simpleware

converting 3D images into numerical models

Presented at the COMSOL Conference 2008 Hannover

Image Based-Mesh Generation for realistic Simulation of theTranscranial Current Stimulation

Ash Harkara
Business Manager

Presentation overview

Company overview

Software solutions

Case study

Summary

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Company overview

Simpleware

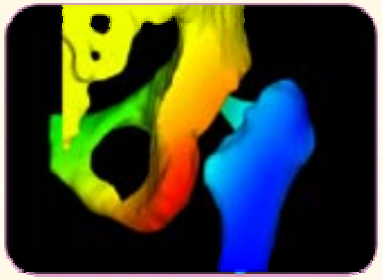
Develop and Sell world-leading image processing environment for the conversion of 3D images into models

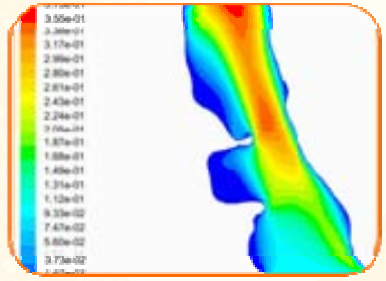
- Founded in December 2000
- Based in Exeter, United Kingdom
- Global customer base
- World-wide reseller network

What we provide: Software

For conversion of 3D images into high quality models and meshes, which can be directly used for:

- Computer Aided Design (CAD)
- Finite Element Analysis (FEA)
- Computational Fluid Dynamics (CFD)
- Rapid Prototyping (RP)



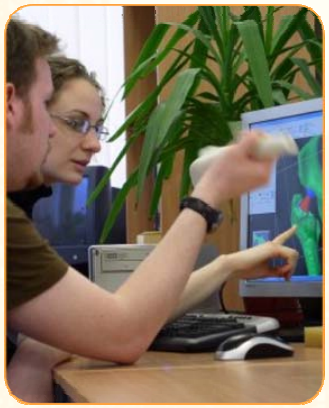


What we provide: Services

- Scanning and conversion services:
  - Phillips fMRI Scanner
  - Spiral CT Scanner
  - Converted to FEA, CFD, and/or STL and CAD files

- RP production of parts in:
  - Polymer (Laser SinterStation)
  - Metal (Selective Laser Melting Machine)

- Software development & support:
  - Adaptation of technology for tailored solutions
  - Full technical support



Industries Applications

Image-based meshing software and services for industrial applications in:

- Materials
- Natural Sciences
- Medical

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Process: Software solutions

Process overview - from scan to model

Scan data

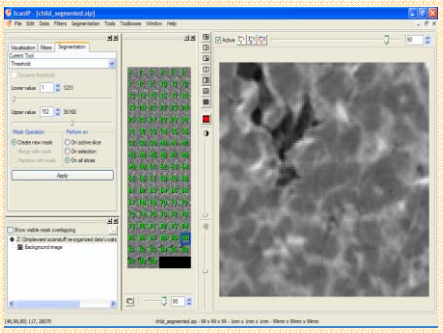
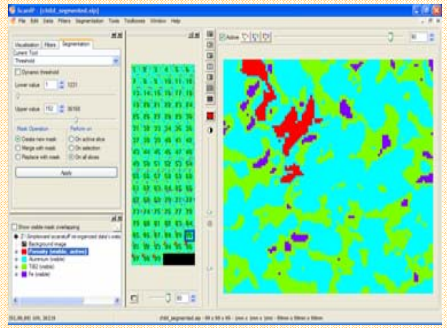
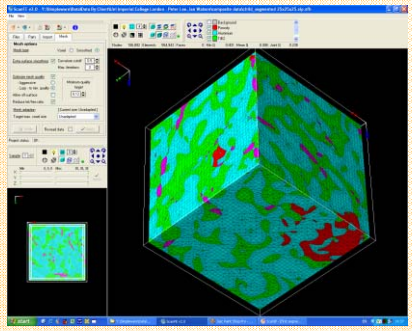


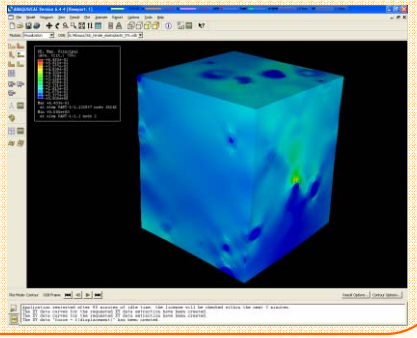
Image processing



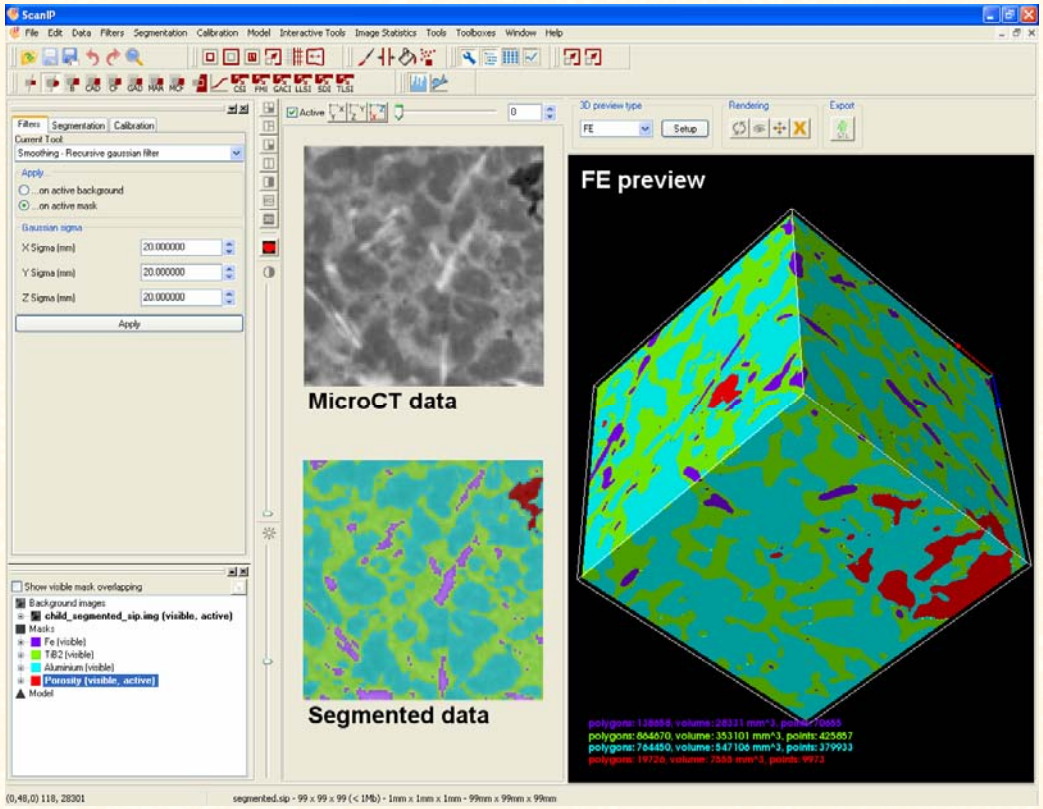
Meshing



FE/CFD mesh & surface model

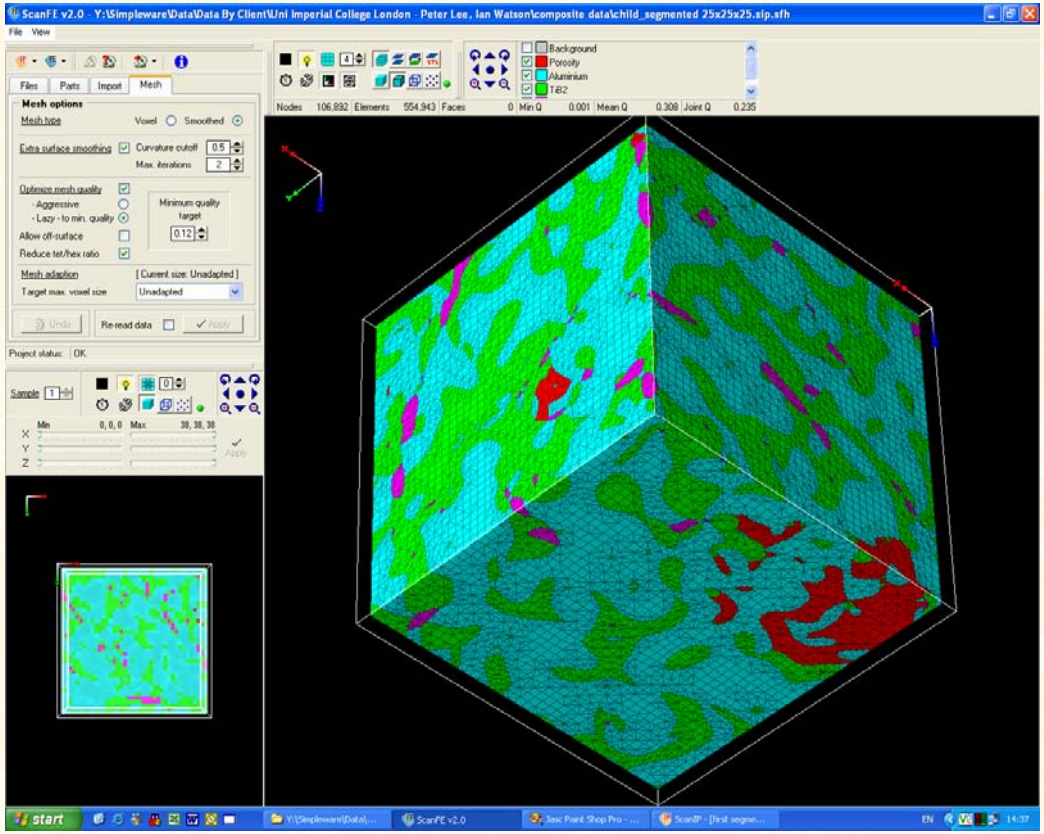


ScanIP software
Image Processing/Segmentation



- Import industrial CT, MicroCT, X-ray tomography (XMT) files
- Segmentation
- Visualisation of complex data sets
- Conforming multi-part watertight STL meshes
- Accuracy contingent only on image quality
- Low distortion tesselation

+ScanFE module
FE/CFD mesh generation



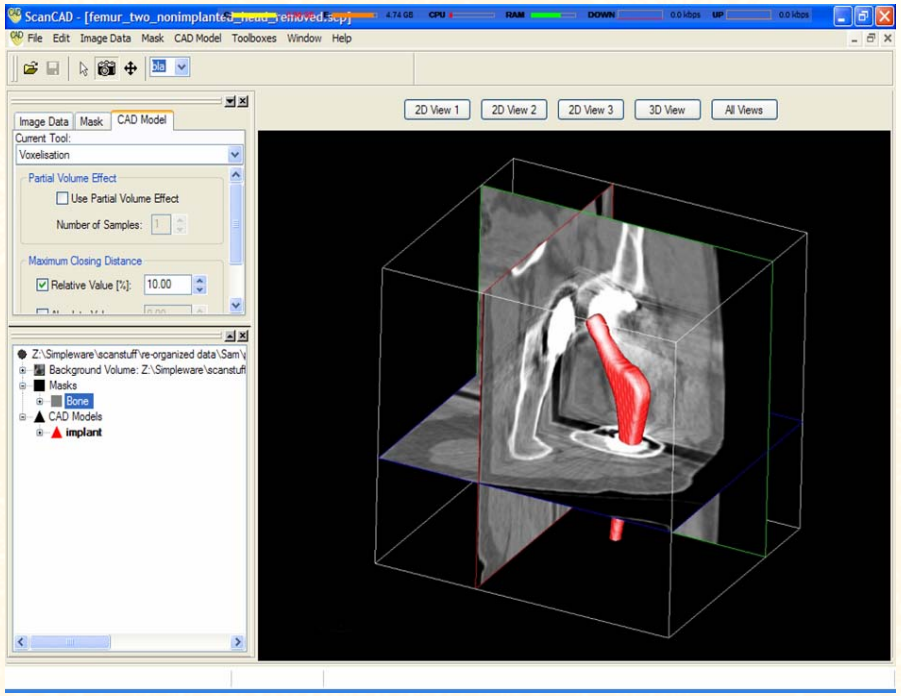
- Single-step conversion to multi-part volumetric mesh
- User defined adaptive meshing
- Assignment of complex material properties based on signal strength
- Direct export to Abaqus, Ansys, Fluent, COMSOL, etc.

  (no re-meshing necessary)
- FE model is exact replica of the STL

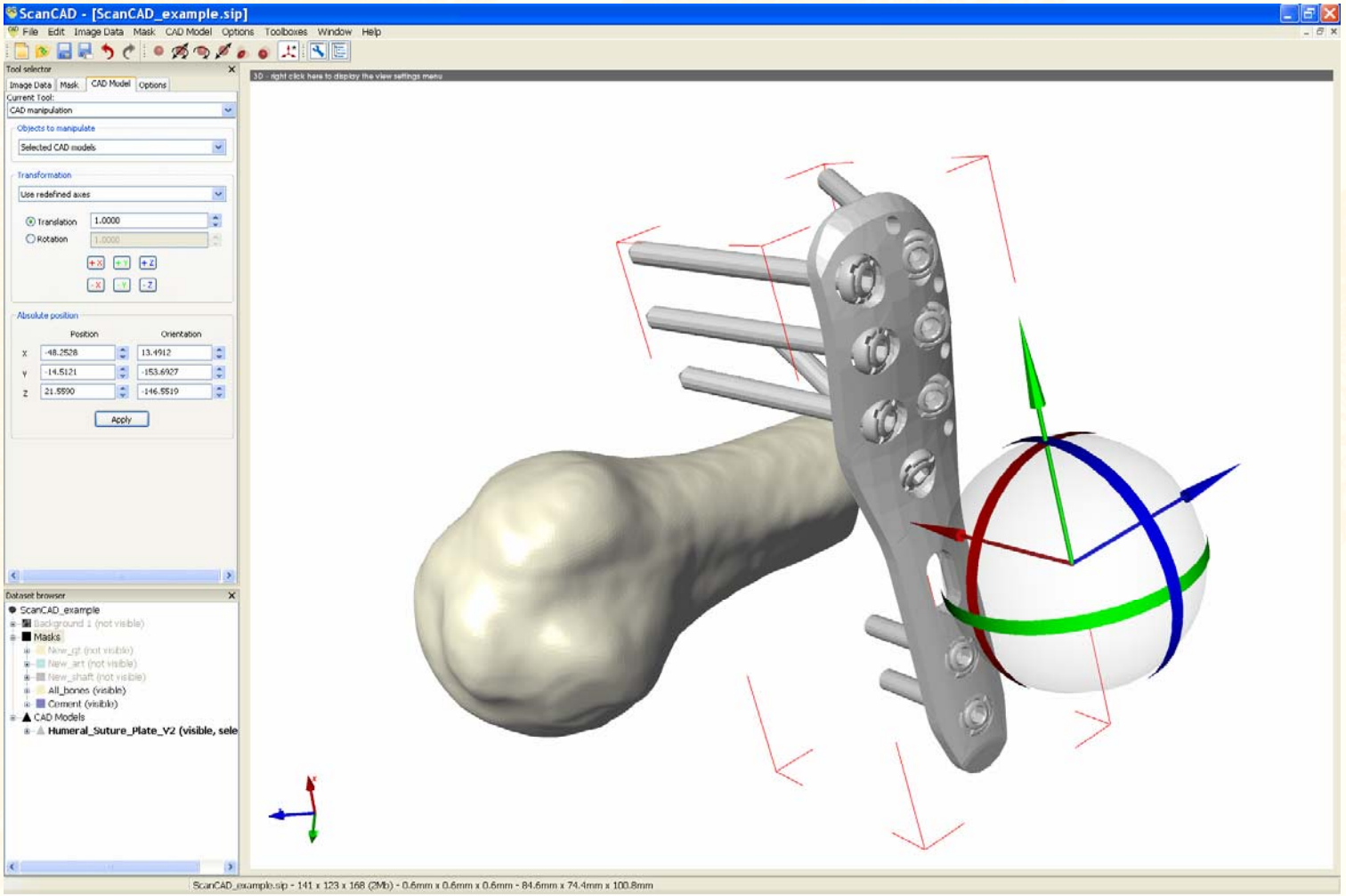
+ScanCAD module
Import and positioning of CAD data

Features and benefits:

- Direct import of most common CAD formats and support of multiple CAD imports
- Intuitive 3D positioning widget
- Export of multi-part STL models (e.g. bone – implant)
- Automated meshing for FE/CFD analysis



Proximal humerus fracture



Segmented masks from scan and imported CAD implant

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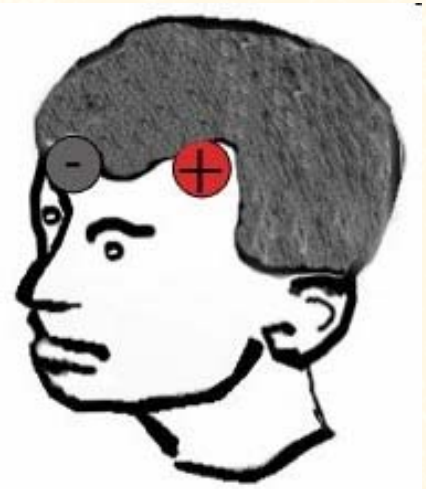
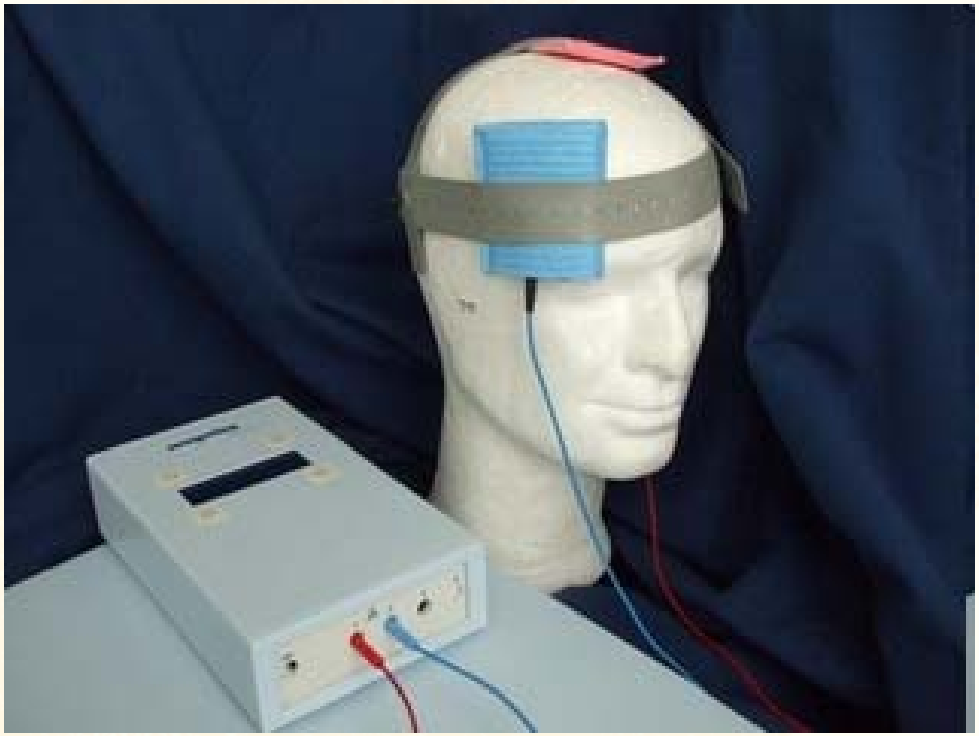
Applications and Case study

TRANSCRANIAL CURRENT STIMULATION

WHAT IS TRANSCRANIAL CURRENT STIMULATION ??





TCS is the application of currents delivered through the scalp to modulate brain activity.

Benefits of TCS :

Actively explored as a non-invasive therapeutic option for the treatment of neurological/psychological diseases…including depression, stroke, epilepsy, learning disorders, relieving pain.

Cheap and ease of use.

However:

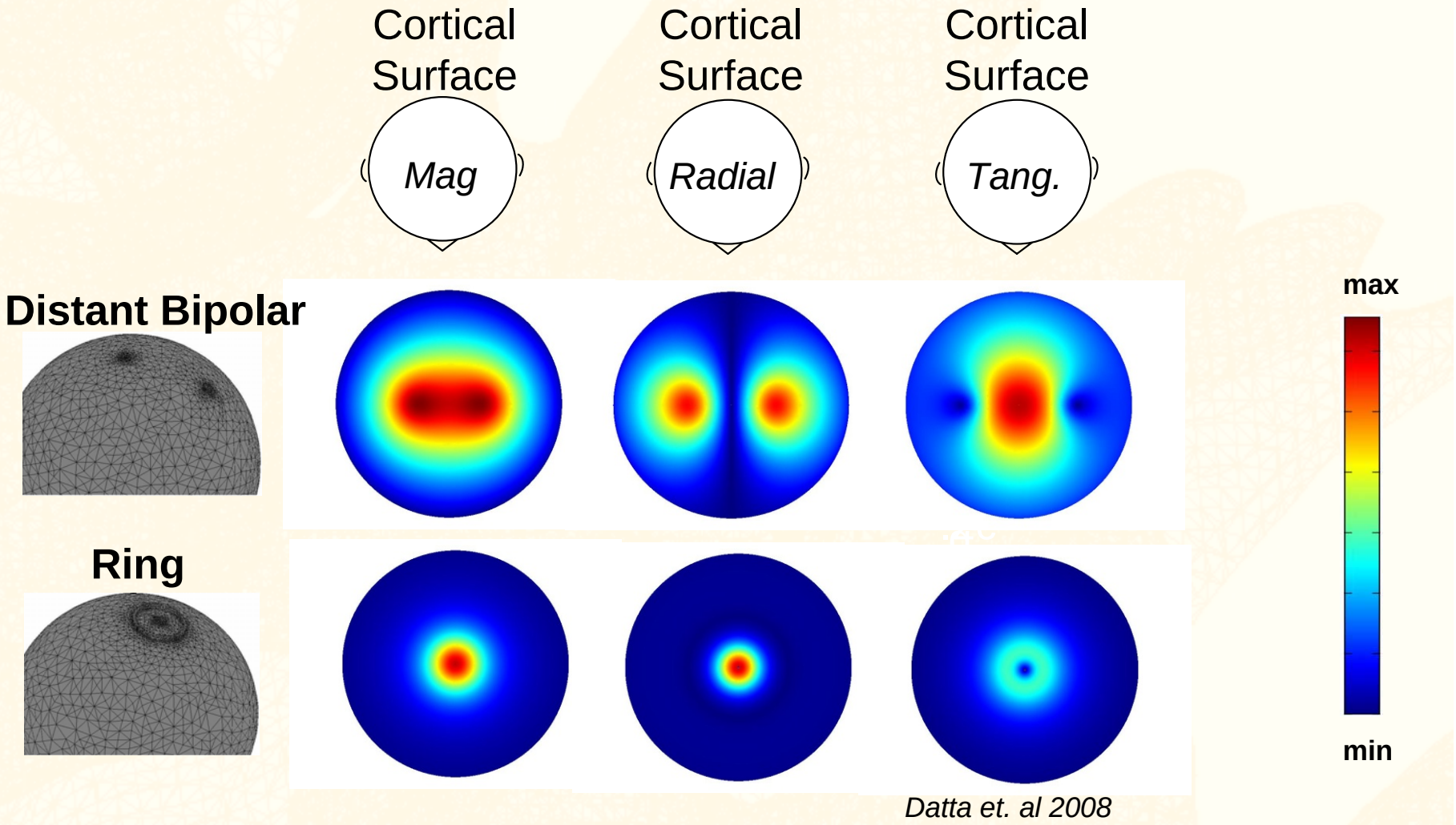
A critical factor for TCS 'efficacy' and 'safety' is the spatial focality of stimulation.

Spatial focality = spatial extent of induced electric field in the brain

Currently used clinical protocol is '*unfocal*'

Objective :
Examine Optimised electrode configuration and to develop Modulation maps that may guide anatomically and functionally targeted TCS application.

PROOF OF CONCEPT



Datta et. al 2008

More accurate head model desired in a clinical setting…….

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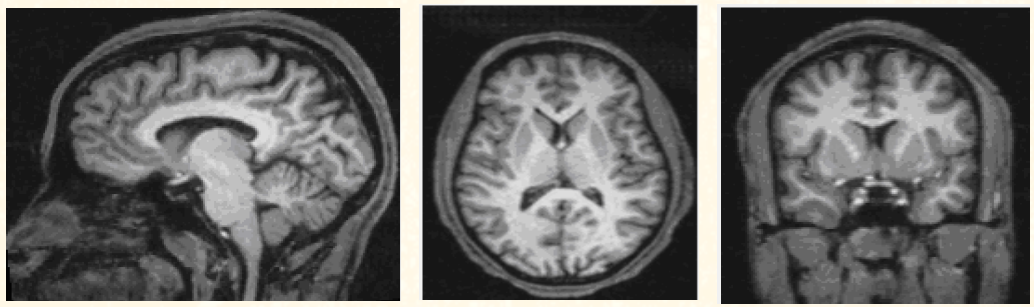
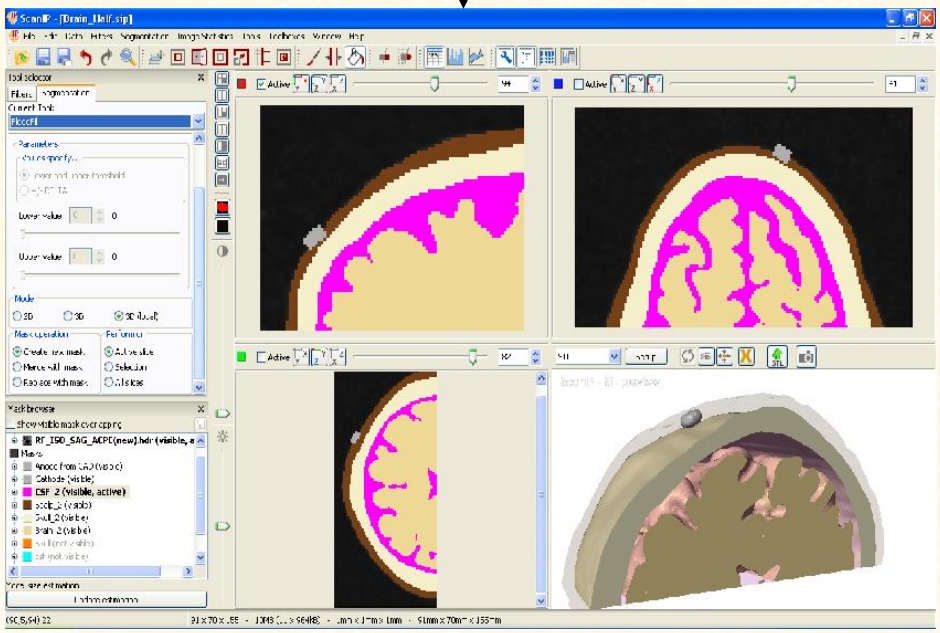
MRI DERIVED FINITE ELEMENT MODEL



Smoothing and segmentation algorithms of SIMPLEWARE LTD.



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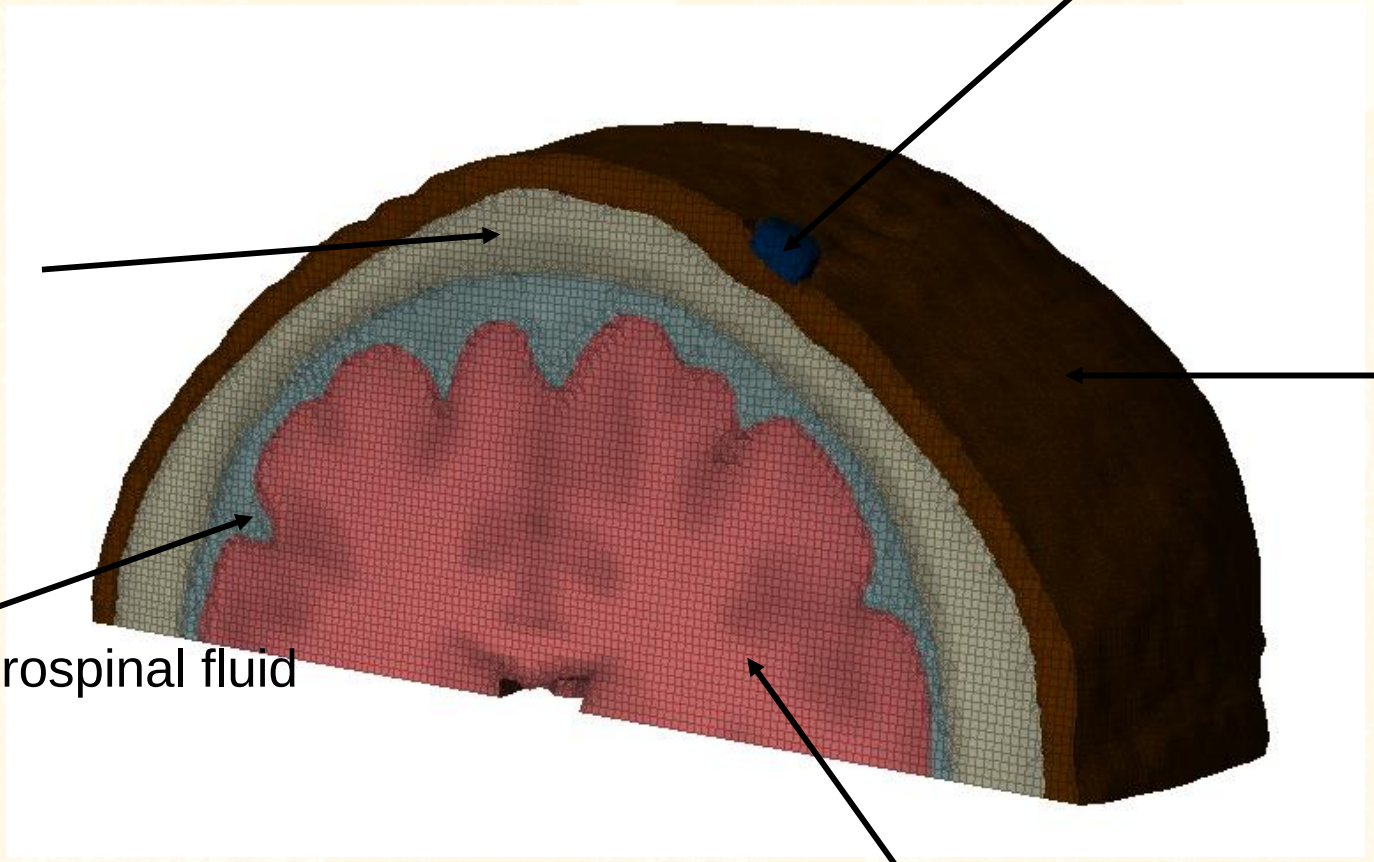
SUBDOMAIN SETTINGS



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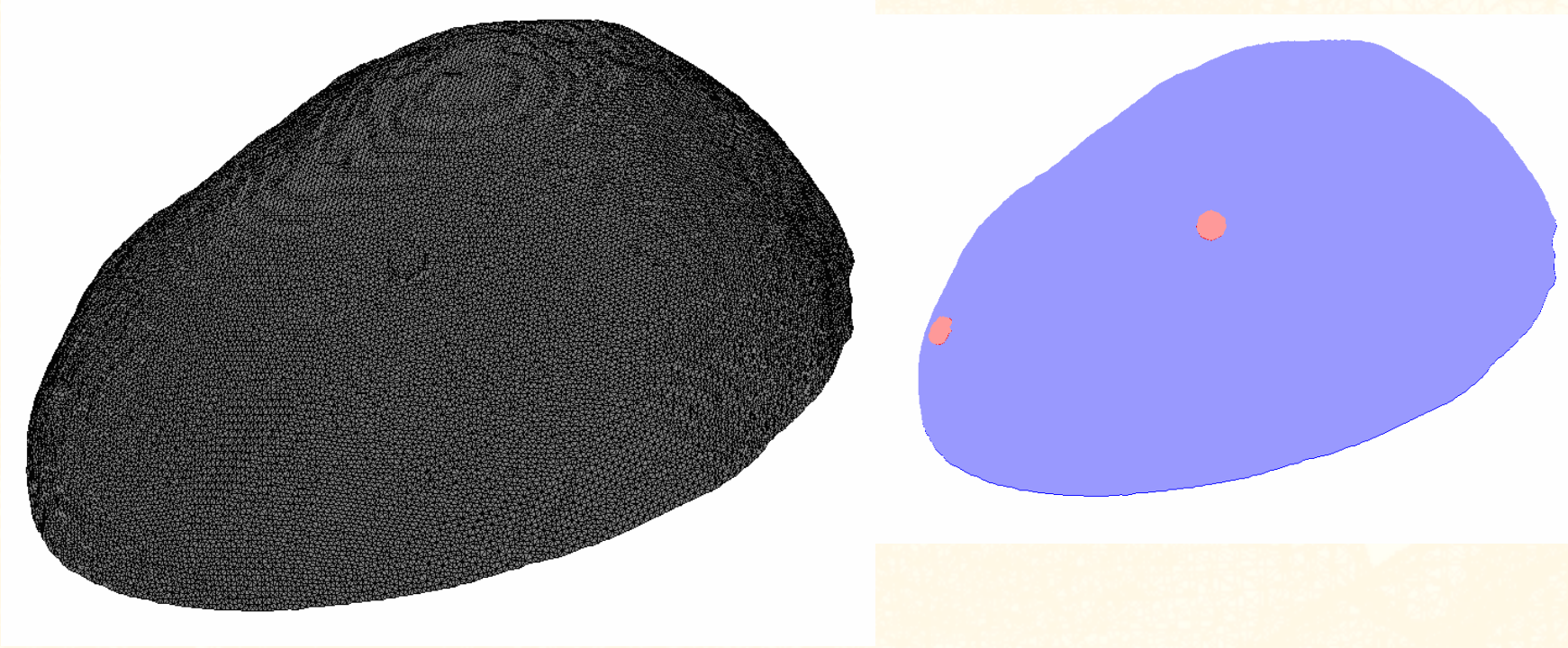
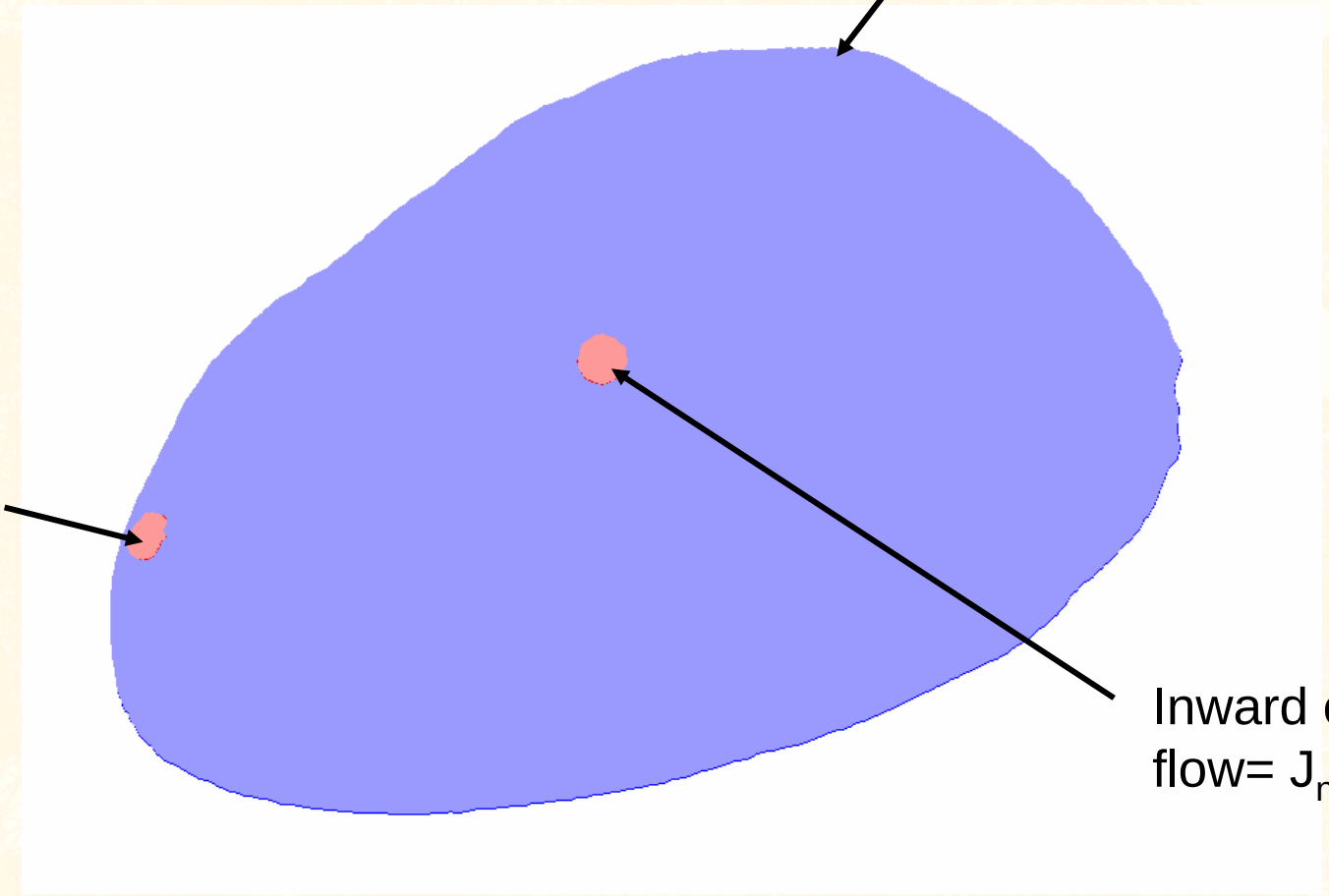
Meshes generated using SIMPLEWARE are imported into COMSOL



BOUNDARY SETTINGS

All external surfaces insulated



Ground boundary condition

Inward current flow= J_n

PHYSICS OF THE PROBLEM

The electric field in a volume conductor:

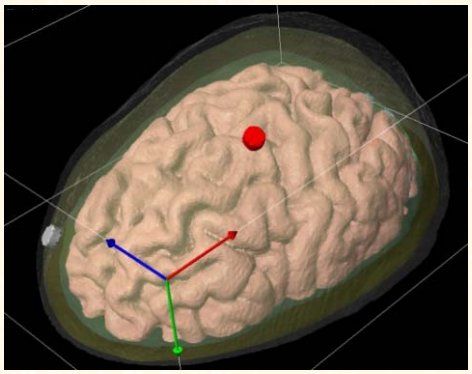
$$\nabla.(\sigma \nabla V) = 0$$ (V: potential; σ: conductivity)

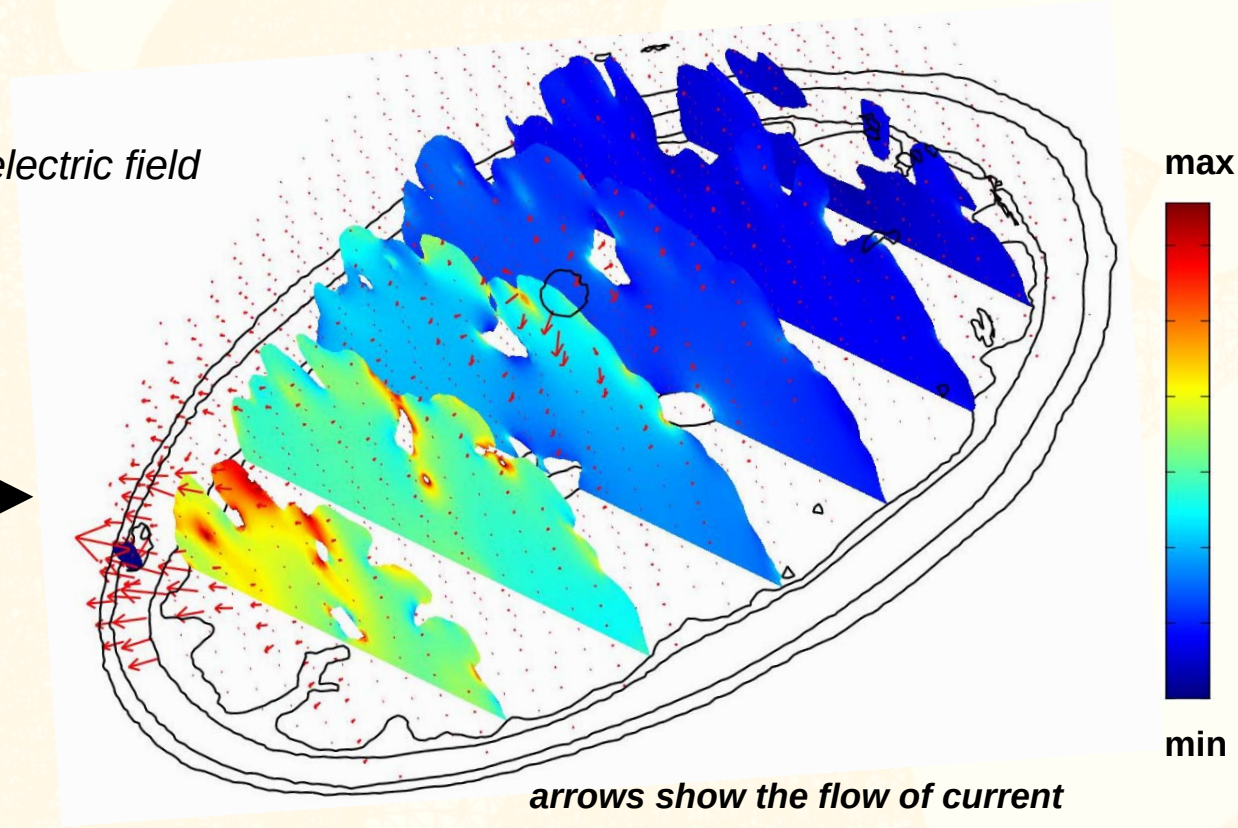
uniform conductivity assumption → Laplacian equation

SOLVER USED: conjugate gradients

TOLERANCE: 1e-8.

DISTANT BIPOLAR CONFIGURATION





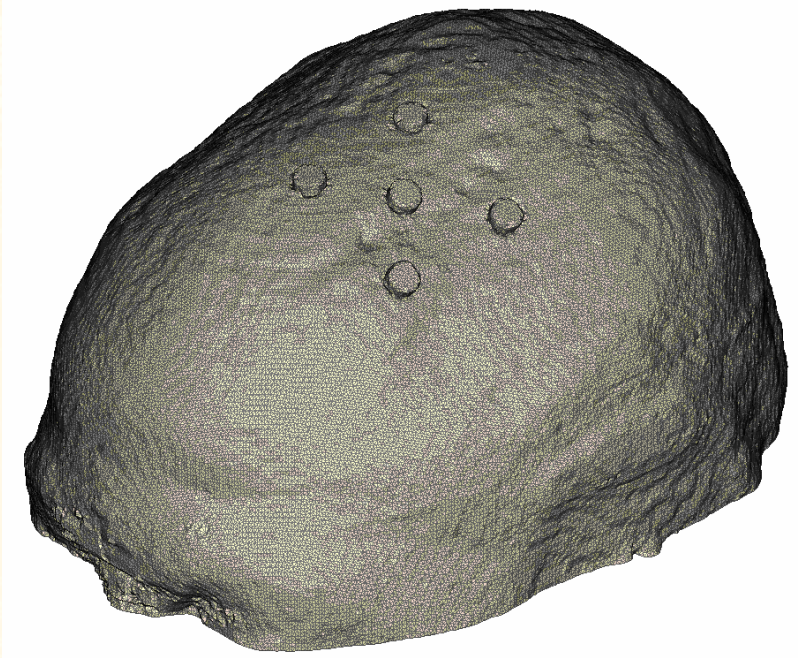
Commonly used configuration is poorly focused…..

HOW TO PRACTICALLY IMPLEMENT A RING ELECTRODE ON THE HEAD…

- Head shape not smooth

- Impossible to maintain similar electrode-scalp impedance at all points….

PROPOSED CONFIGURATION

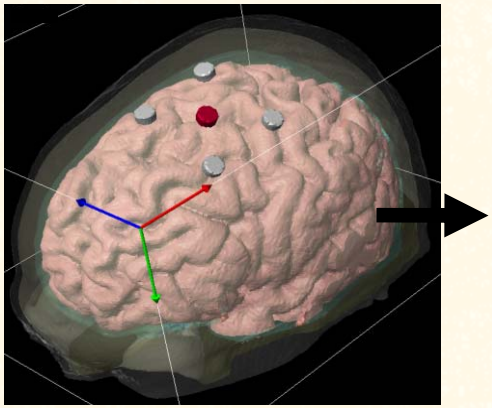


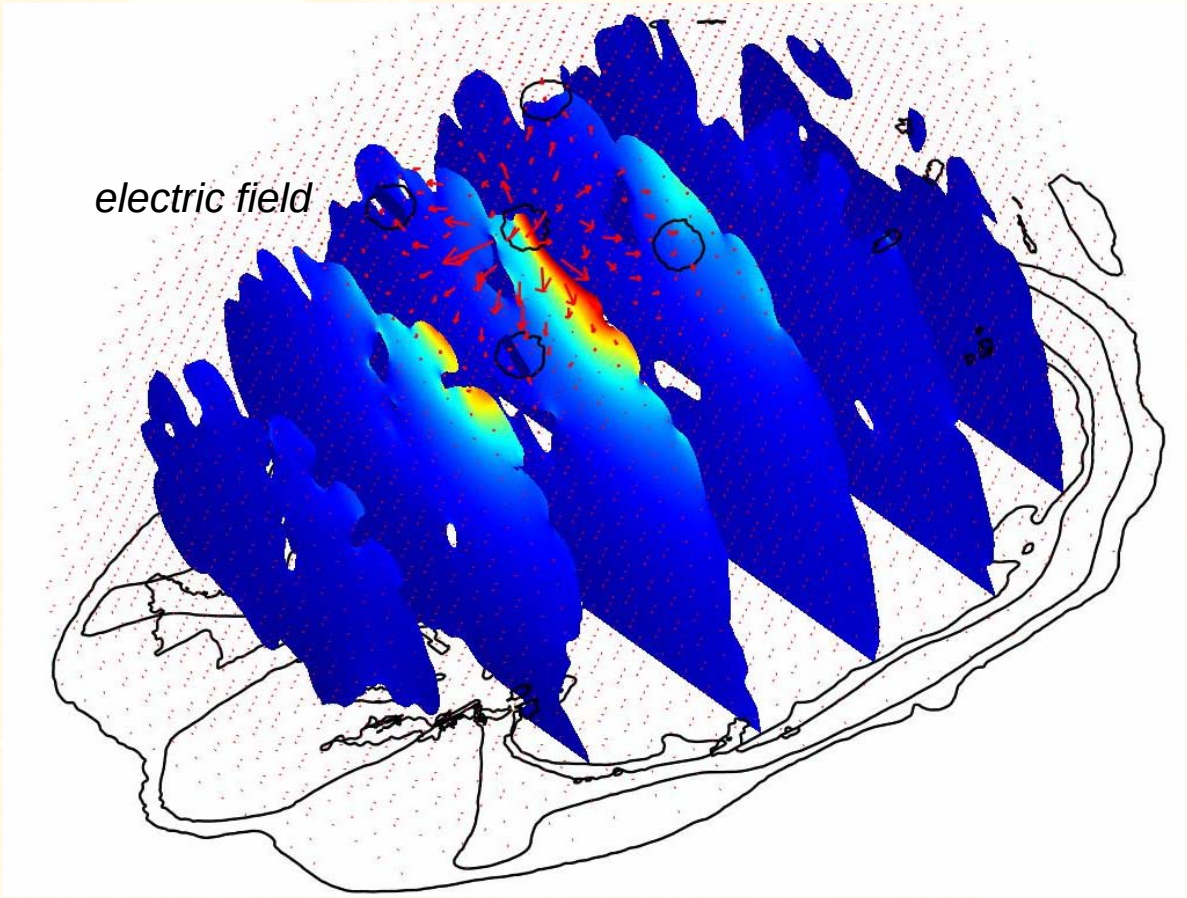
Would need more current to obtain similar efficacy…

Calculate using a FEM model…

Advantage of using a ring configuration….

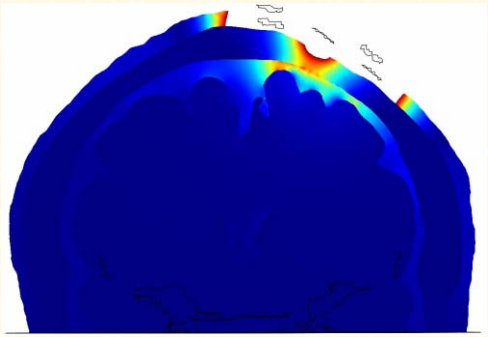
4 x 1 RING CONFIGURATION



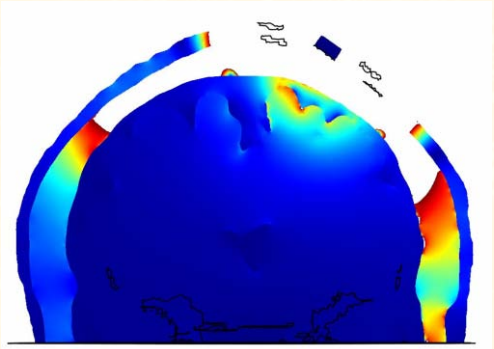


4 X 1 configuration leads to significant increases in focality

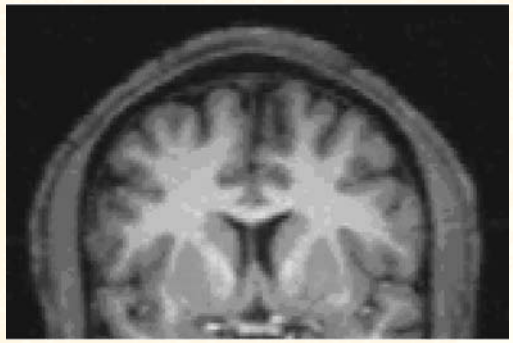
Guided by the FEM model, a **novel head gear** was developed to position the return electrode(s) and the active electrodes appropriately based on user needs….



Current Density in brain / CSF

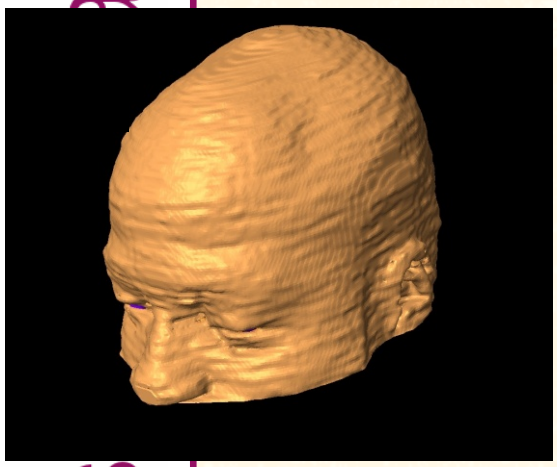


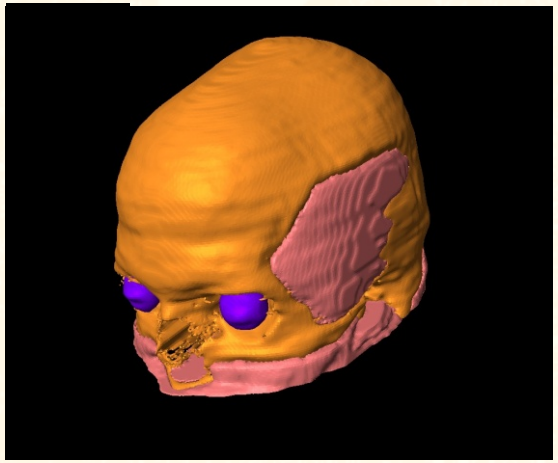
E-field in brain / CSF

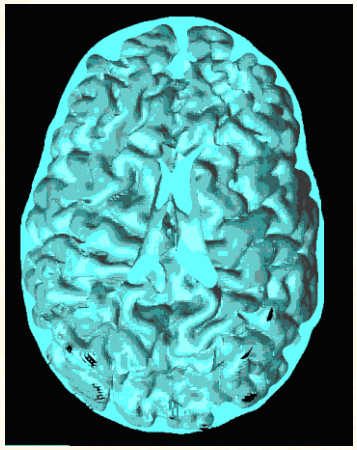


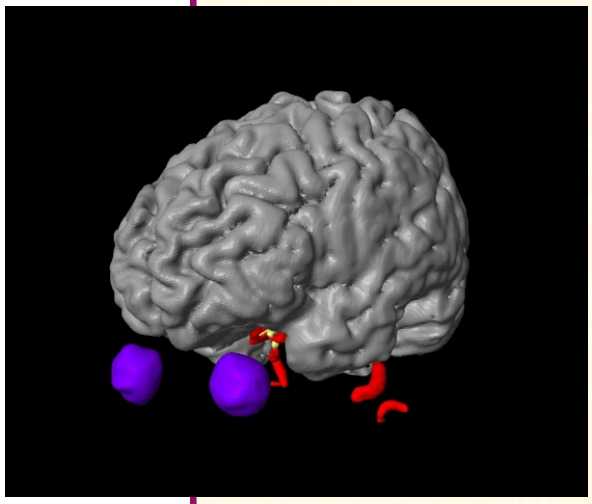
MRI slice

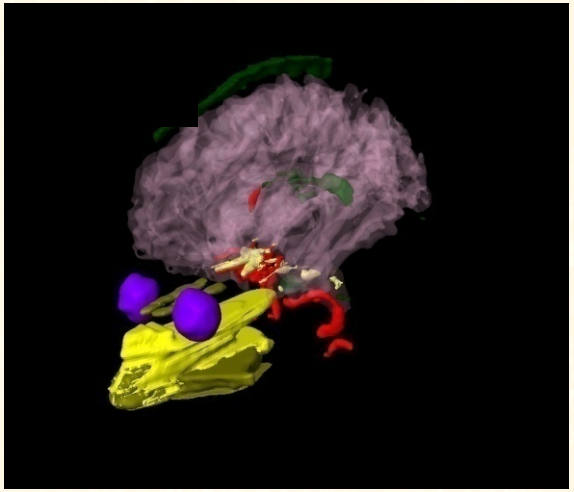
Our models give sub-gyri/sulci specificity

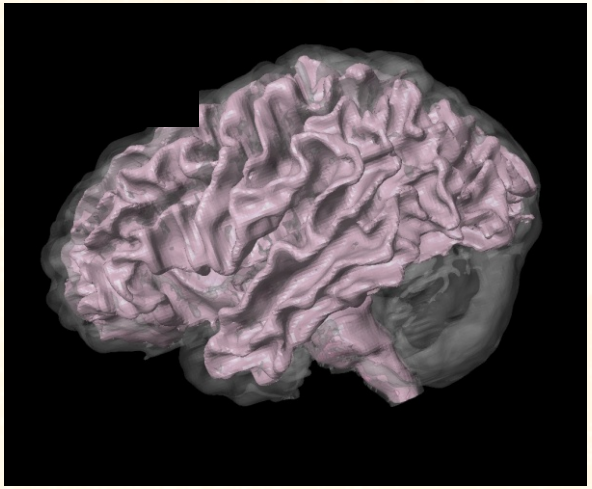












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Summary

Superficial cortical regions can be selectively targeted using a 4 x 1 system.

Spatially optimal 4×1 ring configurations were selected based on the model predictions such that the peak induced cortical electric field was comparable to standard 2 electrode (bipolar) tDCS protocols.

Using Simpleware software you can

- **Robust and accurate models** for simulation/analysis -

- Explore **influence of parameters on response of system** (**sensitivity studies)**; contribution of different phases, influence of assumed interfacial mechanics, …

Advantages:

- Accuracy
- User Friendliness and very easy to use
- Material properties
- Coupled problems can be modelled seamlessly
- Suitable for Micro-CT data

ACKNOWLEDGEMENTS

COMSOL Inc., Pejman Sehatpour (NKI), Eric Wasserman (NIH).

Abhishek Data : Department of Biomedical Engg. The city college of New York, University of New York. USA.

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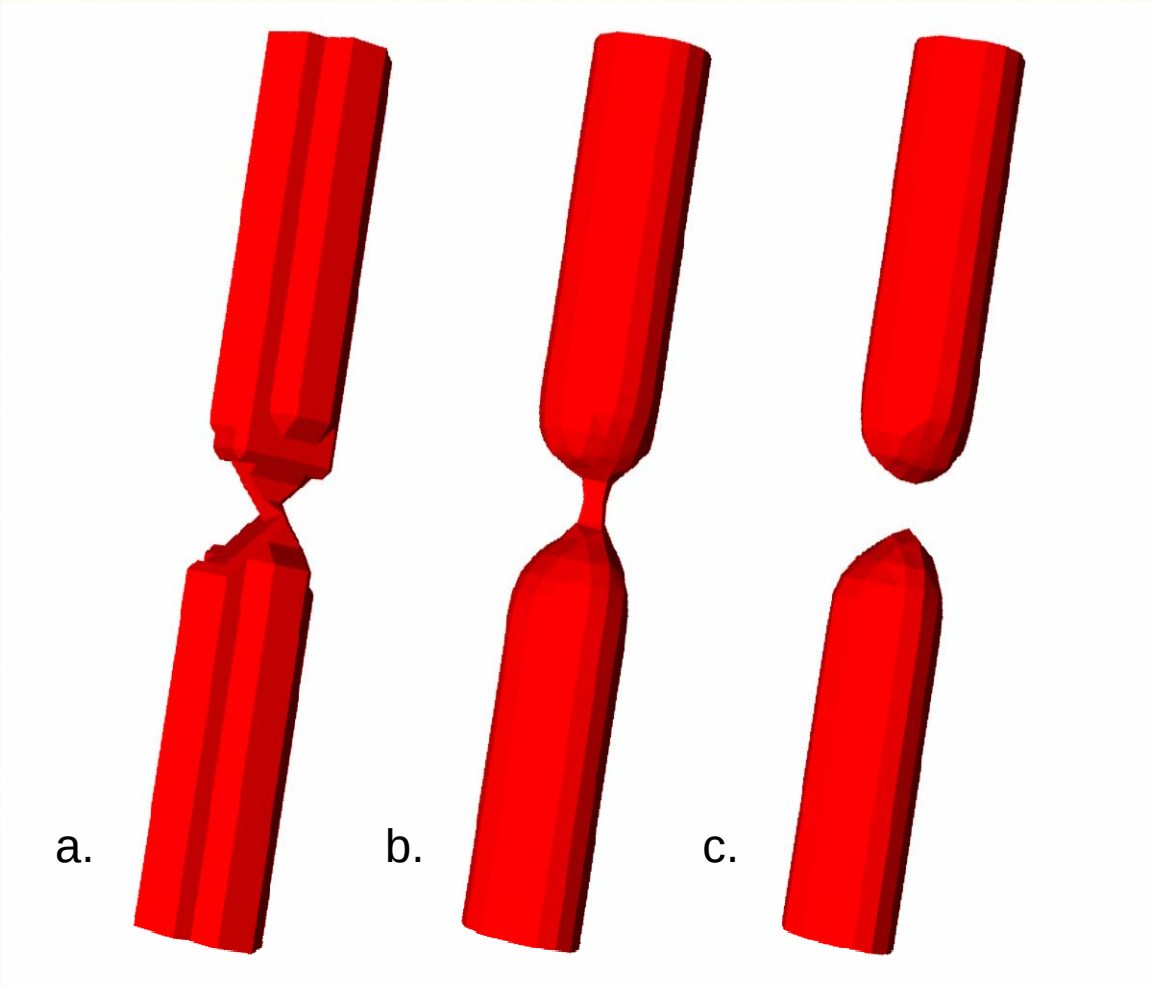
Accelerate your Success With ScanIP/ScanFE/ScanCAD

Q&A

Imaged-based accuracy: Topology preservation

No loss of structures



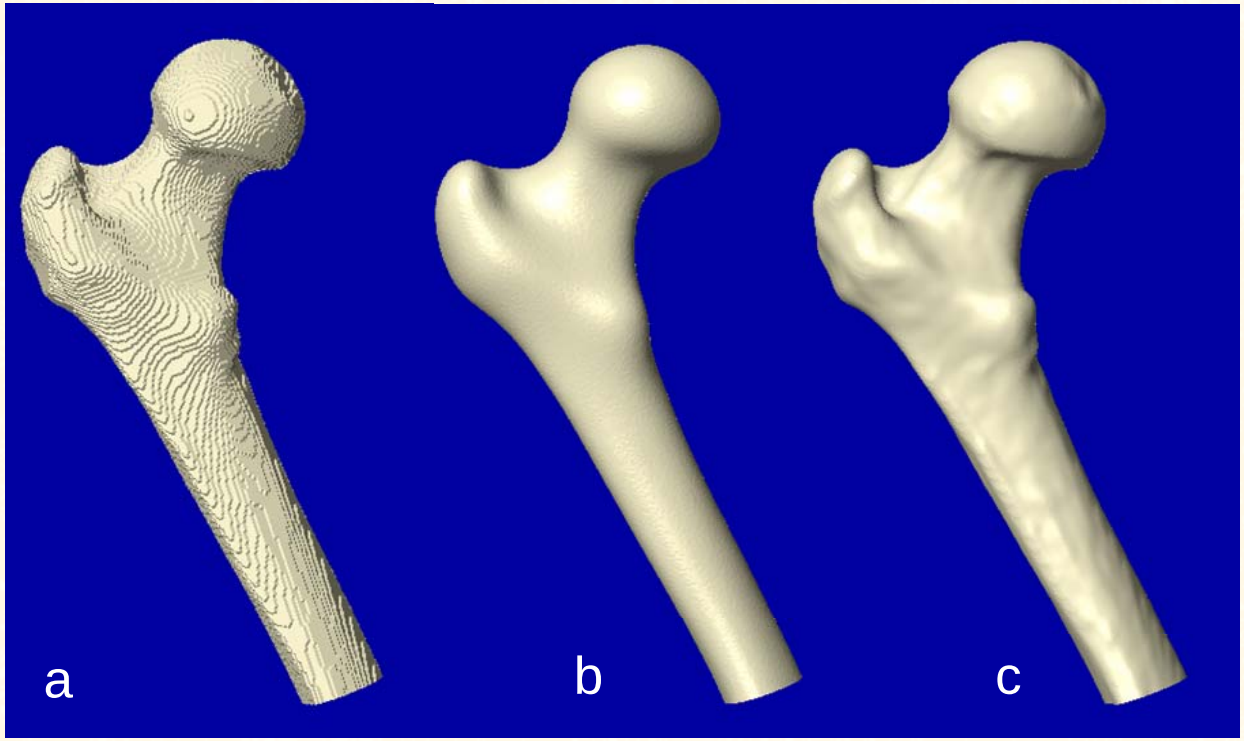
a. Original image, unsmoothed

b. Topology preserving smoothing

c. Non-topology preserving smoothing

Image-based accuracy: Volume preservation

Smooth without loss or gain of volume



a. Original image, unsmoothed (203,238 mm^3).

b. Traditional smoothed (180,605 mm^3, Δvolume = -11.14%)

c. Simpleware developed (202,534 mm^3, Δvolume = -0.35%)

User defined mesh refinement

Meshes of variable element density