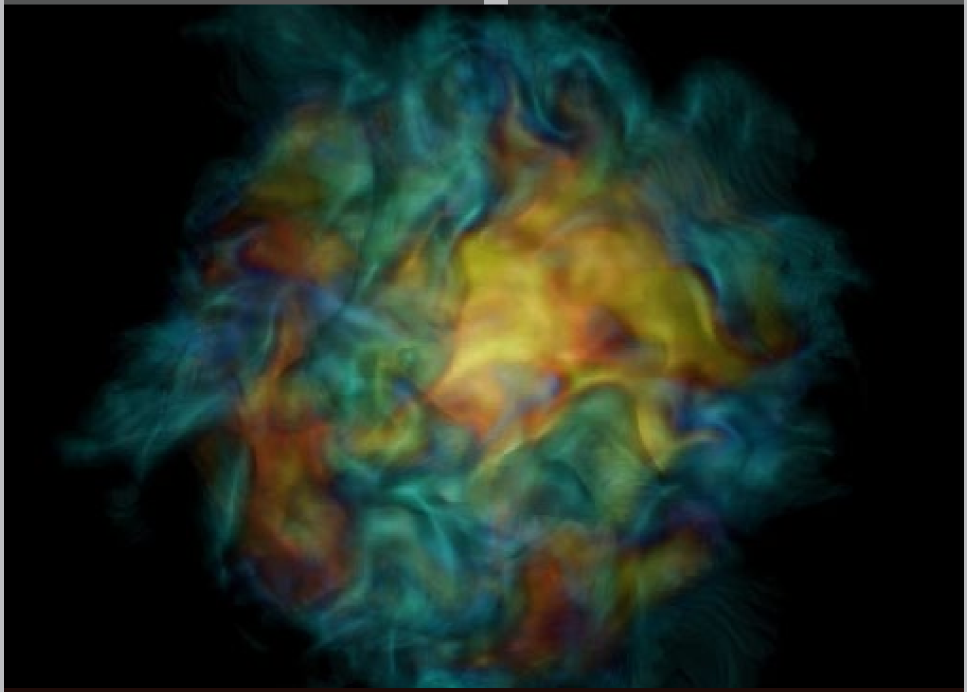
The Problem. Detailed simulation of fundamental combustion processes are an important tool to improve engine and power plant design. In particular, simulations are aimed at understanding transient effects difficult to observe experimentally, such as local flame extinction. The goal of this project is to provide scientists with new tools to define and analyze features of interest, e.g. extinction / re-ignition regions, robustly and efficiently in large scale data.

The Solution. We are using topological approaches to define and extract features of interest. These include, for example, the definition of extinction regions as local level sets, the analysis of dissipation elements as crystals in the Morse-Smale complexes, or the extraction of ridges as Jacobi sets. For each topological structure we have developed or are in the process of developing discrete algorithms that due to their combinatorial nature are unaffected by numerical problems and can be implemented robustly independent of the complexity of the underlying data. Furthermore, we take advantage of the inherently hierarchical nature of topological structures to remove noise and analyze the data at different scales. This allows a stable analysis of, for example, dissipation element so far have been considered notoriously unstable and sensitive to noise.



We focus on data from the JET simulation, a temporally-evolving turbulent CO/H2 jet flame undergoing extinction and reignition at different Reynolds numbers. The simulations were performed with up to 0.5 billion grid points. We have implemented a new code base for computing the Morse-Smale (MS) complex required for this segmentation. The new code is designed to be parallelizable, which will allow in-situ computation of statistics. Furthermore, the new code maintains gradient information, allowing the extraction of higher dimensional manifolds. Here we see the identification of the centers of the basins of mixture fraction.

The Impact. Our techniques have enabled the extraction and analysis of a variety of features of interest in large scale turbulent combustion simulations. These have provided new insights into the creation and evolution of extinction / re-ignition regions that are of fundamental interest to the scientists. In particular, we have provided new feature based statistics that go beyond the traditional global characterizations of flame behavior and allow detailed, local analysis.



Image, created by VACET, from a movie of CASTRO simulation output for Adam Burrow's team showing the variable entropy.

Astrophysics: The Community Astrophysics Consortium

The Problem. To ensure that the visualization and analysis needs of the astrophysics community, and specifically the Computational Astrophysics Consortium (CAC), are met. This involves (i) providing them tools for bread-and-butter functionality, (ii) providing support, (iii) helping with high end movies, and (iv) helping with high-end analysis.

The Solution. VACET is providing and deploying to the CAC with production quality visualization tools to meet day-to-day needs. We are also providing support to the CAC by fielding questions that come up in solving specific science problems, as well as providing in-depth consulting for creating \difficult" images and movies as well as helping to devise new methods for high-end analysis.

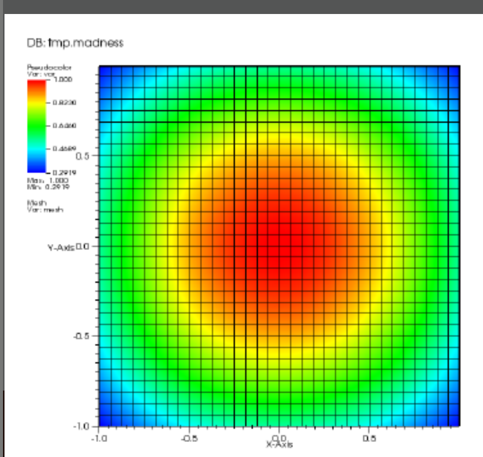
The Impact. We are successfully delivering a production-quality visual data exploration and analysis tool to the SciDAC astrophysics community, thereby enabling new ways of exploring and understanding scientific data as well as enabling cost savings through reduced duplication of effort (they don't have to build or buy a tool to meet their visualization needs). Visualization results have been used by CAC members in presentations and publications that describe new science.

Computational Chemistry and the MADNESS Team

The Problem. The MADNESS code currently lacks almost any sort of scientific visualization and analysis postprocessing capability. There is not one simple scientific goal, but instead we are attempting to enable scientific investigation, introspection, code debugging, and data exploration.

The Solution. We plan to deliver these capabilities by utilizing as much of VisIt as possible, at least initially enabling the scientists to explore their data directly. For other projects this could have been as simple as writing a new file format reader. Here, however, we lack a data file format entirely, and the data model is a poor match for the VTK architecture on which VisIt (and similar scientific tools) are based, as it is a deep quadtree-AMR structure with extremely high-order elements (up to 20th order) and up to a 6 dimensional basis. Therefore, the data file format is being developed as a collaboration between the MADNESS developers and the VACET team, and file format readers and support infrastructure for VisIt written with the special requirements of their data model in mind.

The Impact. By pursuing this project, we will enable many types of scientific discovery using the MADNESS simulation code which are difficult, or impossible, without robust analysis and visualization tools. Specific scientific problems are not yet being addressed, as we are not yet at the stage where analysis can even be performed, let alone identifying shortcomings with the available tools.



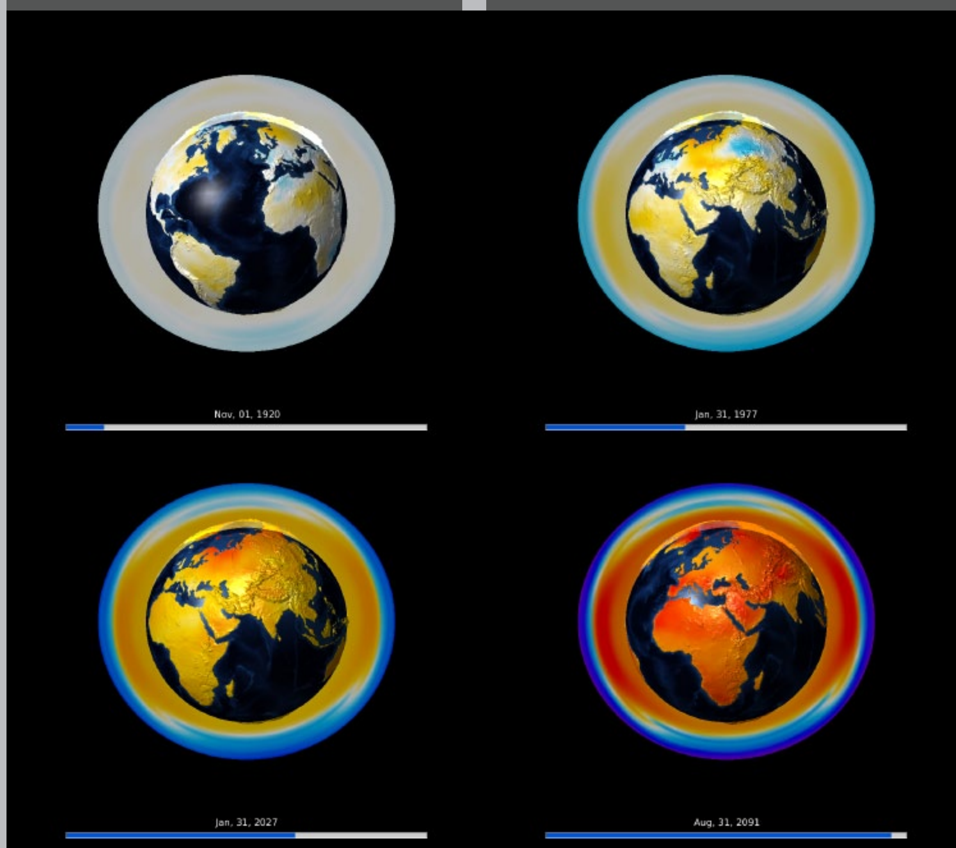
Resampling of the MADNESS quad-tree hierarchy onto a regular mesh.

Climate: Deploying Advanced 3D Visualization to the Climate Community through ESG/CDAT

The Problem. With the increasing reliance on large scale simulations to understand and predict the global climate, tools that facilitate the analysis and distribution of climate simulations are becoming evermore crucial. The climate community needs a small set of tools that is broadly applicable, standardized, collaborative, and reliable to fully exploit the existing simulation capabilities. The Climate Data Analysis Tools (CDAT) framework provides such a platform for many standard 2D visualization and analysis techniques but must be extended to include 3D visualization and more advanced feature based analysis techniques.

The Solution. The goal is support the efforts of the global climate community to better understand and predict climate. In particular, the focus is on developing advanced visualization and analysis capabilities and deploying them into the Climate Data Analysis Tools (CDAT) framework. Our mission includes the following elements: (1) Deploying advanced visualization capabilities into the CDAT tool and create a clear path for similar integration in other tools. (2) Extending the visualization software to incorporate domain specific requirements, data formats, and vector field visualization. (3) Supporting time-dependent and cross-dataset comparison, visualization and analysis. (4) Developing new analytic capabilities for climate data (first deployed into CDAT/VCDAT). (5) Developing a visualization and data analysis scenario for understanding of complex coupled phenomena such as the multi-scale dynamics the complete carbon cycle on earth.

The Impact. We are deploying new capabilities in CDAT and are thus extending one of the most used tool in the climate community. Even with the current prototypical tools we have created several high profile visualizations and animations. In particular, we have created an animation showing that while the lower atmosphere is warming the outer atmosphere is cooling. This is a strong indication that the warming effects are not caused by a change in solar activity but are rather directly related to the insulating effects of carbon dioxide.



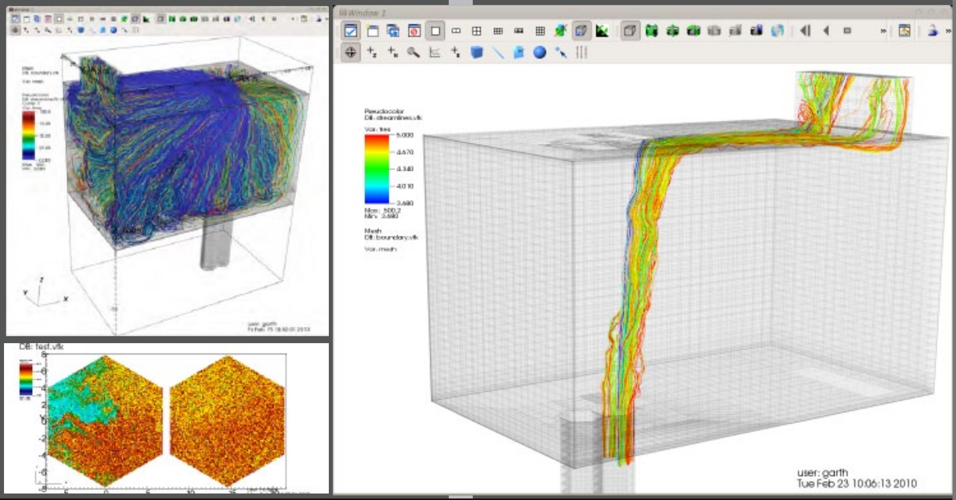
Frames from the complete video which was shown at the climate meeting in Copenhagen, demonstrates the use of visualization to communicate an important insight. The insight in this example is that the outer layer of the atmosphere is cooling while the lower layer is warming.

Nuclear Energy

The Problem. To meet the visualization and analysis needs of the NEAMS (the Office of Nuclear Energy's supercomputing program: Nuclear Energy Advanced Modeling and Simulation) and specifically Argonne's Nek5000 code team. The lead of the Nek code, Paul Fischer, is funded by the Office of Science's base program for math and is an INCITE awardee. The needs are met by: (i) providing them tools for bread-and-butter functionality, (ii) providing support, (iii) helping with high end movies, and (iv) helping with high-end analysis.

The Solution. To provide tools for bread-and-butter functionality, we are deploying VisIt to the Nek team. Providing support means we are responding to questions that come from Nek. We help to create advanced movies and animations for the Nek team. And we help them to perform high-end analysis (examples below).

The Impact. We have met their bread-and-butter needs and have also helped answer some science questions.



Top left: An illustration of 10,000 streamlines moving through the fish tank. Bottom left: We placed particles at regular intervals along the inlet. We then advected the particles and calculated the residence time. This picture colors the initial position of the particle by the duration of residence. You can see a "fast track" on the left inlet, where particles are able to get to the outlet more quickly. Right: We rendererd only those particles with quick residence time. These particles correspond to the cyan areas of the previous image.

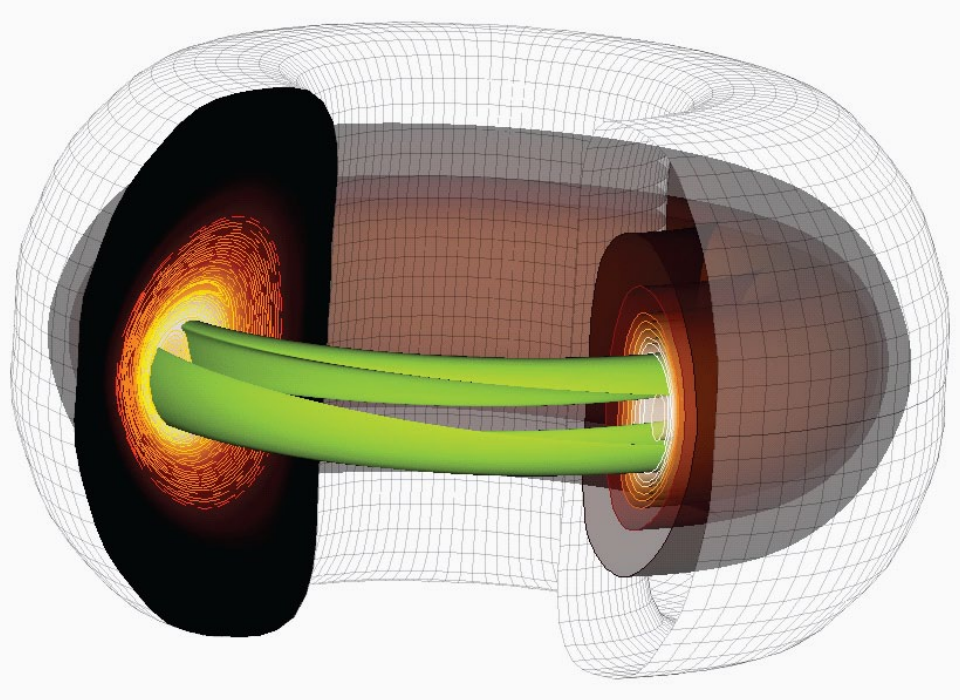
Fusion: Fieldline Analysis and Poincare Plots

The Problem. Physicists are currently studying the affects of magnetic islands that form in plasma. These islands cause defects in the magnetic field and the current flow resulting in contact between previously separate regions. This contact results in hot areas coming into contact with cool areas which leads to core cooling. A common way of viewing simulation results with an eye towards understanding island formation is the Poincare plot. Physicists would like to have tools that allow them to be able to automatically generate Poincare maps of the magnetic field and detect the island formation and track them over time. To help increase understanding of islands, it is helpful to display other simulation variables in conjunction with the Poincare plot. Such data may be scalar (electric potentials) or vector data (magnetic fieldlines) and may have its own visualization requirements.

The Solution. Our objective is to develop tools for the robust analysis of toroidal fieldlines, include high quality Poincare plots, and to deploy these new technologies in production form to the fusion community.

The Impact. These new visualization techniques will help to increase scientific understanding about heat transport in highly stochastic fields, such as those produced by DOE fusion simulation codes.

We are deploying these new capabilities to multiple fusion code teams in DOE to achieve wide impact. Our deployment vehicle is VisIt, a production-quality visualization application. Thus, our R&D effort is able to leverage a large, existing investment in software and release engineering.



A 2:1 magnetic island chain that dominates the inner core of the simulation. Shownt with in the inclusion of iso-temperature surfaces showing the affect of the magnetic field on the plasma.

NEURALCIRCUITRECONSTRUCTION

Introduction

Deciphering and reconstructing complete neuronal networks is one of the grand challenges in neuroscience. Defining connectomes or complete network maps for canonical regions of any tissue requires robust cataloguing of classes, mapping of statistically distinct patterns and tracing of characteristic connections. Serial-section transmission electron microscopy (ssTEM) is capable of providing the image data necessary for reconstructing the connectivity of large-scale neural networks. With automated image acquisition, we can now capture approximately 4000 tiles in 24hrs. There are two major computational barriers to large-scale reconstruction of neural circuity from ssTEM: volume assembly and process tracking/synapse detection.

Registration and Mosaicking

In [1] we demonstrate completely automatic and robust approaches for mosaicking of TEM sections from thousands of tiles and for three-dimensional volume assembly by section-to-section registration. Our algorithm uses the shift property of Fourier transform applied at the tile to determine translations between tiles. The same property of the Fourier transform is also used at a sub-tile level to correct non-linear deformations between tiles and between sections [1,2]. Figure 1 shows a mosaic of a single-section from transgenic rabbit retina acquired and assembled with these tools. Currently, the time required for mosaicking a section is less than the time required for the acquisition of that section.

Reconstruction Tools

Tracking neuronal processes is fundamentally an image segmentation problem. The textured nature of the images due to specimen preparation renders traditional methods for medical image segmentation of little use in this application. However, the texture is due to staining of the intracellular structures which is needed for reliable detection of synapses. Mischenko has demonstrated that a perceptron learning algorithm combined with post-processing can be used for membrane detection in textured TEM images [3]. In [4,5] we show how local context information can be combined with such a simple classifier to improve membrane detection in TEM images (see figure 2). Once membranes in a section are detected, individual cells can be segmented and tracked across the volume [6] (see figure 3). Our goal is to improve the accuracy of membrane detection in TEM images to the point where the amount of user time for editing of the results becomes comparable to the image acquisition time.

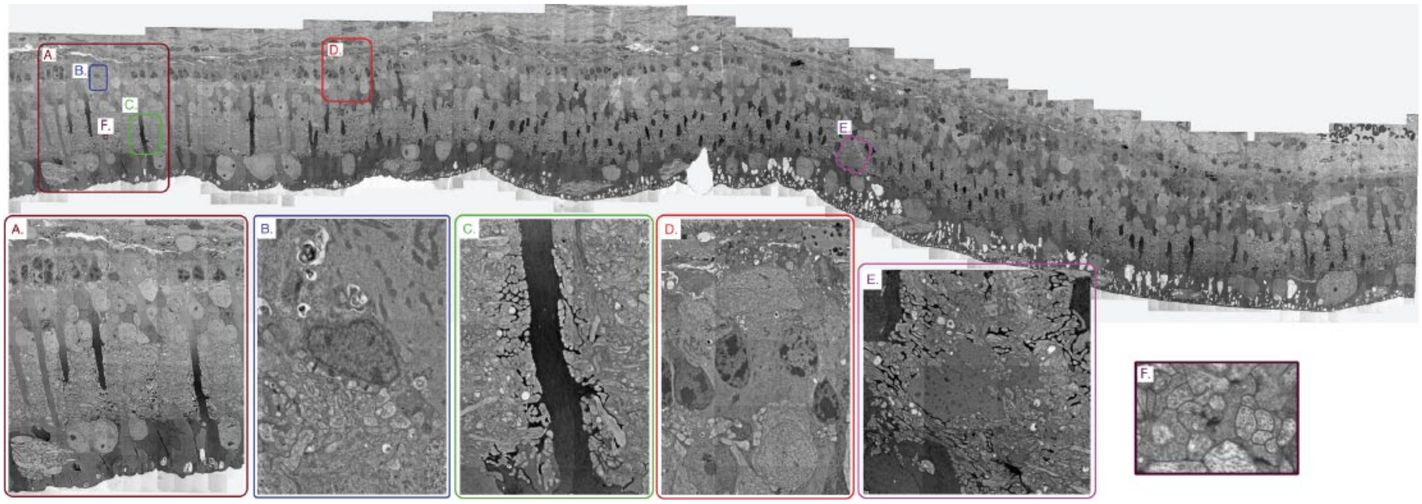
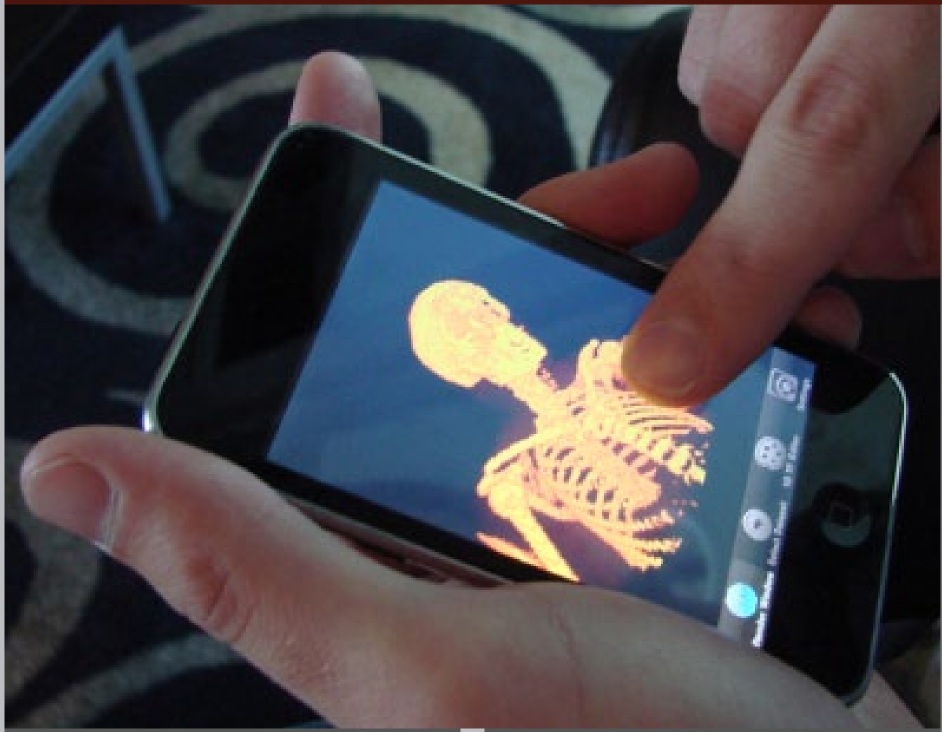


Figure 1. Image of a transgenic rabbit retina is a mosaic of over 2200 separate TEM assembled in a completely automated fashion through solutions derived from the previous funding phase of this project. Each tile is an image with approximately 4000 x 4000 pixels. Insets show several areas at varying levels of zoom to demonstrate the amount of information available in the mosaic.

ImageVis3d mobile



Computer program turns complex data into brilliant images

By Jed Boal. KSL.com

University of Utah scientists Jens Krueger and Tom Fogal have developed ImageVis3D, a three-dimensional (3-D) imaging program that converts complex data into colorful pictures that can be viewed with an iPhone or iPad. The researchers say ImageVis3D takes abstract phenomena and data and converts it into something that can be seen and better understood.

“The average computer user can now visualize and look at their data in real time, regardless of how large it is,” Fogal says. The program enables users to manipulate a wide range of 3-D images of medical, scientific, and engineering data, he says.

The technology could help teach a new generation of computer-savvy, visually-oriented students, according to Fogal. It also could lead to being able to download more complex material onto even smaller computer devices.

A birds-eye view of a research reactor’s core is displayed on an iPhone using ImageVis3D software developed by the University of Utah’s Scientific Computing and Imaging Institute. The red-colored fuel rods are absorbing the most neutrons during the fission reaction inside the core. The university’s Nuclear Engineering Program developed an interface so computer simulations of nuclear reactor cores can be generated on iPhones, iPods, iPads or other computers. The simulations are used in research and to help train a new generation of nuclear engineers.

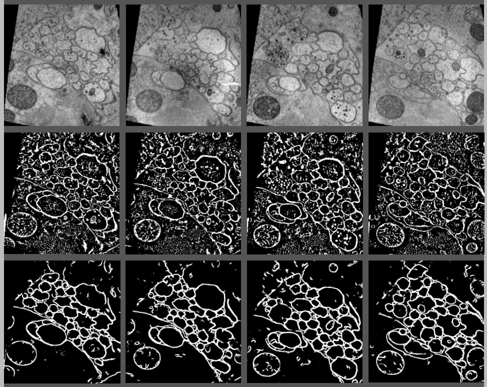


Figure 2.
Row 1: Cross-section of the ventral nerve cord from a nematode C. elegans acquired using EM.
Two demonstrated segmentation techniques:
Row 2: Thresholded boundary confidences from a single artificial neural network trained using Hessian eigenvalues[3]
Row 3: Artificial neural networks, run in serial, trained using stencils and auto-context[5]

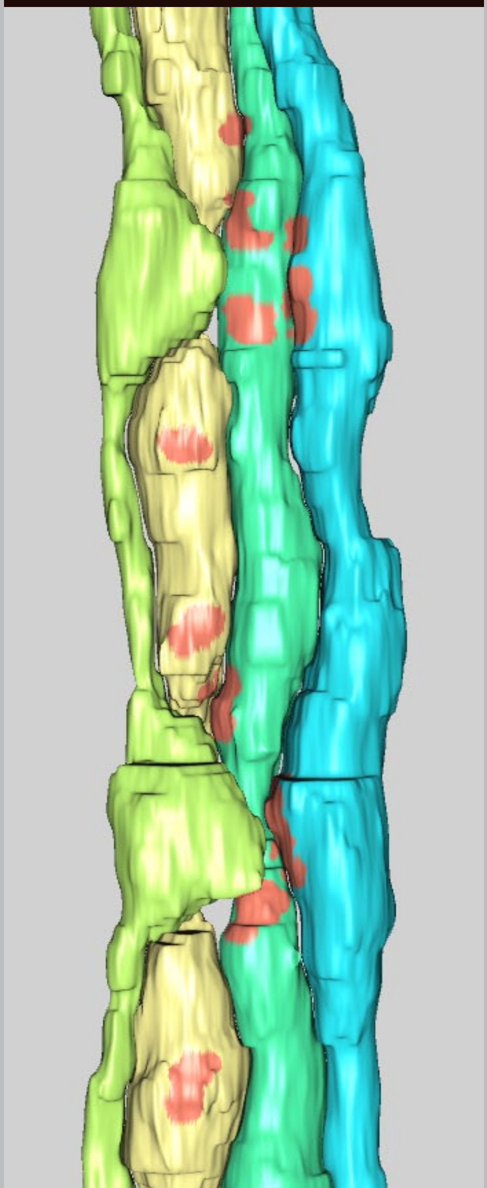


Figure 3. Reconstruction of the ventral nerve cord (top) and nearby muscles (bottom) of the C. elegans.

SCI Faculty

CHRIS JOHNSON

Dr. Johnson founded the SCI research group in 1992 which has since grown to become the SCI Institute employing over 150 faculty, staff and students. Professor Johnson serves on several international journal editorial boards, as well as on advisory boards to several national and international research centers.

Professor Johnson was awarded a Young Investigator's (FIRST) Award from the NIH in 1992, the NSF National Young Investigator (NYI) Award in 1994, and the NSF Presidential Faculty Fellow (PFF) award from President Clinton in 1995. In 1996 he received a DOE Computational Science Award and in 1997 received the Par Excellence Award from the University of Utah Alumni Association and the Presidential Teaching Scholar Award. In 1999, Professor Johnson was awarded the Governor's Medal for Science and Technology from Governor Michael Leavitt. In 2003 he received the Distinguished Professor Award from the University of Utah. In 2004 he was elected a Fellow of the American Institute for Medical and Biological Engineering, 2005 he was elected a Fellow of the American Association for the Advancement of Science, and in 2009 he was elected a Fellow of the Society for Industrial and Applied Mathematics (SIAM).

- Director, SCI Institute
- Co-Director, The Center for Integrative Biomedical Computing (CIBC)
- Distinguished Professor, Computer Science
- Research Professor of Bioengineering
- Adjunct Professor of Physics
- Faculty Member, Computational Engineering and Science (CES) Program
- Faculty Member, Brain Institute
- Co-Founder, Visual Influence Inc.
- Co-Editor, The Visualization Handbook

WEB 3850
phone (801) 581-7705
fax (801) 585-6513
crj@sci.utah.edu

ROB MACLEOD

My education has included degrees in Physics (B.Sc.), Electrical Engineering (M.Sc.) and Physiology (Ph.D.) from far away places like Halifax, Nova Scotia and Graz Austria. I came to Utah in 1990 as a post-doc, met Chris, and we have been causing trouble ever since.

I am an associate director of the CVRTI and have a research group there focussing on cardiac electrophysiology, the study of the heart's electrical activity. Within the SCI Institute, I am a member of the executive committee responsible for the biomedical research projects, especially the NIH NCRR Center. I also teach physiology and about bioelectric fields in Bioengineering, where I head the computational track in both the graduate and undergraduate programs.

- Associate Professor
- Associate Chair, Undergraduate Studies
- Associate Director, Scientific Computing and Imaging Institute (SCI).
- Associate Director, Nora Eccles Harrison Cardiovascular Research and Training Institute (CVRTI)
- Co-Director, NIH NCRR Center for Integrative Biomedical Computing

WEB 4602
phone (801) 585-7596
fax (801) 585-6513
macleod@cvrti.utah.edu

CHUCK HANSEN

Charles Hansen received a BS in computer science from Memphis State University in 1981 and a PhD in computer science from the University of Utah in 1987. He has been a member of the faculty at Utah since 1997. From 1989 to 1997, he was a Technical Staff Member in the Advanced Computing Laboratory (ACL) located at Los Alamos National Laboratory, where he formed and directed the visualization efforts in the ACL. He was a Bourse de Chateaubriand PostDoc Fellow at INRIA, Rocquencourt France, in 1987 and 1988. From Fall 2004 to Spring 2005, he was a Visiting Professor at ARTIS/GRAVIR IMAG/INRIA Grenoble France.

Professor Hansen's research interest focuses on building tools and systems that assist in the comprehension of massive amounts of scientific data. These have included exploiting novel data structures for rapid data access and processing of visualization algorithms. With the advent of the programmable GPU, his background in parallel algorithms has provided unique opportunities for novel methods exploiting the hardware. With students, he has explored time-dependent methods for accelerating isosurface extraction, parallel image based rendering techniques for visualization, interactive multidimensional volume rendering and advanced volume graphics that include modeling and shading, the combination of haptics and visualization for perceptualization of data, and remote visualization.

- Professor of Computer Science, School of Computing
- Faculty Member, Scientific Computing and Imaging Institute
- Associate Director, Scientific Computing and Imaging Institute

WEB 4692
phone (801) 581-3154
fax (801) 585-6513
hansen@sci.utah.edu

MARTIN BERZINS

Martin Berzins received his PhD from the University of Leeds in 1981.

Martin's research area is the study of serial and parallel novel computational algorithms for the numerical solution of partial differential equations (p.d.e.s). This area is part of the discipline of Scientific Computing. The physical problems that are modeled by p.d.e.s are of great importance to a wide range of both industrial and academic research groups. Examples range from being able to design better harbors to understanding environmental pollution, modeling the behavior of lubricants in a car engine or modeling fires and explosions.

The approach taken in this research has been to derive numerical methods with adaptive error control and develop software on both serial and parallel computers for a broad, mathematically-defined problem class. This has made it possible for users from different physical applications areas to solve their problems by creating a mathematical model which fits inside the general problem class.

Martin's current research areas are:
• Parallel adaptive mesh algorithms for tera-scale and peta-scale computers
• Adjoint based error estimation and error control algorithms
• Positivity preserving high-order methods
• Analysis of methods used in modeling fires and explosions in the Utah CSAFE project

• Professor of Computer Science
• Director, School of Computing
• Faculty, Scientific Computing and Imaging Institute
• Visiting Professor, University of Leeds

WEB 3803
phone (801) 585-1545
fax (801) 581-5843
mb@cs.utah.edu

ROSS WHITAKER

Ross T. Whitaker received his B.S. in Electrical Engineering and Computer Science/ Engineering Physics at Princeton University in 1986 and his M.S. and PhD in Computer Science at the University of North Carolina in 1991 and 1993. Professor Whitaker works in the Scientific Imaging and Computing Institute, and he runs the Image Processing Laboratory. He conducts research in image processing, computer vision, pattern recognition, and visualization. His approach to problems in these domains is usually based upon my background in differential geometry, differential equations, and signal processing.

• Associate Professor of Computer Science

WEB 3893
phone (801) 587-9549
fax (801) 585-6513
whitaker@sci.utah.edu

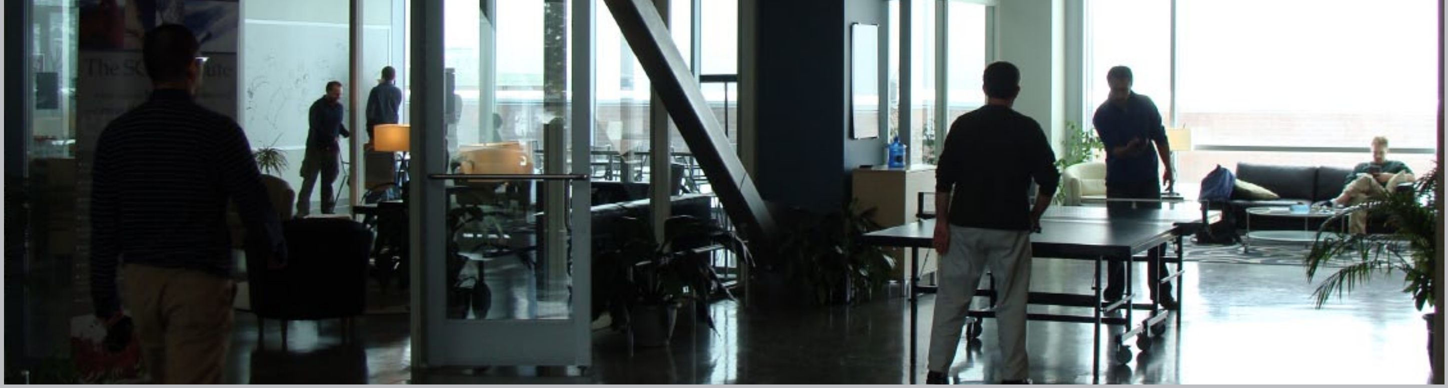
MIKE KIRBY

Robert M. ("Mike") Kirby received his B.S. in Applied Mathematics and Computer and Information Sciences from Florida State University in 1997, his M.S. in Applied Mathematics from Brown University in 1999 and his M.S. in Computer Science from Brown University in 2001, his Doctor of Philosophy in Applied Mathematics from Brown University in 2003.

Professor Kirby's research focus is on large- scale scientific computing and visualization, with an emphasis on the scientific cycle of mathematical modeling, computation, visualization, evaluation, and understanding. His primary research interests are: Computational Science and Engineering, High-Order Methods: Algorithm Development and Applications, Scientific Visualization, Concurrent Programming: Verification and Applications, and High Performance Computing.

• Associate Professor of Computer Science
• Adjunct Associate Professor of Bioengineering
• Adjunct Associate Professor of Mathematics

WEB 3602
phone (801) 585-3421
fax (801) 581-5843
kirby@sci.utah.edu



VALERIO PASCUCCI

Valerio Pascucci is an associate professor in the School of Computing and a member of the SCI faculty. Before joining SCI, Dr. Pascucci served as a Project Leader at the Lawerance Livermore National Laboratory, Center for Applied Scientific Computing (from May 2000) and Adjunct Professor at the Computer Science Department of University of California Davis (from July 2005). Valerio earned a Ph.D. in computer science at Purdue University in May 2000, and a EE Laurea (Master), at the University “La Sapienza” in Roma, Italy, in December 1993.

Dr. Pascucci's research interests include: data analysis, topological methods for image segmentation, progressive and multi- resolution techniques for scientific visualization, combinatorial topology, geometric compression, computer graphics, computational geometry, geometric programming, and solid modeling.

• Associate Professor of Computer Science

WEB 4646
phone (801) 587-9885
fax (801) 585-6513
pascucci@sci.utah.edu

JEFF WEISS

Dr. Weiss received his B.S. in Bioengineering from the University of California, San Diego in 1989, and his M.S. in Bioengineering from the University of California, San Diego in 1990. He completed his Ph.D. in Bioengineering at the University of Utah in 1994. Dr. Weiss received postdoctoral training in computational biomechanics as a finite element analyst working with the Applied Mechanics Group and the Methods Development Group at Lawrence Livermore National Laboratory. Dr. Weiss was a Research Assistant Professor of Bioengineering at the University of Utah from 1994-1998, and a tenure-track Assistant Professor of Biomedical Engineering at the University of Arizona from 1998-2000. He joined the Bioengineering Department at the University of Utah in August 2000, and he is currently an Associate Professor of Bioengineering and an Adjunct Assistant Professor of Orthopaedics. In 2006 he was elected a Fellow of the American Institute for Medical and Biological Engineering.

• Associate Professor, Bioengineering
• Adjunct Associate Professor, Orthopedics

WEB 2602
phone (801) 587-7833
fax (801) 585-6513
jeff.weiss@utah.edu

SARANG JOSHI

Dr. Sarang Joshi has joined SCI as an Associate Professor of the Department of Bio Engineering. Before coming to Utah, Dr. Joshi was an Assistant Professor of Radiation Oncology and an Adjunct Assistant Professor of Computer Science at the University of North Carolina in Chapel Hill. Prior to joining Chapel Hill Dr. Joshi was Director of Technology Development at IntellX, a Medical Imaging start-up company which was later acquired by Medtronic. Sarang's research interests are in the emerging field of Computational Anatomy and have recently focused on its application to Radiation Oncology. Most recently he spent a year on sabbatical at DKFZ (German Cancer Research Center) in Heidelberg, Germany, as a visiting scientist in the Department of Medical Physics where he focused on developing four dimensional radiation therapy approaches for improved treatment of Prostate and Lung Cancer.

He holds numerous patents in the area of image registrations and has over 50 scholarly publications.

• Associate Professor of Bioengineering

WEB 3692
phone (801) 587-7961
fax (801) 585-6513
sjoshi@sci.utah.edu

GUIDO GERIG

Guido Gerig was recruited from the University of North Carolina at Chapel Hill to the University of Utah under the USTAR program. He received his Ph.D. in 1987 from the Swiss Federal Institute of Technology, ETH Zurich, Switzerland. Guido Gerig joined the faculty at UNC Chapel Hill as Taylor Grandy professor in August 1998 and with a joint appointment in the Departments of Computer Science and Psychiatry. In 2008, he accepted a new faculty position at the School of Computing and Scientific Computing and Imaging Institute (SCI) at the University of Utah, with adjunct appointments in Biomedical Engineering and Psychiatry.

Guido Gerig began research in the area of medical image analysis in 1985 at ETH Zurich, Switzerland. Since then, he has led a large number of national and international projects with close multidisciplinary collaboration between medicine, engineering, statistics, industry, and computer science. He is the director of the UTAH Center for Neuroimage Analysis (UCNIA) and supports a number of clinical neuroimaging projects with methodology for image processing, registration, atlas building, segmentation, shape analysis, and statistical analysis. Current key research topics are analysis and modeling of the early developing brain, longitudinal analysis of multi-shape complexes, and new methodologies for statistical analysis of white matter using diffusion tensor imaging. Method developments are driven by challenging clinical applications that include research in schizophrenia, autism, multiple sclerosis, infants at risk for mental illness and aging. New tools and methods are open source and are made available to public.

- Professor of Computer Science.
- Adjunct Professor of Bioengineering.
- Adjunct Professor of Psychiatry
- Faculty Member, Brain Institute.
- Director, UTAH Center for Neuroimage Analysis (UCNIA)
- Adjunct Professor of Computer Science, UNC Chapel Hill
- Adjunct Professor of Psychiatry, UNC Chapel Hill

WEB 3686
phone (801) 585-0327
fax (801) 581-5843
gerig@cs.utah.edu

TOM FLETCHER

Tom Fletcher received his B.A. degree in Mathematics at the University of Virginia in 1999. He received an M.S. in Computer Science in 2002 followed by a Ph.D. in Computer Science in 2004 from the University of North Carolina at Chapel Hill.

Dr. Fletcher's research is focused on creating novel methods at the intersection of statistics, mathematics, and computer science to solve problems in medical image analysis. He is currently collaborating with researchers in Autism and Alzheimer's disease at the University of Utah on the statistical analysis of combined imaging modalities, including structural MRI, DTI, fMRI and PET in longitudinal studies.

- Assistent Professor of Computer Science

WEB 4686
phone (801) 587-9641
fax (801) 585-6513
fletcher@sci.utah.edu

TOLGA TASDIZEN

Dr. Tasdizen currently leads an interdisciplinary research effort to build computational tools for reconstructing neural circuit diagrams from large numbers of very high resolution microscopy images. Dr. Tasdizen also collaborates with researchers in the Center for Alzheimer's Care Imaging and Research (CACIR) and the Department of Neurology where he holds an adjunct faculty position.

Dr. Tasdizen will serve as the SCI Institute's second USTAR faculty member. USTAR is an innovative, aggressive and far-reaching effort to bolster Utah's economy with high-paying jobs and keep the state vibrant in the Knowledge Age. The USTAR Support Coalition and the Salt Lake Chamber sought public and private investment to recruit world-class research teams in carefully targeted disciplines. These teams will develop products and services that can be commercialized in new businesses and industries.

- Assistant Professor, Department of Electrical and Computer Engineering

WEB 3887
phone (801) 581-3539
fax (801) 585-6513
tolga@sci.utah.edu

ORLY ALTER

Orly Alter is a USTAR Associate Professor of Bioengineering and Human Genetics at the Scientific Computing and Imaging (SCI) Institute at the University of Utah. She joined the University of Utah in 2010 from the University of Texas at Austin, where she is now an Adjunct Associate Professor of Mathematics. She was awarded an NSF CAREER Award in 2009, and a National Human Genome Research Institute (NHGRI) R01 grant in 2007. Additional support for her work comes from the American Institute of Mathematics and Cancer Research UK. In 2005, Alter was selected to give the Linear Algebra and its Applications Lecture of the International Linear Algebra Society. She received an NHGRI Individual Mentored Research Scientist Development Award in 2000. From 1999 to 2003, she was a Sloan Foundation/DOE Postdoctoral Fellow in Computational Molecular Biology in the Department of Genetics at Stanford University.

Alter received her Ph.D. in Applied Physics at Stanford University in 1999. In her thesis work she established the quantum theoretical limits to the information which can be obtained in the measurement of a single physical system about the system's quantum wavefunction, its time evolution and the classical potentials which shape this time evolution. For this work she was an American Physical Society Outstanding Doctoral Thesis Research in Atomic, Molecular, or Optical Physics Award Finalist in 1998. Today Alter's thesis work, which was published as a book by Wiley in 2001, is recognized as crucial to the field of gravitational wave detection.

• Associate Professor, Bioengineering

WEB 3803
fax (801) 585-6513
orly@sci.utah.edu

MIRIAH MEYER

Miriah is a USTAR assistant professor in the School of Computing at the University of Utah and a faculty member in the Scientific Computing and Imaging Institute. Her research focuses on the design of visualization systems for helping scientists make sense of heterogeneous data. She obtained her bachelors degree in astronomy and astrophysics at Penn State University, and earned a PhD in computer science from the University of Utah. Prior to joining the faculty at Utah Miriah was a postdoctoral research fellow at Harvard University and a visiting scientist at the Broad Institute of MIT and Harvard.

Miriah was awarded a Microsoft Research Faculty Fellowship in 2012, as well as named to MIT Technology Review's TR35 and Fast Company's list of the 100 most creative people. She is the recipient of a NSF/CRA Computing Innovation Fellow award, and an AAAS Mass Media Fellowship that landed her a stint as a science writer for the Chicago Tribune.

• Assistant Professor, Computer Science

WEB 4887

fax (801) 585-7045
miriah@sci.utah.edu

GREG JONES

Dr. Jones previously served as our Associate Director from 2000 to 2005. He was then called by Governor Jon M. Huntsman to serve as the State Science Adviser to the Governor of Utah and Director of the Utah Economic Clusters Initiative from 2005 to 2007. He was awarded the 2007 Medal for Science and Technology by Utah Governor Jon M. Huntsman for his science leadership to the State of Utah. Most recently, he served as the Executive Director of Research at the Moran Eye Center.

As Associate Director of the Scientific Computing and Imaging Institute, Greg contributes to both the day-to-day operation and the ongoing advancement of the Institute. He is actively engaged in the management of the several large research centers within SCI and the development of external funding sources for Institute activities. He helps oversee the internal information technology group and members of the media development team.

• Associate Director, Scientific Computing and Imaging Institute

WEB 3853
phone (801) 587-9825
fax (801) 585-5613
greg@sci.utah.edu

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There is an American proverb that says: “It doesn’t work to leap a twenty-foot chasm in two ten-foot jumps.” Everyday the SCI Institute is engaged in far reaching scientific computing and imaging research in which we attempt to leap the twenty-foot chasm. This leap is not possible without the help we receive from our donors. Federal research funds have become more restricted and more risk adverse, so that only the ten-foot jump is possible. The SCI Institute needs support from its donors to help us in leaping the chasm required to bring far reaching advances to all the fields touched by scientific computing and imaging.

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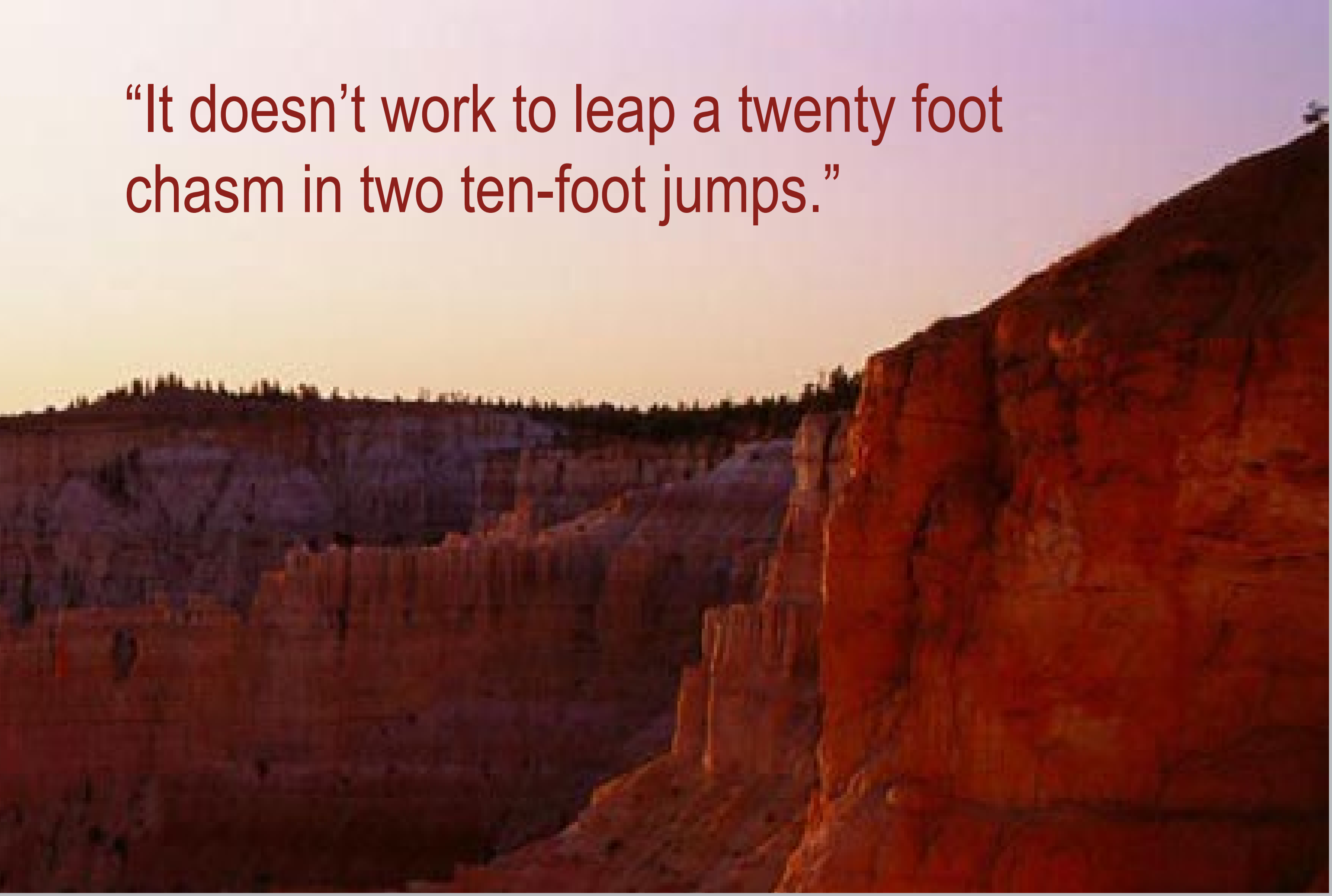

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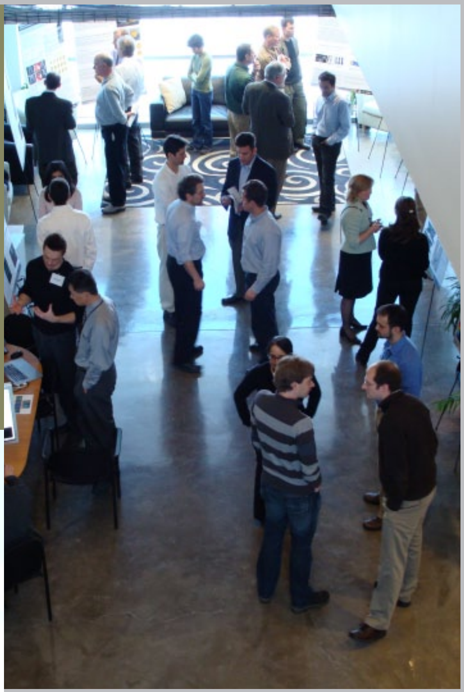

Scientific Computing and Imaging Institute
72 S. Central Campus Drive, Room 3750
Salt Lake City UT 84112
Phone: 801-585-1867
Fax: 801-585-6513

Scientific Computing and Imaging Institute
72 S. Central Campus Drive, Room 3750
Salt Lake City UT 84112
Phone: 801-585-1867
Fax: 801-585-6513