# Model Creation in SCIRun

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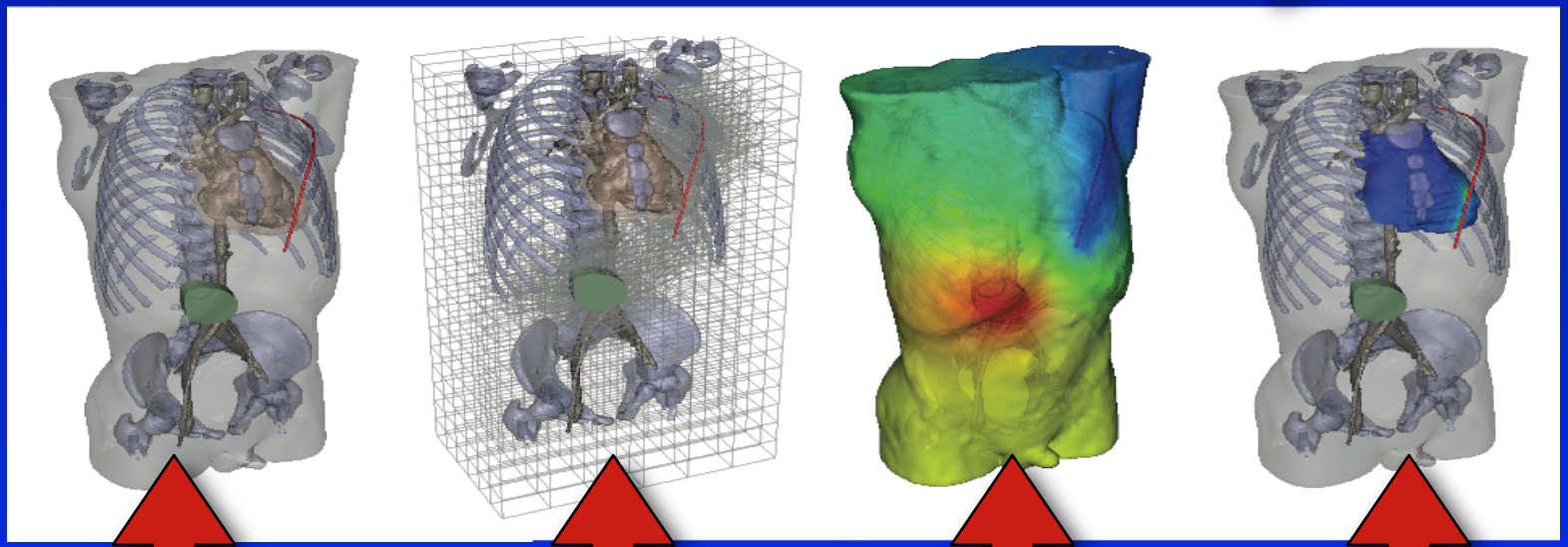
# Model Creation



## 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

**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.

Extentions:

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

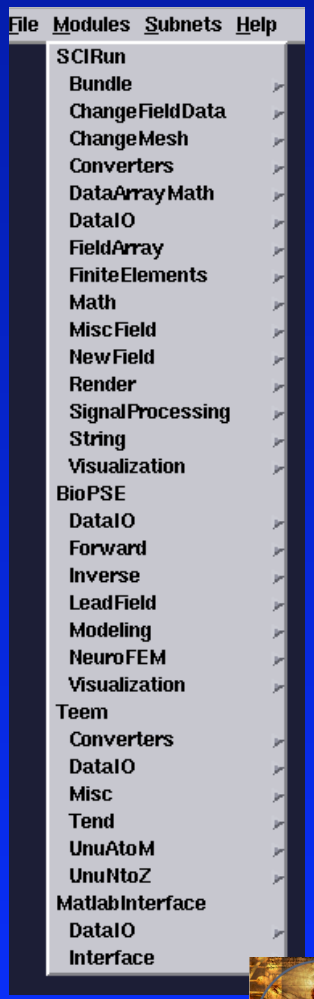
SCIRun 1

- 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

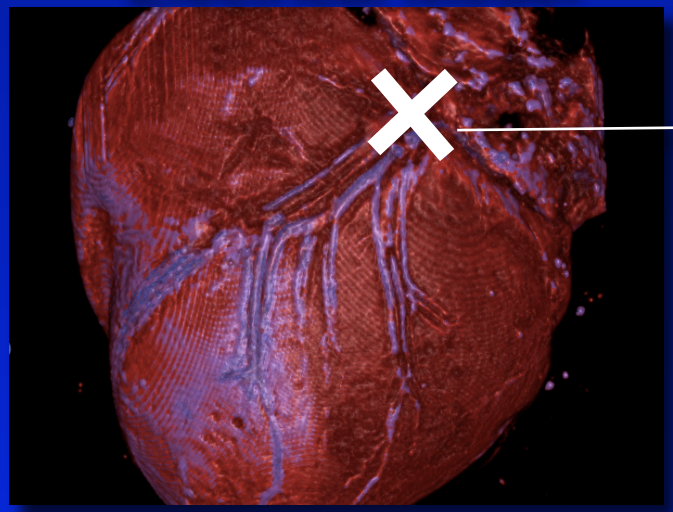


# Example 1: Quasi-static Bidomain Model

# Ischemia Model

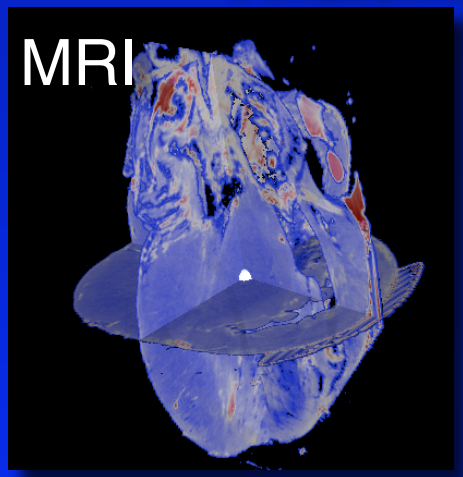
**Model Creation**

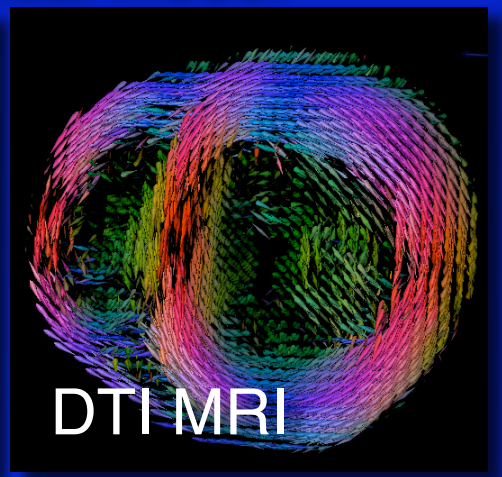
Electrical Model



Flow control to
simulate reduced flow

Anatomical Model




Goal: To build a specific models for each experiment

# Conceptualizing a model

Model Creation

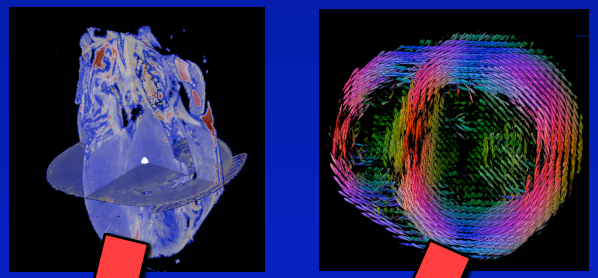
Bidomain model:

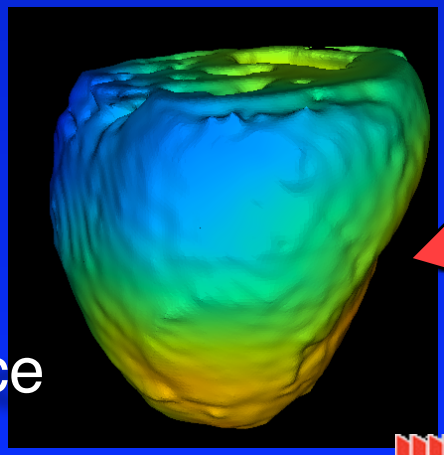
$\nabla \cdot \Sigma_i \nabla \phi_i = I_{mem}$ and $\nabla \cdot \Sigma_e \nabla \phi_e = -I_{mem}$

Transmembrane potential:

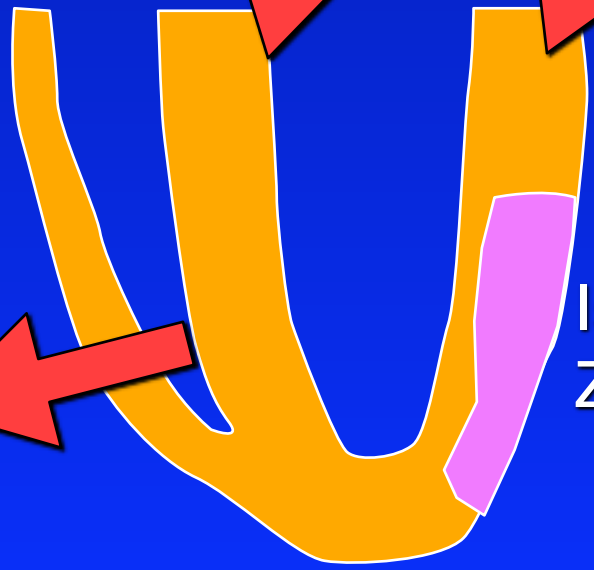
$\phi_m = \phi_i - \phi_e$

For comparison with experiment one wants to solve $\phi_e$





Quantity as function of space



Ischemic Zone

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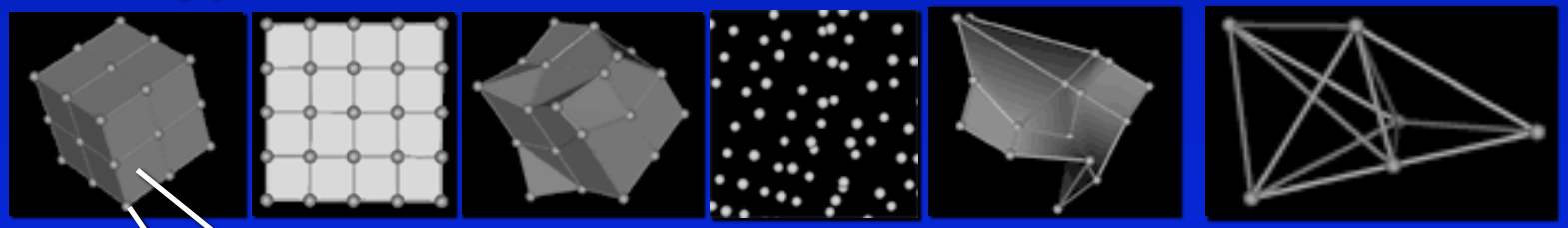
# SCIRun Concepts

## Model Creation

Spatial parameters in SCIRun are modeled by Fields

A field is a mesh + data

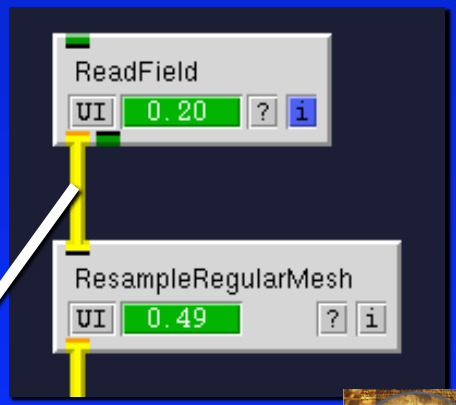
Mesh types



Data located inside the element

OR

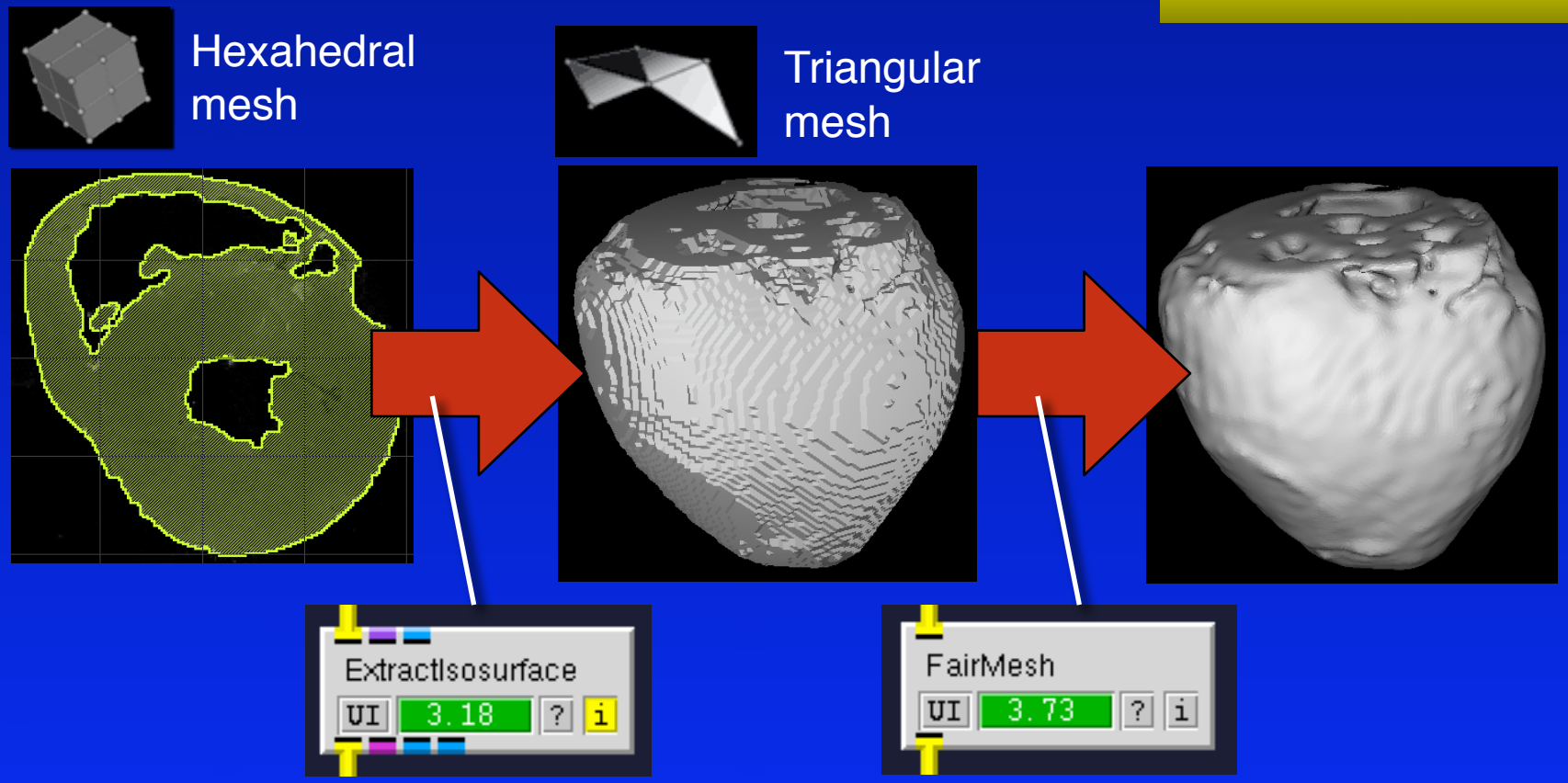
Data located at the nodes




Fields are **yellow** data pipes

# Generating a Smooth Isosurface

**Model Creation**




Marching Cubes Algorithm
(available for each mesh type)

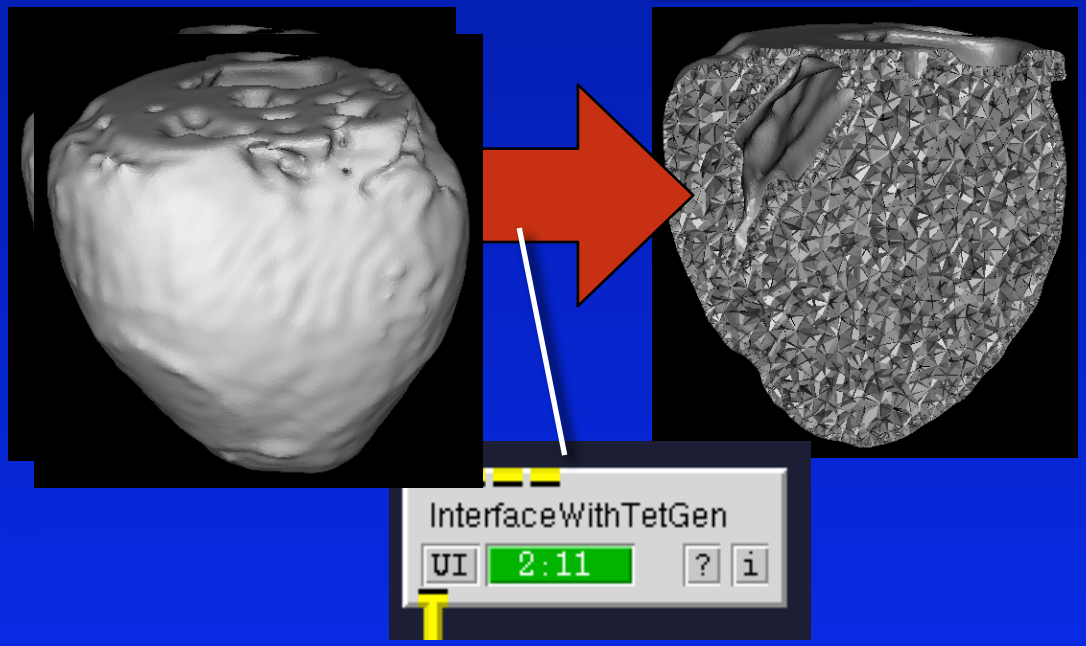
Taubin's Mesh Fairing Algorithm
(also Desbrun weights available)

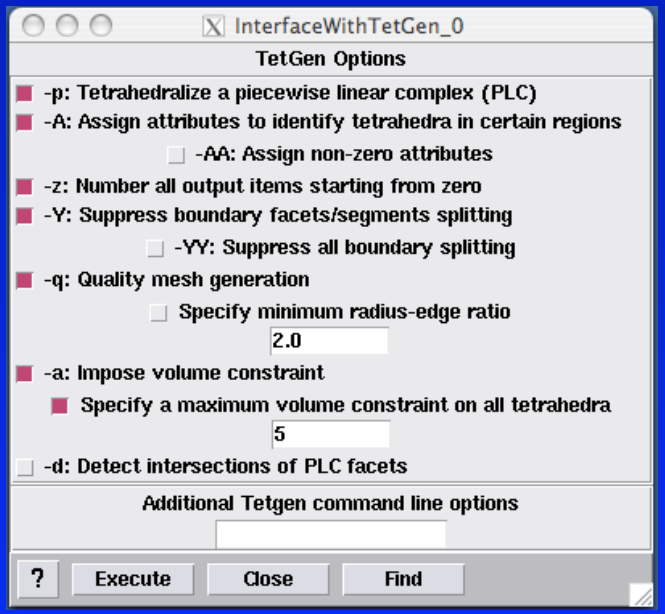
# Generating a Tetrahedral mesh

**Model Creation**

Triangular mesh

Tetrahedral mesh




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

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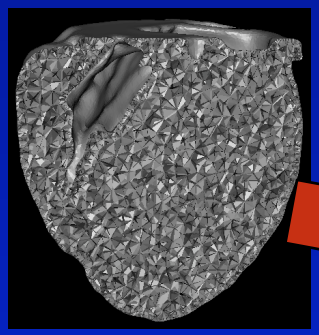
# SCIRun Demo 1

Model Creation

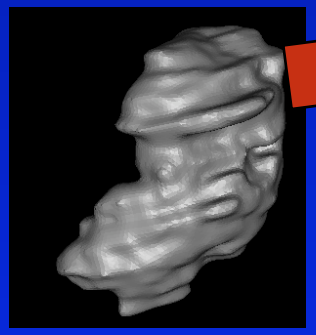
## Live SCIRun Demo - Building a TetMesh

# Distance Fields

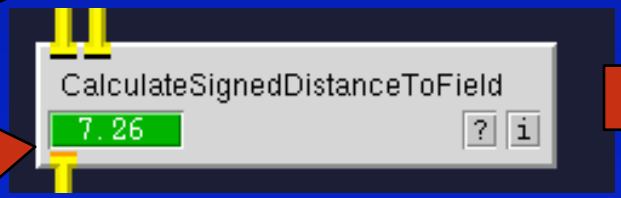
**Model Creation**

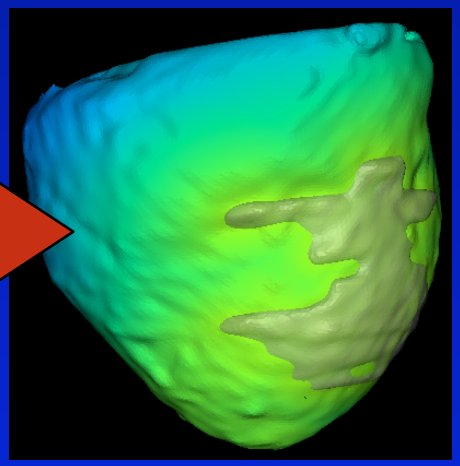


Heart Mesh



Ischemic Zone



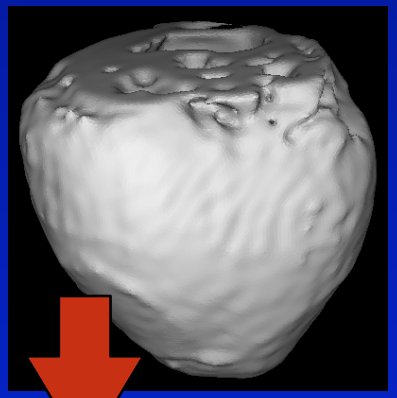



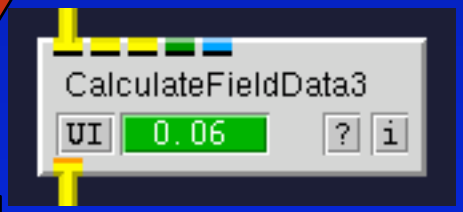
Ischemic zone can be defined by the distance to the border zone

Both a DistanceField and SignedDistanceField are available

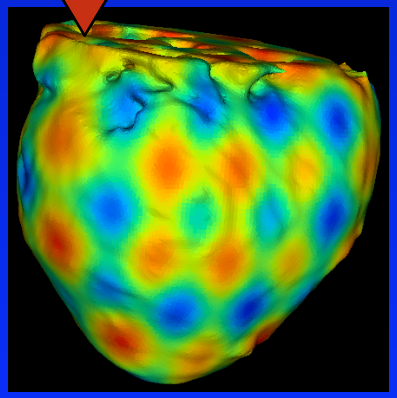
SCIRun 4.1 will also contain TruncatedDistanceField and will return the value of the closest point

# Field Calculator Module






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



**Model Creation**

Data Values

Data Location

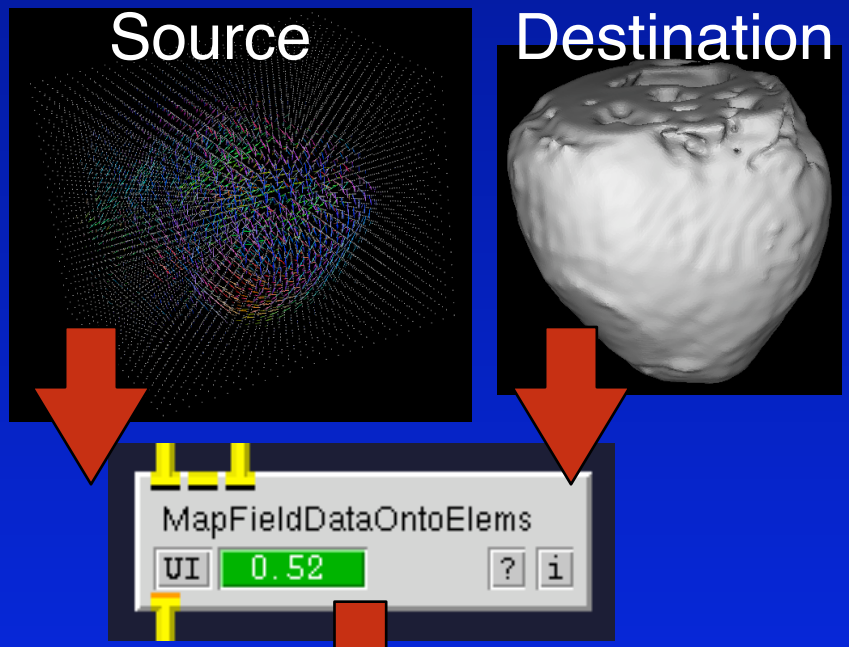
...

Math Expression using Scalars, Vectors, and Tensors

New Value

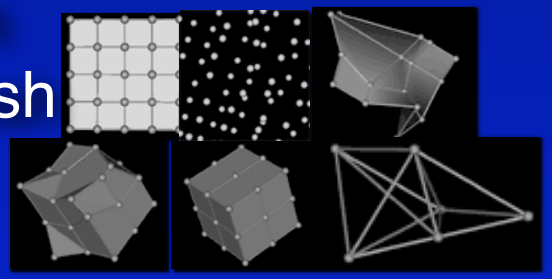
- Stream architecture: computations in blocks of 128 values
- Many functions for dealing with tensors, vectors and scalars
- Consistently integrated in many SCIRun modules
- Extensible architecture

# Mapping Modules



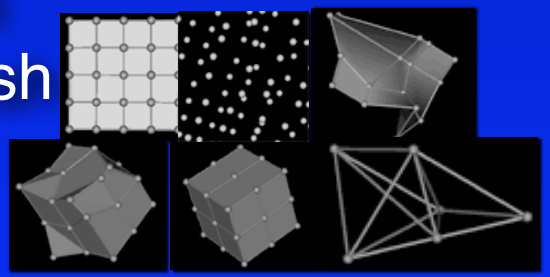

**Model Creation**

Data on any mesh



MapFieldDataOntoElems
MapFieldDataOntoNodes

Data on any mesh



- Interpolation
- Finding Closest Values
- Finding Closest Nodes

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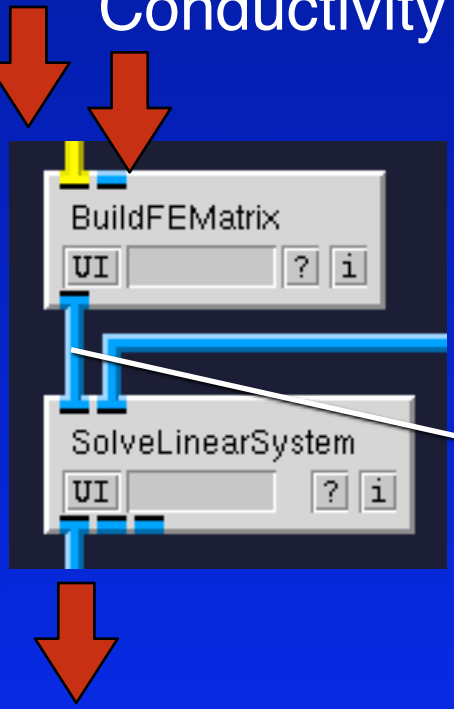
# Finite Element Modules

Definition of conductivity
Conductivity Table

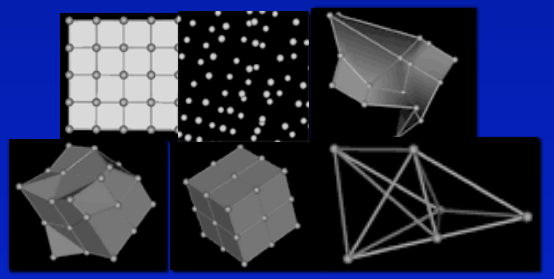



Right hand site

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

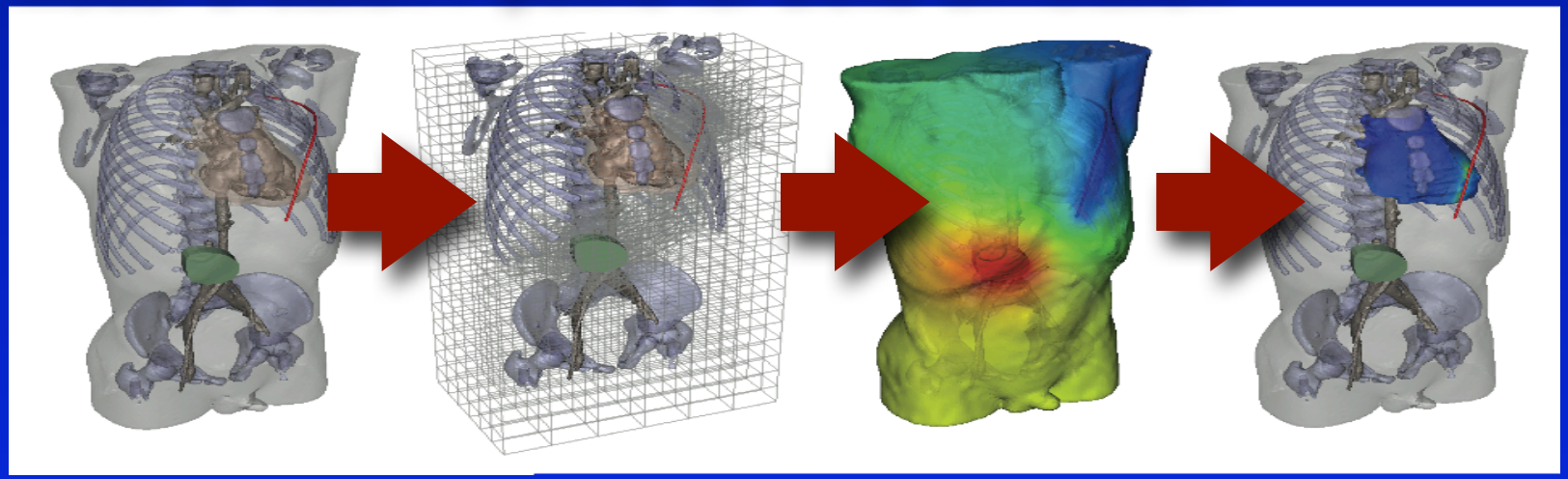
## Live SCIRun Demo - Calculator/DistanceField

# Defibrillation Simulations

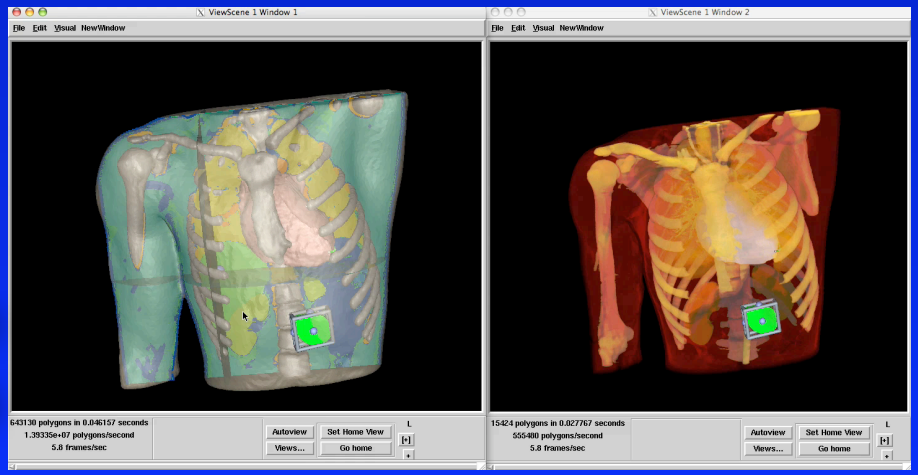
# Defibrillation Simulation Pipeline

**Model Creation**

## Model Creation Pipeline for Defib Simulation



Generating custom electrode configurations

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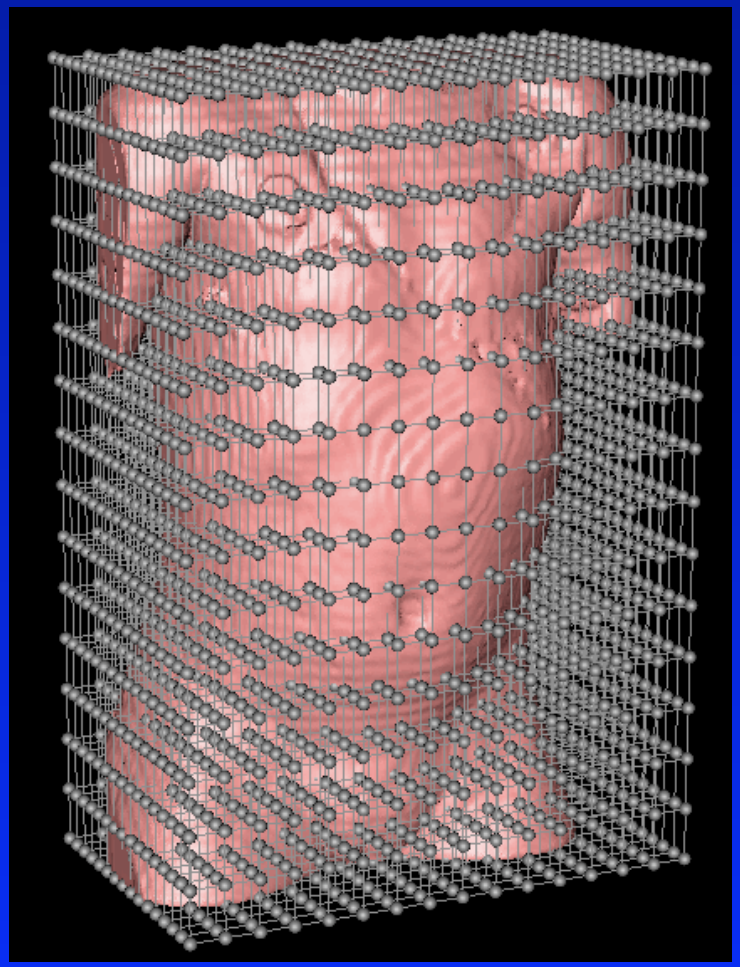
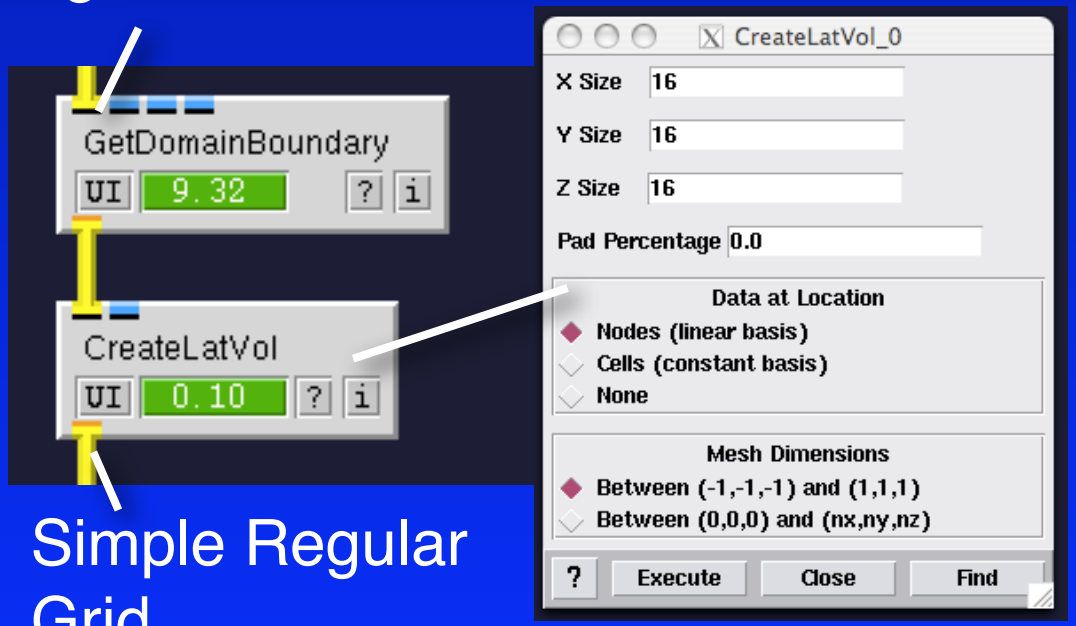
# Hexahedral Meshing

## Model Creation



For Multi Material Models
Regular grids are used

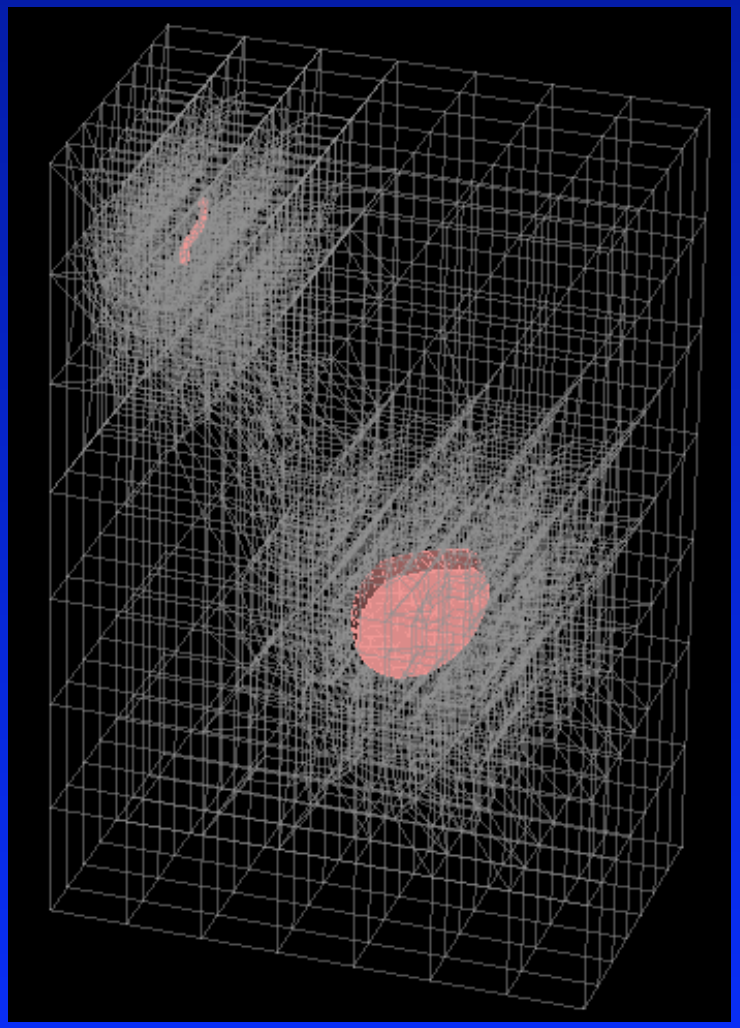
Segmented LatVoMesh



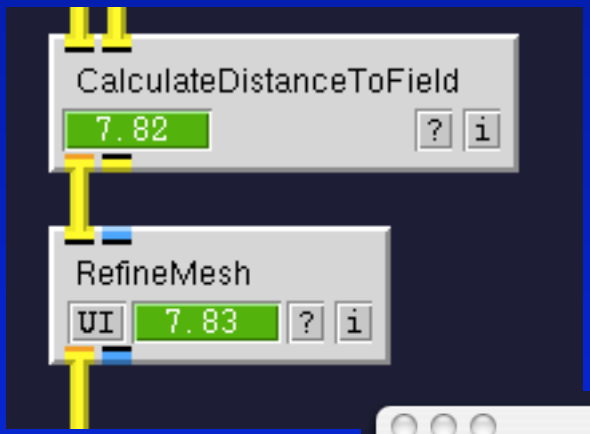

Simple Regular Grid

# Hexahedral Mesh Refinements

**Model Creation**

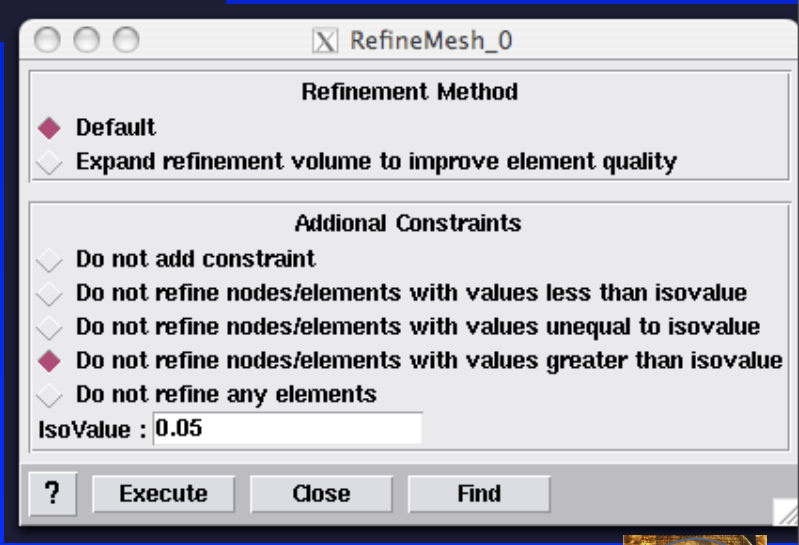


Regular grid




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

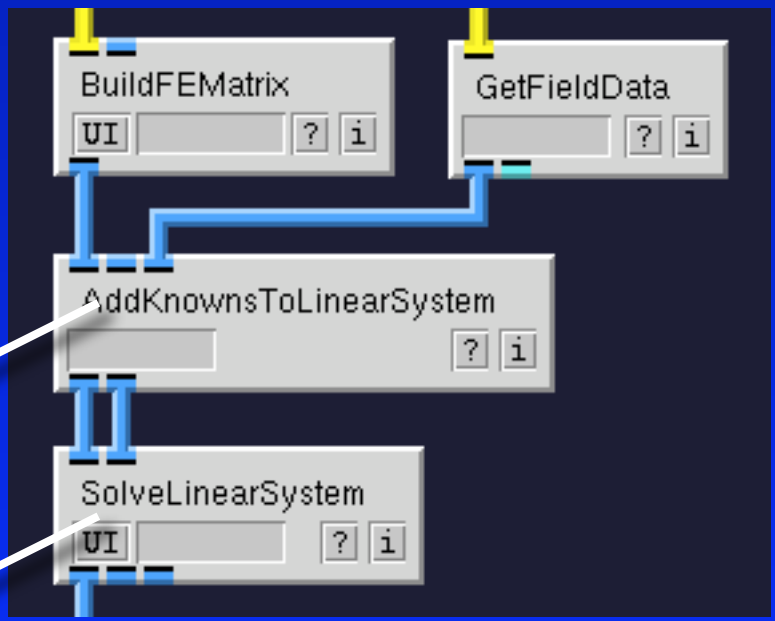
unknowns

Modifying the linear system

Solving the linear system

Field with conductivities

Field with boundary condition



# Future directions

# SCIRun 4.1 and higher

# SCIRun 4.1

## Model Creation

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

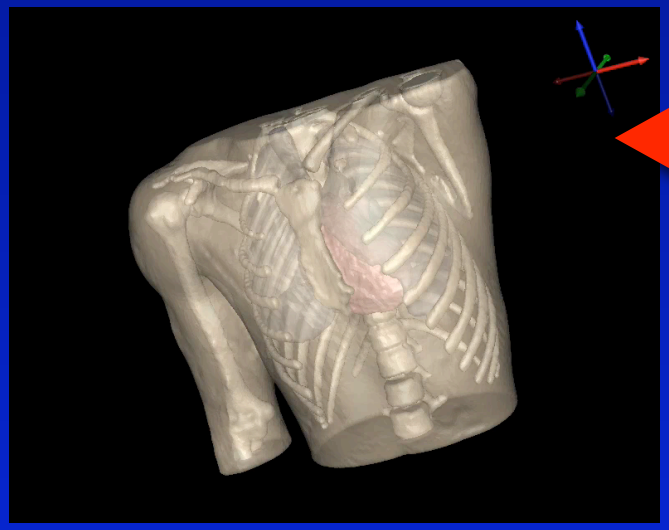
New Scheduler / Module logic

Multi material meshing pipeline

Developer documentation

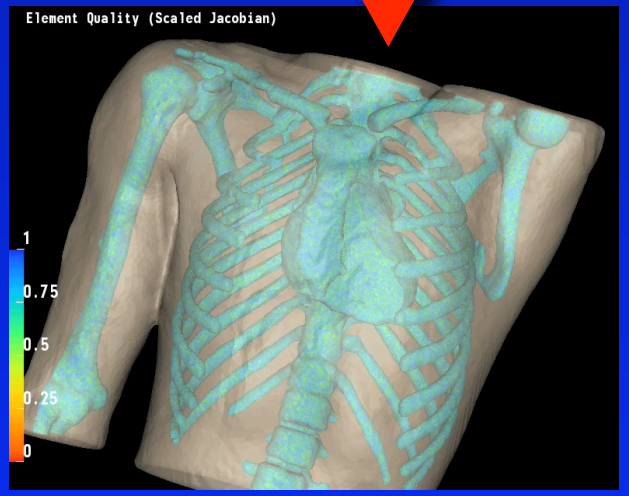
# Meshing in SCIRun 4.x

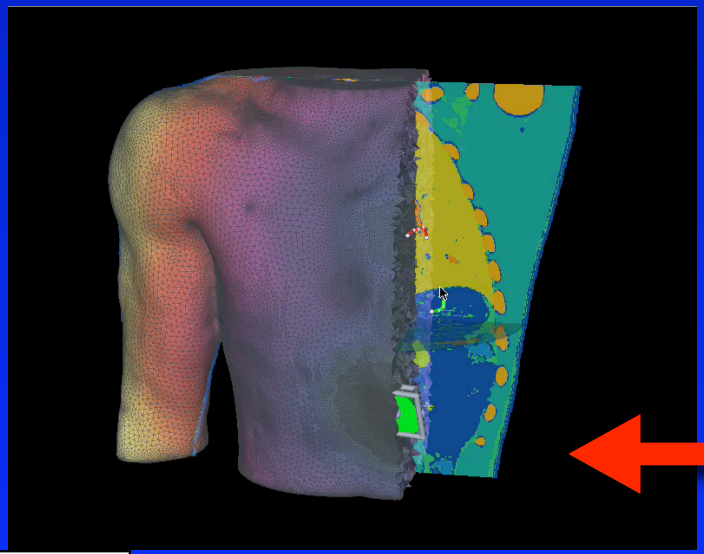
## Model Creation



Generating surface models

Evaluating element quality

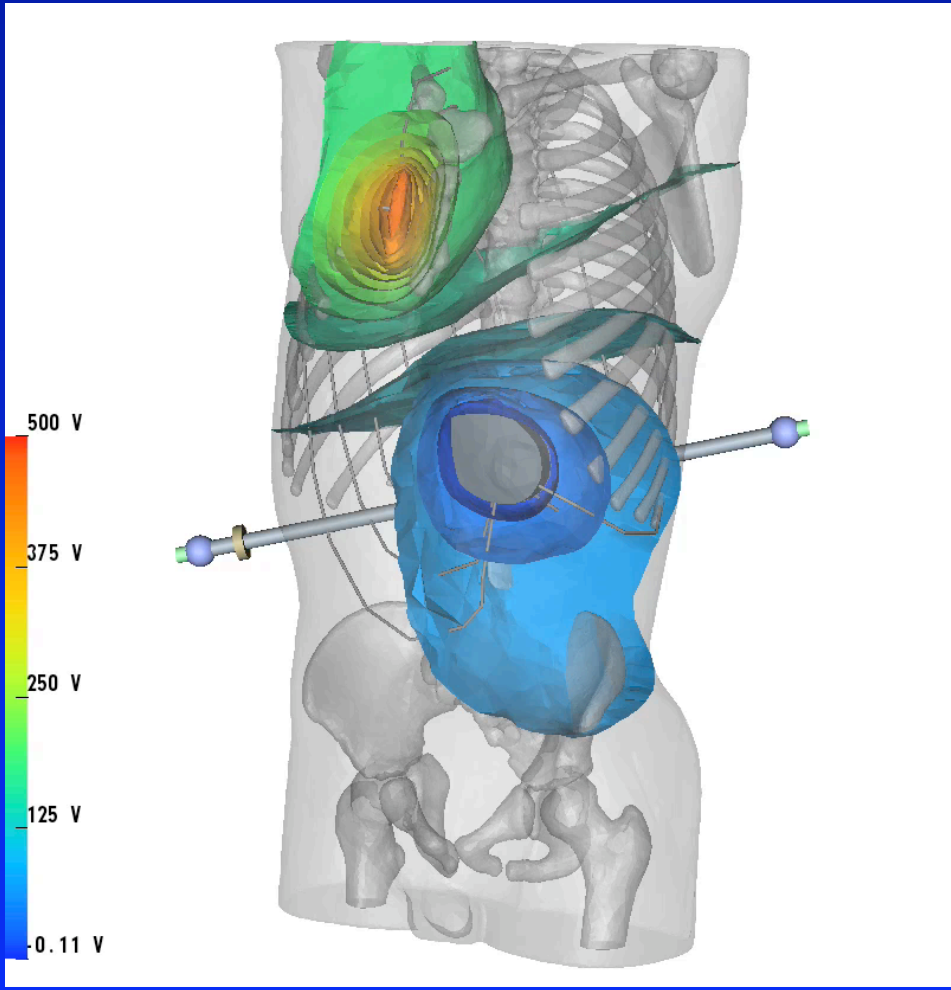


Refinement and electrode embedding

# New Defibrillation Model

## Model Creation



# Last lab session

## Model Creation