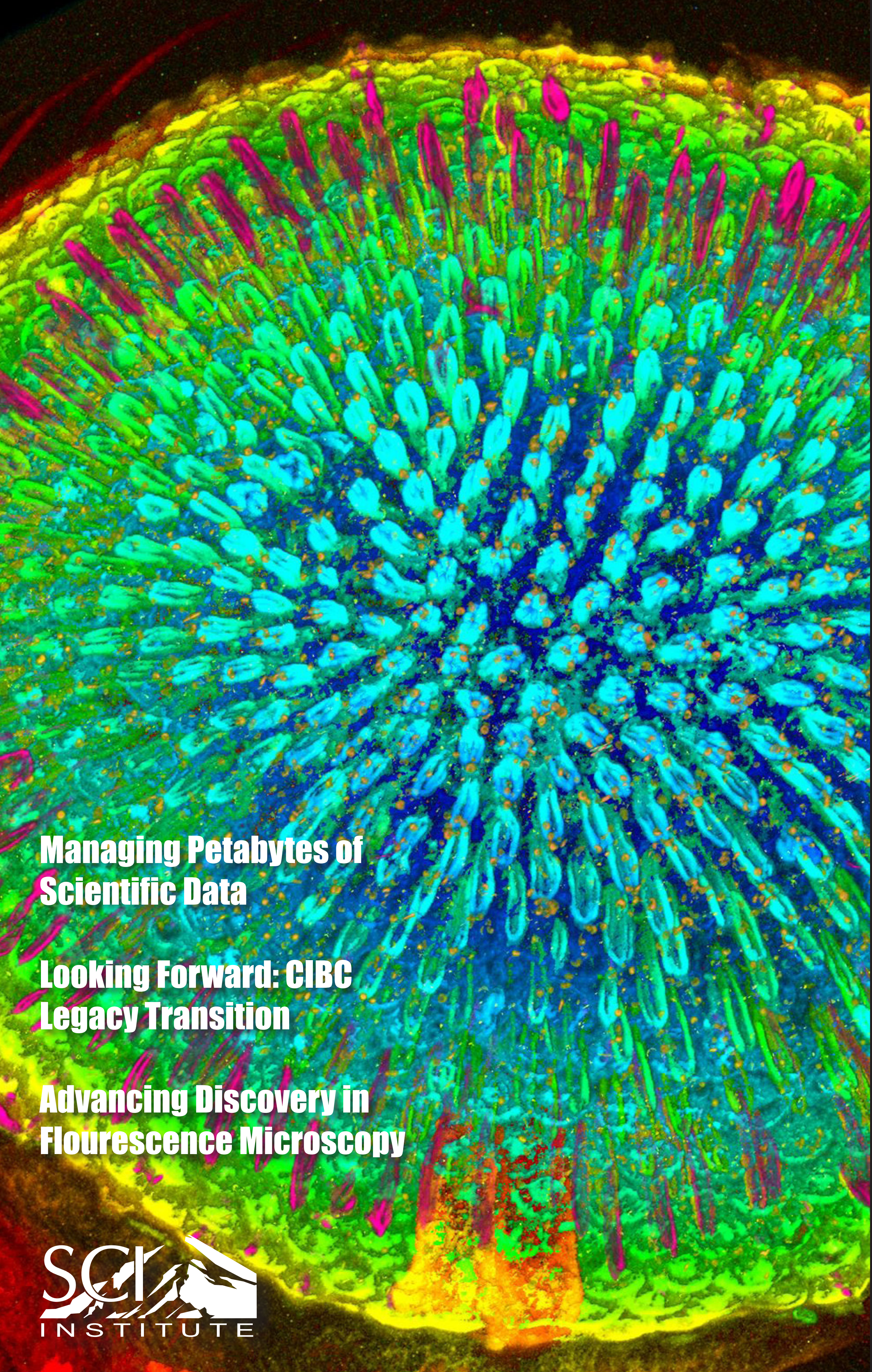
Fall 2021

FRESH TRACKS™



Managing Petabytes of Scientific Data

Looking Forward: CIBC Legacy Transition

Advancing Discovery in Flourescence Microscopy

SCI INSTITUTE

From the Director

I am honored and excited to take on the role of Director of the Scientific Computing and Visualization (SCI) Institute at the University of Utah.

We are witnessing the beginnings of a new era in scientific exploration. This revolution is driven in part by the increasing scales, pervasiveness, and timely availability of data; the disruptions in computing and other enabling technologies; and the emergence of new methodologies, for example, based on artificial intelligence and machine learning. We are also experiencing new models and modalities for interacting and collaborating. These opportunities are being further catalyzed by our national priorities and investments in the industries of the future, including artificial intelligence, quantum information systems, advanced wireless, biotechnologies, and advanced manufacturing. While these trends have the potential for transforming every aspect of science and society, they are challenging traditional research methods and structures, and are bringing a new urgency to multidisciplinary and transdisciplinary research and education.

Over the years, SCI has established itself as an international leader in computational and data-enabled science and engineering research and education. From developing new methods and technologies for data-driven scientific exploration to pioneering new structures for multidisciplinary research, SCI has an extremely impressive record of achievement and recognitions. I believe that SCI is well poised to take on a leadership role in this scientific revolution.

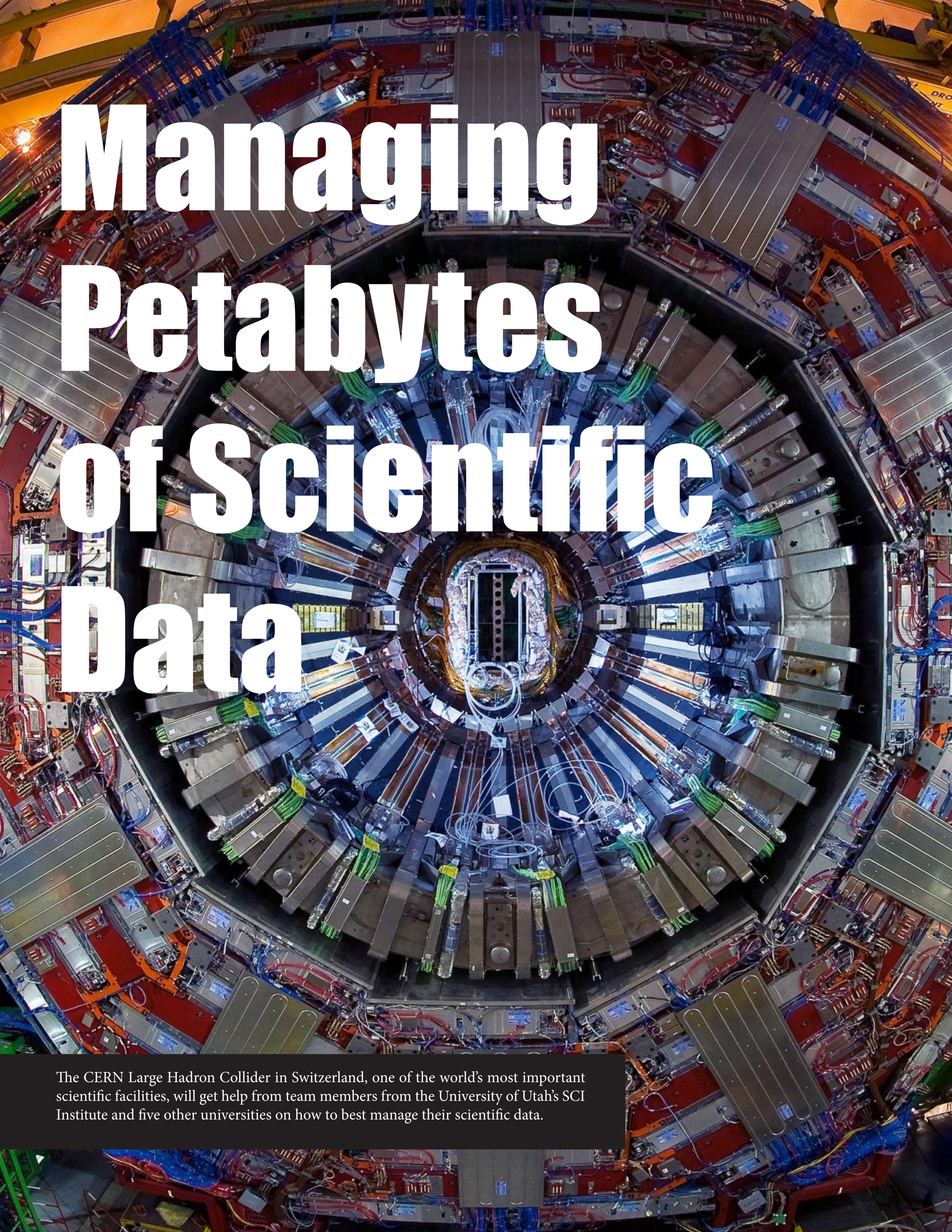
I welcome the opportunity to build on the tremendous expertise, assets, and achievements at SCI; to connect with and complement the strenghts across the U; to promote diversity and equity at SCI and more broadly; and to lead SCI to a future of even greater achievements and a transformative impact on science and society.

- Dr. Manish Parashar
Director, Scientific Computing and Imaging Institute

In This Issue

On the cover: Visualizing the eye of a drosophilia with FluoRender

Managing Petabytes of Scientific Data



The CERN Large Hadron Collider in Switzerland, one of the world's most important scientific facilities, will get help from team members from the University of Utah's SCI Institute and five other universities on how to best manage their scientific data.

The world's most important scientific facilities, from the CERN Large Hadron Collider to the National Radio Astronomy Observatory, deal with massive amounts of data every day that are mined, stored, analyzed, and visualized. It's a colossal task that requires help from the top minds in data management to handle.

The National Science Foundation (NSF) is turning to expert computer scientists from the University of Utah's Scientific Computing and Imaging Institute (SCI) and five other top universities to help large-scale research projects manage their data.

The new CI Compass project, an NSF center of excellence, is dedicated to helping these research facilities cope with their "data lifecycle" more effectively and affordably. CI Compass is funded by an $8 million, five-year NSF grant.

"The NSF has invested hundreds of millions of dollars in large facilities, such as massive telescopes and oceanographic observatories. The problem is that each has become a technological island, and it's difficult for them to complete their scientific mission and get up to speed in their data needs," says SCI faculty member Valerio Pascucci, who is also the director of the U's Center for Extreme Data Management Analysis and Visualization and co-lead on the CI Compass project.

Joining the U in this new center are researchers from Indiana University, Texas Tech University, the University of North Carolina at Chapel Hill, the University of Notre Dame, and the University of Southern California. In addition to Pascucci, the Utah research team includes School of Computing research associate professor Robert Ricci and researchers Giorgio Scorzelli and Steve Petruzza.

The team will be collaborating with other major facilities and research projects, including the IceCube Neutrino Observatory, the National Superconducting Cyclotron Laboratory, the Ocean Observatories Initiative, and the Laser Interferometer Gravitational-Wave Observatory.

Each of these facilities and projects generates terabytes and petabytes (one petabyte is a million gigabytes) of data that goes through a data lifecycle of being mined, analyzed, curated, and distributed to the public, Pascucci says.

Dr. Valerio Pascucci

The idea for the CI Compass began three years ago with a pilot project that was based on a collaboration among five NSF-funded facilities. The goal was to identify how the center could serve as a forum for the exchange of cyberinfrastructure knowledge across varying fields and facilities, establish best practices, provide expertise, and address technical workforce development and sustainability.

The NSF has invested hundreds of millions of dollars in large facilities and each has become a technological island.

Data from the collapsed Arecibo radio telescope are being safely moved and preserved to the Texas Advanced Computing Center of UT Austin. (Credit: Arecibo Observatory).

Looking Forward

The CIBC Legacy Transition

Female head and brain model data repository and pipeline. The data repository includes high-resolution T1 and T2-weighted magnetic resonance images (MRI), diffusion-weighted images (DWI), functional MRIs (fMRIs), and electroencephalogram recordings. From these images, we created diffusion tensor images (DTI), an eight-layer head and brain segmentation, and a 3D tetrahedral mesh in two resolutions, and we performed isotropic and anisotropic forward simulations studies.

What's Next for the CIBC Software Suite?

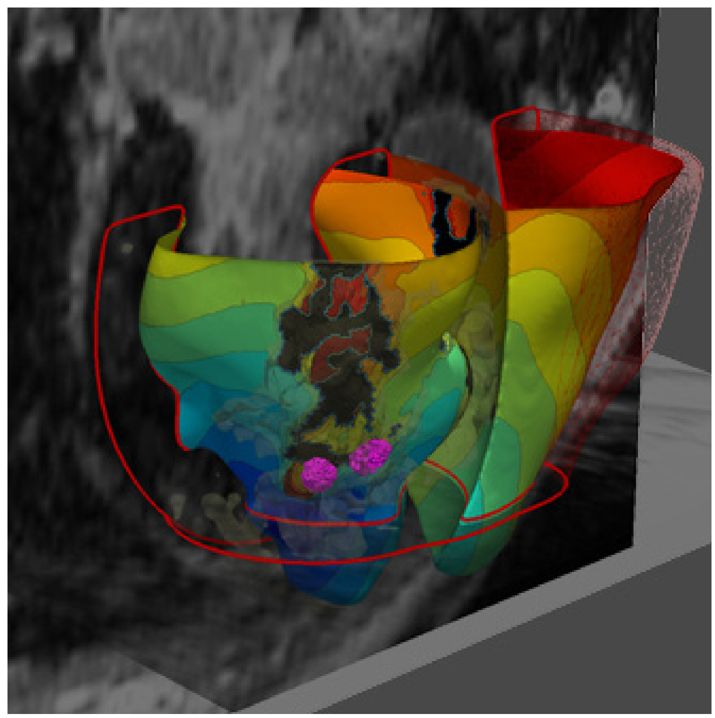
The Center for Integrative Biomedical Computing (CIBC) has an established, twenty-year record as a Biomedical Technology Research Resource (BTRR) whose focus has been technical research and development in the area of image-based modeling and simulation. The resulting legacy of scientific publications, novel algorithms, computational approaches, and especially a suite of software tools and data sets, can continue to support a vibrant research community even as the twilight requirements of the BTRR program dictate a time limit on NIH P41 funding.

However, although already in heavy use with thousands of downloads, many of the existing, open-source, software tools require additional hardening, documentation, and user-interface support to reach their full potential. More important, the software engineering and infrastructure, even though they represent the highest standards available from an academic center, are not yet robust and flexible enough to sustain easy maintenance and extension by a community outside the CIBC, a key element to ensuring the continued health and growth of the impact of these tools beyond the lifetime of the BTRR. Finally, there are existing collaborators and Driving Biomedical Project (DBP) partners whose research would suffer with the pending cessation of operations of the BTRR.

We have received funding for a three-year transition plan to achieve long-term sustainability of the software and data resources that the CIBC has produced. The goal of this plan is to complete the conversion of all the technical products achieved over the lifetime of the Center into well-crafted, validated computer code with all the necessary support for both users and future maintainers of the code base.

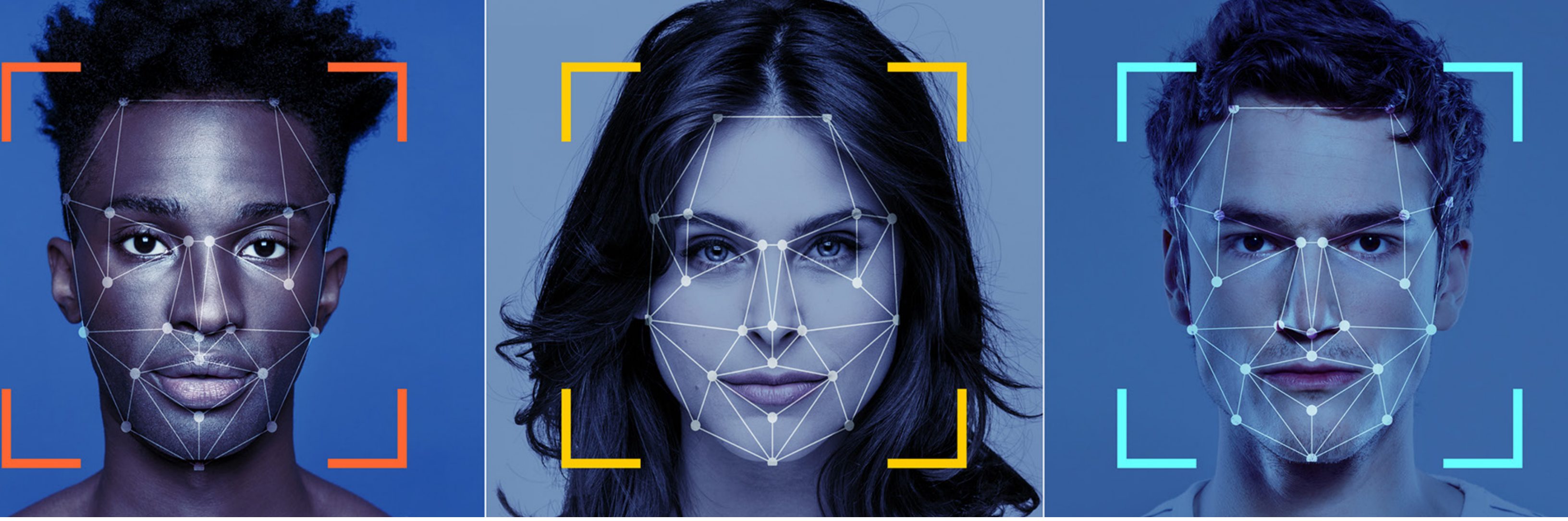
We seek to convert our open-source software into something far more valuable: community-supported and sustained software. The conversion will require the assistance of a professional software house that is familiar with the necessary steps and with the technical domain of our center, Kitware Inc.

Kitware is a company with a long history of helping biomedical researchers to develop highly complex software packages and libraries, including VTK, ITK, 3D Slicer, and ParaView. Members of the CIBC have collaborated with Kitware in the past, so there is a proven relationship on which to pursue the proposed transition plan. This combination of the domain-specific knowledge of the specific tools within the twenty years of the CIBC, along with the ability of Kitware to support and deploy software and data, will ensure a successful transition and a lasting legacy from this BTRR.



A 3-D virtual heart created with CIBC software by our collaborators at Johns Hopkins University.

We have a responsibility to the users of our software, insuring their research will continue its positive impact on the community.



Deep Learning and AI:
Insuring Fairness, Privacy, and Security

The past decade has witnessed the great success of deep learning in broad societal and commercial applications. However, conventional deep learning relies on fitting data with neural networks, which is known to produce models that lack resilience.

For instance, models used in autonomous driving are vulnerable to malicious attacks, e.g., putting an art sticker on a stop sign can cause the model to classify it as a speed limit sign; models used in facial recognition are known to be biased toward people of a certain race or gender; models in healthcare can be hacked to reconstruct the identities of patients that are used in training those models.

The next-generation deep learning paradigm needs to deliver resilient models that promote robustness to malicious attacks, fairness among users, and privacy preservation. This project aims to develop a comprehensive learning theory to enhance the model resilience of deep learning. The project will produce fast algorithms and new diagnostic tools for training, enhancing, visualizing, and interpreting model resilience, all of which can have broad research and societal significance.

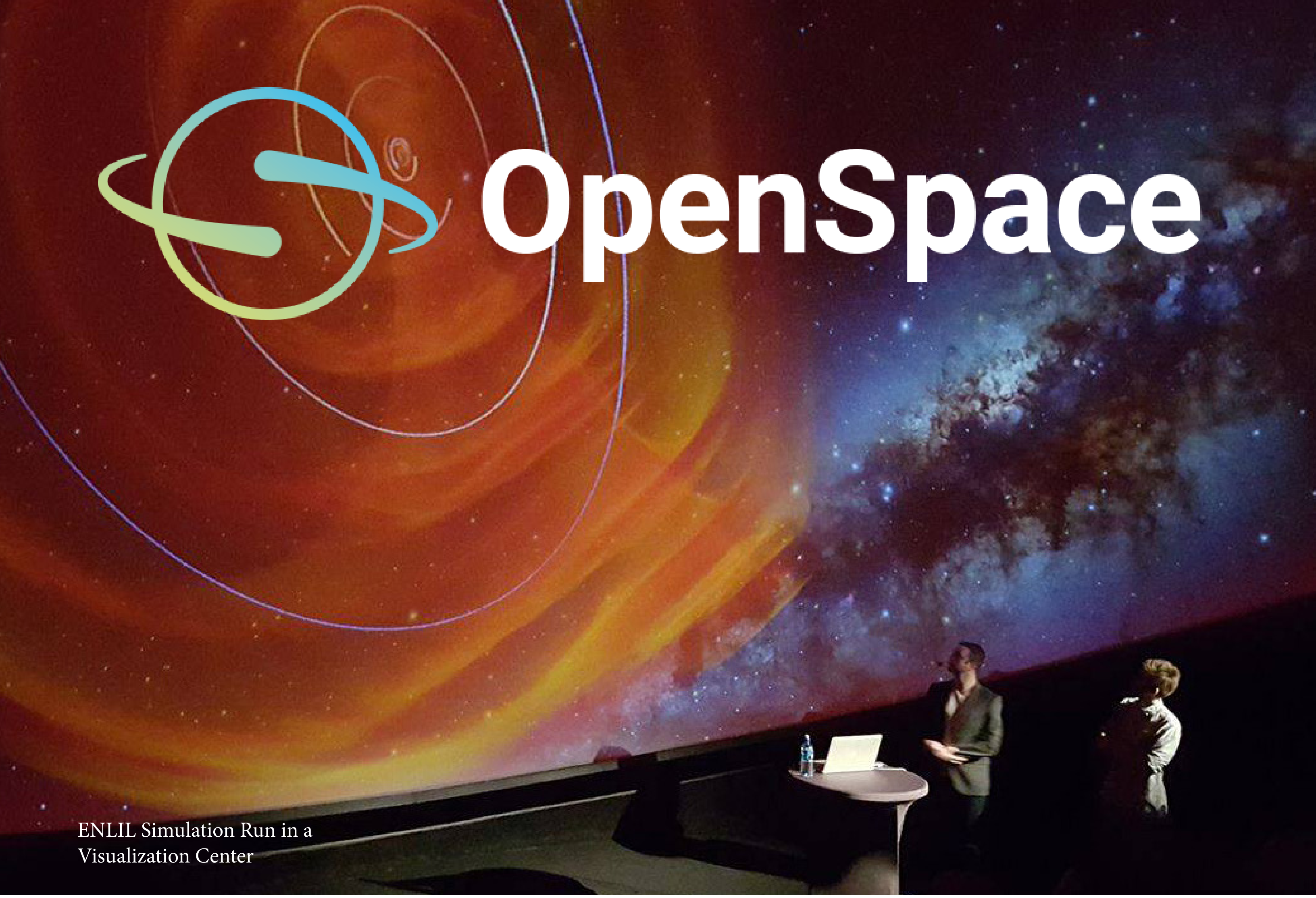
In this joint project, the investigators will collaboratively develop a comprehensive minimax learning theory that advances the fundamental understanding of minimax deep learning from the perspectives of optimization, resilience, and interpretability. These complementary theoretical developments, in turn, will guide the design of novel learning algorithms with substantially improved computational efficiency, statistical guarantees, and interpretability. The research includes three major thrusts. First, the investigators will develop a principled nonconvex minimax optimization theory that supports scalable, fast, and convergent gradient-descent-ascent algorithms for training complex minimax deep learning models. The theory will focus on analyzing the convergence rate and sample complexity of the developed algorithms.

Second, the investigators will formulate a measure of vulnerability of deep learning models and study how minimaxity can enhance their resilience against data, model, and task deviations. This theory will extend the statistical limits of deep learning. Lastly, the investigators will establish the mathematical foundations for a set of novel visual analytics techniques that increase the model interpretability of minimax learning. In particular, the theory will provide guidance on visualizing and interpreting model resilience.

This is a joint project among Bei Wang (SCI and School of Computing, University of Utah), Yi Zhou (Department of Electrical and Computer Engineering, University of Utah) and Jie Ding (School of Statistics, University of Minnesota).

"We need accurate and resilient models -- models that are more robust and less overfitted, and that perform well on diverse data sets beyond the test set."

Dr. Bei Wang



ENLIL Simulation Run in a Visualization Center

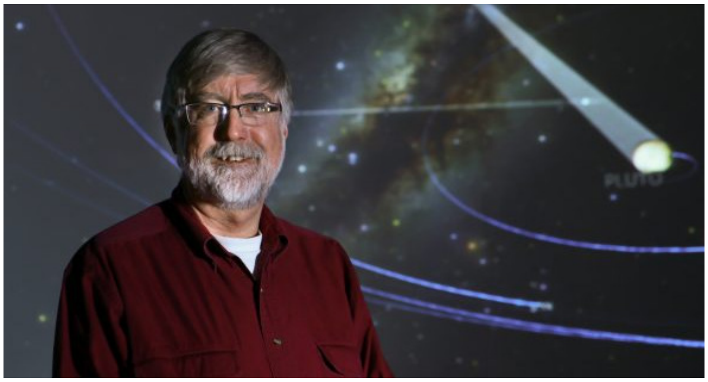
OpenSpace Renewed for Five More Years

OpenSpace is open-source interactive data visualization software designed to visualize the entire known universe and portray our ongoing efforts to investigate the cosmos.

Funded in part by NASA, OpenSpace brings the latest techniques from data visualization research to the general public. OpenSpace supports interactive presentation of dynamic data from observations, simulations, and space mission planning and operations. OpenSpace works on multiple operating systems, with an extensible architecture powering high-resolution tiled displays and planetarium domes. It makes use of the latest graphic card technologies for rapid data throughput. In addition, OpenSpace enables simultaneous connections across the globe, creating opportunies for shared experiences among audiences worldwide.

The grant is a collaboration with the American Museum of Natural History (AMNH), NYU, and the University of Linkopping, Sweden. As part of the renewal, Chuck Hansen (SCI, School of Computing) and his team will significantly strengthen OpenSpace as a visualization and live presentation tool with extensions such as Domecasting to connect numerous venues, supporting shared experiences across the country and around the globe, enabling scientists to import data directly from software packages, hosting user-generated content, and making it available to the wider user-community. The team will also enhance interaction modes and presentation tools and enable informal science institutions to create novel high-quality immersive experiences for their audiences.

You can learn more about OpenSpace and the exciting software they are providing at openspaceproject.com



Dr. Chuck Hansen

Advancing Discovery in Fluorescence Microscopy

Mouse forearm visualized with FluoRender

FluoRender is a software package for interactive visualization and analysis of multichannel and multidimensional fluorescence microscopy data.

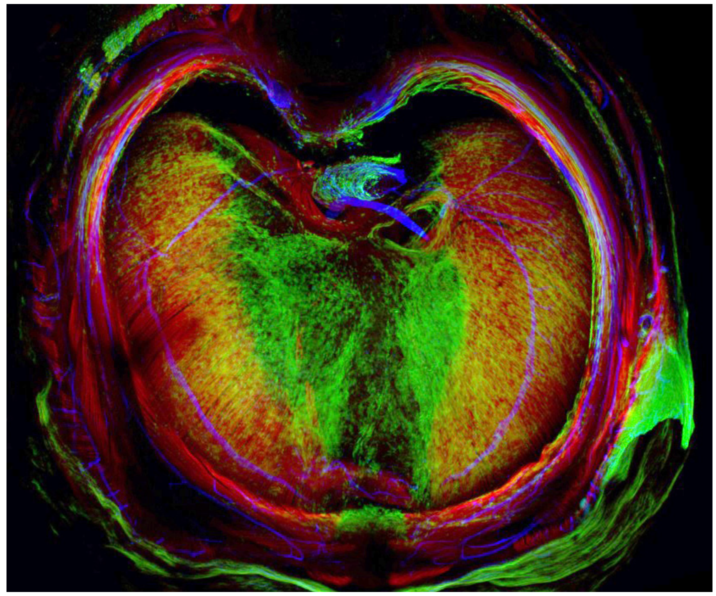
FluoRender is an interactive tool built upon a slice-based volume rendering kernel. FluoRender is capable of reading multiple channels of confocal volumes with a variety of formats, rendering and mixing channels with different modes, applying image enhancements, playing back time-sequence confocal data, extracting structures by painting on the volume rendered results, and visualizing polygon models from extracted structures along with volumetric data. Despite offering many integrated functionalities, the design of FluoRender provides a very accessible and intuitive interface to its users. FluoRender has been freely available for over 10 years and has contributed to many applications in biological research.

Confocal microscopy often focuses on extraction and comparison of geometric and topological properties of fine structures. FluoRender's advanced visualization capabilities facilitate qualitative analysis of confocal microscopy data; however, quantitative analysis typically requires extracting and measuring important features from the images, which has led the FluoRender team to add interactive segmentation functions to the software package.

FluoRender uses morphological diffusion for region growing. This method generates stable results for confocal data in real time. Furthermore, Fluorender's interaction scheme exposes to users the capabilities of a powerful visualization pipeline and lets them paint directly on volume rendering results in order to identify desired structures. A close integration of visualization and segmentation techniques within one tool allows users to extract structures of interest from their visualization workflow. In turn, segmentation further improves visualization results by removing occluding structures or emphasizing important structures.

This project will continue to serve the pressing needs of biologists utilizing fluorescence microscopy for flexible and reliable data analysis. FluoRender also addresses the problems in fundamental biomedical research that demand rapid measurements and workflow prototyping. The new round of NIH funding will allow further research and development in the following areas:

Interactive and collaborative measurement and analysis of large multidimensional microscopy data.
We will add rapid measurement tools specifically designed to meet the needs of three pilot studies of our close collaborators at the University of Utah. FluoRender will take full advantage of the latest graphics processing unit (GPU) computing techniques and streamed processing to handle large data at interactive speed, ensuring the success of the collaborative projects.



Mouse diaphragm visualized with FluoRender

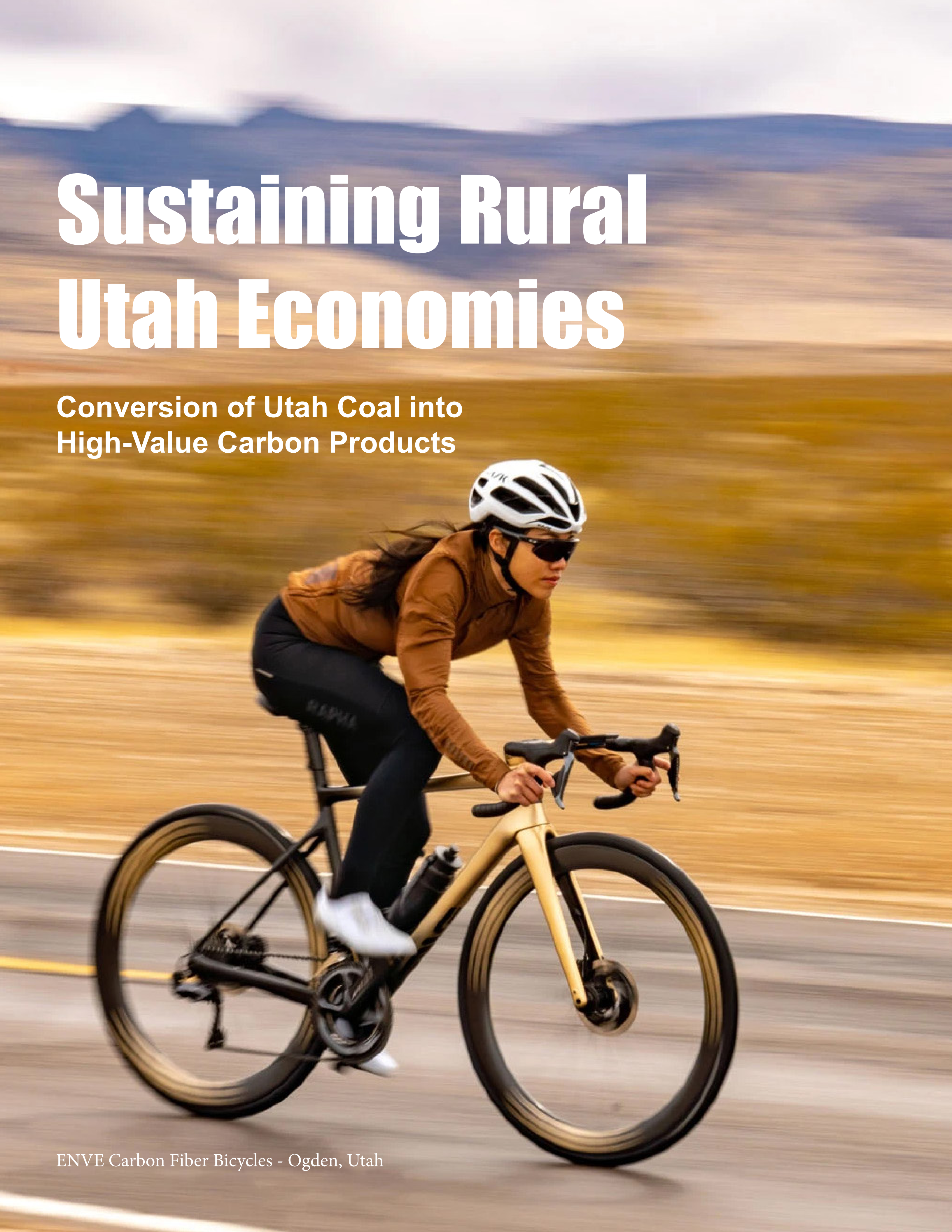
Applying machine learning to workflows and analysis.
We will support diverse data analysis needs from FluoRender users and provide automatic workflow assembly using machine learning. We will incorporate user interactions in a human-in-the-loop approach to address the problem of insufficient training examples and enhance interpretability of machine learning.

Immersive volumetric data presentation.
We will support the augmented reality (AR) headsets and holographic displays for immersive data analysis. These emerging display technologies will have more natural user interactions than the virtual reality (VR) devices and be advantageous for analyzing 3D data in scientific research.

Dr Yong Wan, chief architect of FluoRender

Sustaining Rural Utah Economies

Conversion of Utah Coal into High-Value Carbon Products

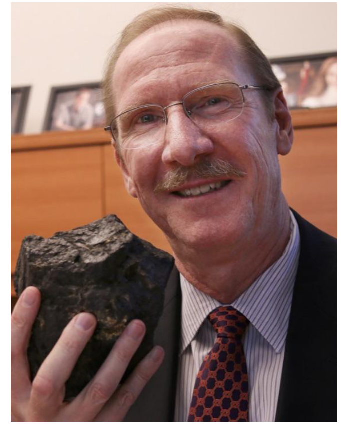


ENVE Carbon Fiber Bicycles - Ogden, Utah

The University of Utah's Scientific Computing and Imaging (SCI) Institute and Department of Chemical Engineering have been selected by the State of Utah to develop new data exploration and visualization capabilities, create new computer modeling tools to optimize materials, and perform laboratory-scale research on methods to support innovations focused on creating new solid carbon products made from Utah coal.

The team's research into the conversion of coal into high-tech products stands to revolutionize Utah's recovering coal industry and to accelerate the R&D and commercialization efforts necessary to manufacture new products at scale.

Dr. Chris Johnson



Dr. Eric Eddings

"The State of Utah's $500,000 investment in the SCI Institute and Department of Chemical Engineering efforts to develop new experimental computer modeling and data visualization capabilities is a excellent example of how SCI and the University of Utah can partner with the State of Utah to bring about long-term economic growth," said SCI's director, Manish Parashar. "Such partnerships that translate innovations in computing and data into broad, far-reaching scientific and societal impact are integral to SCI's mission."

This research provides an opportunity that enables Utah's coal-based, rural economies to again flourish, as new manufacturing techniques and processing plants come online in the future.

Application of the new technologies emerging from the research of the SCI Institute and Department of Chemical Engineering include carbon electrodes used in the batteries of electric cars, large-scale power storage associated with wind and solar power generation, or other consumer products yet to be invented.

One sustainable business model would be to construct a processing plant adjacent to an existing Utah coal mine that could produce coal-derived pitch required for the manufacture of carbon fiber and other carbon-based products and applications.

"The University of Utah expects that there will be new products and applications identified during our research that use carbon fiber created from Utah coal," said Eric Eddings, chair of the Department of Chemical Engineering. "Our goal is to see our research improve the overall economics of converting Utah coal into innovative products."

Utah researchers will take advantage of SCI's internationally renowned capabilities in computer modeling, scientific visualization, simulation, and data science, along with the cutting-edge experimental facilities within the Department of Chemical Engineering, to lead to new discoveries in the commercialization of coal-to-carbon products.

"These technical innovations have the real potential to help create economic opportunities for Utah's rural communities located in coal country," said project principal investigator and SCI Institute founder, Chris Johnson.

Carbon Fiber Bows - Hoyt Archery - Salt Lake City, Utah

KLOS Carbon Fiber Guitars - Provo, Utah

News and Notes

Honors and Awards

Manish Parashar Named ACM Fellow

Jeff Weiss Receives Distinguished Research Award

Alexandra Allan Wins Best Poster Presentation CMBBE 2021

Ingo Wald, SCI Alum, Wins Academy Award

Chris Johnson Receives the Leonardo Award

Wilson Good Wins Young Investigator's Award at Computing in Cardiology

Bei Wang Receives DOE Early Career Research Program Award

Chris Johnson Joins the NSF CISE Advisory Committee

Brian Zenger Receives University of Utah Graduate Fellowship

Lindsay Rupp Awarded NSF Graduate Research Fellowship and **Jake Bergquist** Receives Honorable Mention

Chris Johnson and **Charles Hansen** Inducted into The IEEE Visualization Academy

Sarang Joshi Elected as a Fellow of the American Institute for Medical and Biological Engineering (AIMBE)

Charles Hansen Appointed Distinguished Professor

Congratulations to **Sudhanshu Sane** who had two first-authored papers receive Best Paper Awards in one week. The first was at the International Conference on Computational Science, where more than 650 papers were submitted this year. The Second was at the 2021 Eurographics Symposium on Parallel Graphics and Visualization (EGPGV).

"**Investigating In Situ Reduction via Lagrangian Representations for Cosmology and Seismology Applications**" Sudhanshu Sane, Chris R. Johnson, and Hank Childs

"**Scalable In Situ Computation of Lagrangian Representations via Local Flow Maps**" Sudhanshu Sane, Abhishek Yenpure, Roxana Bujack, Matthew Larsen, Kenneth Moreland, Christoph Garth, Chris R. Johnson, and Hank Childs

Meet Max Sergeev - SCI's New Manager of Accounting & Finance

Max has over a decade of experience in accounting, finance, and federal grants/contracts management and has spent most of his career at the U. Prior to joining SCI, he worked at the Institute for Clean and Secure Energy and in the office of the Senior VP for Health Sciences Research Unit. Max earned his BS in Accounting and MBA from the University of Utah.

SCI Bids Farewell to Outstanding Faculty Members

Chris Butson earned his PhD in Biomedical Engineering from the University of Utah. His postdoctoral training was at the Cleveland Clinic and spent the next six years as a member of the Biotechnology & Bioengineering Center at the Medical College of Wisconsin, and as an associate professor in the Departments of Neurology, Neurosurgery, Psychiatry & Behavioral Health. Chris Joined the SCI faculty in 2014 and has since accepted a new position as professor & Fixel Endowed Chair of Neurotherapeutics at the University of Florida.

Miriah Meyer began her SCI life as a graduate student and completed her PhD in 2008. After graduating, she accepted a postdoctoral research fellowship at Harvard University. She joined SCI as an associate professor in 2011, co-creating the Vis Design Lab with Alex Lex. Miriah has recently accepted a position as a professor in the Division of Media & Information Technology at Linköping University, Sweden.

Deb Zemek - Keeping the Institute Alive During a Global Pandemic

In March 2020, the word came down that everyone had to quarantine at home. This meant that everyone had to pick up and move their equipment home for the foreseeable future. Quietly and rather somberly, people packed up and moved out. The uncertainty we all faced was unprecedented. As we all tried to grasp what this meant, we set up our home offices and settled in.

Our building at first was unlocked, as were the elevators, which left our floors unprotected. We decided that a couple of us could come in, those of us who needed to be here in the building to keep things going. For a lot of the time I was alone. It was really unnerving to be here alone. It was like time had stopped. The quiet was like a blanket, stifling at times. I would put music or TV on just to have a break from the silence. I gathered up everyone's plants and put them all in an empty office so I could take care of them.

Continued on next page

Faculty Focus on Jeff Weiss

Jeff Weiss received his bachelor's and master's degrees in bioengineering at the University of California, San Diego, his doctorate in bioengineering at the University of Utah in 1994, and completed postdoctoral training with the Applied Mechanics Group at Lawrence Livermore National Laboratory.

Jeff joined the U as a tenure-track faculty member in 2000, as a biomedical engineering assistant professor and associate professor in 2003. He was associate chair and Director of Graduate Studies for the department from 2006 to 2009 and was named professor in 2010. He is also a faculty member of the U's Scientific Computing and Imaging Institute.

Jeff directs the Muskuloskeletal Research Laboratory, and his research focuses on experimental and computational biomechanics, primarily applied to the musculoskeletal and cardiovascular soft tissues. He developed and validated techniques for subject-specific computational modeling of joint mechanics and applied these techniques to the mechanics of knee ligaments and patient-specific modeling of mechanics in the hip. Weiss also developed finite-element-based techniques to incorporate medical image data directly into biomechanics analyses for strain measurement.

Weiss has received the William H. Harris Award from the Orthopaedic Research Society, the ASME Van C. Mow Medal, the ASME YC Fung Young Investigator Award, and a National Science Foundation CAREER Award. He was elected as a Fellow of the American Institute for Medical and Biological Engineering and Fellow of the American Society of Mechanical Engineers.

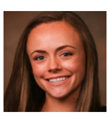
Continued from previous page

We thought it would only last for a couple of months.

Everything shut down. The University sent almost everyone home and locked all the buildings. All of the offices were sanitized with tape across them so we could tell if anyone had entered them. The elevator was locked. The skeleton crew continued to come in most days to keep things running. We stocked up on cleaning supplies as much as we could, and I cleaned several times a day. Things we took for granted suddenly got very difficult. Deliveries had to be rerouted. Things that were previously taboo were now the only way we could do them. Zoom, which we had all used a couple of times, was a household word. I had to keep track of anyone who stepped foot on our floors, just in case. The days turned into weeks and then months. It seemed like it would never end. We lost track of people and worried that something had happened to someone and we didn't know. I think for most people it was extremely stressful and continues to be for some. Things are still not back to "normal," but there are more people coming in and it's nice to have company here! A lot has changed, but ultimately, the SCI family will prevail.

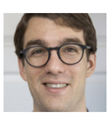
- Deb

SCI Graduates 2020-21



Shana Black - Multimodal Neuroimaging to Guide Therapeutic Approaches for Neuropathic Pain After Spinal Cord Injury

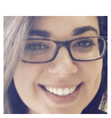
Markus Foote - Image Analysis in Global Health: Application to Greenhouse Gas Monitoring and Radiotherapy Motion Management



Will Usher - Adaptive Multiresolution Techniques for I/O, Data Layout, and Visualization of Massive Simulations

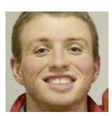
Brian Zenger - Experimental Examination of Partial Occlusion Acute Myocardial Ischemia

Praful Agrawal - Estimating Optimal Generative Models for Statistical Shape Analysis

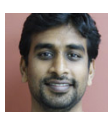


Carolina Nobre - Visualizing Multivariate Networks

Jared Zitnay - Molecular Level Collagen Mechanical Damage in Tendons



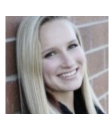
Gordon Duffley - Utilizing Technology to Improve Deep Brain Stimulation Programming



Ashok Jallepalli - Visualization and Feature Detection of High-Order Simulation Data

Sourabh Palande - Utilizing Topological Structures of Data for Machine Learning

Jocelyn Todd - Chondral Defects and Chondrolabral Damage in the Hip



Kara A. Johnson - Deep Brain Stimulation for Tourette Syndrome: Multicenter Studies to Identify Predictors of Therapeutic Response

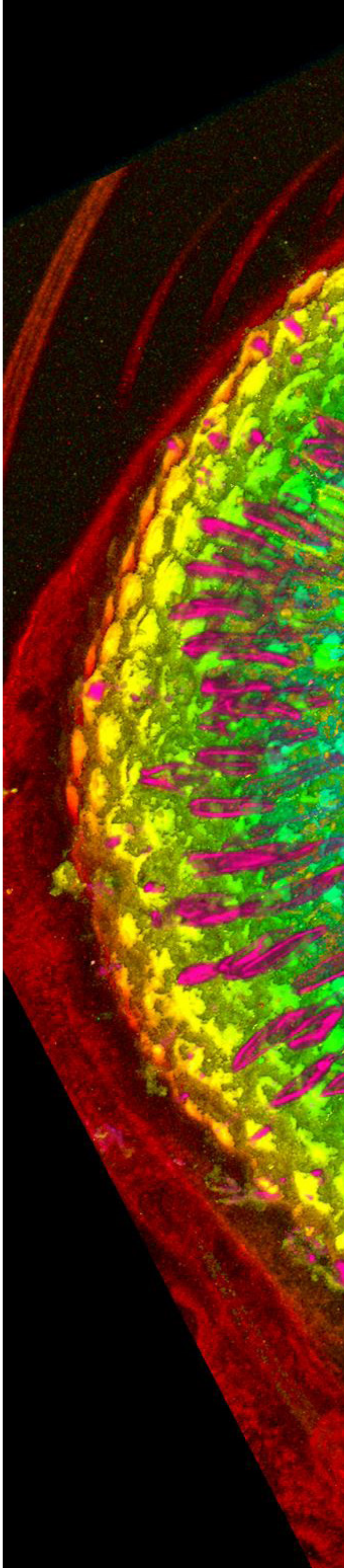
Wilson W. Good - Characterizing the Transient Electrophysiological Signature of Acute Myocardial Ischemia

Blake Zimmerman - Improving Treatment Assessment of Magnetic Resonance Guided Focused Ultrasound

Eleanor Wong - Classification and Regression Methods for Functional Brain Network Analysis

Anuja Sharma - Temporal Modeling and Analysis of Distribution-Valued Functional Curves: Application to Diffusion Tensor Imaging

Damodar Sahasrabudhe - Enhancing Asynchronous Many-Task Runtime Systems for Next-Generation Architectures and Exascale Supercomputers



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