Integrating Visualization with Modeling and Simulation for Biomedical Applications

(A Course Proposal for IEEE Visualization 2002)

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Abstract:

In this tutorial, we will discuss the importance of integrating visualization tools with modeling and simulation tools for biomedical computational science. Traditionally, these components exist as disparate packages, resulting in wasted time and a cognitive disconnect between the effects of model changes on simulation results. A much more efficient system is one which integrates modeling, simulation, and visualization, in a single unified framework. In this tutorial we will introduce such a system: the Biomedical Problem Solving Environment, *BioPSE*. BioPSE is an open source software architecture for the interactive investigation of biomedical applications. We will provide a general overview of dataflow programming, will give an introductory overview of the BioPSE system, and will detail four research projects that are currently using BioPSE for their biomedical exploration..

Course Overview:

The traditional scientific computing pipeline is a non-integrated, batch mode, sequential system. The tools used for modeling the geometric domain of the problem are separate from the tools that approximate the governing equations and simulate the science, which in turn are separate from the tools used for visualizing and analyzing the results. Because the tools are separate, a significant amount of time is wasted saving temporary results, converting between file formats, moving data, and manually tracking various iterations. More importantly though, as the amount of time grows between when changes are made in the first stage (*e.g.*, altering the geometric model) and the effects of those changes are seen in the last stage (*e.g.*, changes to the streamlines), it becomes increasingly difficult to recognize and gain insights about the cause-effect relationship.

A far more efficient scenario is one in which the modeling, simulation, and visualization components are integrated into a single modular software architecture. In such a system, changes in one stage of the pipeline would immediately propagate to the other stages, allowing for the interactive investigation of many different parameters without the tools getting in the way. This "what if?" process is essential for iterative design, and is fundamental to scientific exploration, discovery, and analysis. It is precisely this vision that has driven the development of the Biomedical Problem Solving Environment, *BioPSE*. BioPSE is an open source software system that is currently being developed, distributed, and supported through the NIH NCRR Center for Bioelectric Field Modeling, Simulation, and Visualization, housed in the SCI Institute at the University of Utah.

In this course, we will begin by motivating the integration of modeling, simulation, and visualization tools into a common problem solving environment. We will describe the design of BioPSE, and will briefly review the underlying concepts of dataflow and computational steering. We will conclude the first portion of our course by demonstrating the BioPSE system, and providing an overview of the visualization capabilities of the system.

For the second part of the course, we will dive deeper into the functionality of BioPSE in the context of examining several real-world bioelectric field problems. Scientists currently using BioPSE to model, simulate, and visualize their data will describe both their driving application and how they are presently using BioPSE to investigate their research. Each speaker will conclude by presenting a demonstration of his application running in BioPSE.

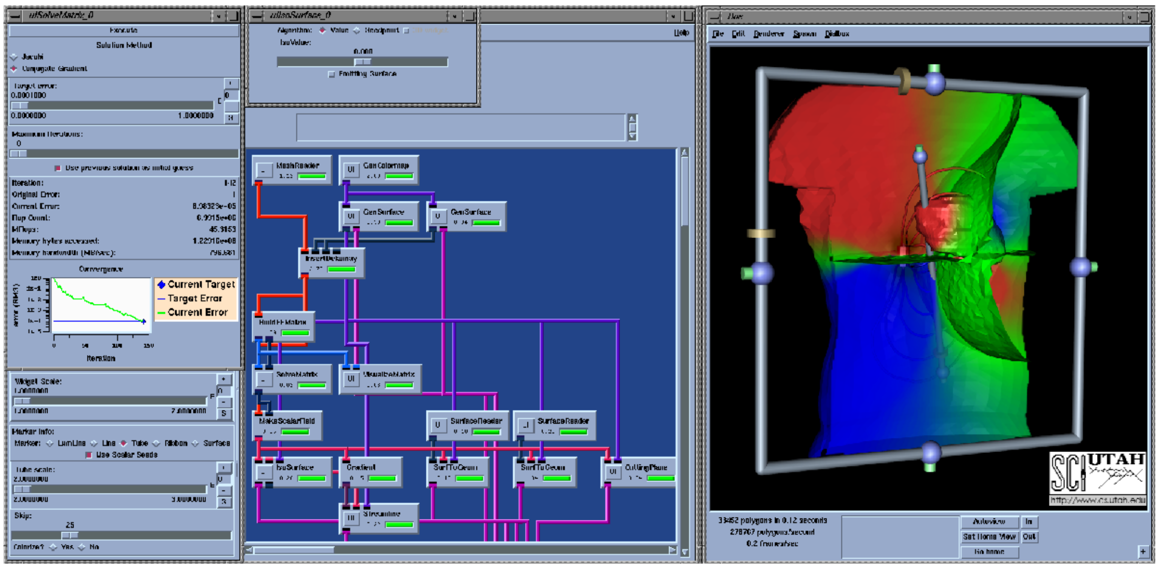

Figure 1. The BioPSE system integrates modeling, simulation, and visualization, in a unified framework.

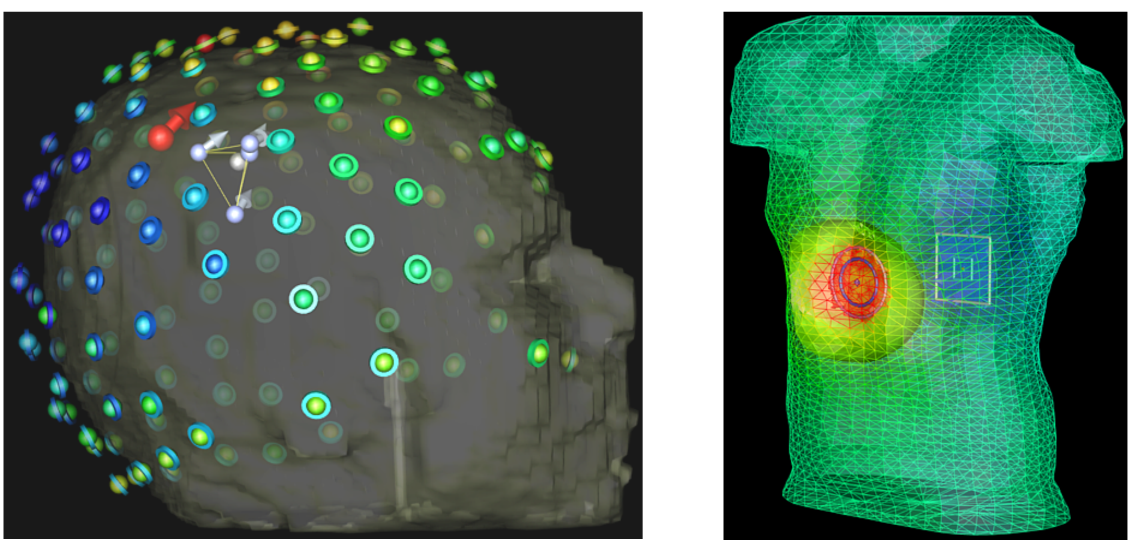

Figure 2. Neuorscience and electrocardiography research problems are explored using BioPSE .

Course Vital Statistics:

Duration:	Half Day
Format:	Lectures and Case Studies
Level:	All
Target Audience:	Computational Scientists

Prerequisites:

Basic knowledge of math and science, as well as a general familiarity with at least one scientific software system (*e.g.*, MATLAB, Iris Explorer, vtk).

Speaker Information:

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Speaker Biosketches:

David Weinstein is a PhD candidate in the School of Computing at the University of Utah, as well as the Technical Manager for the NIH NCRR Center for Bioelectric Field Modeling, Simulation and Visualization. In his capacity as Technical Manager, Weinstein has coordinated the scientific development of the BioPSE software system. Weinstein’s research interests include modeling, simulation, and visualization for the forward and inverse EEG problems.

Weinstein received B.A. degrees in Computer Science and Applied Mathematics from the University of California, Berkeley, in 1993. He was awarded a University of Utah, Graduate Research Fellowship in 1994, and was an NSF Graduate Research Fellow from 1994-1997.

Marty Cole is the Software Manager for the NIH NCRR Center for Bioelectric Field Modeling, Simulation, and Visualization. As Software Manager, Cole coordinates the development and support of the BioPSE software system.

Cole received his B.S. in Computer Science from the University of Utah in 1997. After graduation, Cole worked in the 3Dpaint division of Parametric Technologies Corporation. Cole joined the Scientific Computing and Imaging Institute as Software Manager in 2000.

Chris Johnson directs the Scientific Computing and Imaging Institute at the University of Utah where he is a Professor of Computer Science and holds faculty appointments in the Departments of Physics, and Bioengineering. His research interests are in the area of scientific computing. Particular interests include inverse and imaging problems, adaptive methods, problem solving environments, large-scale computational problems in medicine, and scientific visualization. Professor Johnson was awarded a Young Investigator's (FIRST) Award from the NIH in 1992, the NSF National Young

Investigator (NYI) Award in 1994, and the NSF Presidential Faculty Fellow (PFF) award from President Clinton in 1995. In 1996 he received a DOE Computational Science Award and in 1997 received the Par Excellence Award from the University of Utah Alumni Association and the Presidential Teaching Scholar Award. In 1999, Professor Johnson was awarded the Governor's Medal for Science and Technology.

Steven Parker is a Research Assistant Professor in the School of Computing at the University of Utah. As a member of the Scientific Computing and Imaging (SCI) Institute, he continues the development of SCIRun, which was the basis of his PhD dissertation and which forms the basis for a number of projects in the SCI institute. He is also the software architect for the Center for Accidental Fires and Explosions, where he works on creating a problem solving environment for a complex multi-physics simulation running on thousands of processors.

His primary research agenda involves bringing together his varied research interests: scientific visualization, computational steering, high performance computing, computer graphics, problem solving environments, component architectures, parallel programming, distributed computing, and visual programming. In particular, he attempts to use programming languages, parallel computing and systems software to bring about new approaches for scientific computing and visualization.

Rob MacLeod received both his B.Sc. ('79) in Engineering Physics and his Ph.D. ('90) in Physiology and Biophysics from Dalhousie University. His M.Sc. ('85) in Electrical Engineering came from the Technische Universitat, Graz, Austria. He is an Associate Professor in the Department of Internal Medicine (Division of Cardiology) and Assistant Professor in the Department of Bioengineering at the University of Utah. He is a member of the Scientific Computing and Imaging (SCI) Institute, and a co-director of the Nora Eccles Harrison Cardiovascular Research and Training Institute. His research interests include computational electrocardiography (forward and inverse problems), experimental investigation and clinical detection of cardiac ischemia and repolarization abnormalities, and scientific computing and visualization. He has presented in previous IEEE Visualization conferences and at the Visualization in Biomedical Computing meeting, and published in Computer Graphics and Applications as well as a range of electrocardiology and biomedical engineering journals.

Dana Brooks received the PhD degree in Electrical Engineering in 1991, the MSEE in 1988, and the BSEE in 1986, all from Northeastern University. In addition he earned a BA in English from Temple University in 1972. He was the recipient of a National Science Foundation Graduate Fellowship in 1988 and an American Electronic Association Fellowship in 1987.

Dr. Brooks' research interests focus primarily on biomedical applications of digital signal and image processing. His current projects in the area of electrocardiography include work on the inverse problem of electrocardiography, on quantification of multi-sensor time-varying electrical patterns on the heart and torso surface, on the development of realistic bounds on a large number of measures of these patterns, and on the use of the wavelet transform to study both these multi-sensor patterns as well as single-lead signals. He also has research interests in higher-order spectra, and digital signal processing with chaotic signals and systems.

Robert McCarley is a graduate of Harvard College (summa cum laude) and Harvard Medical School, trained at the Brigham and Women's Hospital and Mass. Mental Health Center. He is Professor and Chair of the Harvard Department of Psychiatry at the Brockton/West Roxbury VAMC, where he is the Director of the Neuroscience Laboratory and the VA Center for Basic and Clinical Neuroscience Studies of Schizophrenia, and Deputy Chief of Staff for Mental Health Services. His research interests are in the neurobiology of behavior. He has chaired the clinical neuroscience and biological psychopathology NIMH study committee, the NIMH Carmel conference on Neuroimaging and has been a member of several NIH, VA and APA mental health task forces. International recognition and awards for his work have come from many European countries, as well as from Australia, Canada, India, Israel, Japan, and Korea. In 1998 he received the American Psychiatric Association Research Award. He has more than 150 peer-reviewed publications and is currently a member of the editorial boards of the Journal of Neuroscience, Sleep Research, Biological Psychiatry and Psychophysiology.

Craig Henriquez is an Associate Professor of Biomedical Engineering at Duke University and is a member of the Duke Computational Electrophysiology research group. His group is interested in the application of the bidomain model to diseased tissue to investigate how changes in tissue structure (both natural and diseased induced) and changes in ionic current flow influences the nature of conduction and the onset of arrhythmia. Dr. Henriquez's group is also interested in developing realistic models that will enable investigators to better interpret electrophysiological measurements made in the clinic. He is presently applying the concepts needed in large scale cardiac models to the development of biological neural networks to the cortical-cortical interactions in the brain that underlie a particular motor task.

Course Syllabus:

1st Session (90 minutes)

INTRODUCTION AND OVERVIEW [Johnson]	(30 minutes)
COMPUTATIONAL STEERING [Parker]	(30 minutes)
Component Architectures	
Dataflow Programming	
Steering in SCIRun	
BIOPSE SYSTEM [Weinstein and Cole]	(30 minutes)
System Overview	
Biomedical Tools	
Introductory Examples	

--- BREAK ---

2nd Session (100 minutes)

EXPERIMENTAL ELECTROCARDIOGRAPHY [MacLeod]	(20 minutes)
Science Overview	
BioPSE Implementation and Demonstration	
CELLULAR SIMULATIONS OF CARDIAC ACTIVITY [Henriquez]	(20 minutes)
Science Overview	
BioPSE Implementation and Demonstration	
INVERSE ELECTROCARDIOGRAPHY [Brooks]	(20 minutes)
Science Overview	
BioPSE Implementation and Demonstration	
CLINICAL NEUROSCIENCE [McCarley]	(20 minutes)
Science Overview	
BioPSE Implementation and Demonstration	
GENERAL QUESTION AND ANSWER SESSION [All]	(20 minutes)