The Utah Integrated Environment for Image Based Modeling, Simulation, and Visualization

Rob MacLeod, Dana Brooks, Mike Steffen, Burak Erem, Darrell Swenson and Jeroen Stinstra, Ross Whitaker, and Chris Johnson.

University of Utah, SCI Institute, Bioengineering Department
Northeastern University
Tell a Simple Story....

“Pie in the Sky”

Bridges
Pies in the Sky
Pies in the Sky
The Problem Solver’s Toolbox for Bioelectricity and Biomagnetism

or the

“This Old House Approach to Maxwell’s Equations”
Models

Utah Torso

Weinstein Head Model
Forward/Inverse Problem

Forward problem

Epicardial Activation/Potentials

Geometric Model

Body Surface Potentials

Inverse problem

T. Oostendorp
Pie Based Inverse Problem

Model

Sim

Core

Vis

BioPSE
The Present

Center for Integrative Biomedical Computing (CIBC)

Driving Biological Projects

Biomedical Researchers and Clinicians

CIBC Research and Software Pipeline

IBM
SIM
EST
VIS
The Pipeline

- Image acquisition & processing (image processing)
- Identification of structures (image processing and segmentation)
- Generation of volume model (meshing)
- Discrete points e.g., sensors
- Application of tissue parameters/boundary conditions and computation (simulation, estimation)
- Verification & evaluation of results (simulation, error visualization)
- Boundary conditions
- Measured Data
- Fitting of geometric surfaces (geometric modeling)
- Visualization

Meshless approaches
Surface based approaches
Image Visualization
Image Based Shape Analysis

Average Hand

Average Hand
Left Atrial Shape Analysis

First Mode

-2σ  +σ  Mean  +σ  +2σ

First Mode
Segmentation with Seg3D
The Pipeline

- Image acquisition & processing (image processing)
- Identification of structures (image processing and segmentation)
- Fitting of geometric surfaces (geometric modeling)
- Generation of volume model (meshing)
- Application of tissue parameters/boundary conditions and computation (simulation, estimation)
- Verification & evaluation of results (simulation, error visualization)

- Discrete points e.g., sensors
- Meshless approaches
- Surface based approaches
- Boundary conditions
- Measured Data

Visualization
BioMesh3D

Input Labelmap (e.g. from Seg3D)

Stage 2: Material Interface
Stage 3: Medial Axis
Stage 4: Sizing Field
Stage 6: Distribute Particles
Stage 8: Volume Mesh

Output Tetrahedral Mesh (Scaled Jacobian Coloring)
Geometric Mesh Construction

Multisurface Conformal Meshing

Surface Normal
Tetrahedral Volume Mesh
Prism Elements
Epicardial Surface

Talk
Josh Levine
Versatile Modeling

Includes: vasculature, recording needle electrodes, fiber structure.
The Pipeline

Image acquisition & processing (image processing)

Identification of structures (image processing and segmentation)

Discrete points e.g., sensors

Fitting of geometric surfaces (geometric modeling)

Generation of volume model (meshing)

Application of tissue parameters/boundary conditions and computation (simulation, estimation)

Boundary conditions

Measured Data

Meshless approaches

Surface based approaches

Verification & evaluation of results (simulation, error visualization)

Visualization
The Toolkit

Data Sources
- EP Experiments
- ECGSim
- Clinical EP
  - BSPM
  - EAM

Geometric Models
- Body surface
- Epicardium
- Torso volume
  - (In)homogenous
- Heart volume

Source Formulation
- Epicardial potentials
- Activation times
- Discrete sources
- ...

Forward solution method
- Boundary element
- Finite element

Inverse solution method
- Tikhonov, TSVD
- Isotropy
- WBPR
- Activation based Gauss-Newton
- Variational form regularizer
- ...

Interactive Visualization
Example: Forward Solutions
Example: Inverse Solution

Activation-based inverse solution with ECGSim heart geometry
Phantom Validation Data

Utah torso tank with isolated heart
Defibrillation Computational Pipeline

1. Solve Laplace’s equations
2. Project the Electric Field onto Myocardial Volume
3. Estimate Effectiveness

Poster
Wed 12:00
Defibrillation simulation and validation
Defibrillation simulation and validation
Clinical Inverse Solutions

Stovicek, et al

Early Activation
Download SCIRun

(Latest Version 4.5)

Version: 4.5

Released: TBD

[Release Notes]

Note: SCIRun 4.5 is the latest DEVELPMENT build, which contains beta versions of new functionality that we are currently developing. For a STABLE release please download version 4.4.

<table>
<thead>
<tr>
<th>File</th>
<th>Product</th>
<th>Version</th>
<th>Size</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCIRun_4.5_20100813_oex64.dmg</td>
<td>SCIRun</td>
<td>4.5</td>
<td>98 MB</td>
<td>oex64</td>
</tr>
<tr>
<td>SCIRun_4.5_20100813_oex32.dmg</td>
<td>SCIRun</td>
<td>4.5</td>
<td>97.3 MB</td>
<td>oex32</td>
</tr>
<tr>
<td>SCIRun_4.5_20100813_source.tgz</td>
<td>SCIRun</td>
<td>4.5</td>
<td>65.8 MB</td>
<td>source</td>
</tr>
<tr>
<td>SCIRun_4.5_20100813_linux.tgz</td>
<td>SCIRun</td>
<td>4.5</td>
<td>65.8 MB</td>
<td>linux</td>
</tr>
<tr>
<td>SCIRunData_4.5_20100813_data.gz</td>
<td>SCIRunData</td>
<td>4.5</td>
<td>546.8 MB</td>
<td>data</td>
</tr>
<tr>
<td>SCIRunData_4.5_20100813_data.zip</td>
<td>SCIRunData</td>
<td>4.5</td>
<td>547 MB</td>
<td>data</td>
</tr>
<tr>
<td>SCIRun_4.5_20100817_win64.exe</td>
<td>SCIRun</td>
<td>4.5</td>
<td>25.5 MB</td>
<td>win64</td>
</tr>
<tr>
<td>SCIRun_4.5_20100817_win32.exe</td>
<td>SCIRun</td>
<td>4.5</td>
<td>23 MB</td>
<td>win32</td>
</tr>
</tbody>
</table>
Post Doctoral Fellowship:

The NIH Center for Integrative Biomedical Computing (CIBC, www.sci.utah.edu/cibc) at the Scientific Computing and Imaging (SCI) Institute, University of Utah, invites applications for a post-doctoral researcher for interdisciplinary research at the intersection of biomedical image analysis, geometric modeling, simulation, numerical methods, and scientific visualization.
Join the Utah SCI/CIBC Team
More Information

The Center for Integrative Biomedical Computing
at the University of Utah

www.sci.utah.edu/cibc