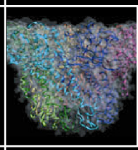
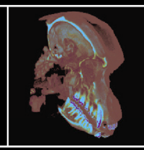
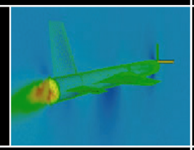
i-LIGHT SYMPOSIUM 2005

PURDUE UNIVERSITY

INDIANA UNIVERSITY



Indiana's premier forum for high performance networking, computing, and advanced visualization

SEPTEMBER 21 – 22, 2005

# I-LIGHT SYMPOSIUM 2005 PROCEEDINGS

I-LIGHT

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## Acknowledgments

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Any opinions, findings and conclusions, or recommendations expressed in the 2005 I-Light Symposium Proceedings are those of the researchers and authors and do not necessarily reflect the views of the granting agencies.

# I-LIGHT Symposium

September 21-22, 2005
University Place Conference Center
Indiana University-Purdue University Indianapolis
Indianapolis, Indiana

Dear Colleagues,

On behalf of Purdue University and Indiana University, we thank you for participating in the 2005 I-Light Symposium, Indiana's premier forum for high performance networking, computing, visualization, and collaboration.

This year's Symposium features an impressive array of timely information presented through presentations, demonstrations, and poster sessions by researchers and information technologists from campuses across the state highlighting advances in high performance computing, visualization, and networking, that focus on ways the I-Light network can enrich your endeavors.

We encourage you to take this opportunity to explore possibilities for collaboration, research, and scholarship using the I-Light Optical Fiber Infrastructure that connects Indiana University Bloomington, Indiana University–Purdue University Indianapolis, and Purdue University with each other and with Internet2.

Yours sincerely,

Jim Bottum
Vice President for Information Technology
Purdue University

Michael McRobbie
Vice President for Information Technology and CIO
Vice President for Research
Indiana University

Gary Bertoline
Associate Vice President for Discovery Resources and Director of the Envision Center
ITaP, Purdue University
Purdue University
I-Light 2005 Co-Chair

Eric Wernert
Associate Director for Research and Academic Computing
Indiana University
I-Light 2005 Co-Chair

I-LIGHT

# Program
# Wednesday, September 21, 2005

| | |
|---|---|
| **8:00-9:00am** | **Check-in, Poster Setup, Continental Breakfast** |
| **9:00-9:15am** | **Welcome Remarks**<br>Michael McRobbie<br>Vice President for Research and Information Technology<br>Indiana University |
| **9:15-10:10am** | **Plenary Session:**<br>**"Virtual Reality Center as a Campus-wide Research Resource"**<br>Carolina Cruz-Neira, Ph.D.<br>Virtual Reality Applications Center<br>Iowa State University |
| **10:40-11:55am** | **Parallel Session 1:**<br>Engineering Applications - UPCC Auditorium<br>Advanced Interfaces I - UPCC 118<br>Scientific Visualization I - UPCC 132 |
| **11:55-1:10pm** | **Lunch – University Place Bistro** |
| **1:10-2:05pm** | **Plenary Session:**<br>**"The OptIPuter"**<br>Jason Leigh, Ph.D.<br>Electronic Visualization Lab<br>University of Illinois at Chicago |
| **2:35-3:50pm** | **Parallel Session 2:**<br>Telecollaboration I - UPCC Auditorium<br>Information Visualization I - UPCC 118<br>Systems Development - UPCC 132 |
| **4:15-5:30pm** | **Parallel Session 3:**<br>Telecollaboration II - UPCC 132<br>Scientific Visualization II - UPCC Auditorium<br>Educational Applications - UPCC 118 |
| **6:00-8:00pm** | **Reception & Demos**<br>Informatics and Communications Technology Complex |

## Thursday, September 22, 2005

| | |
|---|---|
| **8:30-8:40am** | **Welcome Remarks**<br>James Bottum<br>Vice President for Information Technology<br>Purdue University |
| **8:40-9:35am** | **Plenary Session:**<br>**"Imaging and Visualization: Cell to Organism"**<br>Greg Jones, Ph.D.<br>SCI Institute<br>University of Utah |
| **9:45-11:00am** | **Parallel Session 4:**<br>Bio-Medical Applications - UPCC Auditorium<br>Information Visualization II - UPCC 118<br>Advanced Interfaces II - UPCC 231 |
| **11:10-11:30am** | **"Broader Impacts of I-Light and Inter-Institution Collaborations"**<br>Craig A. Stewart<br>Associate Vice President for Research & Academic Computing<br>Indiana University<br>Gary Bertoline<br>Associate Vice President for Discovery Resources and Director of the Envision Center, ITaP<br>Purdue University |
| **11:30-12:30pm** | **Lunch – University Place Bistro** |
| **12:30-1:30pm** | **Plenary Session:**<br>**"The NSF's Evolving Cyberinfrastructure Program"**<br>Guy Almes, Ph.D.<br>Program Director, Directorate for Computer and Information Science and Engineering, Shared Cyberinfrastructure Division<br>National Science Foundation |
| **1:30-1:50pm** | **"Overview of TeraGrid Activities at IU and Purdue"**<br>M. Scott McCaulay<br>TeraGrid Site Lead<br>Indiana University<br>Sebastien Goasguen<br>TeraGrid Site Lead<br>Purdue University |
| **1:50-3:05pm** | **Grid Systems and Applications I** |
| **3:15-4:55pm** | **Grid Systems and Applications II** |
| **4:55-5:00pm** | **Closing** |

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# I-Light: A Network for Collaboration Between Indiana University and Purdue University

Craig A. Stewart[1] and Gary Bertoline[2]

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## Abstract

Indiana University and Purdue University have collaborated in the development and deployment of advanced information technology systems and services since before the development of the I-Light network. The I-Light network has enabled dramatic new possibilities for collaboration in the development of cyberinfrastructure in the State of Indiana. I-Light, and the cyberinfrastructure created by Indiana and Purdue Universities, has enabled new research discoveries by the State's leading researchers. Collaboration between IU and Purdue has brought significant federal grant money into the state in support of information technology, and the I-Light network has increased the competitiveness of IU and Purdue for major federal funding of research and development activities in the State. The I-Light network has, directly and indirectly, improved the quality of life in Indiana.

## Introduction

The I-Light Network [2] is the basis for the advanced research cyberinfrastructure of the State of Indiana and the foundation of research collaborations between the two largest and best research universities in the State: Indiana and Purdue. Cyberinfrastructure is a new term coined as an analogy with other types of infrastructure, such as the nation’s electrical infrastructure. Cyberinfrastructure refers to an infrastructure for knowledge. [16] It is composed of high performance computers, massive data storage systems, data resources, advanced instruments, sensor networks, and people all linked together by advanced software and high performance networks to improve research productivity and enable new breakthroughs not in other ways possible. The purpose of this paper is to review the history of research collaborations predicated on the development, deployment, and use of the collective cyberinfrastructure resources of Indiana University (IU) and Purdue University (Purdue) – collaborations that have made possible dramatic new research results and have brought economic benefits to the State of Indiana.

## History of IU and Purdue collaboration so far this century

Indiana and Purdue Universities began collaborating in networking and research computing late in the 1990s. Together, they requested funding for a high-performance, optical-fiber network that would connect Indiana University’s Bloomington campus, Purdue University’s

West Lafayette campus, and the joint Indiana University-Purdue University at Indianapolis. In 1999, the Indiana General Assembly approved the creation and funding of the I-Light network with a $5.3M state appropriation. The I-Light network was officially lit by Governor O'Bannon on Dec 11, 2001.

Collaboration in research computing between Purdue and IU began in 2000, when IU and Purdue led a joint display at the 2000 Supercomputing Conference (with the University of Notre Dame as a partner). The annual Supercomputing Conference Series [11], put on by the Association of Computing Machinery and Institute of Electrical and Electronics Engineers (IEEE), is the largest and most important conference in supercomputing, grid computing, and advanced networking in the world. The joint IU/Purdue/Notre Dame display, titled “Research@Indiana,” represented the first time in the history of the conference that all of the major research universities of any state had come together to disseminate information about and promote their home state. This display made quite an impression both in the quality of the display itself and the collaborative effort to promote the State of Indiana.


**Figure 1. Photograph of joint Indiana University, Purdue University, University of Notre Dame display at SC00 in Dallas, Texas**

IU and Purdue deepened their relationship in research computing significantly during 2001. At that time, both universities had large IBM SP supercomputers. Purdue's was located in West Lafayette; IU's was geographically distributed between Indianapolis and Bloomington. IU's IBM SP supercomputer was upgraded in 2001 to become the first university-owned supercomputer in the nation capable of one trillion mathematical operations per second. Purdue’s IBM SP was smaller in calculation speed, but included more memory per processor than IU’s. This created an opportunity to collaborate that benefited both universities. IU and Purdue agreed to periodically link their supercomputers together via the I-Light network, using special capabilities of the IBM SP software and the I-Light network. Several significant scientific accomplishments resulted from this, including the following:

- *A realistic simulation of the 9/11 Pentagon airplane crash.* This simulation used the finite element method (FEM) to model the airliner’s interaction with the steel-reinforced concrete columns of the building, and used realistic visualization techniques to produce a high quality animation of the crash. FEM modeling produces a mesh of millions of interacting elements governed by complicated equations which require many hours of computation to solve. Onetenth of a second of this simulation took 95 hours of computation on a supercomputer. [7]

- *The creation of the Center for Computational Homeland Security at Purdue University.* Using a Synthetic Environment of Analysis and Simulation (SEAS) the Center performs regular simulations of cyberterrorism, bioterrorism, and infrastructure terrorism scenarios, and the governmental, commercial, and economic responses to them. In one simulation in particular, federal, state, and local officials tested and analyzed the responses to a bioterrorism scenario on campus using hand-held wireless computers linked via I-Light. [8][9]

- *The SC2003 High Performance Computing Challenge Award.* The project, "Global analysis of arthropod evolution," won the HPC Challenge Award in the category of "Most Geographically Distributed Application." The science behind the project was to determine if six-legged arthropods are a single evolutionary family, or if "six-leggedness" has arisen multiple times, independently, during the course of evolution. Analysis of evolutionary relationships based on DNA sequences requires massive amounts of computer time. For this project, the University Information Technology Services (UITS), the Indiana University Center for Genomics and Bioinformatics (CGB), and the High Performance Computing Center of the University of Stuttgart (HLRS) put together a global computing grid that had components in every continent but Antarctica to solve the problem. The I-Light linkage played an important role in this grid. [4][13]

Based on the success of the periodic aggregation of IU and Purdue supercomputers, the two universities entered into a cycle sharing agreement, meaning that researchers at IU could use Purdue supercomputers when there was unused capacity on those systems, and vice versa. One of the critical facts about supercomputers is that they do not age gracefully. The useful life of a supercomputer is somewhere between three and five years. Computing cycles that are unused are simply lost forever. By forging an agreement between IU and Purdue that ensured all supercomputers would be used to their practical maximums, the two universities ensured that the State's investment in these supercomputers would result in the maximum benefit to the state and the nation. More than one million hours of processor time were shared during the subsequent years in which this agreement was in effect.

Purdue and Indiana continued their joint leadership of a display at the annual Supercomputing conference; in 2001 and 2002 the collaborative display focused on the State of Indiana involved the Rose-Hulman Institute of Technology as well as Indiana, Purdue, and Notre Dame. This display greatly elevated the national reputation of the state as a whole in advanced information technology.

2003 saw a quantum leap in the depth of the relationship between Purdue and Indiana, as the two universities jointly wrote a proposal to the National Science Foundation to become partners in the TeraGrid. The TeraGrid is the world's largest, most comprehensive distributed cyberinfrastructure for open scientific research [14], and is the National Science Foundation's flagship effort to build a national cyberinfrastructure. The two universities were awarded a total of $2,985,199 from 2003 to 2005 to provide computing, data, and advanced visualization resources for use by the national research community. The collaborative relationship between Indiana and Purdue Universities has deepened and become more productive as a result of the joint participation in the TeraGrid. It has provided opportunities for the staff and faculty of the two universities to work together more effectively. Together Purdue and Indiana have worked within the TeraGrid to ensure the delivery of tangible benefits to researchers of every state in the nation, including Indiana. At the same time, participation in the TeraGrid has created better administrative vehicles for certain activities. For example, the TeraGrid provides a mechanism for allocation of computing cycles to researchers, thus eliminating the need for the cycle sharing agreement between Purdue and IU. Indiana and Purdue Universities have received four subsequent federal grant awards directly related to the TeraGrid, and the TeraGrid will be a focal point of collaboration within the State and with the nation for years to come.


**Figure 2. Map of the sites participating in the NSF-funded TeraGrid "Extensible Terascale Facility" project. http://www.teragrid.org/**

The Purdue/Indiana collaboration has aspects that go well beyond grid computing and supercomputing. Indiana and Purdue Universities provide important data resources to researchers in the State of Indiana and to the nation (via the World Wide Web and the TeraGrid). A few of the most important data resources are:

- *Purdue Terrestrial Observatory* – a real-time remote sensing ground station array, receiving a wide range of spectral data, over a wide range of spatial resolutions. The data is sent from sensors carried on American, European, Canadian, Japanese and Russian satellites. This data is then deposited real-time into GIS, distributed to research labs, and archived for future research. [10]

- *State of Indiana GIS Data* – a collection of more than 7.5 terabytes of Indiana geospatial data, including aerial photos, topographic maps, and digital elevation data, available for download to the public, and connected to Indiana University's Massive Data Storage System (MDSS). [3]

- *Life sciences data via the IU Centralized Life Science data set* – a SQL-based interface for querying a variety of public Life Sciences data, including sequence databanks and non-relational datasets that have been transformed into relational tables so that they can be searched and used more effectively. [6]

Another way in which Purdue and Indiana Universities bring distinction to the state is through management of cutting-edge 3D visualization facilities. The Purdue Envision Center is an interdisciplinary, high-performance visualization facility to support research and teaching at Purdue University. The Center allows Purdue faculty to display and visually interact with scientific data in innovative ways, and to advance the fields of visualization and perception through research and development in computer graphics hardware and software. [1]

**Figure 3. Purdue researchers analyze aerial photographs in The Purdue Envision Center**

In 2005, Indiana University installed on the IUPUI campus a reconfigurable virtual reality theater in the ICTC building. The MoVE Lite system from BARCO's Virtual and Augmented Reality Division provides an immersive experience using one of the highest resolution and brightest 3D projection systems anywhere. The displays may be driven from any of several advanced computing platforms, including an SGI Onyx4, an SGI Prism, and an Opteron-based Linux cluster, and features wireless, optical tracking of multiple input devices over a 30' x 10' space. The flexible configurability and the range of computing systems and input devices allow researchers, educators, and artists to tailor the VR theater for their applications and audiences. The BARCO VR Theater can support scenarios ranging from wide screen design reviews for collaborative teams, to panoramic, semi-immersive visualization for classes, to fully immersive artistic environments for small groups. [5]

IU and Purdue are at work right now extending their collaboration through research in virtual environments, in which we will link the advanced visualization facilities located in West Lafayette and Indianapolis.

**Figure 4. Visitors to the ICTC explore and interactive virtual reality piece of art by IU Assistant Professor Margaret Dolinsky**

## It's about the science

Collaboration between two great universities and bringing grant money into the State is important, but new science and new innovations are what matter most. Here are a few of the scientific collaborations now going on that are facilitated by the I-Light network, and the collaborations that have developed between Indiana and Purdue Universities as a result:

- *Collaborative Initiative on Fetal Alcohol Spectrum Disorder.* Fetal Alcohol Spectrum Disorder is a suite of maladies that affect children whose mothers drank alcohol while pregnant. Researchers in the IU School of Medicine, Purdue School of Science, and IU's University Information Technology Services are collaborating to design new and better ways to diagnose FASD with optical 3-D scanners; data for the consortium as a whole is being stored at IU – an effort made possible by I-Light. [12]
- *The Indiana Center for Insect Genomics.* The Indiana Center for Insect Genomics aims to develop new ways to control insect pests by better understanding their genomics and genetic vulnerabilities. This institute is supported by an Indiana 21st Century Center of Excellence Award, and will make use of the grid cyberinfrastructure available within the State of Indiana. The Center itself is a collaboration of the Purdue University Department of Entomology, the University of Notre Dame Center for Tropical Disease Research and Training, and the IU Bloomington Center for Genomics and Bioinformatics. [15]
- *The Purdue Center for Computational Homeland Security.* The Center for Computational Homeland Security focuses on the creation, validation, and implementation of new technology, knowledge, and tools to be used in aiding homeland security. The center brings together people, technology, and infrastructure capitalizing on Indiana's advanced computational TeraGrid and 21st Century funded Synthetic Environment for Analysis and Simulations (SEAS) technology. The CCHS has already made extensive use of simulations running simultaneously on Purdue and IU supercomputers in West Lafayette, Indianapolis, and Bloomington. [8][9]
- *Telecollaborative Class Instruction.* Drs. Eric Wernert (UITS, Indiana University) and Dr. Laura Arns (IT@P, Purdue University) used the telecollaborative capabilities of the I-Light network to team teach a course called "Introduction to Virtual Environments." This course was taught simultaneously to Purdue and IU students by Drs. Arns and Wernert – and this capability was made possible by the I-Light network.

## Impact on the State of Indiana

The collaboration between Purdue and Indiana Universities in research computing, built on the capabilities of the I-Light network, has had tremendous benefits for the State of Indiana. I-Light has benefited the research and educational missions of Indiana and Purdue Universities. In many areas where IU and Purdue do not compete, because of different areas of focus and concentration, the I-Light network has strengthened the grant competitiveness of each of the universities. In some areas where IU and Purdue might compete – such as IT infrastructure – they have most often chosen to collaborate. As a result, the State of Indiana is one of just six states in the nation that are home to resource providers who are responsible for the TeraGrid (the others are California, Illinois, Tennessee, Pennsylvania, and Texas.) Hundreds of millions of dollars of federal grant money are brought into the State of Indiana each year by Indiana and Purdue Universities. The I-Light network and the State's advanced cyberinfrastructure have been critical assets as IU and Purdue have successfully competed for federal grant funding.

Purdue and Indiana Universities compete in many contexts. But by carefully collaborating on infrastructure, and on select grant opportunities, the State of Indiana's two leading research universities are enabling new research and the development of new technologies, making possible discoveries and therapies that improve human health, and creating high paying jobs thanks to federal grant dollars – thus improving the overall quality of life for Hoosiers.

## Acknowledgements

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The authors would like to thank the staff of Information Technology @ Purdue and University Information Technology Services of Indiana University, and the Pervasive Technology Labs of Indiana University, who have made possible the exciting activities reported here. The authors would also like to thank the faculty of Purdue and Indiana Universities, whose research it is our rewarding job to support.

This paper is dedicated in honor of two colleagues who helped forge the relationships between Indiana and Purdue Universities – Mary Moyars-Johnson and the late David Moffett, both former Associate Vice Presidents of Purdue University.

## References


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[16] Wikipedia. "Cyberinfrastructure." <http://en.wikipedia.org/wiki/Cyberinfrastructure>

# Featured Speakers

***Carolina Cruz-Neira, Ph.D.***
*Virtual Reality Applications Center*
*Iowa State University*
*Ames, Iowa*

Dr. Carolina Cruz is the Stanley Chair in Interdisciplinary Engineering and a professor in the Industrial and Manufacturing Systems Engineering Department at Iowa State University in Ames, Iowa. She is also the founder and vice president for business relations of Infiscape.

Until 2005, she was the associate director of the Virtual Reality Applications Center and the associate chair of the Human-Computer Interaction Graduate Program at Iowa State University. In 1997, she was featured by Business Week magazine as a "rising research star" in the new generation of computer science pioneers. In March of 2000, Dr. Cruz received the Iowa State Foundation Award for Early Achievement in Research. In June 2001, she received the Boeing A.D. Welliver Award.

Providing applicability and simplicity has driven her research as a computer engineer. These two factors have defined her three current areas of work, all of them in the context of virtual reality:

Complex software systems that integrate a variety of hardware components to create advanced immersive environments, including the development of collaborative paradigms among geographically distributed virtual reality sites and resources;
Applications of VR technology in science, engineering, and art;
Usability studies of working virtual environments.
Dr. Cruz completed her doctoral studies in Electrical Engineering and Computer Science (EECS) at the Electronic Visualization Laboratory (EVL) at the University of Illinois at Chicago in May 1995. Her Ph.D. dissertation included the design of the CAVE(TM) Virtual Reality Environment, the CAVE Library software specifications and implementation, and preliminary research on CAVE-Supercomputing integration. She shares the Record of Invention of the CAVE with Tom DeFanti and Dan Sandin.

In 1991, she received a Master's degree in EECS at EVL at the University of Illinois at Chicago and graduated cum laude in systems engineering at the Universidad Metropolitana at Caracas, Venezuela in 1987.

# Wednesday, September 21 – 9:15am-10:10am

### Virtual Reality Center as a Campus-wide Research Resource

The Virtual Reality Applications Center (VRAC) was created in 2000, evolving from the Iowa Center for Emerging Manufacturing Technologies and centralizing research activities in the area of virtual reality and interactive graphics. VRAC started as a small group of five faculty and twelve students; today it houses forty-five faculty from all colleges on campus and over 200 students. Its current funding is from federal and private sources in the form of grants, contracts, and donations. This talk will discuss the successes and struggles required to create, grow, and sustain VRAC within the university environment, as well as the challenges faced along the way.

***Jason Leigh, Ph.D.***
*Electronic Visualization Lab*
*University of Illinois at Chicago*
*Chicago, Illinois*

Dr. Jason Leigh is an associate professor of computer science and co-director of the Electronic Visualization Laboratory (EVL) at the University of Illinois at Chicago (UIC).

His current areas of interest include: developing techniques for interactive, remote visualization of massive data sets over high-speed photonic networks; and supporting long-term collaborative work in amplified collaboration environments.

Dr. Leigh is co-chair of the Global Grid Forum's Advanced Collaborative Environments research group and is a co-founder of the GeoWall Consortium. He now leads EVL's research on the OptIPuter, a cluster of distributed computers interconnected by photonic networks.

Leigh has led EVL's tele-immersion research agenda since 1995 after having developed the first networked CAVE application in 1992. The outcome of his work has been in active use by General Motors, Hughes Research Labs, Searle/Monsanto, members of the NSF-funded PACI Alliance, the Next Generation Internet and Internet2, and collaborators around the world including: the Cooperative Research Centre for Advanced Computational Systems in Australia, Institute of High Performance Computing in Singapore, Intelligent Modeling Laboratory at Tokyo University, and the National Center for High-Performance Computing in Taiwan; and many others.

## Wednesday, September 21, 1:10-2:05pm

### The OptIPuter

The OptIPuter is a project examining a new model of computing in which ultra-high-speed networks form the backplane of a planetary-scale computer. OptIPuter research focuses on developing technology to enable the real-time collaboration and visualization of very large, time-varying data sets for the earth sciences and the biosciences. This presentation describes the synergistic international network, middleware, visualization, and collaboration research that is needed to provide an end-to-end solution for research scientists.

***Greg Jones, Ph.D.***
*Scientific Computing and Imaging Institute*
*University of Utah*
*Salt Lake City, Utah*

Dr. Greg Jones joined the SCI Institute in April of 2000, where he is presently the associate director. His previous experience includes positions in research, industry, and management. During his graduate years at the University of New Mexico's School of Medicine, he combined fluorescence spectroscopy with mathematical modeling methods to describe intra-molecular interactions between bacterial lipopolysaccharide and lipopolysaccharide binding protein, an acute phase, hepatic protein. After receiving his Ph.D. in Biomedical Sciences in 1997, Dr. Jones did post-doctoral work in the Department of Radiology at the University of Utah as a member of the Functional Brain Imaging Group where his work focused on functional MRI and magnetoencephalography. Before joining the SCI Institute, he worked as a senior project manager in the Health Sciences Group for Storage Technologies Inc. Dr. Jones holds a Bachelor's degree in physics from the University of New Mexico and a Masters of Business Administration from the Executive MBA Program at the David Eccles School of Management at the University of Utah.

# Thursday, September 22, 8:40-9:35am

### Imaging and Visualization: Cell to Organism

The next decade will see an explosion in the use and the scope of medical imaging and the fuel for this fire will be the combination of our increasing abilities in the study of genetics, new imaging techniques, and advances in biomedical computing and visualization. From Leonardo Da Vinci's anatomical drawings, to Wilhelm Roentgen's first X-ray of the human hand, to today's use of computer graphics and virtual reality to "fly through" three-dimensional reconstructions of magnetic resonance imaging (MRI) data, researchers have for centuries used visualization in their quest to understand human physiology. Each new visualization technique has brought researchers closer to capturing the complexity and beauty of human anatomy and physiology. Though the complexity of the human body still outstrips the capabilities of even the largest computational systems, and will do so for some time to come, computer scientists working with physicians and imaging researchers will continue to produce higher resolution and more informative interactive visualizations of physiologic systems. The advances in genetic research, computation sophistication, hardware performance, and imaging techniques will continue to feed one another, bringing the overall field closer to the end goals of improving diagnosis and treatment while effectively decreasing medical costs.

***Guy Almes, Ph.D.***
*National Science Foundation*

Guy Almes is a Program Officer in the Office of Cyberinfrastructure at the National Science Foundation. There, he oversees a number of activities including the Extensible Terascale Facility.

While at NSF, Dr. Almes is a 'rotator', whose home institution is the Internet2 project, where he serves as Chief Engineer. Dr. Almes is a leader and a pioneer in the development of the Internet.

He was the founder and director of Sesquinet, an NSFnet regional network for Texas universities, colleges and corporations. He has served as Chairman of the Federation of American Research Networks (FARnet) and Chairman of the Interconnectivity Working Group and the IP Performance Metrics Working Group of the IETF.

Dr. Almes was a member of the computer science faculties at the University of Washington and Rice University. The author of many technical papers on operating systems, software and networking, his current research interests are in the design of advanced wide-area networks appropriate for supporting advanced university applications, network performance measurement and analysis, and application of advanced Internet functionality, such as quality of service and multicast protocols.

Dr. Almes received his B.A. in Mathematics and Engineering, magna cum laude, and M.E.E. from Rice University and his Ph.D. in Computer Science from Carnegie Mellon University. A native of Texas, Dr. Almes and his family reside near White Plains, New York.

# Thursday, September 22, 12:30-1:30pm

### The NSF's Evolving Cyberinfrastructure Program

With origins in the NSF Supercomputer Center program and NSFnet program of the late 1980s, NSF is now enabling science and engineering users through its evolving Cyberinfrastructure program. Current resources supported by that program, including the TeraGrid, and representative science enabled through it will be described. Recent organizational and programmatic changes in NSF's Cyberinfrastructure program and the significance of performance and security will be discussed.

# Session Abstracts

## Parallel Session 1
## Wednesday, September 21 – 10:40am-11:55am
## Engineering Applications

#### 3-D Stereo of Fluid Dynamics and Heat Transfer in a Blast Furnace Hearth

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A blast furnace which converts iron oxide represents the predominant iron-producing process in the U.S. Maximizing the campaign life of blast furnaces is critical to the economic vitality of an integrated steel mill. The campaign life of an iron blast furnace depends on hearth wear. Conditions inside the furnace are generally inferred from the response of thermocouples / heat flux sensors embedded in the refractory. Since measurements inside an operating hearth are not possible, computational fluid dynamics (CFD) has become a useful too to elucidate the internal condition. In this work, a 3-D comprehensive computational fluid dynamics (CFD) model has been developed for simulating the actual blast furnace hearth in which both hot metal flow and the conjugate heat transfer thorough the refractories have been included. The model has been validated using measurement data from Ispat Inland No. 7 blast furnace with good agreement between measured and predicted refractory temperature profiles. This CFD model is being utilized to 1) visualize the flow, temperature and erosion patterns; 2) understand the impact of internal conditions of the hearth on wear patterns and on the true nature of on-line measurements; and 3) design monitoring and controlling strategies for prolonging the campaign life.

#### Advanced Virtual Manufacturing Laboratory (AVML) for Training, Education, and Research

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A high fidelity web-based virtual environment – Advanced Virtual Manufacturing Laboratory (AVML) – that uses advanced visualization techniques is presented. The dynamic virtual reality system is interactive and allows for the simulation of advanced manufacturing. Currently, the system supports CNC (Computer Numerically Controlled) milling, a versatile machining process that is widely used in industry.

The system provides a safe, cost-effective, and highly flexible and accessible tool for training and education as well as product realization. More specifically, the AVML provides the following training functions for users via the Internet: (a) interaction with a fully-functional virtual CNC milling machine, including real-time machining of parts, (b) training on key operating procedures of modern CNC machines, and (c) intelligent virtual tutor that gives a lecture describing the concepts of CNC milling and the components of the milling machine, as well as assistance with hands on training on the virtual machine.

The environment is driven by three software modules that communicate with each other using a TCP/IP network socket interface; these modules are: (1) a CNC Milling machine simulator, (2) a virtual-environment display engine, and (3) an intelligent-agent engine. The modules run on a single computer in a seamless web-based framework. The AVML can run on desktop or laptop personal computers. It can also run on more sophisticated systems such as a CAVE (for fully-immersive virtual reality visualization and simulation).

The AVML enables colleges and universities to easily and inexpensively provide students with effective, safe, and highly accessible training on advanced machine tools. It can also be used by machine tool manufacturers to provide online training, reducing or eliminating the need for onsite and/or live training classes for customers.

The work, which is still underway, has been presented in several conferences and symposia, including ASME, ASEE, ICCIE, and Solutions Conference 2005.

The methodology and its implementation, and the resulting virtual system for CNC machining will be presented. On the other hand, the current system's capabilities and functionality will be demonstrated in the CAVE, which is currently available in the Advanced Visualization Laboratory at IUPUI.

### Using Information Visualization as a Vital Component of an Assembly Process Simulation

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This paper discusses a course redesigned to meet the industry's demand of Product Lifecycle Management (PLM) literate workforce. The objective of this interdisciplinary course is to introduce students to manufacturing engineering theories coupled with an industry-sponsored project. One of the main requirements of this course is the building of an assembly line simulation. One of the main outcomes of the assembly line simulation is its ability to allow for design visualization and verification. This project exposes students to topics including design visualization, process design, process verification, and workspace ergonomics. Moreover, practices of project management and critical chain are built into this industry project. The end goal is to prepare students not only with the knowledge of PLM but also the capability of problem solving, communication, self-motivated teamwork, and leadership.

# Parallel Session 1
# Wednesday, September 21 – 10:40am-11:55am
# Scientific Visualization I

### Multi-Scale Planetary Dynamics Aided by Stereo Visualization

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Understanding the origin and evolution of planetary bodies requires integrating numerical modeling with observations and experiments from diverse fields. The calculations of creeping flow in planetary interiors are becoming increasingly complex because we find it necessary to include physical processes and interactions between processes that occur on multiple length and time scales. While the calculations computationally challenging, presenting the results in a coherent fashion has become an even greater challenge. We have found enormous benefit from using passive stereo animations. For collaborative work, these animations are also an ideal form of data compression. This talk will illustrate some of the discoveries made possible with stereo animation.

For more information, see: http://web.ics.purdue.edu/~sking/ED31E-04.htm

### Interactive Visual Analytics of Multi-million Atom Nemo-3D Quantum Dot Simulations

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In this work we present a graphics hardware-accelerated direct volume rendering system for visualizing multivariate wave functions in semi-conducting quantum dot (QD) simulations. The simulation data contains wave functions of multiple electron orbitals for up to tens of millions of atoms, computed by the NEMO3-D quantum device simulator software run on large-scale cluster architectures. These atoms form two interpenetrating crystalline Face Centered Cubic lattices (FCC). We have developed compact representation techniques for the FCC lattice within PC graphics hardware texture memory, hardware-accelerated linear and cubic reconstruction schemes, and new multi-field rendering techniques utilizing logarithmic scale transfer functions. Our system also enables the user to drill down through the simulation data and execute statistical queries using general-purpose computing on the GPU (Graphics Processing Unit).

### Real-time Visualization of Large Particle Simulation

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In this research presentation we discuss the simulations and visualization systems that are used to study rapid granular flows of particles that are tens of microns and larger. Specifically results from these kinds of simulations are used to investigate particle-phase phenomena and to obtain parameters for large-scale continuum models of industrial processes such as risers and dilute phase pneumatic conveying lines. Simulations of these kinds usually contain several hundreds of thousands of particles to millions of particles. Visualization system allows to visualize complex features such as sequence of 3D couette shear flow system with thousands to millions of hard sphere particles with a particular solids volume fraction and coefficient of restitution. The shear is maintained with Lees-Edwards Periodic Boundary Conditions and is in the absence of gravity. It is also assumed that fluid effects are negligible. Due to large number of particles and the complexity of its movements, we used several display systems such as ultra-high resolution IBM T221 LCD screen, and tiled wall display. The 22” LCD screen allows visualizing complex detailed rendering, such as this particle simulation, in a resolution of 3840x2400 pixels (9.2 million pixels) at 200 pixels per inch density. Still for very large particle simulation single workstation and single display system is not sufficient either for the computation or for the display quality. So other possibilities such as running this simulation in a cluster based high resolution 3D stereoscopic tiled display wall is used.

# Parallel Session 1
# Wednesday, September 21 – 10:40am-11:55am
# Advanced Interfaces and Applications I

### Rapid Building of Cheap and Scalable Passive, Stereoscopic, Tiled Display Wall Using Commodity Products

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In the last decade computation power has increased considerably and as a result so has the complexity of the scientific problems. Often visualization of these scientific data sets allows the researchers to understand the problem better. As the complexity of the problems increase the need for visualizing the large data sets increases considerably. These kinds of scientific visualization often require high resolution display to visualize large complex models. One way to achieve high-resolution display is through a tiled display wall. Tiled display wall contains several components and technical factors to build in-house with much difficulty. Commercially available tiled display walls are often very expensive since these kinds of displays are custom built. In this paper we discuss our research experience in designing and building an in-house, one of the largest passive stereoscopic display wall in the country (USA) in the academic environment, a 3x4 passive stereoscopic tiled display wall using commodity components. We discuss multiple components, different parameters and issues, step-by-step instructions to rapidly design, build and align a passive stereoscopic tiled display wall using standard, mid-range digital light processing (DLP) projectors and cheap off-the-shelf components. The goal of this paper is to provide a practical and affordable approach to rapidly build a scalable passive stereoscopic tiled display wall.

### The John-e-Box

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Recent advances in commodity graphics and projection hardware have motivated many notable research projects and community discussions about the potential of these technologies to make advanced visualization more broadly accessible. However, the actual realization of this promise on a significant scale is challenging, requiring strong institutional commitment, expert technical support, and a broader visualization context. This paper describes an ongoing effort at Indiana

University (IU) to develop a commodity-based, large-format, 3D stereo display system and to deploy a collection of such systems to a range of classrooms, laboratories, galleries, and learning environments throughout the IU system and the State of Indiana. To date, these systems have been used in over 30 projects by investigators in 15 departments across four different IU campuses. In addition, this technology has been used to reach well over 3,000 individuals through a series of coordinated outreach efforts. This initiative is also notable for fostering new interpersonal collaborations and inter-departmental cooperation, for enabling non-traditional applications in education and artistic expression, and for providing an interface to other advanced information technology efforts.

For more information, see: http://www.avl.iu.edu/technology/affordable/

### Location-Aware Multimedia Delivery in an Art Museum

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A key theme in today's information age is the ability to get information where and when it is most relevant. Translated into an art museum, this suggests the need to deliver information to visitors as they wander through the galleries. Audio tours have been available in art museums for several years, and commonly include narration about the artist and the art, as well as quotes, music, or dialogue to augment the printed information available in the gallery and enhance the visitors' experience of the art work.

Today's technologies make it possible to deliver full multimedia tours, including visualizations, to the museum visitor. Handheld PDAs have advanced in power to the point where they are capable of displaying imagery, animations, and narration. Wireless networking makes it possible to stream content to the handheld in an on-demand fashion. Finally, location tracking strategies are emerging where it is possible to use existing wireless networking infrastructure to determine a visitor's location within the museum. Once we know a visitor's location, we can stream the appropriate visualization to their handheld for playback.

This talk will describe our efforts to determine a visitor's location using 802.11 wireless networking, in a project carried out with the Indianapolis Museum of Art. We describe the use and performance of the Ekahau location identification software, and our enhancements to tune and improve accuracy in the reported position. We also describe an alternative model for positioning, currently in experimental use within the ICTC building.

# Parallel Session 2
# Wednesday, September 21 – 2:35pm-3:50pm
# Telecollaboration I

### Effective Distance Learning Through Sustained Interactivity and Visual Realism

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We describe an ongoing project whose goal is to develop a distance learning system that extends the real classroom to seamlessly accommodate remotely located students. This way distance learning becomes an integral but unobtrusive part of proven conventional on-campus learning. The system will convey to both remote and local participants a strong sense that the remote participants are actually present in the classroom. The sense of presence will be enabled by:

Interactivity. The system will support high-bandwidth, low-latency, uninterrupted, and secure communication between the participants.

High-quality graphics. The system will provide realistic visual descriptions of the classroom, instructor, students, and of the lecture materials by combining segmented high-resolution real-time video with pre-downloaded photorealistic 3D models and with presentation materials.

### AGJuggler

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AGJuggler is a project developed at the Envision Center for Data Perceptualization at Purdue University. The main objective in this study is to make collaborative experiences and interactions richer with the incorporation of Virtual Reality tools inside a collaborative framework. This is accomplished by offering: an improved sense of presence; synchronous distributed visualization; real time interaction and a customizable solution for implementing virtual reality within a collaboration environment.

The Access Grid™ is the collaboration environment used for the study; while the API used for programming virtual reality applications is VRJuggler.

For more information, see: http://people.envision.purdue.edu/~dioselin/AGJuggler/

## Enabling Collaborative Science with Cooperative Computing

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Despite the advent of cheap, plentiful computing power, even the most skilled of users struggle against a rising tide of complexity. Scientists in a variety of fields depend upon large scale computing to produce and share new results, yet are hamstrung by the limited capabilities for sharing and the immense number of failure modes in today's computing systems. To attack this problem, we must attack several fundamental problems in the design of operating systems, distributed systems, and programming languages. Our goal is to make it easy for non-specialists to efficiently share computing resources and data products across the wide area, while maintaining security and control of their own resources. We call this model "cooperative computing" and are developing a wide array of tools to assist the practicing scientist in his/her work. In this talk, we will present a variety of novel computing tools and describe how they have been applied to problems in bioinformatics, molecular dynamics, and high-energy physics.

For more information, see: http://www.cse.nd.edu/~ccl/

# Parallel Session 2
# Wednesday, September 21 – 2:35pm-3:50pm
# Information Visualization I

### Bringing the Lab into the Market and the Market into the Lab: Using Technology to Measure and Manage the Customer Experience

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In recent years, there have been several innovations in measuring how customers shop retail stores and respond to changes at the point of purchase. These include using virtual reality simulations to recreate the store environment in the laboratory and measure consumers' decision processes, and using video cameras and other location sensing devices to track customer shopping patterns in the store. When these methods are combined with conventional research techniques, such as exit interviews and the analysis of shopping basket data, they provide a rich understanding of how consumer goals interact with the shopping environment to determine behavior.

Two studies will be presented demonstrating how these research techniques can be used to analyze the shopping process and measure the impact of changes in the store environment on consumer behavior. The first study used computer-aided video observation and transactional data to track how customers shopped in two consumer electronics stores over the entire 2003 holiday season. The research revealed that purchase conversion rates on "Black Friday" (the day after Thanksgiving) were significantly lower than other days of the holiday season due to long lines, crowding, and out-of-stock conditions. The second study used virtual reality simulations to test the impact of making changes to a store's layout and signage on product sales and price sensitivity. The study found that store design can have a substantial impact on shoppers' likelihood of penetrating the store and making a purchase and that consumers are less price sensitive when the psychological (time/effort) costs of shopping are lower.

The presentation will conclude with a demonstration of how video-based customer tracking can be combined with virtual reality simulations to remotely monitor and manage the customer shopping experience.

### Development and Understanding of Consumer Demand in Retailing with Visual Technology: A Demand-Side Research and Analysis

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Retailing is an industry that works with lean profit margins and constant changes in consumer demand. Portfolio management of product categories is becoming critical for stores to ensure the profitability of their operations. Currently, one of the important issues that major retail chains and, on a more macro scale – shopping malls, encounter is how to generate and direct consumer traffic from one product category or a section of the mall to another in order to maximize the overall profit. The aim of this research is to understand, fundamentally and objectively, the cognitive and psychophysical responses of the individual consumer to stimuli such as store layout, signage, and color. To achieve these goals, we developed and exploited a new research tool – an immersive virtual environment for retailing and shopping. This research tool enables the systematic study of consumer responses, on an individual consumer basis, to the atmospheric factors of signage, color, and layout.

The novelty of the proposed project for demand-side analysis is an unprecedented ability to investigate real-time consumer behavior in a realistic retail setting while still exerting strict laboratory control, thereby permitting careful, objective psychophysical measurement. This project consists of the following segments: (1) A photorealistic virtual store through stereoscopic rendering technology; (2) a software system that is able to manipulate different atmospheric factors (signage, color and layout), while allowing real-time navigation through the environment; (3) psychophysical measures for monitoring consumers' response time and accuracy in selecting the cued product categories; and (4) two objective indices of consumer behavior, namely sensitivity and subjective bias in the selection of a product or a product category, based on the psychophysical responses of consumers to these atmospheric stimuli.

### Analysis and Visualization of Technology Data in the US

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We apply diverse data analysis and visualization techniques to a dataset of technology companies in the US from 1989 to 2003. Our goals are to understand (1) the birth, growth, and death of companies over the 15 year time span, (2) the geospatial distribution of different industries in US, (3) the correlation of the increase in number of employees and sales for companies that change their geographical locations at least six times, and (4) sudden increases in the number of employees and in sales for the different industries in the complete time span.

To understand the first goal we display nodes representing companies on a base map of the US. We generate a 15-frame animation, one frame for each year. Node coloring is used to identify new or dying companies. This provides a good overview of the dataset. For the second goal we generate similar maps for each industry with every year on the same map. This allows us to compare the size and geographical distribution of the different industries.

To address the third goal, for individual companies we plot the sales and employees on a line chart and add bars to indicate when moves occur. We also place a map of the company's trajectory in the background. This visualization allows us to see the relationship between the movements of the company and its sales and number of employees.

For the final goal we perform a simple burst analysis calculating the number of companies in each industry that have a burst for sales and for employees. We show the bursts of each industry on line charts, one for sales and one for employees. From these charts we can see when the different industries experienced major growth.

While first insights could be gained, the dataset appears to be too limited to provide definite answers to questions that business experts would ask. The complementary web page with details on the presented analysis and supplementary material is available at: http://iv.slis.indiana.edu/ref/iv05contest/.

This work was also submitted to the IEEE InfoVis 2005 Contest.

# Parallel Session 2
# Wednesday, September 21 – 2:35pm-3:50pm
# Systems Development

### Developing Reliable Complex Software Systems in a Research Environment

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As computational science projects become more ambitious, many research projects rely on complex custom software to help process data and generate results. This software is often developed in an ad-hoc manner over the lifetime of the project by a combination of the PI, students, collaborators, and consultants. While effective at small scales, as the size and complexity of the software and data increases, this approach can lead to software that is difficult to use and maintain. Eventually, development and maintenance tasks can consume a disproportionate amount of time and resources, at which point many researchers become software developers first and scientists second. In this talk, we describe the software engineering challenges inherent in modern academic research labs and provide practical approaches to solving them. These techniques are based on our experience developing large software systems with the Biocomplexity Institute (CompuCell3D), Randy Heiland's Scientific Data Analysis Lab (data visualization), Katy Börner's InfoVis Lab (ICV, Network Bench), the Boost C++ project (Boost Graph Library), Open MPI, and other academic and industrial projects. We will present the software engineering and resource management strategies we applied to these projects that led to increased research productivity and a marked improvement in the quality of the software. Many of the core ideas have their foundation in industrial software engineering, but required adjustments to be effective in academic settings. Throughout the presentation, we will highlight these differences and demonstrate many unique aspects of academic software development. We will also discuss strategies for funding software development and provide details on the organizational structures we have found most effective. Ultimately, we will demonstrate how understanding the intricacies of managing academic software development can help research groups use custom software to enhance rather than hinder their programs.

### High Performance Real-Time Interactive Visualization Technologies Using PC Clusters

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Traditionally desktop-based graphics rendering has been done using a single personal computer (PC) on a single monitor. With the latest developments in graphics hardware and computing power, a single PC is used to drive multiple displays at the same time. But the complexity of scientific visualization applications increased tremendously so that a single PC could not render complex scenes in real-time even to single display, not to mention multiple displays. This single PC, single/multi display configurations have several limitations, such as insufficient computing power, trade-off between rendering quality vs. display area, especially to render complex scenes

in real-time. In this paper, the author presents an approach that describes the use of commodity cluster to render complex scenes to a single monitor, and/or to different tiled display configurations in real-time. Our approach provides more flexibility and ability to customize the computing power, rendering quality and display area as required. Several hardware configurations, software applications, and specialized graphics libraries will be discussed that utilizes the latest hardware and software components. System bottlenecks due to hardware and software limitations will also be elaborated along with possible solutions and workarounds to achieve maximum performance. Based on this performance study, we will suggest multiple solutions and configurations to provide better insight to what hardware and software is vital and should be obtained as technology progresses in the future.

### Developing and Deploying a Robust System for 3D Surface Scanning and Analysis

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3D surface scanning is an evolving field that encompasses a wide variety of technologies and applications. For the past three years, the UITS Advanced Visualization Lab has been working with researchers in the IU School of Medicine, the Anthropology and Computer Science departments at IUPUI, and an international consortium of collaborators to develop an integrated system of hardware, software, and methodology to enable the reliable and accurate scanning of human heads and faces.

This NIH-funded collaboration is utilizing 3D surface scanning technology to supplement traditional physical measurements in the diagnosis and study of fetal alcohol spectrum disorders (FASD). Craniofacial anthropometry has been used to assess and describe abnormal craniofacial variation and the facial phenotype in many syndromes. It has also been used in the clinical setting as a diagnostic aid and as a means of objectifying clinical descriptions of individual patients. Through the use of 3D scanning, the project seeks to develop novel methods for assessing facial variations to provide more accurate diagnoses of the level of alcohol exposure. Moreover, by organizing the surface scans of subjects and control individuals in a database, researchers will be able to perform novel queries, comparisons, and longitudinal studies. This project has developed three portable 3D scanning systems that have been deployed to a variety of locations throughout the US as well as sites in Europe and Africa.

This talk will focus on our experiences in developing a robust and accurate 3D surface scanning system for the FASD project, including the evaluation of competing technologies, the development of software procedures for stitching, measurement, and analysis of models, and the challenges of international technology deployment. We will also highlight some of the outgrowth applications of this technology, including scanning of objects for forensics, cultural heritage, and digital art.

# Parallel Session 3
# Wednesday, September 21 – 4:15pm-5:30pm
# Educational Applications

### Stereoscopic Visualization of Scientific and Medical Content

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The use of stereoscopic display medium is now in use at the Ruth Lilly Health Education Center (RLHEC) in Indianapolis to help educate nearly 100,000 students annually. The stereoscopic display is helping to revolutionize a subject area to students K-12 in a subject matter that traditionally has been a very difficult area to learn. Content created by the research team at the IUPUI School of Informatics has been implemented to fit into the curriculum of the RLHEC. Future plans of the RLHEC include distributing this content to other health centers around the state, country, and globally, through high speed networks.

This presentation will display on a portable John-E-Box, or other portable stereo display system available to the School of Informatics, the display of a number of stereoscopic animations created for the RLHEC, including subjects such as The Cell, The Circulatory System, The Nervous System, The Immune System and The Respiratory System. Also displayed will be content created for the simulation of Hip and Knee Replacement Surgery, and simulations of real world data of biological macro-molecules.

Presentation will also include a description of content research procedures, pre-visualization methods, production methods, stereoscopic creation techniques, production issues and post-production methods. Considerations of the limitations and benefits of the stereoscopic medium will be discussed, as well as these considerations regarding the production of the stereoscopic content. A PowerPoint presentation can accompany the John E Box demonstration to further explain the production pipeline.

### The GameSeum

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The GameSeum project is a proposal to use game engine technology to allow a Museum to exhibit itself and the engage patrons through game technologies and networks in ways not currently possible.

Game technologies have developed over the past 30 years to the point where extremely robust game technologies are available in a variety of low cost forms. World Forge is open source game technology which can be used to create massive 3D online role playing games on the web through campus and home personal computers connected to internet via DSL and cable modems. The Unreal Engine, which makes the extremely popular and profitable game Unreal, is available for free to develop non-commercial games of incredible complexity and beauty. The Torque game engine from GarageGames can be purchased for $100 with few restrictions on commercial use and development.

Game engine technology, while inexpensive, is not as ubiquitous and easy to use as Microsoft Word but the technology is moving in that direction. It is not far fetched to imagine a time within the next 5 years when students and community members will be as likely to have operating versions of game engines on their laptops, broadband accessible, as they are today to have word processing, graphic programs and interactive design tools such as Flash and Director from Macromedia.

How this would this work?

Most games begin with a game world, which can be explored. This space used to be 2 dimensional but today most games present the player with a 3 dimensional space where the game is played. The GameSeum project is a game project in the sense that there is a game world and there are rules for how the game is played just as basketball has a game world of the court and the rules for how the game is played fairly and how the game is won. The Museum will be the game master of this project controlling what the player has access to and what the rules of play are. This is not a proposal where anything will be destroyed or defaced in any fashion. This is not a proposal where players will be shooting anything. This is a proposal where the players come to the Museum to learn and appreciate art just as they do in the real world. That said, there would be players, which means there will be possibilities to learn in new ways.

Since this is a virtual space and not limited by physics it would not be necessary for any exhibit to actually come down. Depending upon the needs of the Museum staff exhibits could remain up indefinitely. Since it is a virtual space the Museum staff could exhibit material not normally exhibited in the museum due to size and fragility. Museum staff can also explore structural changes to the Museum before they are implemented. But, perhaps the must interesting possibilities are present from the patron's point of view. Since it is a virtual space patrons could customize their person views of the Museum, as they need. Patrons could create their own personal commentary on art works both texturally or with audio or video. Patrons could also collaborate with the Museum staff.

At this stage we are imagining the possibilities but only with the GameSeum project as a working game simulation of the Museum can we realize possibilities we can't even imagine. This presentation will be a visual essay of the possibilities the GameSeum would offer for entertainment, education, research and funding.

### Mathematical Models and Graphics Using Squeak

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We present an open source educational software environment called Squeak (squeakland.org) and describe a Squeak project we developed that is intended to enhance mathematics appreciation and learning. Squeak can be described as a programming environment for young people (K-8) or, for that matter, for a person of any age who may feel intimidated by computers and computer programming languages. Dr. Alan Kay, a renowned computer scientist and educator, is the driving force behind Squeak. Using a simple, but powerful, graphical user interface, a child begins by painting a two-dimensional object and then creates a script (an object-oriented program) that affects the behavior of that object. Creating a script is easily performed by dragging & dropping tiles that change the attributes or actions of the object. By creating multiple objects and scripts, a child can quickly create a complex, dynamic artificial world. We have constructed a Squeak project which introduces children to the concept of mathematical modeling – using the language of mathematics to describe (model) various phenomena in the world around us. We initially focus on modeling things found in nature (e.g., mountains, trees, plants, and clouds.)

# Parallel Session 3
# Wednesday, September 21 – 4:15pm-5:30pm
# Scientific Visualization II

### Visualization for Discovery of Knowledge from Scientific Data

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The discovery of knowledge from scientific data is quite challenging because of the vast amounts of typically disparate data that are needed for insight. Because the visual channel of humans has a very high bandwidth, our approach is to present the data in an advanced visualization environment utilizing a high-resolution display with 3-dimensional (3D) interaction. However, the information needs to be presented to the domain expert in a form that is natural for the scientific domain expert, without burdening the expert with issues concerning data representation and management.

We will report on the beginning development of a computer-based system for scientific discovery in the chemical sciences that enables the scientist/engineer to effectively manage and visualize widely disparate types of data. The types of data that are represented include spreadsheets, 2D and 3D graphs, chemical structures, molecular orbitals, etc., where the different representations of data can be changed at will. For example, a chemist that is developing a new catalyst for producing a cleaner diesel fuel or a new polymer or any of a number of other applications naturally thinks in terms of 2D chemical structures, 3D structures of molecules and molecular orbitals; thus, instead of examining a traditional 3D scatter plot of some catalyst performance data versus some descriptors of the catalyst structure that uses colored symbols, the chemist can select a point on the graph which will then display the chemical structure. If the expert desires additional information concerning that point, the expert can connect to the synthesis data (text description), experimental characterization data (2D plots) or molecular simulations (3D stereographic images). The details of these changes in data representation and fidelity of information are hidden from the domain expert so that they can focus their activities on scientific discovery not data management and/or representation.

The system that has been developed is scaleable so that it can be used on a dual monitor PC, a multi-head display or a large tiled wall whatever device is most appropriate and available. Since the user interface is the same on this range of display devices, the scientific domain expert only has to learn how to use one system.

### Zero-Crossing Iso-Surfaces in Volume Datasets

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This paper describes a new surface extraction method for volume datasets by applying iso-surface extraction techniques to the zero-crossing edges in a volumetric domain. A volume dataset is first filtered using a Laplacian of Gaussian filter to generate a zero-crossing field. A marching cube process will then be able to extract the entire zero-crossing surface that may be viewed selectively based on various intensity ranges and gradient scales. This new technique provides a more efficient surface navigation and extraction mechanism, as well as more accurate surface details, than the traditional iso-surface techniques.

### Use of Purdue's DRE for Creating Nanotechnology Visualizations

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This presentation focuses on the use of Purdue's Distributed Rendering Environment (DRE) in the creation of animated visualizations for a nanotechnology exhibit. Purdue's DRE allows users to distribute rendering jobs across campus and utilize idle cycles for creating 3D imagery. The net result is a dramatic reduction in the amount of time that it takes to render 3D visualizations. In this particular case, nine animated visualizations were created in less than three months. Without the DRE, there would not have been enough computational power available to the team to complete the task in the allotted time. Three-dimensional visualizations that portrayed the uses of nanotechnology in the following areas were created: agriculture, computation, sports, medical, manufacturing, and military.

# Parallel Session 3
# Wednesday, September 21 – 4:15pm-5:30pm
# Telecollaboration II

### Instruments and Sensors on the Grid: The CIMA Middleware Project

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The integration of scientific instruments with computations and scientific data management is an important problem in creating usable cyberinfrastructure. Instruments are still largely disconnected from downstream analytical software and the scientific productivity of instruments can be greatly enhanced using existing Grid services for location, allocation, scheduling, and access control. This problem is becoming critical as three issues continue to grow in importance in research: 1) investments in geographically extended (e.g., international) collaborations organized around large shared instrument resources; 2) increasingly real-time use of instruments by remote researchers both for "first look" activities and pipelined data acquisition and reduction; and 3) sensor networks with hundreds to thousands of nodes being deployed.

The Common Instrument Middleware Architecture (CIMA) project aims at grid-enabling instruments as real-time data sources to improve accessibility of instruments and to facilitate their integration into the Grid. A primary challenge addressed by this research program is to develop a generalized approach to instrument middleware that allows existing and new instruments to be integrated into Grid computing environments.

CIMA middleware is based on current Grid implementation standards, and is accessible through platform independent standards such as Web Services. In keeping with the design goal of general applicability, CIMA interfaces are being developed for a variety of instrument and controller types from large shared facilities (synchrotron X-ray sources, robotic optical telescopes) to small embedded industrial controllers and sensor nets and micro-sensor packages such as MOTEs, developed for the DARPA SmartDust program.

Other issues being explored include extending the accessibility of instruments to new classes of users (e.g. student remote access to advanced materials science facilities at national labs), use of instruments by software agents, and increasing the longevity, flexibility and durability of software systems for instruments and sensors.

Within Indiana CIMA implementations are linking X-ray diffraction facilities at IU and Purdue over the I-Light network. This provides a uniform infrastructure for researchers in the state to find a facility with capabilities that meet their needs and to interact with the technicians and instruments there remotely. This talk will include a demonstration of the remote access capabilities of a CIMA-enabled X-ray diffraction crystallography laboratory.

For more information see: http://www.instrument-middleware.org/

## Virtual-Reality 3D Interactive Interface for the Teleoperation of Robotic Systems

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Virtual reality is a high-end human-computer interface allowing user interaction with simulated environments in real-time and through multiple sensorial channels. The application of virtual reality technologies in Internet robot teleoperation is an emerging research field.

The objective of this research is to develop a more interactive and immersive 3D virtual reality interface for Internet robot teleoperation in order to improve the stability and alleviate the time delay between the user and robot. Updating 3D graphical models of robot and working environment in real-time can provide the user with a more interactive and friendly interface to "see" and control the robot in the real world. Force, size and shape feedbacks will help the user get more immersed into the simulated virtual reality. A high-level supervisory script language will generate commands for different kinds of robots and be flexible for both robot programmers and regular users. A multi-user collaborative environment will be developed for complex experiments.

The implementation of the research can apply Internet robot teleoperation to some specific medical and biological experiments. While dealing with highly contagious biological viruses, some medical and biological experiments are hazardous for researchers. By applying this virtual reality teleoperation system to carry out these dangerous tasks, researchers can be protected to stay away from the harmful work. Some designed medical experiments will be conducted with this system and the performance of the system will be analyzed on the stability, the response time, discrepancy of virtual and real world to further improve the stability of the system.

## Loose Minds in a Box at Purdue

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As explained by Performance Director Jimmy Miklavcic, InterPlay: Loose Minds in a Box (LMIB) is a multi-site distributed performance where six geographically remote sites utilize Access Grid technology to integrate each local performance into a global work. The concept of LMIB revolves around the idea of being constrained in a box. The box is a metaphor for the physical, social, political or psychological constraints that we and/or others place upon us. The box also represents a sense of place in the realm of the virtual as well as in our conscience. (Miklavcic, 2005)

The Envision Center for Data Perceptualization at Purdue University participates in Loose Minds in a Box with a local piece that includes a motion capture (mocap) segment and a virtual reality (VR) segment. During the performance, a dancer moves between the mocap area and the VR area several times. The mocap segment allows the dancer to control a character composed of boxes; it also uses the Shared MIDI Service (Ayromlou, 2005) to remotely control sound being generated at Montana. The VR segment includes an interactive application running in an immersive Flex virtual reality system where the dancer uses tracking devices to interact with the world; it also includes the same application running collaboratively by using AGJuggler (Gonzalez and Arns, 2005) to allow remote audiences to interact with each other.

# Parallel Session 4
# Thursday, September 22 – 9:50am-11:05am
# Biomedical Applications

### Intelligent Biomedical Literature Mining and Knowledge Visualization

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Biological literature databases continue to grow rapidly with vital information that is important for conducting sound biomedical research. As data and information space continue to grow exponentially, the need for rapidly surveying the published literature, synthesizing, and discovering the embedded "knowledge" is becoming critical to allow the researchers to conduct "informed" work, avoid repetition, and generate new hypotheses. Knowledge, in this case, is defined as one-to-many and many-to-many relationships among biological entities such as gene, protein, drug, disease, etc. The knowledge discovery process basically involves identification of biological object names, reference resolution, ontology and synonym discovery, and finally extracting object-object relationships. We have developed a system called BioMap, using the entire MEDLINE collection of (over 12 million) bibliographic citations and author abstracts from over 4600 biomedical journals worldwide and to develop an interactive knowledge network for users to access this secondary knowledge.

The BioMap "knowledgebase" may significantly enhance the ability of biological researchers with diverse objectives to efficiently utilize on-line resources, generate methods for analysis of biological data such as identifying biological pathways, and provide computerized support for disease target and new drug discovery. The extracted knowledge is further mined to discover directional associations, transitive associations, and hyper associations among biological entities. These relationships form large knowledge graphs and we have developed information visualization tools to display and to interact with such knowledge spaces.

## Dynamic Volume Rendering and Life Cycle Planning for Intensity Modulated Radiation Therapy (IMRT) Treatment

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For some decades, radiation therapy has been proved successful in cancer treatment. The major task of radiation therapy is to impose a maximum dose of radiation to the tumor cells. The IMRT technology makes it possible to deliver radiation more precisely by dividing the accelerator head into smaller units called "beamlets" that can be manipulated independently. This treatment planning requires a time consuming iterative work between a physician and an IMRT technician. The state of the art current technique is to determine the IMRT treatment plan at the beginning and use it without changing it in the course of the treatment. However, the assumption of fixed 'target volume' throughout the IMRT treatment, is very limiting given that the tumor shrinks in response to the radiation therapy. In this research, we apply time-varying volume rendering technique to the IMRT treatment and develop a proof-of-concept prototype system that enables capturing and relating the time dependent changes of the irradiated volume throughout the course of treatment. This prototype system will enable the researchers to explore different what-if scenarios, such as determining the 'Target Treatment Volume' depending on the delivered dose of radiation.

## Mining Digital Geometry Data for Medical Diagnosis

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This paper describes a new approach of mining polygon mesh surface datasets of human faces for a medical diagnosis application. The goal is to explore the natural patterns and 3D facial features that can provide diagnostic information for Fetal Alcohol Syndrome (FAS) disorder. Our approach is based on a digital geometry analysis framework that applies data mining and pattern recognition techniques to digital geometry (polygon mesh) datasets from 3D laser scanners and other sources. Novel 3D geometric features are extracted and analyzed to determine the most discriminatory features that best represent FAS facial characteristics. As part of a collaboration

with the NIH International Consortium for FASD, the techniques developed here are being applied and tested on real patient datasets collected by the NIH Consortium both within and outside the US.

# Parallel Session 4
# Thursday, September 22 – 9:50am-11:05am
# Information Visualization II

### Mapping Science

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About 40 years ago, Derek J. deSolla Price suggested studying science using the scientific methods of science. Today, research on 'Mapping Knowledge Domains' – see PNAS 101 (Suppl. 1) Apr 6, 2004 -- aims to develop methods to analyze, model, and visualize the structure and evolution of science.

When mapping sciences, knowledge and expertise is extracted from digitally available literature, patent, grant and other data as well as from information about the producers and consumers of those data sets. Advanced data analysis techniques in combination with spatial metaphors, geographic principles, and cartographic methods are applied to organize, visualize, and communicate the semantic relationships inherent in the data.

The ultimate goal of mapping sciences might be an interactive cartographic map of all of science, with continents representing the major research areas such as, e.g., biology or physics, dots denoting major authors, PIs, papers or news, dynamically evolving research frontiers, blinking 'hot' papers and topics, etc. This map could be used to teach and understand the evolving structure of all of science, to identify major experts, to find and read the most relevant papers and patents, to see the effects of resource allocation decisions, to study social networks, etc. Last but not least, it would provide a unique bird's eye view of major experts in specific areas and mankind's knowledge in general.

This talk will present recent results on mapping science on a small and large scale. It will discuss the cyberinfrastructure needed to store and process large scale scholarly datasets and to serve the resulting maps to diverse user groups. We will also introduce the 'Places and Spaces' science exhibit (http://vw.indiana.edu/places&spaces/) that was created to demonstrate the power of maps for the navigation and management of physical places and abstract semantic spaces.

### Table-Based Navigation of the Indianapolis Museum of Art Collection

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This talk describes the etx, an installation created to allow visitors to the Indianapolis Museum of Art interact with the collection. The etx installation includes a table-top display where users interact with the application. Imagery is also projected to three walls in the room, creating a sense of immersion in the application. Visitors interact with the etx application by pointing to and selecting from digital images of works that float on a tabletop. Through interaction with the application, participants can request details about the works of art, such as time period or artist. Participants can also explore how one item from the collection relates to other items in the collection.

The etx is based on the PercepTable technology, developed at the Visualization and Interactive Spaces Lab, part of the Pervasive Technology Labs at Indiana University. At the PercepTable, users interact by gesturing with small tools that can be moved on the table. Camera-based tracking, using algorithms developed in the Lab, is used to track users' movements.

This talk will present an overview of the etx installation, including the history of the application, details of its implementation, and the collaboration involved to create the exhibit. We will also show what we have learned from studying patterns of user interaction with the etx installation.

### Distribution Services for 2005 Indiana Orthophotography Project

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A first-of-its-kind statewide orthophotography project is rapidly expanding Indiana's geographic information systems (GIS) data resources and will support new ways to visualize Indiana. This landmark collaboration involving the Department of Homeland Security, the Geographic Information Council (IGIC), and Indiana's ninety-two counties is generating terabytes of seamless, accurate statewide aerial photography and elevation data. This project will support the GIS needs of non-profits, state agencies, university researchers, and the general citizens of Indiana in such diverse activities as watershed management, economic development, and homeland security.

Data Management Support (DMS), a unit within University Information Technology Services, will discuss the 2005 Orthophotography Project's data distribution needs and challenges of creating enterprise database services. DMS will present an overview of the Indiana Spatial Data Service (ISDS), an enterprise web and database service supported by Indiana University's high performance computing and networking infrastructure. DMS will also present information regarding the Indiana Spatial Data Portal (ISDP), a geographic archival service supported by Indiana University's massive data storage system.

For more information, see: http://gis.iu.edu for access to the ISDS and ISDP.

# Parallel Session 4
# Thursday, September 22 – 9:50am-11:05am
# Advanced Interfaces and Applications II

### The Solar Journey Project

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The Solar Journey Project is six-year, multi-institution collaboration focused on the development and application of advanced visualization, modeling, virtual reality and analysis tools to virtual astronomy. While the specific scientific objective of this research is a better understanding of the local galactic neighborhood of our Sun, this collaboration has also resulted in the development of a range of new visualization technologies, including: multi-scale techniques for overcoming the precision limitations of graphics hardware; navigational techniques for effectively traversing many orders of spatial magnitude, methods for physically-based star rendering, and a software framework to seamlessly integrate real-time analysis with high-quality batch rendering. Specific productions highlighted in this talk include several high-quality animated shorts (including one shown in the SIGGRAPH 2000 Electronic Theater), an interactive CAVE application, and a 20-minute production for the multi-projector laser dome at the Beijing Planetarium.

For more information, see: http://www.cs.indiana.edu/~soljourn/

### Motion Capture Visualization for Ergonomic Analysis and Safety Design

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Motion capture data can be used as the input to computer-based ergonomic analysis tools. A key objective is to improve safety and reduce the need for prototyping. New design concepts such as the Virtual Build and justification of redesign in automotive assembly are facilitated by this motion capture capability. Once more is known about the transfer of information from the visualizations from virtual to real, the interaction with some new designs can be simulated, so as to reduce the need for prototyping. Until these digital human modeling simulation capabilities are more developed, motion capture visualization will be an important tool for digital human model development. In the future, motion capture can still be an effective tool in digital human model validation. Improved safety through motion capture and related virtual reality visualization has the potential for reducing costs of workplace injury and insurance in manufacturing, transportation, government and health care.

### Using mixed physical/virtual interfaces to enhance social aspects of educational games

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Interactive tabletop displays, like MERL's DiamondTouch provide a large touch-sensitive surface that allows for simultaneous multi-user finger-based interaction. Each user's touch completes a low current circuit with the table and a discrete pad placed on the floor or on the user's chair. A fine grid of antennas embedded in the surface detect the precise position of the touch and can differentiate between each user, allowing up to four users to interact with the table simultaneously and independently. The table can detect detailed motion of the fingers and hands and can approximate pressure sensitivity using the strength of signal.

We have used the DiamondTouch table along with tangible interface elements – physical objects with embedded sensors – to support a novel form of collaborative learning where collocated groups of children interact with a virtual world through a mixed digital/physical interface. We hope to use this application to study how children learn together in this new environment and how their path to understanding differs from traditional desktop interfaces and non-co-located learning situations.

In order to focus the learning experience on group learning and sharing, we have designed a game which allows children to explore the "Tragedy of the Commons" – the situation that arises when a small number of greedy participants spoil a shared resource for themselves and for everyone else. The game allows players to place sheep out to graze in a shared pasture, competing to see who can harvest wool the fastest without destroying the pasture. This requires players to come to an agreement with other players about how to allocate resources, encouraging players to think about their relationships with each other, not just their performance in the virtual world.

Our implementation of this game allows players use the DiamondTouch table to manipulate the game world directly by touching and dragging sheep through the environment while using a tangible interface – the "Sheep Shaker" – to add their sheep to the pasture. The mixed physical/virtual interface has been designed to give players a greater sense of their personal role in the game and prevent them from dissociating from their virtual identity.

The next stage of our research plan is to explore how small groups of students use the prototype system to play the collaborative game and to investigate whether a shared tabletop surface like the DiamondTouch table and tangible technologies can support new kinds of collaborative learning.

# Grid Systems & Applications
# Thursday, September 22 – 1:50pm-3:05pm
# Grid Systems & Applications I

### ORNL and TeraGrid: An Overview

*John Cobb*
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The Oak Ridge National Laboratory (ORNL) has recently undergone a renaissance with new programs and facility construction connected with the Department of Energy's Office of Science National Leadership Computing Facility (NLCF) at the National Center for Computational Sciences and the Spallation Neutron Source (SNS.) Additionally an aggressive wide area dark fiber initiative called FutureNet has allowed the connection of these infrastructures to national high performance networks. One component of these new activities is ORNL's Neutron Science TeraGrid Gateway (NSTG) which is a project partner in the National Science Foundation's TeraGrid project. The SNS expects orders of magnitude larger data and analysis needs than current neutron sources. The NSTG is focused on providing advanced TeraGrid cyber-infrastructure to meet the new scale of needs of SNS users. The NSTG is physically co-located with the NLCF resources and utilizes FutureNet infrastructure to connect to the TeraGrid backplane. Its user facing interface is a Science Gateway portal providing data management, application services, and SNS user identity management.

### Grid Technology for Real Time Streams

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A growing number of applications involve real-time streams of information that need to be transported in a dynamic high-performance reliable secure fashion. Examples include sensor nets ranging from science to the military, mobile devices on ad-hoc networks and collaboration with at the simplest a multitude of audio-video streams. Further it is attractive to view the sources, sinks and filters of these streams as Web or Grid services so we can realize the pervasive interoperability of a service oriented architecture. We have been developing this idea systematically using an open source-based infrastructure, NaradaBrokering, that forms a distributed set of message brokers that implement a publish/subscribe software overlay network.

This environment supports multiple protocols (including UDP, TCP, and parallel TCP) and provides reliable message delivery with a scalable architecture. The infrastructure can supply message oriented middleware support for Web services with support of WS-Eventing, WS-Notification, WS-Reliable Messaging and WS-Reliability. Conventional support of SOAP will be augmented by "fast XML/SOAP schemes" that will transport the SOAP infoset efficiently and will allow Web services to exchange streams (sets of messages) with high performance. We describe four applications that illustrate the capabilities of this system; collaboration with audio video and shared display streams, integration of hand-held devices to a Grid, and the linkage of real-time GPS sensors to Geographical Information Systems implemented as Web services. The final example links annotations to video streams showing how composite streams can be supported for real-time annotation. Challenges here are efficient archiving and metadata systems allowing "instant" rewinding and replay of any stream. This latter capability is demonstrated for remote sports coaching.

For more information, see:
http://www.naradabrokering.org
http://www.globalmmcs.org

## Building and Deploying Community Nanotechnology Software Tools on nanoHUB.org – Atomistic Simulations of Multimillion-Atom Quantum Dot Nanostructures

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The Network for Computational Nanotechnology (NCN) is a multi-university, NSF-funded initiative with a mission to lead in research, education, and outreach to students and professionals while at the same time deploying a unique web-based infrastructure to serve the nation's National Nanotechnology Initiative. The primary NCN outreach vehicle is our web site http://nanoHUB.org, which currently provides interactive on-line simulation and educational resources such as tutorials, seminars, and on-line courses. In 2004, over 3,200 users used the educational and outreach resources. Over 1,000 users performed over 60,000 on-line simulations. The raw web page hits exceeded 3.7 million. Around 30 research codes are available ranging from toy-models to sophisticated simulation engines. The NCN provides the resource for models, simulation and computation without any software installation for users via web-delivery. All the NCN services are free of charge and reach a broad audience.

One facet of this infrastructure involves the development of new "community codes" that provide the nanoscience research community with new capabilities and that lay a foundation for a new generation of CAD tools. Each research team has a research mission to move its field ahead and an equally important mission to contribute resources to the NCN's infrastructure. One such community tool is NEMO-3D (dynamo.ecn.purdue.edu/~gekco) which has been publicly released and recently expanded in its capabilities through detailed numerical performance analysis.

The growth of self-assembled semiconductor quantum dots (QDs) is driven by strain, induced by the mismatch of the lattice constants of the QD material (in this work, InAs) and that of the barrier material (GaAs). The resulting long-range strain field strongly modifies the energy diagram of the system, and has to be accounted for in realistic simulations of QD electronic properties. The nanoelectronic modeling tool NEMO-3D is designed to provide quantitative estimates of QD-bound electron and hole states by treating the system on the atomistic level. It captures the strain by adjusting the positions of constituent atoms so as to minimize the total elastic energy computed in the VFF Keating model. The displacements of atoms from their bulk positions are incorporated into the 20-band nearest-neighbor sp3d5s* tight-binding Hamiltonian.

A single dome-shaped InAs QD, with height of 1.8 nm and diameter of 19.2 nm, positioned on a 0.6-nm-thick wetting layer (WL), embedded in a GaAs barrier material is considered. Since strain is a long-range phenomenon, it has to be computed in a domain much larger than the quantum dot itself, while the domain for the electronic calculation can be smaller, since the electronic wave function is confined.

Scaling to tens of millions of atoms: NEMO-3D uses the conjugate-gradient algorithm to find equilibrium positions of atoms, and the Lanczos algorithm to diagonalize the sparse Hamiltonian matrix. In order to extend the treatment to multi-million atom systems, both algorithms are parallelized using MPI. For example, on 16 64-bit Itanium2 CPUs with memory of 11.5 GB/CPU (NCSA TeraGrid) it is possible to compute strain in 200-million-atom, and electronic structure of 35-million-atom devices. NEMO-3D exhibits a linear scaling, both of computational time and memory, as a function of the system size. This work presents a systematic study of the strain calculated within a domain consisting of up to 64 million atoms, followed by an electronic calculation on a subdomain containing up to 21 million atoms. Unique and targeted eigenstates can be extracted from system matrices of order 4Å~108.

# Grid Systems & Applications
# Thursday, September 22 – 3:15pm-4:55pm
# Grid Systems & Applications II

### Parallel Processing and Large Data Visualization in ParaView

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ParaView is an open source scientific visualization tool specifically designed to handle large datasets in distributed computing environments. It is based on the popular open source library VTK (Visualization Toolkit). This presentation will describe the historical evolution of ParaView and introduce its architecture and capabilities.

### Distributed and Parallel Scientific Visualization with ParaView on TeraGrid

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TeraGrid (http://www.teragrid.org) is an NSF-supported national effort to build and deploy the world's largest, most comprehensive, distributed infrastructure for open scientific research. It includes 20 teraflops of computing power distributed at nine sites with facilities capable of managing and storing nearly 1 Petabyte of data, high-resolution visualization environments, and toolkit for grid computing. All the sites are tightly integrated and connected through a network that operates 40 gigabits per second. Indiana and Purdue Universities are connected to TeraGrid via I-Light.

ParaView (http://www.paraview.org) is an extensible, open source multi-platform application for visualizing large data sets. ParaView operates on a wide range of data formats including structured, unstructured grids, and adaptive mesh refinement data sets. ParaView includes suit of visualization algorithms, including contouring, clipping, streamlines, streamribbons, glyphing, and animations. In addition to these features, ParaView offers an advantage of running visualization processes in distributed and parallel fashion for processing large data sets. It runs parallel on distributed and shared memory systems using Message Passing Interface (MPI). ParaView uses the data parallel model. In this model, data is broken into the pieces to be processed by different processors which allows visualizing large data sets. This capability makes Paraview suitable visualization application for TeraGrid environment.

In this presentation, we will show how large data sets, produced by the parallel Computational Fluid Dynamics (CFD) applications can be visualized with distributed and parallel modes of the ParaView on the TeraGrid resources.

Acknowledgement. TeraGrid access was supported by the National Science Foundation (NSF) under the following programs: Partnerships for Advanced Computational Infrastructure, Distributed Terascale Facility (DTF) and Terascale Extensions: Enhancements to the Extensible Terascale Facility, with Grant Number: TG-CTS050003T.

### Browsing Molecules in GEMS

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Biomolecular simulations produce more output data than can be managed effectively by traditional computing systems. Researchers need distributed systems that allow the pooling of resources, the sharing of simulation data, and the reliable publication of both tentative and final results. To address this need, we have designed GEMS, a system that enables biomolecular researchers to store, search, and share large-scale simulation data. The primary design problem is striking a balance between generosity and gluttony. On one hand, storage providers wish to be generous and share resources with their collaborators. On the other hand, an unchecked data producer can be gluttonous and easily replicate data unnecessarily until it fills all available space. To balance generosity and gluttony, GEMS allows both storage providers and data producers to state and enforce policies on the consumption of storage and the replication of data. By taking advantage of known properties of simulation data, the system is able to distinguish between high value final results that must be preserved and low value intermediate results that can be deleted and regenerated if necessary. We have built a prototype of GEMS on a cluster of workstations and demonstrate its ability to store new data, to replicate within policy limits, and to recover from failures.

A recent addition to the GEMS system is a GUI client that may be used to search the metadata catalog, and display 3D molecular structures all in the same client. We would like to perform a demonstration of GEMS' ability to catalog new datasets and display their scientific content on the fly.

## Web Services in Life Science

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Web Services have become a standard in application to application communication over the Internet. As the amount of data in the Life Sciences grows exponentially, researchers turn towards Web Services to provide them with the most up-to-date data, without requiring large in-house databases. We will discuss our approach of utilizing Web Services in several aspects of proteomics including non-synonymous single nucleotide polymorphisms (SNPs), mutations, and structural homology. Using open-source protein visualization applications and integrated Web Services, a researcher can interactively explore large remote databases or submit structures of their own for processing.

For more, see:
http://www.mutdb.org#Web Interface
http://www.lifescienceweb.org/beta#Web Service Interface

# Poster Session Abstracts

## Posters and Poster Session Demonstrations Wednesday, September 21 – 10:10-10:40am; 2:05-2:35pm; 3:50-4:14pm

### Places & Spaces: Cartography of the Physical and the Abstract

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*Deborah MacPherson*
*Accuracy & Aesthetics*

The Places & Spaces exhibit has been created to demonstrate the power of maps. An initial theme of this exhibit is to compare and contrast first maps of our entire planet with the first maps of all of science as we know it. Come see with your own eyes the extent to which maps can be employed to help make sense of the flood of information we are confronted with and how domain maps can be used to locate complex and beautiful information.

This exhibit presents a selected series of maps and their makers along with detailed explanations of why these maps work. The physical prints support the close inspection of high quality reproductions for display at conferences and education centers. It is meant to inspire cross-disciplinary discussion on how to best track and communicate human activity and scientific progress on a global scale. The online part of the exhibit is viewable at: http://vw.indiana.edu/places&spaces/

This exhibit was supported in part by the School of Library and Information Science, Indiana University and a National Science Foundation CAREER grant under IIS-0238261.

### Pedigree Visualization and Navigation

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Traditionally pedigree data has been very useful to present and document complex information of an ethnic or a population subgroup. Various analysis tools were developed around the pedigree data to extract useful information. Recently these pedigree data has posed unprecedented challenges to the scientific community due to their increasing size. Some fundamental analysis tools have become a burden and have strained the conventional workflow. It is important to revisit those tools with the present state of technology and enhance the usability of the software and the efficiency of the workflow. In this poster, we present the design and implementation details of PViN (Pedigree Visualization and Navigation), a scalable and flexible software system that enables visualization, analysis and printing of pedigree database, and compare the present and the past workflow. The following are some compelling reasons for the PViN development: (1) Indiana university's center of hereditary diseases has accumulated very large amounts of hereditary information from various populations for ongoing research projects and has difficulty managing and effectively printing the associated pedigree trees with legacy FORTRAN software; (2) The size of some of these databases (over 40,000 entries covering seven generations) is too large for existing commercial pedigree software to handle; (3) Our researchers and support staff need more effective ways to perform visual analysis tasks, such as the comparison of multiple pedigrees and the cross-referencing of individuals that appear in multiple families (through re-marriage.) The PViN system addresses these fundamental problems while also providing a number of additional features and functions including: context-free drawing routines that enable rendering onto screen and printer contexts interchangeably; a generic framework that allows the system to interface with multiple databases and database servers; a multiple view user interface that provides side-by-side comparisons and "focus+context" rendering; and advanced node searching and cross-referencing capabilities.

### SRS Browser: A Visual Interface to the Sequence Retrieval System

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This paper presents a novel approach to the visual exploration and navigation of complex association networks of biological data sets, e.g., published papers, gene or protein information. The generic approach was implemented in the SRS Browser as an alternative visual interface to the highly used Sequence Retrieval System (SRS) [1]. SRS supports keyword-based search of about 400 biomedical databases. While the SRS presents search results as rank-ordered lists of matching entities, the SRS Browser displays entities and their relations for interactive exploration. A formal usability study was conducted to examine the SRS Browser interface's capabilities to support knowledge discovery and management.

### Third Generation Data Capture and Monitoring for High Interaction Honeynets

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Until very recently researchers for high interaction honeynets faced the problem of how to integrate and relate the multiple data sources they have as network and host information into a unified and complete view. We will demo the current implementation of the third generation data architecture and model for high interaction honeynets which is part of the current honeynet project Linux CD-ROM distribution "roo". This model allows intruders activity to be traced using process trees that also combine network information and IDS entries.

### Scene Tunnel Acquisition for Cityscape Visualization

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This paper proposes a visual representation named scene tunnel to archive and visualize urban scenes for Internet based virtual tour. We scan cityscapes using multiple cameras on a vehicle that moves along streets, and generate scene archive more complete than a route panorama. The scene tunnel can cover high architectures and various object aspects. It contains much less data than video, which is suitable for image transmission and rendering over the Internet. It has a uniformed resolution along the camera path and provides continuous views for virtual traversing of a real city. We have developed image acquisition methods from slit setting, view scanning, to image integration. We have also achieved city visualization with scene tunnels on the Internet by transforming view, streaming data, and providing interactions.

### Zero-Crossing Iso-Surfaces in Volume Datasets

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This paper describes a new surface extraction method for volume datasets by applying iso-surface extraction techniques to the zero-crossing edges in a volumetric domain. A volume dataset is first filtered using a Laplacian of Gaussian filter to generate a zero-crossing field. A marching cube process will then be able to extract the entire zero-crossing surface that may be viewed selectively based on various intensity ranges and gradient scales. This new technique provides a more efficient surface navigation and extraction mechanism, as well as more accurate surface details, than the traditional iso-surface techniques.

**Indiana Center for Biological Microscopy – Interactive 3D Image Processing During Volume Rendering**

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The Indiana Center for Biological Microscopy is a core facility at IUPUI providing university and commercial biomedical researchers with access to state-of-the-art confocal and two-photon laser-scanning microscopes, which can be used to collect multi-channel 3D and 4D (i.e. 3D time series) images of live or fixed specimens. Images are collected using the microscopes, and then transferred over the network to PCs or Macs in either our facility or a researcher's office or lab, for processing and analysis.

But 3D optical microscopy depends heavily on interactive image processing, which often requires that microscopy-specific image processing techniques be incorporated into volume rendering software. Traditionally, 3D imaging programs use graphics processing units (GPUs) to perform real-time volume rendering, but do not use the GPU to perform image processing, due to the limited programmability and low-precision pixel arithmetic used in older GPUs.

We use an extended version of our Voxx volume rendering program and a GeForce 6800 GPU to demonstrate how the improved programmability and higher-precision pixel arithmetic available in newer GPUs can be used to perform real-time image processing during volume rendering of 3D/4D microscopy data.

The combination of our Voxx program, a low-cost GPU-based video board, and a PC or Mac makes a cost-effective 3D imaging workstation for microscopy-based research.

For more information, see; www.nephrology.iupui.edu/imaging/voxx/.

**Real time rendering of route panoramas with GPU**

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Our software will showcase the real-time route panorama rendering in 3D with the use of GPU (graphics processing unit). Our program uses special lens that modifies the vertices in real time with the result of a panorama lens effect. In order to achieve high performance real-time rendering, we implemented the special lens by programming the vertex pipeline of a video card. Our implementation is extremely fast on mainstream computers with video cards that support GPU programming.

For more information, see: http://www.cs.iupui.edu/~jzheng/RP

### Applying Lagrangian-Eulerian Advection to Supernova Simulations

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Simulations run by scientists collaborating on the TeraScale Supernova Initiative involve the complex mechanics of thermodynamics and particle physics and can generate enormous amounts of simulation data. How to represent this data and provide useful services to scientists are two of the challenges for visualization researchers on the project. One of the newer tools used in the exploration of vector fields is called Lagrangian-Eulerian Advection (LEA). This technique provides a rich amount of information compared to earlier methods such as arrow plots. Vector-scalar relationships can be shown by combining LEA with color and contours, while the relative orientation of vector fields can be portrayed by visualizing dot products. Experimentation with these techniques has helped provide insight into the science of these intriguing multivariate datasets.

### Materials Designed by Discovery Informatics

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The building of models to describe significant physical processes is a key activity in science and engineering. Model building involves the intersection of experimental data with theory, where the objective is to determine the relationship between experimentally measured properties and an optimal set of descriptors of the process. The key intellectual challenge is to determine the appropriate descriptors, which is an evolving process as the researcher gains insight about the phenomena.

High throughput experimentation, high throughput computation, dynamically linked databases, and advanced visualization methods offer the possibility of qualitatively changing the model building process. High-resolution visualization with large screens enables the researcher to discover relationships in the data. This is a process in which the researcher modifies the model in real time using the information content embedded in the data.

## Purdue Portable Haptic Display for Large Immersive Virtual Environments

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The Purdue Portable Haptic Display is aimed at developing a platform-independent haptic rendering system that can be easily integrated to large immersive visual displays for multi-modal data perceptualization.

The Envision Center for Data Perceptualization at Purdue University has several kinds of large immersive visual displays including a CAVE and a tiled-wall display along with force-feedback haptic interfaces. However, there exists significant incompatibility between both hardware and software of the haptic interfaces and the visual displays. In order to facilitate the use of the haptic interfaces with the large visual displays, we have conceived the idea of a portable haptic display that has the architecture of distributed rendering through network.

# Demonstration Abstracts

## Evening Demonstrations in the ICTC
## Wednesday, September 21 – 6:00-8:00pm
## VR Theater

### Cabinet of Dreams

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"Cabinet of Dreams" is a 3D virtual reality showcasing highlights of the Chinese art collection at the Indianapolis Museum of Art (IMA). The objects range in date from 1000 BC to the mid-1800s and include wood, bronze, and earthenware ceremonial pieces. An inkstone is a small mountain landscape with a dragon. A brushpot is engraved with lacquers to show scenes of country pursuits. A ritual cooking vessel carries an ancient inscription of a man on a chariot. These magical items were studied both in the IMA archive vault and through digital technology as inspiration towards developing whimsical environments to re-exhibit objects in 3D interactive graphics.

Using VR, the items no longer remain in storage to sit frozen behind glass – they exist in another instance of time and space and are being displayed in real-time 3D stereo vision and audio using projection technology. In the virtual environment, the museum visitor is allowed to approach the precious object with a new sense of proximity, scale and viewing perspectives that real life cannot accommodate. It is a rare moment to be able to view all sides of an object as we did for our data. This type of intimacy could only occur for research purposes with the presence of a museum official.

One of the objects is a Qing dynasty cabinet made of cloisonné, glass, and zitan. The cabinet is the metaphoric center of the installation, reflected in the art and the display device as if it were a modern day Wunderkabinett. By combining the actual cabinet with the virtual dreams inspired by the real objects, computer graphic environments represent a structure of times past as well as a sense of virtual space. The actual cabinet object is on exhibition near the Asian galleries. Its presence hints at the collection of rarities that are hidden within the virtual environment and the museum itself.

The main virtual environment is a series of hallways, sliding doors and rooms. Each room houses a small version of the original cabinet. When approached, the cabinet doors open to display a floating image of another world. As the visitor enters the cabinet, time, sound and space fluctuate and one is transported to that alternate world. Each environment's audio is composed to establish a unique atmosphere based on the history of the object, its functions and its metaphoric environment in the computer graphics world. For example, an ancient wellhead depicts a shaman and tells the story of the eastern sky. In the virtual environment, as one moves closer to the wellhead, the audio changes with the sky, twinkling to night and revealing its constellations. Thirty objects from the museum collection comprise eleven virtual environments.

"Cabinet of Dreams" viewing occurs on 3D stereo display systems and visitors wear 3D glasses while navigating the environments.

### Advanced Virtual Manufacturing Laboratory (AVML) for Training, Education, and Research

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A high fidelity web-based virtual environment – Advanced Virtual Manufacturing Laboratory (AVML) – that uses advanced visualization techniques is presented. The dynamic virtual reality system is interactive and allows for the simulation of advanced manufacturing. Currently, the system supports CNC (Computer Numerically Controlled) milling, a versatile machining process that is widely used in industry.

The system provides a safe, cost-effective, and highly flexible and accessible tool for training and education as well as product realization. More specifically, the AVML provides the following training functions for users via the Internet: (a) interaction with a fully-functional virtual CNC milling machine, including real-time machining of parts, (b) training on key operating procedures of modern CNC machines, and (c) intelligent virtual tutor that gives a lecture describing the concepts of CNC milling and the components of the milling machine, as well as assistance with hands on training on the virtual machine.

The environment is driven by three software modules that communicate with each other using a TCP/IP network socket interface; these modules are: (1) a CNC Milling machine simulator, (2) a virtual-environment display engine, and (3) an intelligent-agent engine. The modules run on a single computer in a seamless web-based framework. The AVML can run on desktop or laptop personal computers. It can also run on more sophisticated systems such as a CAVE (for fully-immersive virtual reality visualization and simulation).

The AVML enables colleges and universities to easily and inexpensively provide students with effective, safe, and highly accessible training on advanced machine tools. It can also be used by machine tool manufacturers to provide online training, reducing or eliminating the need for onsite and/or live training classes for customers.

The work, which is still underway, has been presented in several conferences and symposia, including ASME, ASEE, ICCIE, and Solutions Conference 2005.

The methodology and its implementation, and the resulting virtual system for CNC machining will be presented. On the other hand, the current system's capabilities and functionality will be demonstrated in the CAVE, which is currently available in the Advanced Visualization Laboratory at IUPUI.

### Interactive 3D visualization of kinetic sculpture

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The goal of this project is development of an interactive visualization of a sculpture to be placed on the east side of the College of Technology building on Purdue University West Lafayette campus. The 40 foot tall sculpture represents a torch with three rotating flames. The motion of the flames is initiated by the rotation of a metal disc at the base of the sculpture.

Traditionally, prior to the realization of the final sculpture, the sculptor builds a model to scale, which helps the artist visualize the form and three dimensionality of the object, but doesn't provide any visual feedback on how the sculpture will fit within the surrounding environment. Our visualization allows the sculptor to view and interact with a full scale model, placed in its surrounding environment. The ability to see the object from different points of view and in relation to the other campus buildings has provided the artist with the unique opportunity of truly testing the expressiveness of the art within the environment in which it will reside.

Because proper scale of the sculpture in comparison to the surrounding buildings was so important to the visualization of this project, satellite photos were used and the 3D models were built on top of this overhead reference, using Discrete's 3ds Max. Textures and colors were captured from digital photos of the buildings and were manipulated to maximize the possibility for repetition and reuse. Each model was exported separately into the OpenSceneGraph (www.openscenegraph.org) format for use with VRJuggler (www.vrjuggler.org), to display the virtual environment in immersive devices such as the Purdue Envision Center FLEX. A pair of Fakespace Labs' pinch gloves, along with a 6 degrees-of-freedom tracker by Intersense allows the user to interact directly with the application by detecting when the user makes gestures that can affect the virtual sculpture, such as "grabbing" the sculpture and performing constrained rotations of the metal disc.

### Interactive 3D Sign Language in Immersive Environment

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The general goal of this project (work in progress) is development of an immersive virtual environment in which deaf children can interact with fantasy 3D signers. The interactive signing avatars can be displayed in immersive devices such as the Purdue Envision Center FLEX.

Recently we have created a highly interactive computer animation program (Mathsigner©2004) for learning K-3 arithmetic skills, aimed at deaf children. The program includes 3D animated signers modeled as seamless low-poly meshes and rigged with a human-like skeletal deformation system. The virtual signers are animated using a library of signing clips recorded directly from a signer wearing a 19-markers motion capture optical suit and a pair of 18-sensors cybergloves. Smoothness of motion (in real time) and interactivity are achieved via programmable blending of the motion captured animation segments.

The specific objectives of this work in progress are: (1) display of the Mathsigner© animated 3D signers in an immersive environment (e.g., the FLEX); and (2) realization of a basic interaction between the user and the avatars. A pair of Fakespace Labs' pinch gloves, along with a 6 degrees-of-freedom tracker by Intersense will allow the user to interact directly with the application by detecting when the user makes gestures that can affect the motion of the virtual signer, such as "picking up" a virtual number (represented by a 3D block) thus causing the 3D avatar to come forward and produce the corresponding number sign.

The main challenge presented by this project is the display and interaction with seamless characters that deform organically during motion. In general, characters displayed in immersive environments are segmented characters made of rigid components which rotate without changing shape. In order to display the Mathsigner© 3D characters with realistic deformations during signing motion, we have used Cal3D character animation library (cal3d.sourceforge.net/), along with OsgCal. OsgCal is an adaptor for using Cal3D within OpenSceneGraph (www.openscenegraph.org), the format necessary for use with VRJuggler (www.vrjuggler.org).

The 3D rigged models were exported in different components using the four cal3D file formats: .cmf (Mesh file), .csf (Skeleton file), .caf (animation file), and .crf (texture file). The skeleton was exported first because exports of the mesh and animations need to reference the .csf file. All meshes required a material identifier in order to be exported, and every time a material was changed, the mesh had to be exported along with the new material. Once each separate file for cal3D animation was exported, the files were reassembled within the osg program using the osgCal libraries which allows loading the cal3D data into a model node within the scene graph. Each exported cal3D file can be read into the program through a configuration file, or can be hard coded directly into osgNav. After using osgCal to load the files, we are currently programming the interaction with instances of the model using calls to the osgCal library. We are using startLoop and stopLoop functions to cue animations; in addition, we are experimenting with un-looped animation, changes of animation speed, and blending of multiple animations by assigning them different weight values. Once all the animations are working within the osg program, interaction with the model as a scene graph node will be coded as well.

### The Solar Journey Project

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The Solar Journey Project is 6-year, multi-institution collaboration focused on the development and application of advanced visualization, modeling, virtual reality and analysis tools to virtual astronomy. While the specific scientific objective of this research is a better understanding of the local galactic neighborhood of our Sun, this collaboration has also resulted in the development of a range of new visualization technologies, including: multi-scale techniques for overcoming the precision limitations of graphics hardware; navigational techniques for effectively traversing many orders of spatial magnitude, methods for physically-based star rendering, and a software framework to seamlessly integrate real-time analysis with high-quality batch rendering. Specific productions highlighted in this talk include several high-quality animated shorts (including one shown in the SIGGRAPH 2000 Electronic Theater), an interactive CAVE application, and a 20-minute production for the multi-projector laser dome at the Beijing Planetarium.

For more information, see: http://www.cs.indiana.edu/~soljourn/

# Evening Demonstrations in the ICTC
# Wednesday, September 21 – 6:00-8:00pm
# Passive Stereo/John-e-Box/Other Displays

### Stereoscopic Visualization of Scientific and Medical Content

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The use of stereoscopic display medium is now in use at the Ruth Lilly Health Education Center (RLHEC) in Indianapolis to help educate nearly 100,000 students annually. The stereoscopic display is helping to revolutionize a subject area to students K-12 in a subject matter that traditionally has been a very difficult area to learn. Content created by the research team at the IUPUI School of Informatics has been implemented to fit into the curriculum of the RLHEC. Future plans of the RLHEC include distributing this content to other health centers around the state, country, and globally, through high speed networks.

This presentation will display on a portable John-E-Box, or other portable stereo display system available to the School of Informatics, the display of a number of stereoscopic animations created for the RLHEC, including subjects such as The Cell, The Circulatory System, The Nervous System, The Immune System and The Respiratory System. Also displayed will be content created for the simulation of Hip and Knee Replacement Surgery, and simulations of real world data of biological macro-molecules.

Presentation will also include a description of content research procedures, pre-visualization methods, production methods, stereoscopic creation techniques, production issues and post-production methods. Considerations of the limitations and benefits of the stereoscopic medium will be discussed, as well as these considerations regarding the production of the stereoscopic content. A PowerPoint presentation can accompany the John E Box demonstration to further explain the production pipeline.

### AGJuggler

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AGJuggler is a project developed at the Envision Center for Data Perceptualization at Purdue University. The main objective in this study is to make collaborative experiences and interactions richer with the incorporation of Virtual Reality tools inside a collaborative framework. This is accomplished by offering: an improved sense of presence; synchronous distributed visualization; real time interaction and a customizable solution for implementing virtual reality within a collaboration environment. The Access Grid™ is the collaboration environment used for the study; while the API used for programming virtual reality applications is VRJuggler. For more information, see: http://people.envision.purdue.edu/~dioselin/AGJuggler/

## Developing and Deploying a Robust System for 3D Surface Scanning and Analysis


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3D surface scanning is an evolving field that encompasses a wide variety of technologies and applications. For the past three years, the UITS Advanced Visualization Lab has been working with researchers in the IU School of Medicine, the Anthropology and Computer Science departments at IUPUI, and an international consortium of collaborators to develop an integrated system of hardware, software, and methodology to enable the reliable and accurate scanning of human heads and faces.

This NIH-funded collaboration is utilizing 3D surface scanning technology to supplement traditional physical measurements in the diagnosis and study of fetal alcohol spectrum disorders (FASD). Craniofacial anthropometry has been used to assess and describe abnormal craniofacial variation and the facial phenotype in many syndromes. It has also been used in the clinical setting as a diagnostic aid and as a means of objectifying clinical descriptions of individual patients. Through the use of 3D scanning, the project seeks to develop novel methods for assessing facial variations to provide more accurate diagnoses of the level of alcohol exposure. Moreover, by organizing the surface scans of subjects and control individuals in a database, researchers will be able to perform novel queries, comparisons, and longitudinal studies. This project has developed three portable 3D scanning systems that have been deployed to a variety of locations throughout the US as well as sites in Europe and Africa.

This talk will focus on our experiences in developing a robust and accurate 3D surface scanning system for the FASD project, including the evaluation of competing technologies, the development of software procedures for stitching, measurement, and analysis of models, and the challenges of international technology deployment. We will also highlight some of the outgrowth applications of this technology, including scanning of objects for forensics, cultural heritage, and digital art.