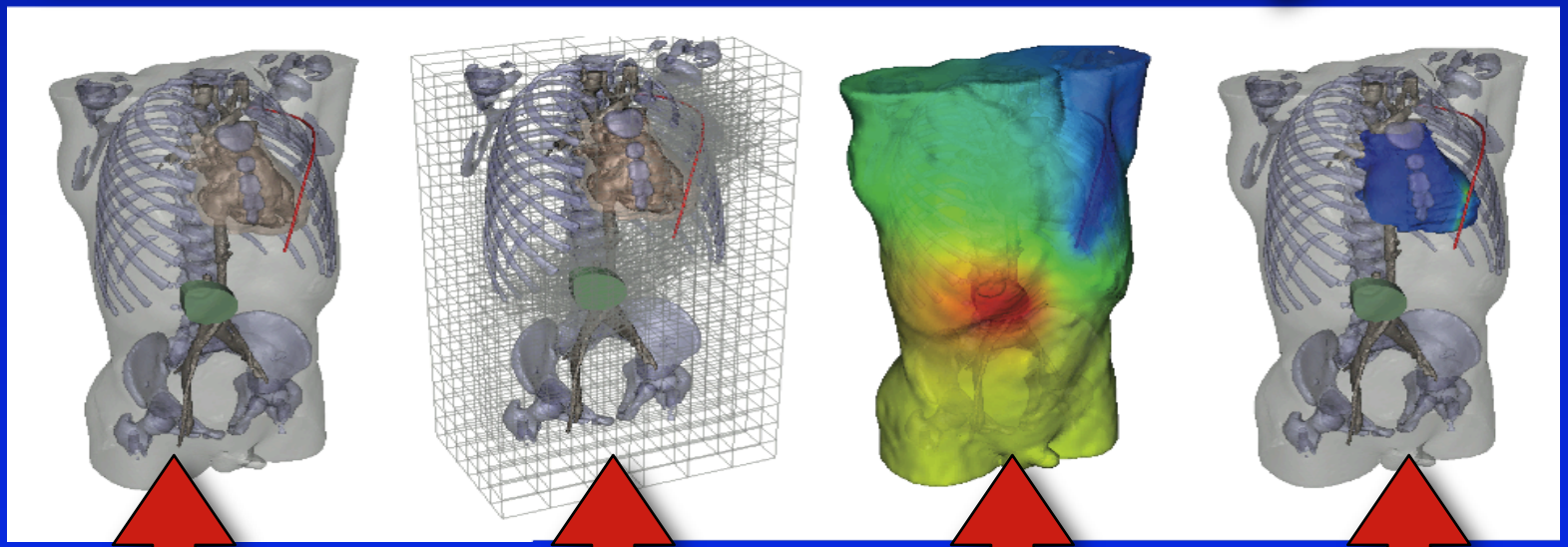
Model Creation in SCIRun

Jeroen Stinstra

Model Creation

Typical Pipeline in SCIRun



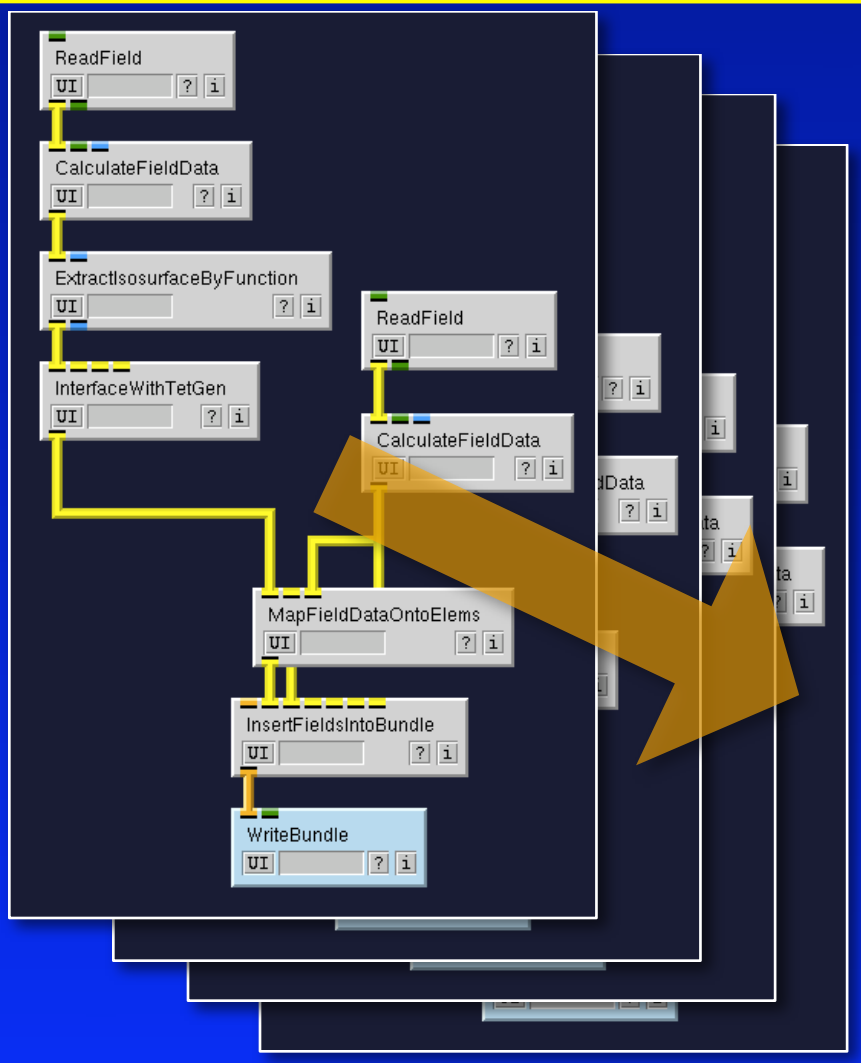
Inserting electrodes

Computational Grid

Solving FE Models

Visualization of Metrics

Pipeline : multiple SCIRun networks



Model Creation

Typical work flow

Data preprocessing.

Building mesh and setting up boundary conditions.

Creating Finite Element model and solving it.

Visualization of results and evaluating scientific metrics

Pipe line

Model Creation

- No pipeline is the same !
- Research pipelines change all the all time.
- Flexible components needed to do the pipe lines.
- Lots of components needed !

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

Model Creation

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

Model Creation

- 1st generation tools
  - Basic tools

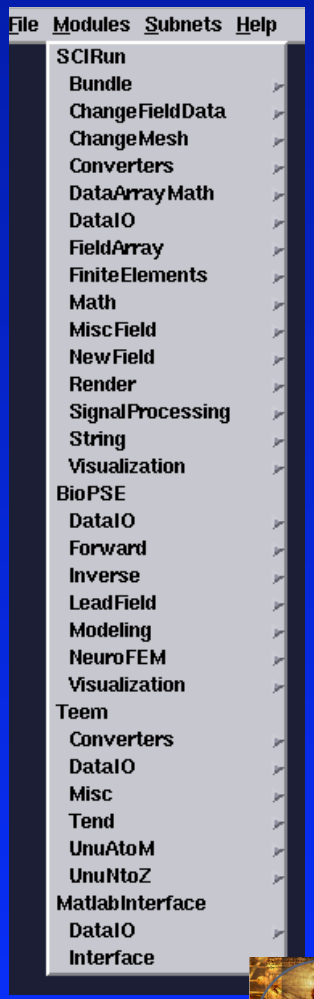
SCIRun 1.0

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

SCIRun/BioPSE 3.0

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

SCIRun 4.0 and higher

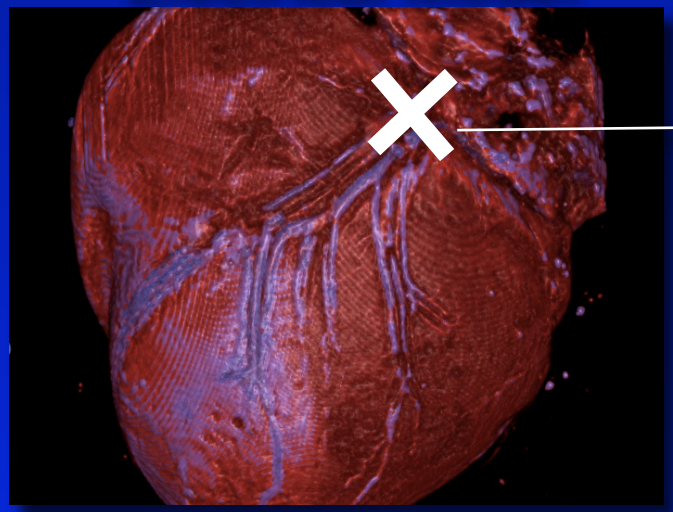


Example 1: Quasi-static Bidomain Model

Ischemia Model

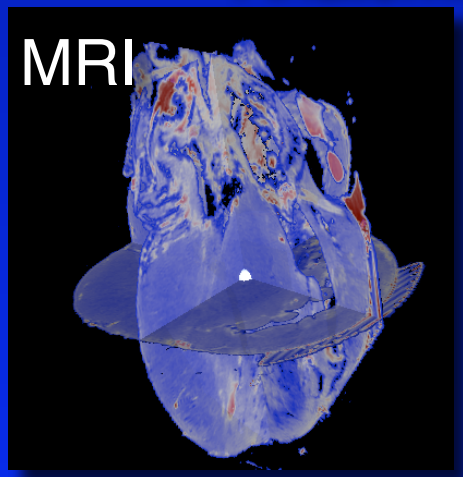
Model Creation

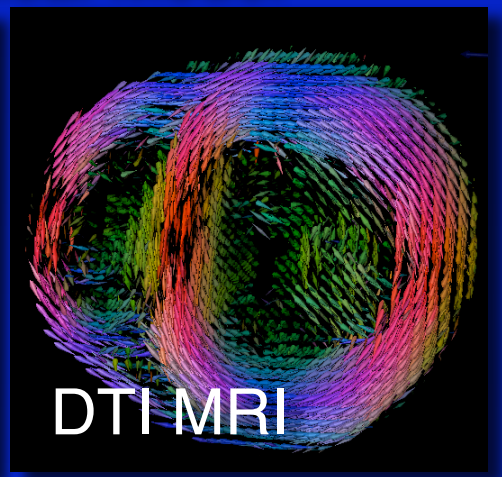
Electrical Model



Flow control to
simulate reduced flow

Anatomical Model





Goal: To build a specific models for each experiment

Conceptualizing a model

Model Creation

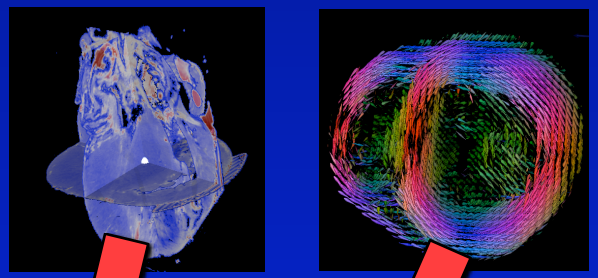
Bidomain model:

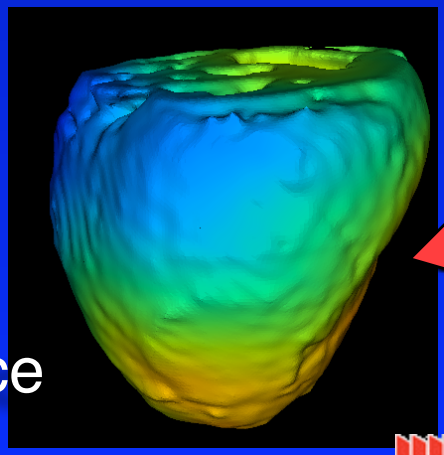
$\nabla \cdot \Sigma_i \nabla \phi_i = I_{mem}$ and $\nabla \cdot \Sigma_e \nabla \phi_e = -I_{mem}$

Transmembrane potential:

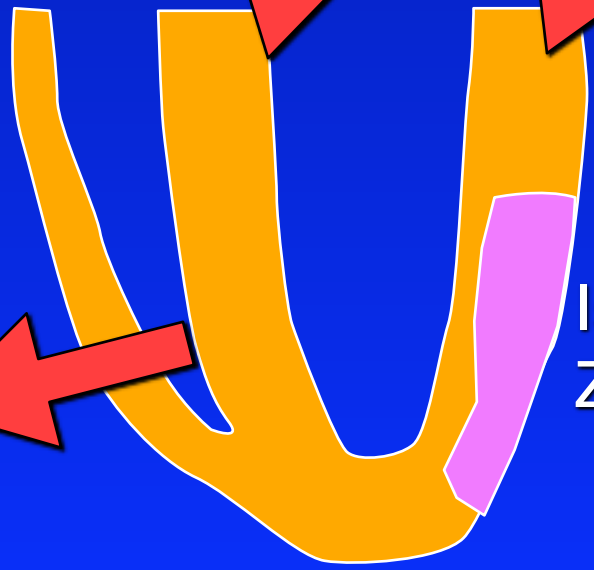
$\phi_m = \phi_i - \phi_e$

For comparison with experiment one wants to solve ϕ_e





Quantity as function of space



Ischemic Zone

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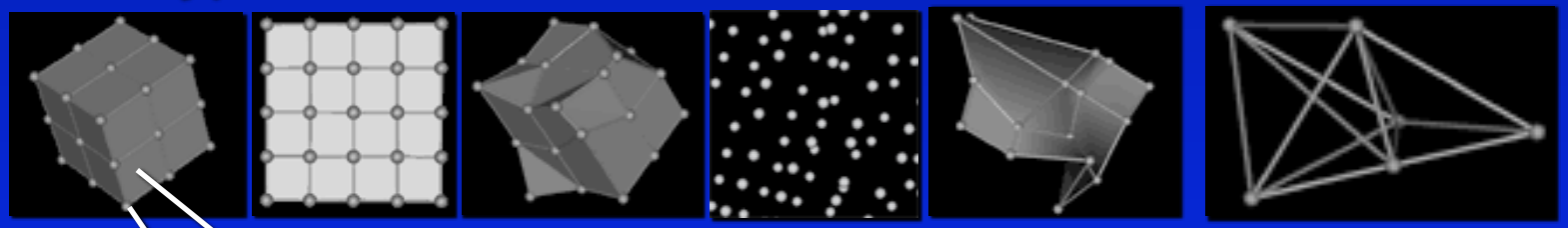
SCIRun Concepts

Model Creation

Spatial parameters in SCIRun are modeled by Fields

A field is a mesh + data

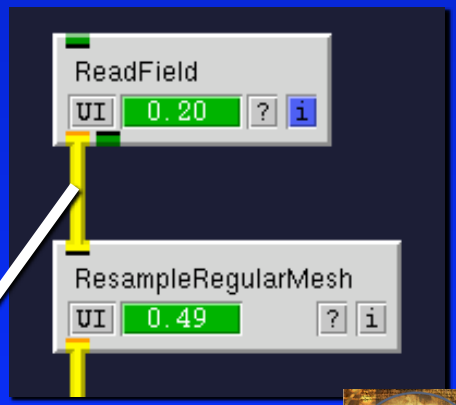
Mesh types



Data located inside the element

OR

Data located at the nodes

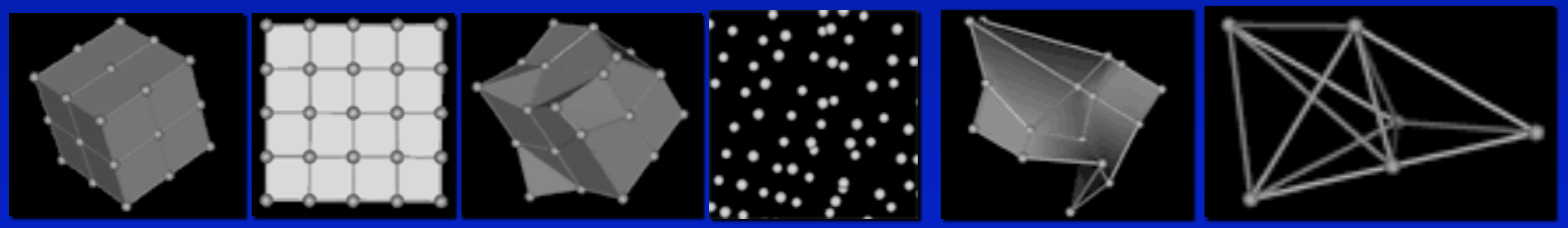


Fields are **yellow** data pipes

The complexities of a field

Model Creation

Mesh -> TetVolMesh, HexVolMesh, LatVolMesh, ...



Element types -> Point, Curve, Triangle, ...

Element order -> Linear, [Quadratic]

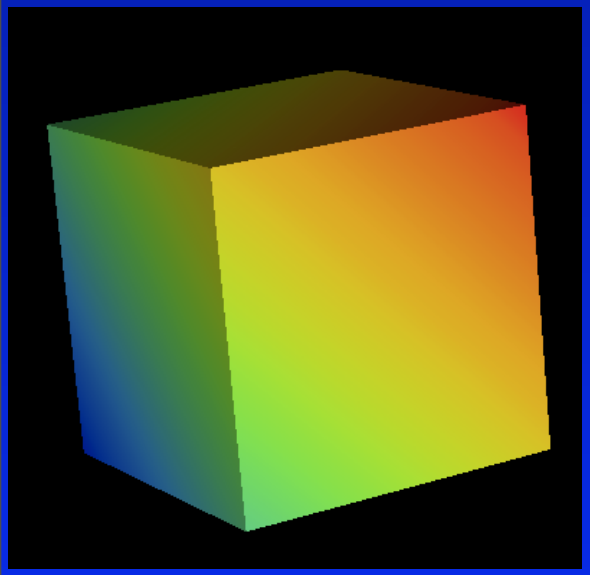
Data location -> NoData, ConstantData, LinearData, [QuadraticData]

Data type -> Scalar, Vector, or Tensor

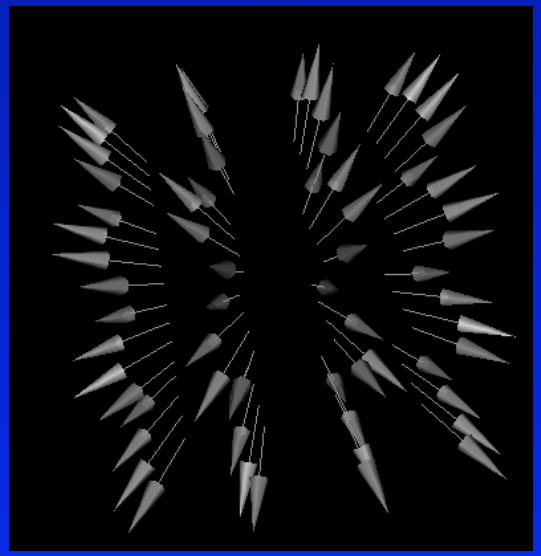
Data format -> char, int, short, long, float, double

Example of parameter Fields

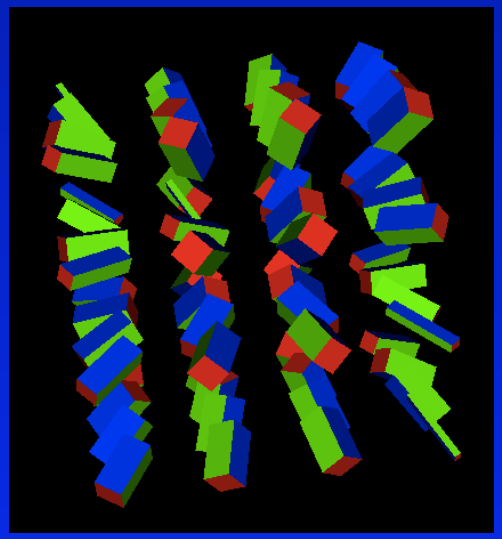
Scalar Data



Vector Data



Tensor Data



Fields in SCIRun 4.0

Model Creation

In SCIRun 4.0 the interface to fields has become more flexible and general:

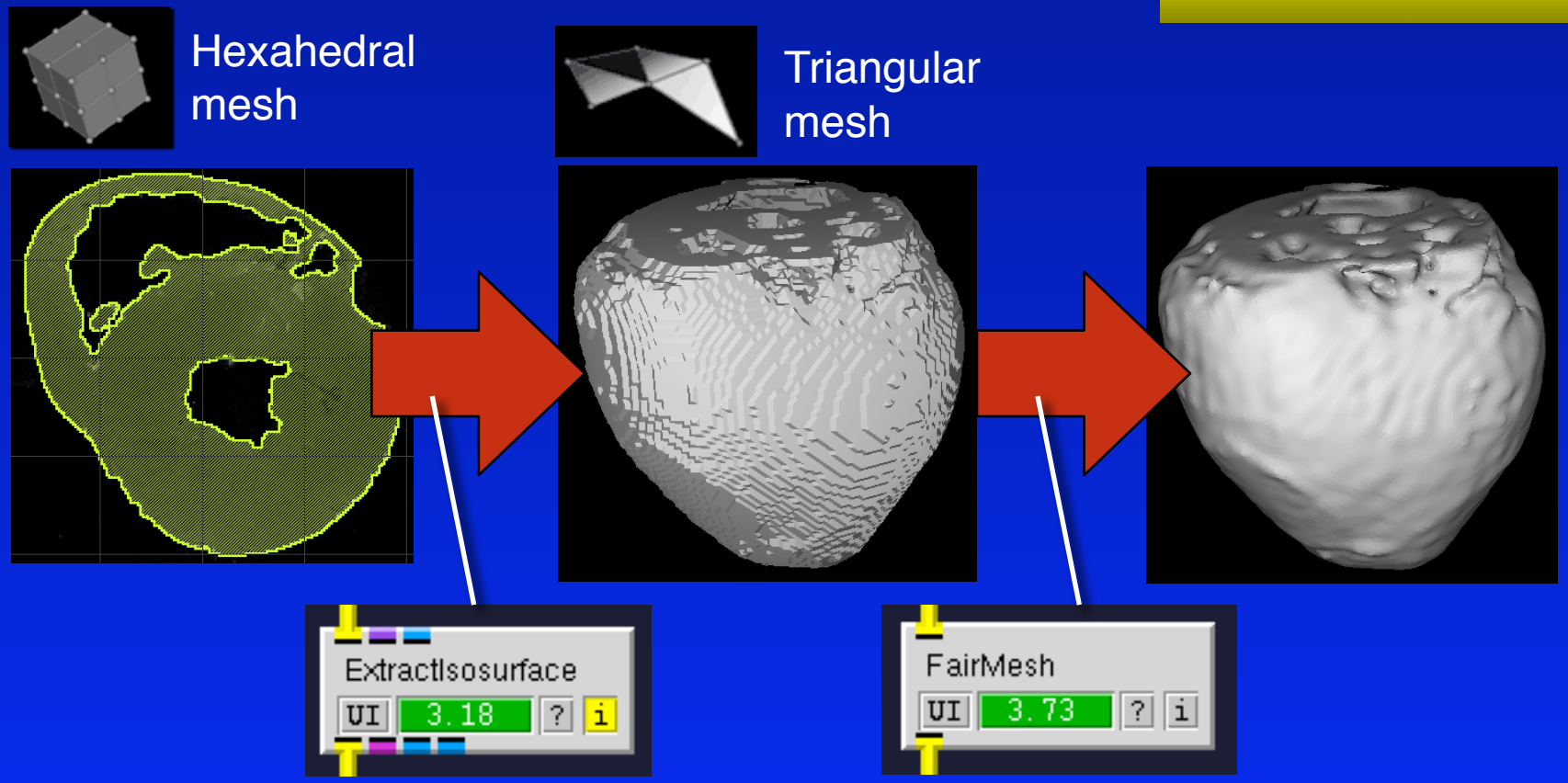
1) The program will choose the best mesh type automatically.

2) Many modules now let the user chooses where data should be located (node or element).

3) Almost all modules will work with both floating point, integer, vector and tensor data.

Generating a Smooth Isosurface

Model Creation



Marching Cubes Algorithm
(available for each mesh type)

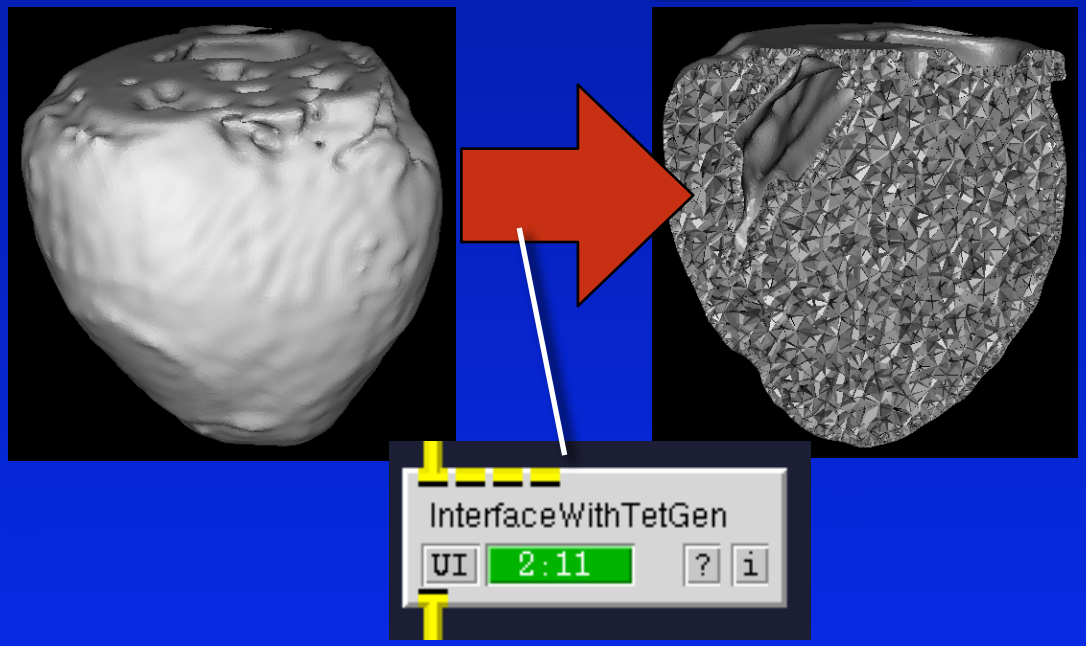
Taubin's Mesh Fairing Algorithm
(also Desbrun weights available)

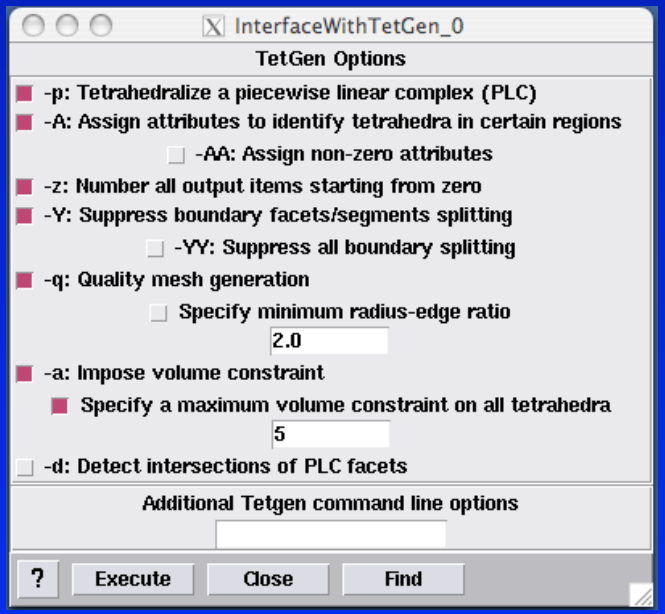
Generating a Tetrahedral mesh with TetGen

Model Creation

Triangular mesh

Tetrahedral mesh





Interface with TetGen mesh generator (allows adding addition points, and setting volume atributes)

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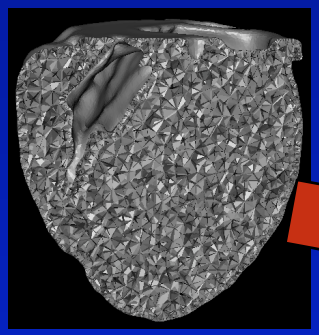
SCIRun Demo 1

Model Creation

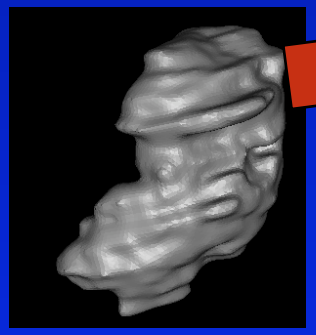
Live SCIRun Demo - Building a TetMesh

Distance Fields

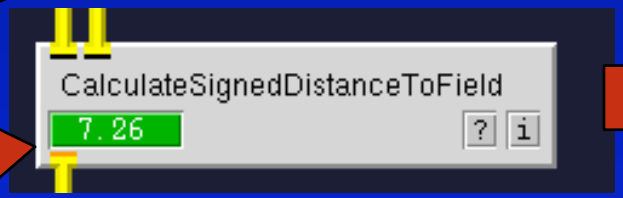
Model Creation

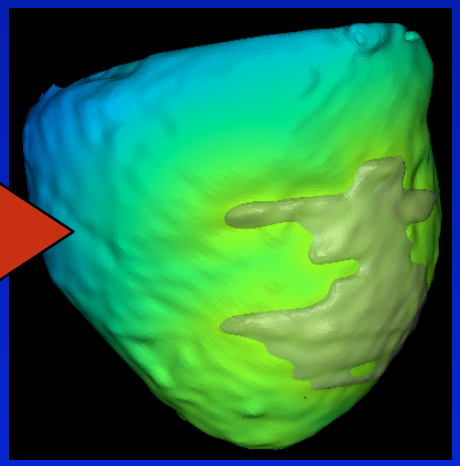


Heart Mesh



Ischemic Zone

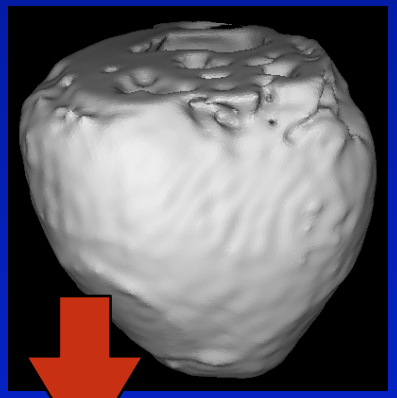


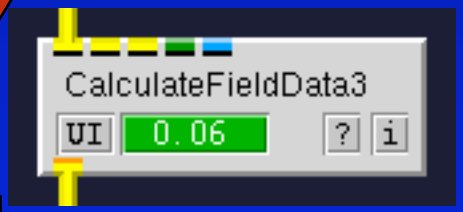


Ischemic zone can be defined by the distance to the border zone

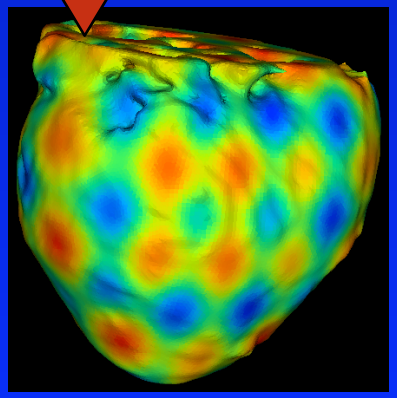
Both a DistanceField and SignedDistanceField, Truncated DistanceFields are available

Field Calculator Module





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



Model Creation

Data Values

Data Location

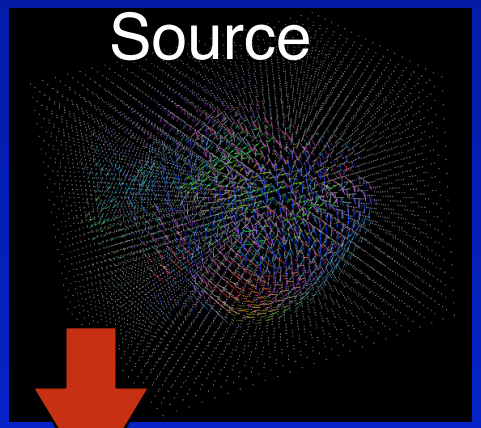
...

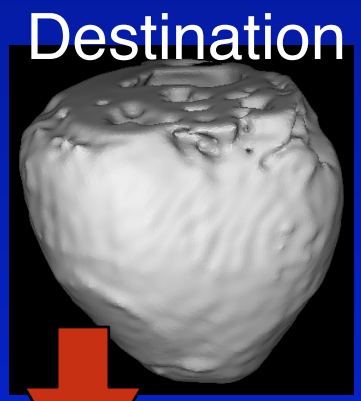
Math Expression using Scalars, Vectors, and Tensors

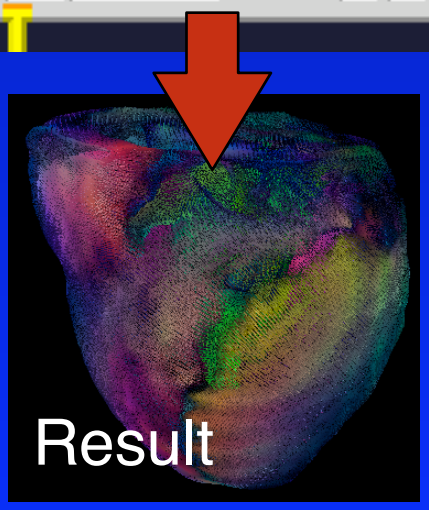
New Value

- Streaming 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



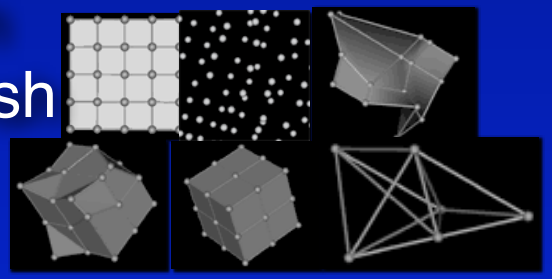




- Interpolation
- Finding Closest Values
- Finding Closest Nodes

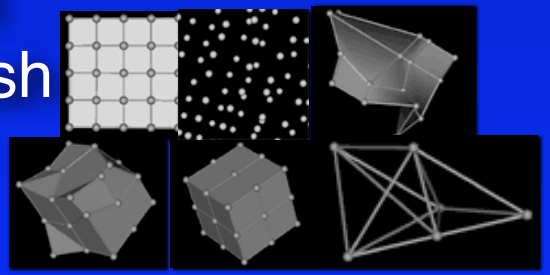
Model Creation

Data on any mesh



MapFieldDataOntoElems
MapFieldDataOntoNodes

Data on any mesh



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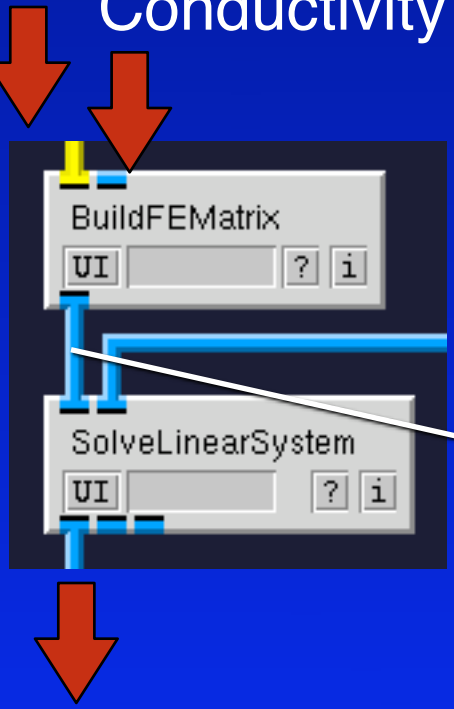
Finite Element Modules

Definition of conductivity
Conductivity Table

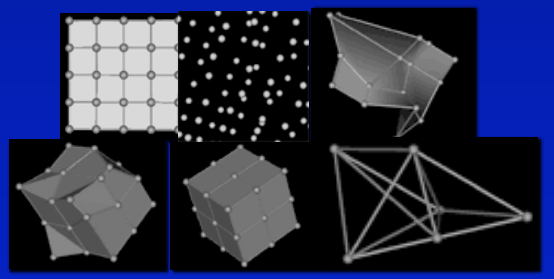


Right hand site

Stiffness matrix

Solution to FE problem

Model Creation



Any Element Type

Conductivity by Element

Scalar and Tensor Conductivities

Indexed Conductivities

More specific FE Tools are still found in the BioPSE package

SCIRun Demo 2

Model Creation

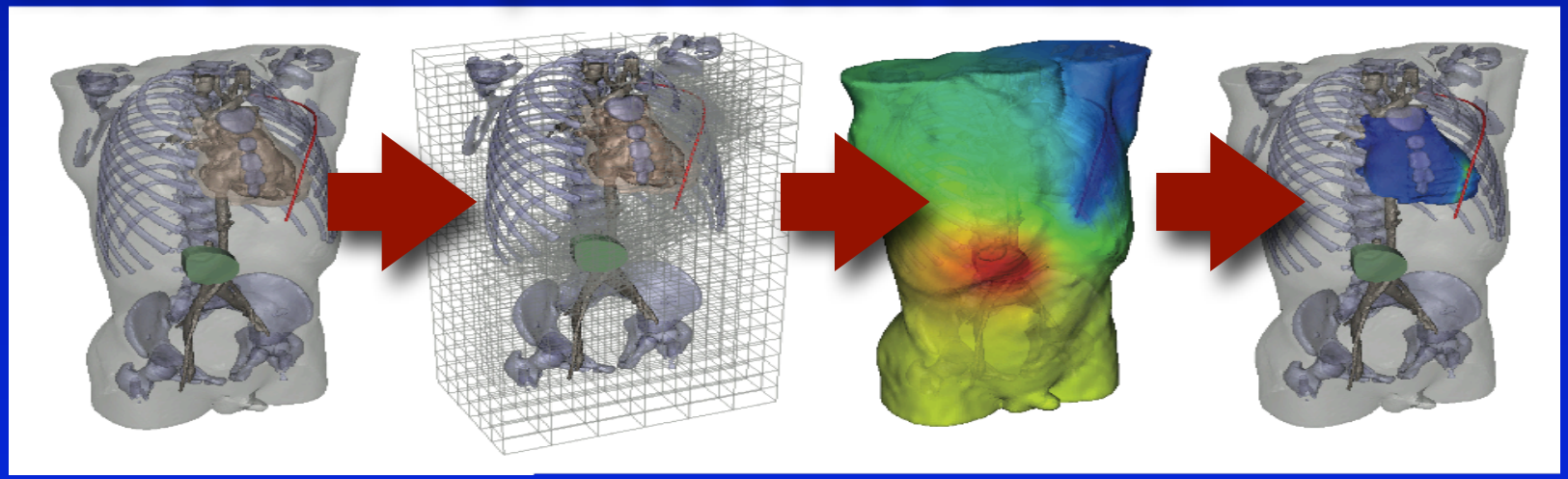
Live SCIRun Demo - Calculator/DistanceField

Defibrillation Simulations

Defibrillation Simulation Pipeline

Model Creation

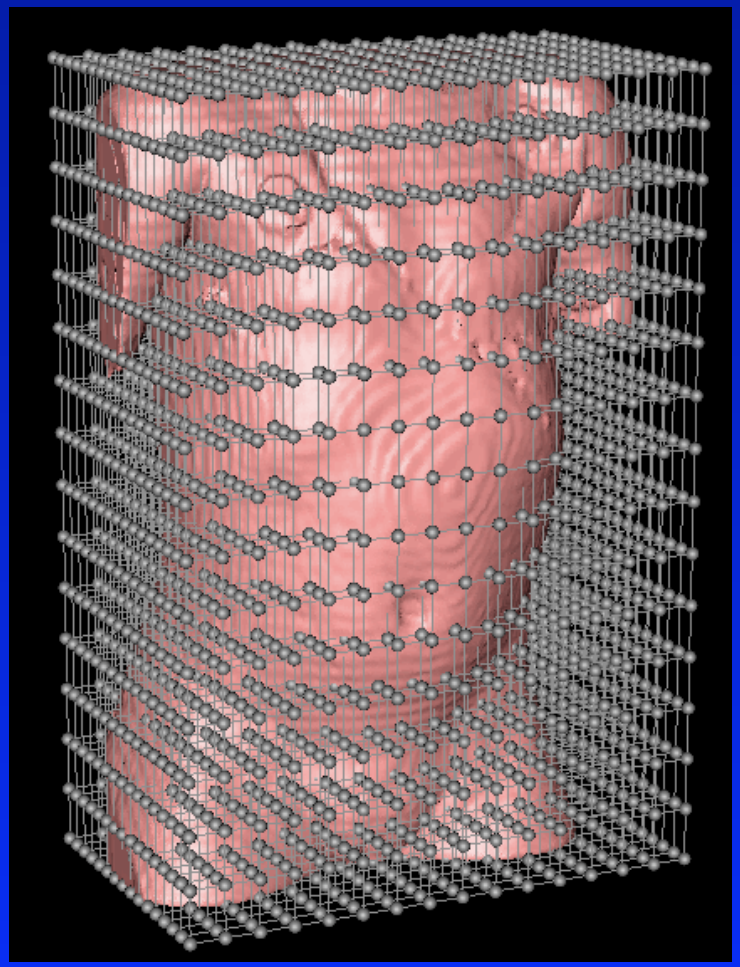
Model Creation Pipeline for Defib Simulation



Generating custom electrode configurations

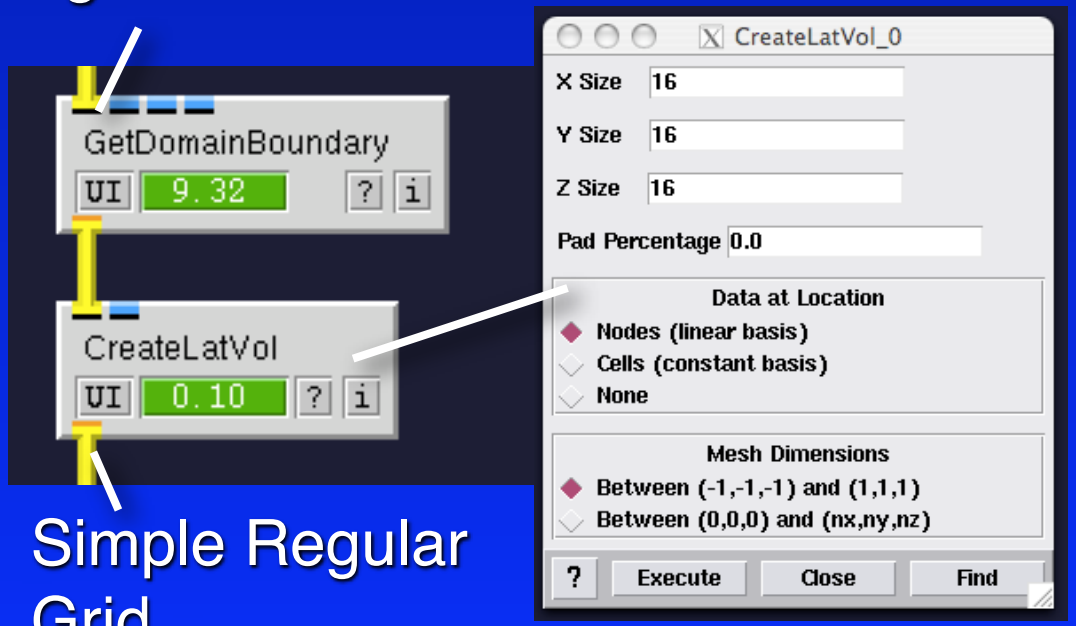
Hexahedral Meshing

Model Creation



For Multi Material Models
Regular grids are used

Segmented LatVoMesh



Simple Regular Grid

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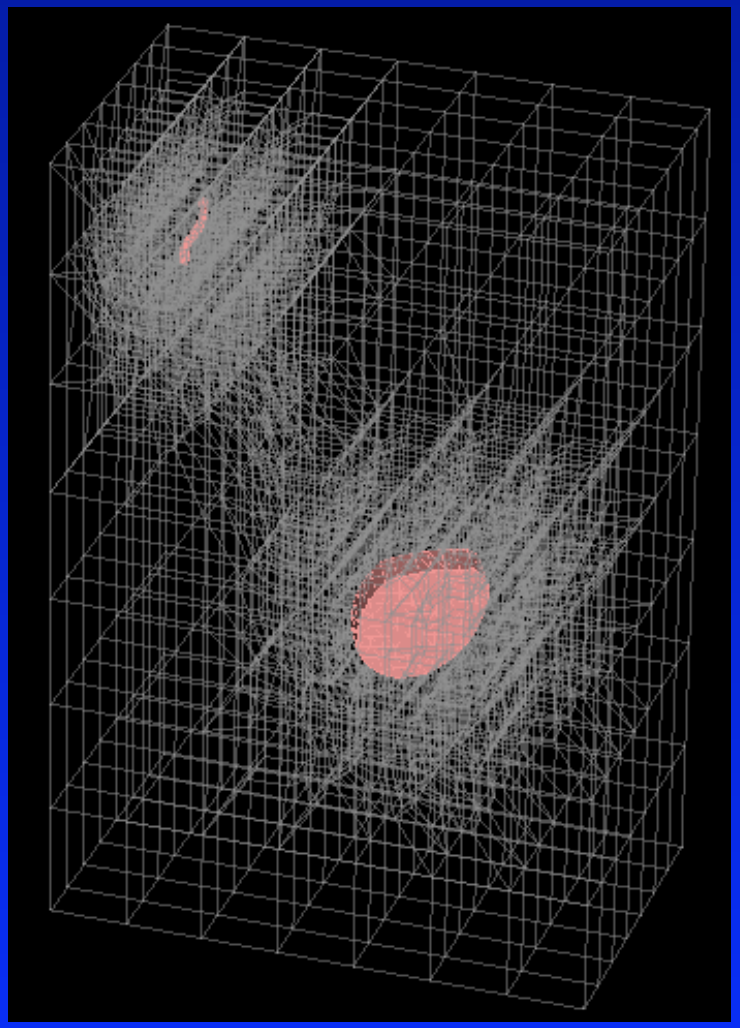
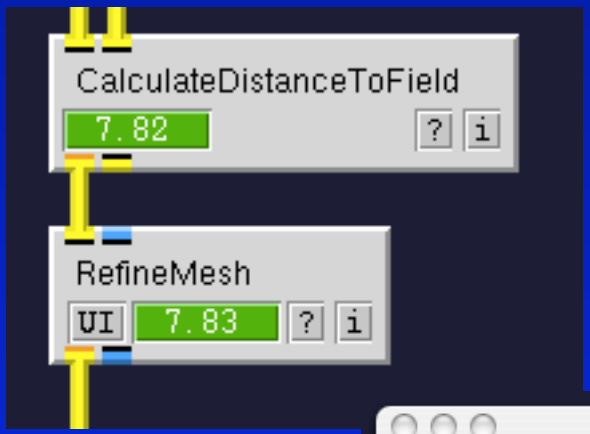
Hexahedral Mesh Refinements

Model Creation

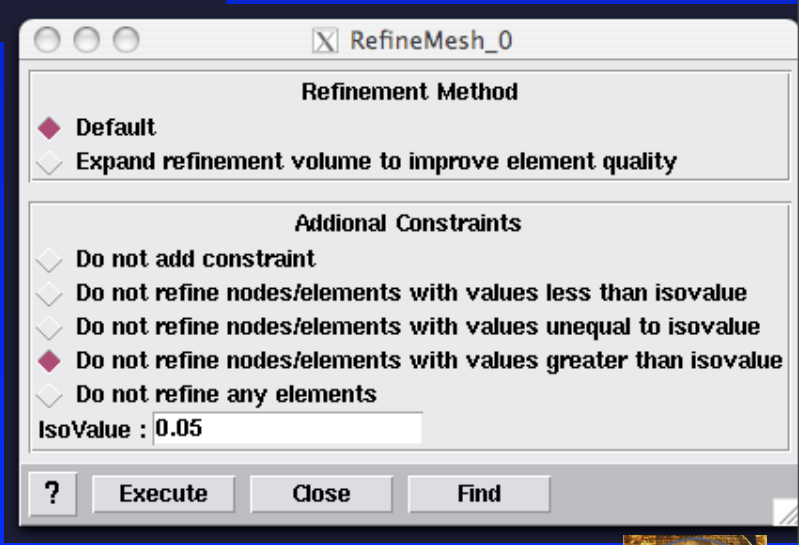


Regular grid



Where are refinements needed?

Refined Unstructured Hexahedral Mesh



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Finite Elements

Model Creation

Boundary Condition: known potentials within electrodes

Potential Vector

100
100
nan
nan
nan
nan
0
0
0

knowns

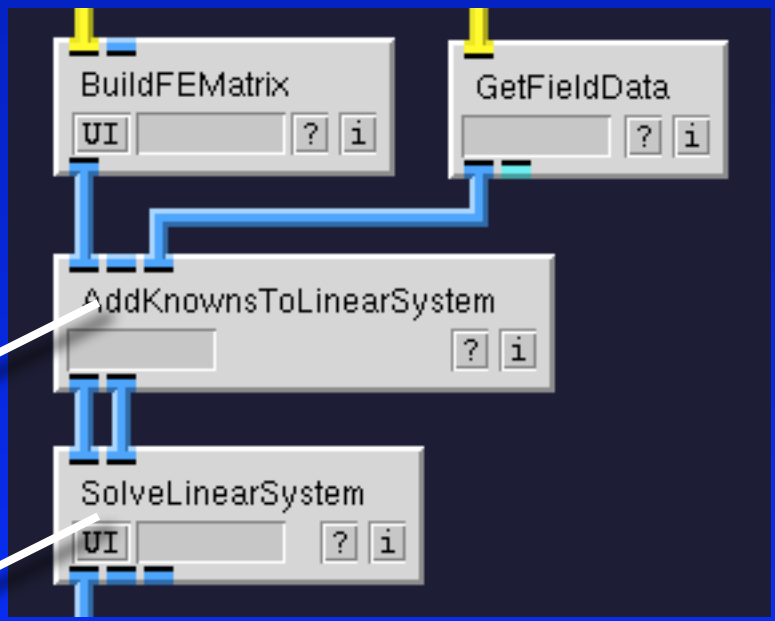
unknowns

Modifying the linear system

Solving the linear system

Field with conductivities

Field with boundary condition



Future directions

SCIRun 4.1 and beyond

SCIRun 4.1

Model Creation

Release scheduled for February 2009.

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

1) Upgrade file readers
2) New Isosurfacing core
3) Electrode Widgets
4) BioPSE/Teem cleanup
5) New documentation
6) Upgrade DistanceFields
7) FieldArrays
8) Code clean up
9) Upgrade MatlabEngine

SCIRun 4.2

Model Creation

Release scheduled for late spring 2009.

For those who cannot wait: intermediate builds will be available at our website once SCIRun 4.1 has been released.

1) Linux binaries
2) Upgrade file readers
3) Quadratic Meshes
4) BioPSE/Teem cleanup
5) More documentation
6) Multi material Meshing tools

SCIRun 4.2 and higher

Model Creation

GUI-less SCIRun / SCIRun server

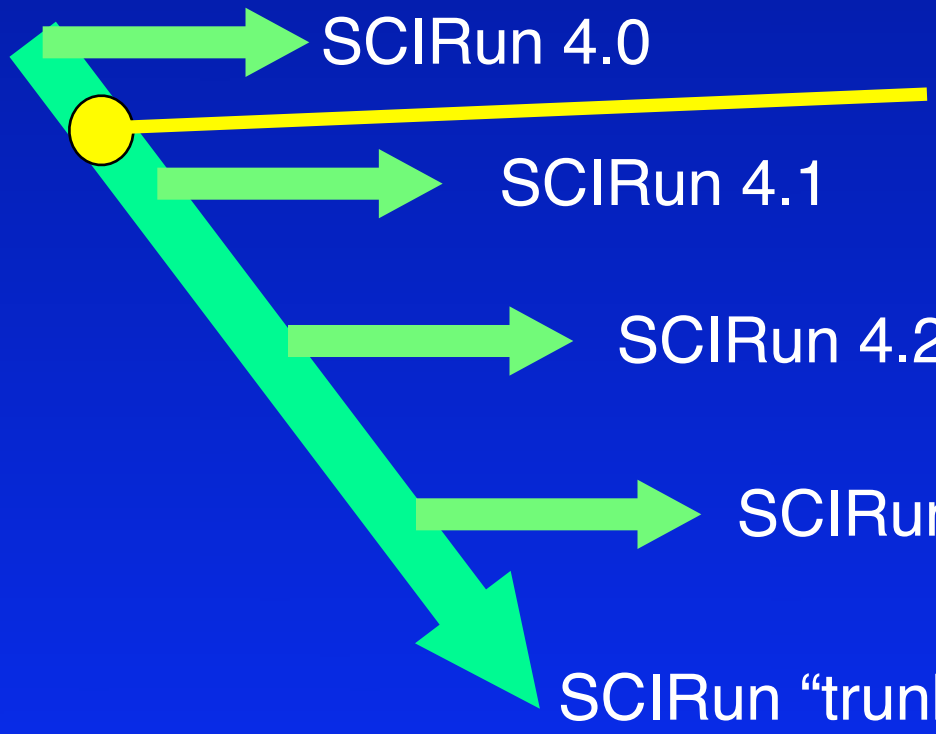
New Scheduler / Module logic

Multi material meshing pipeline

Developer documentation

Release Cycle

Model Creation



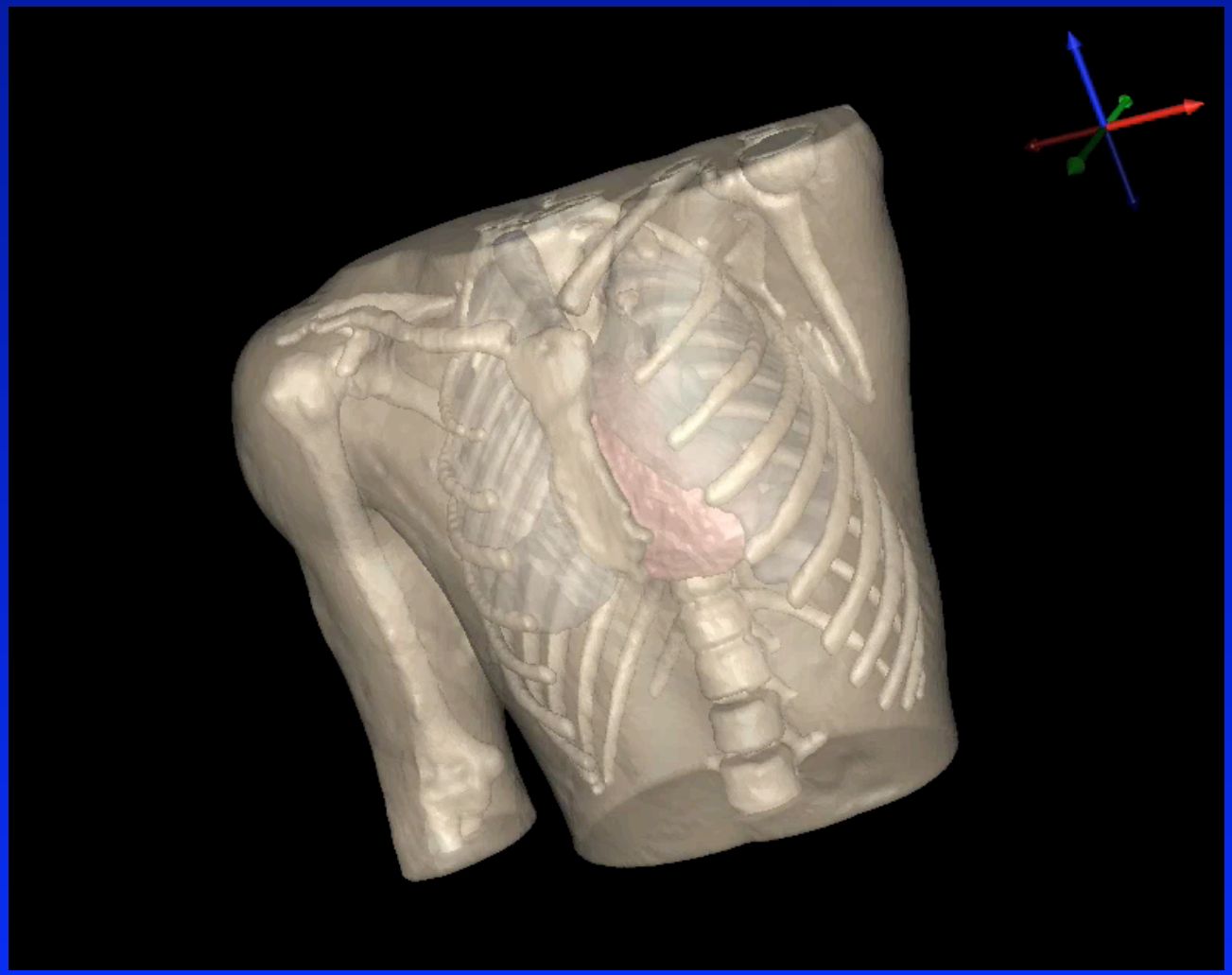
Available from our website
SCIRun 4.0 stable release
SCIRun 4.1 beta pre release

New binaries and source code is made available a few times a month and all downloadable files are encoded by date

Upcoming Features

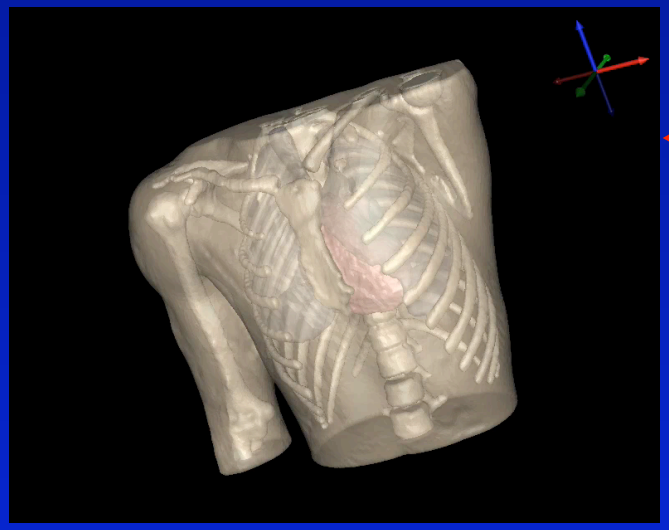
Multi Material Meshing

Model Creation



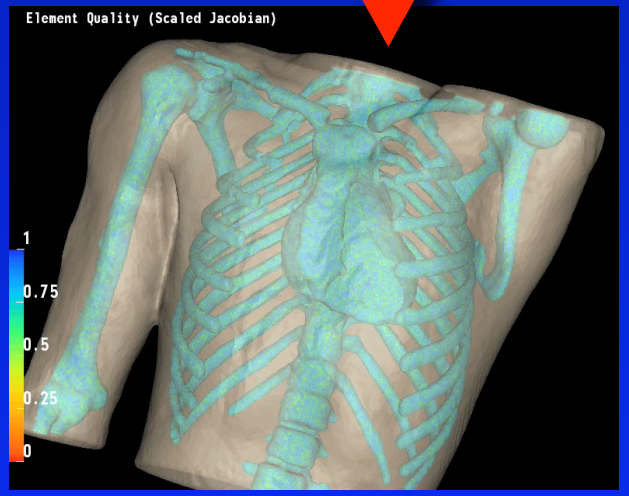
Meshing in SCIRun 4.x

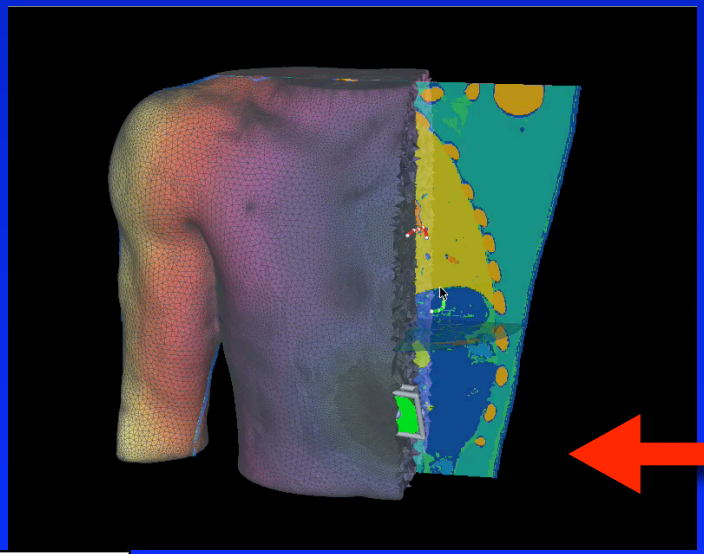
Model Creation



Generating surface models

Evaluating element quality

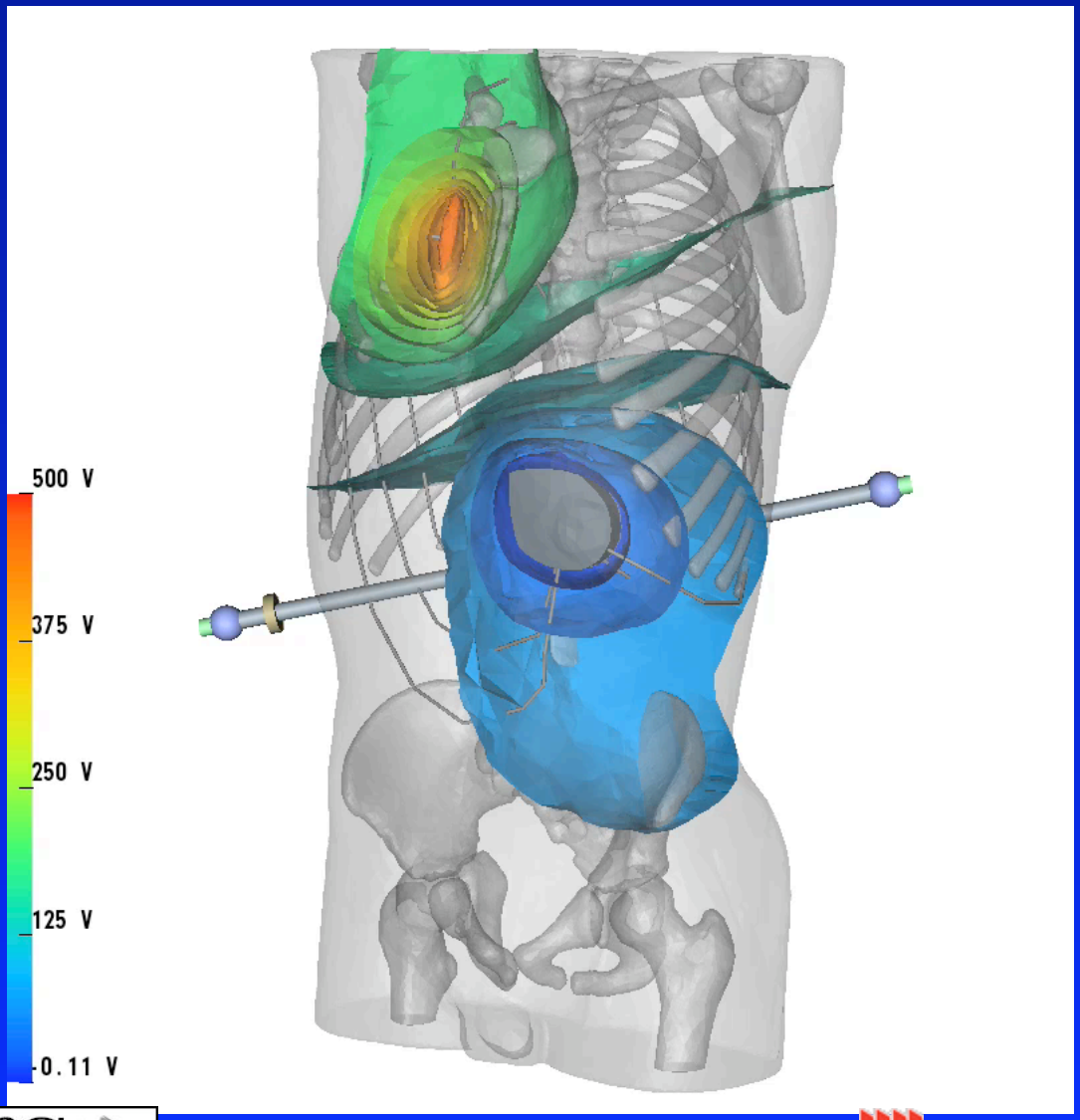




Refinement and electrode embedding

New Defibrillation Model

Model Creation



Development

Model Creation

Although in our lab the multi material modeling is working, code cleanup and tool packaging is still underway.

Generally, code cleanup, porting to different architectures, stabilizing/optimizing code, adding user friendly interfaces and providing documentation can take up to 6 to 8 months

Last lab session

Model Creation