Model Creation in SCIRun

Jeroen Stinstra
Model Creation

Model Creation Pipeline

Inserting electrodes
Computational Grid
Solving FE Models
Visualization of Metrics
Model Creation Tools

Pipeline components:

- Meshing
- Data Mapping
- Mesh Refinement
- Finite Elements
- Linear Solvers
- Boundary Conditions
- Mesh Smoothing
- Mesh Quality
- Integrators
- Streamlines
- Tensor Algebra
- Distance Fields
SCIRun focus

Current focus:
Bioelectric Field problems/ Poisson equations.

Tools:
Meshing tools / Modeling tools have a broader spectrum.
Finite Element tools currently only for bioelectric fields.

Extensions:
SCIRun has a well developed interface to Matlab for simulations that need to bridge gaps in current architecture
BioElectricity Tools in SCIRun

1st generation tools
- Basic tools

2nd generation tools
- BioPSE Package
- Teem Package
- MatlabInterface Package

3rd generation tools
- More general formulated algorithms that are part of the SCIRun core modules

Model Creation

SCIRun 1
- 1st generation tools
- 2nd generation tools
- 3rd generation tools

SCIRun/BioPSE 3.0
- 1st generation tools
- 2nd generation tools

SCIRun 4.0
- 3rd generation tools
Example 1: Quasi-static Bidomain Model
Ischemia Model

Model Creation

Electrical Model

Flow control to simulate reduced flow

Anatomical Model

MRI

DTI MRI

Goal: To build a specific models for each experiment
Conceptualizing a model

Bidomain model:
\[ \nabla \cdot \Sigma_i \nabla \phi_i = I_{\text{mem}} \text{ and } \nabla \cdot \Sigma_e \nabla \phi_e = -I_{\text{mem}} \]

Transmembrane potential:
\[ \phi_m = \phi_i - \phi_e \]

For comparison with experiment one wants to solve \( \phi_e \)

Quantity as function of space
SCIRun Concepts

Spatial parameters in SCIRun are modeled by Fields

A field is a mesh + data

Mesh types

Data located inside the element

OR

Data located at the nodes

Fields are yellow data pipes
Generating a Smooth Isosurface

Model Creation

Hexahedral mesh

Triangular mesh

Marching Cubes Algorithm (available for each mesh type)

Taubin’s Mesh Fairing Algorithm (also Desbrun weights available)
Generating a Tetrahedral mesh

Model Creation

Interface with TetGen mesh generator (allows adding addition points, and setting volume attributes)
Live SCIRun Demo - Building a TetMesh
Distance Fields

Both a DistanceField and SignedDistanceField are available.

SCIRun 4.1 will also contain TruncatedDistanceField and will return the value of the closest point.

Ischemic zone can be defined by the distance to the border zone.
**Field Calculator Module**

- **Model Creation**
  - Data Values
  - Data Location
  - Math Expression using Scalars, Vectors, and Tensors
  - New Value

**RESULT =** \( \sin(0.3 \times X) + \cos(0.3 \times Y) + \cos(0.4 \times Z) \);

- Stream architecture: computations in blocks of 128 values
- Many functions for dealing with tensors, vectors and scalars
- Consistently integrated in many SCIRun modules
- Extensible architecture
Mapping Modules

Model Creation

Source

Destination

MapFieldDataOntoElems

MapFieldDataOntoNodes

Data on any mesh

Interpolation

Finding Closest Values

Finding Closest Nodes
Finite Element Modules

Definition of conductivity
Conductivity Table

BuildFEMatrix
UI

Right hand site
Stiffness matrix

SolveLinearSystem
UI

Solution to FE problem

Any Element Type
Conductivity by Element
Scalar and Tensor Conductivities
Indexed Conductivities

More specific FE Tools are still found in the BioPSE package
Live SCIRun Demo - Calculator/DistanceField
Defibrillation Simulations
Defibrillation Simulation Pipeline

Model Creation Pipeline for Defib Simulation

Generating custom electrode configurations
Hexahedral Meshing

For Multi Material Models
Regular grids are used

Segmented LatVoMesh

Simple Regular Grid
Hexahedral Mesh Refinements

Where are refinements needed?

Regular grid

Refined Unstructured Hexahedral Mesh
Finite Elements

Boundary Condition: known potentials within electrodes

Potential Vector

<table>
<thead>
<tr>
<th>Knowns</th>
<th>Unknowns</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>nan</td>
<td>nan</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Field with conductivities

Modifying the linear system

Solving the linear system

Field with boundary condition
Future directions
SCIRun 4.1 and higher
SCIRun 4.1

Release scheduled for mid Winter 2009.

For those who cannot wait intermediate builds will be available at our website.

1) Linux binaries
2) Upgrade file readers
3) Quadratic Meshes
4) New Isosurfacing core
5) Electrode Widgets
6) BioPSE/Teem cleanup
7) New documentation
8) Upgrade DistanceFields
9) FieldArrays
10) Code clean up
11) Fibrillation Wave tracking
12) Upgrade MatlabEngine
SCIRun 4.2 and higher

Model Creation

- GUI-less SCIRun / SCIRun server
- New Scheduler / Module logic
- Multi material meshing pipeline
- Developer documentation
Meshing in SCIRun 4.x

Model Creation

Generating surface models
Evaluating element quality

Refinement and electrode embedding
New Defibrillation Model
Last lab session

Model Creation