- NFT -

Neuroelectromagnetic Forward Head Modeling Toolbox

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NFT: Introduction

- MATLAB Toolbox for realistic head modeling and forward problem solution.
- Ability to use available subject information
  - T1-weighted 3D MR images
  - Digitized sensor (electrode) locations
- Implements all steps of head modeling
  - Segmentation of MR images
  - Mesh generation
  - Warping of a template head model to sensors
  - Sensor co-registration
  - Forward problem solution

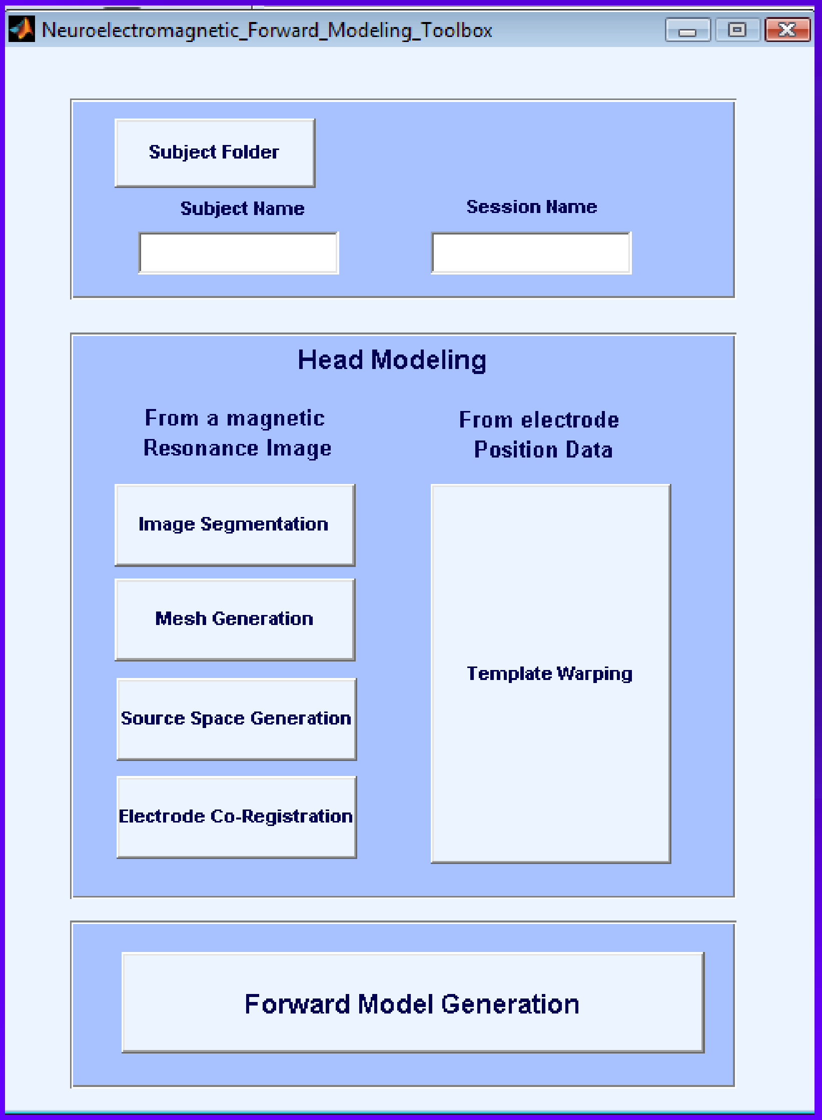
NFT External Programs

- 3rd Party Tools and Libraries Used:
  - ASC:
    - High quality triangulation
  - Qslim
    - Mesh Coarsening
  - MATITK
    - MATLAB interface to ITK image processing toolkit
  - METU-BEM
    - Boundary Element Method (BEM) Solver
- Source code is available for all these components.

NFT: Operation

- T1 MR Images
  - Choose subject
  - Generate head model for subject
    - Segmentation
    - Mesh generation
  - Register sensors to mesh
    - Each set of sensors is a separate session
  - Generate forward model
  - Generate LFM for each session
- Template Mesh
  - Choose subject
  - Select subj sensors
  - Warp template to sensors
  - Generate forward model
  - Generate LFM for sensors

NFT Main Menu



Subject Selection

Head Modeling

Forward Modeling

Subject Selection

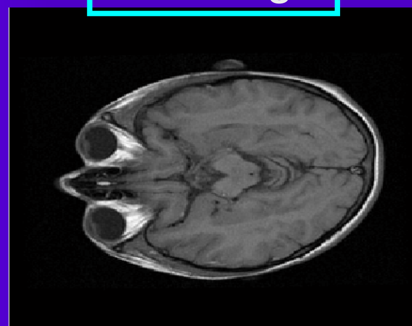
- Select subject folder
- Specify subject name
- Specify session name

Head Modeling from MR Images

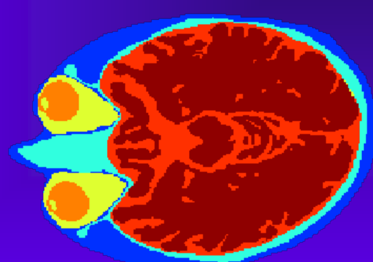
From a magnetic Resonance Image

- Image Segmentation
- Mesh Generation
- Source Space Generation
- Electrode Co-Registration

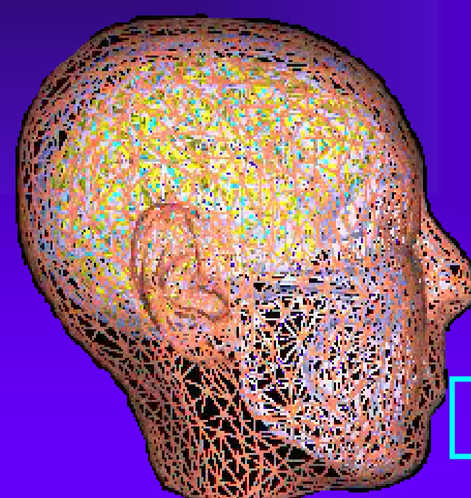
MR image



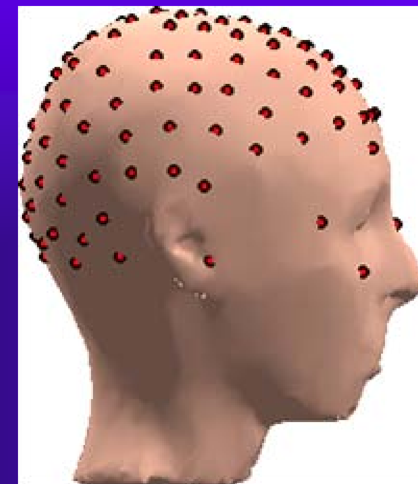
T1-weighted



Segmentation



BEM mesh



Electrode Registration

Preparing MR image for segmentation

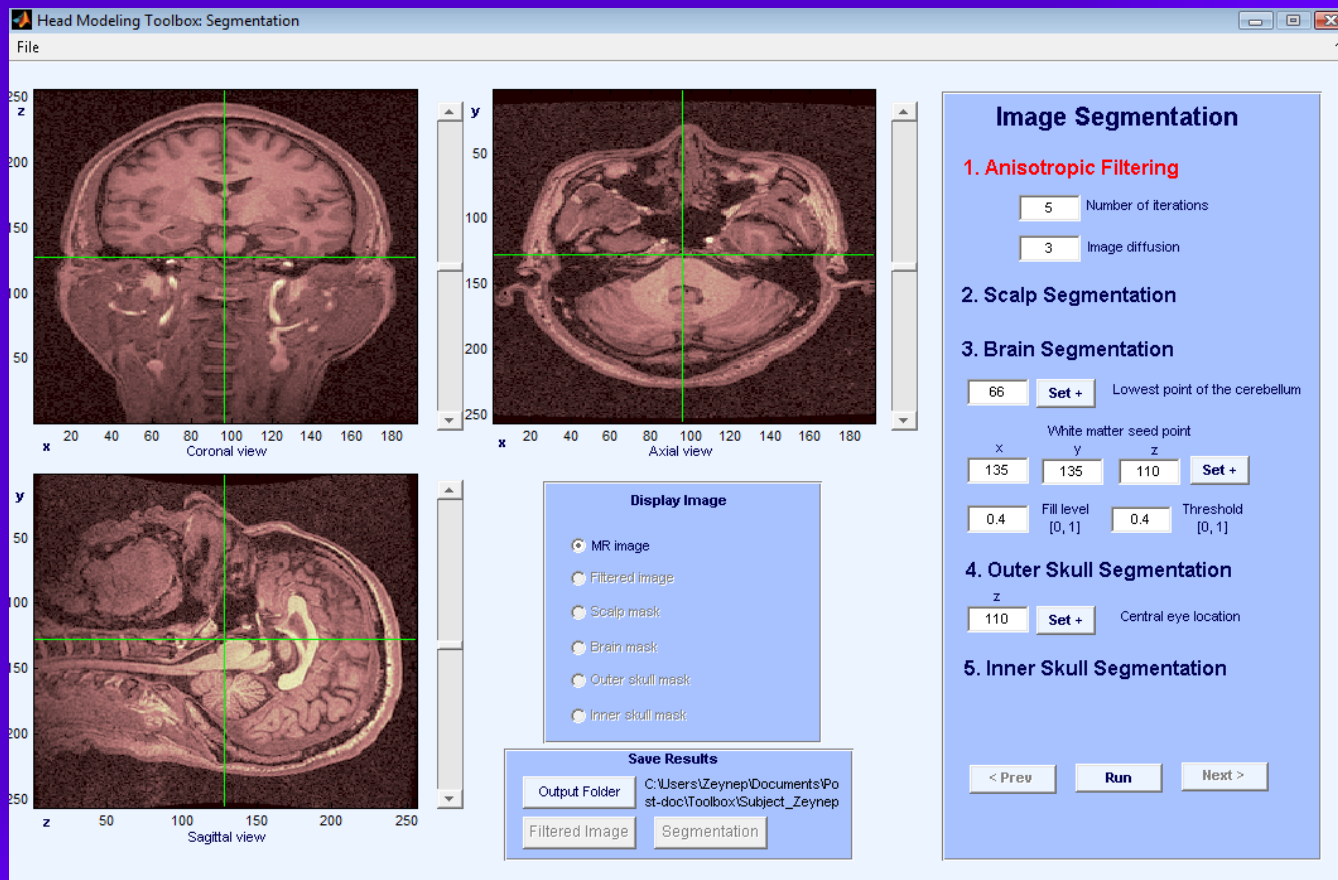
Using FREESURFER:

- Inhomogeneity correction
- Convert to 1x1x1mm volume
- Arrange direction of the image
- Save in analyze format

Image Segmentation

From a magnetic Resonance Image

- **Image Segmentation**
- **Mesh Generation**
- **Source Space Generation**
- **Electrode Co-Registration**

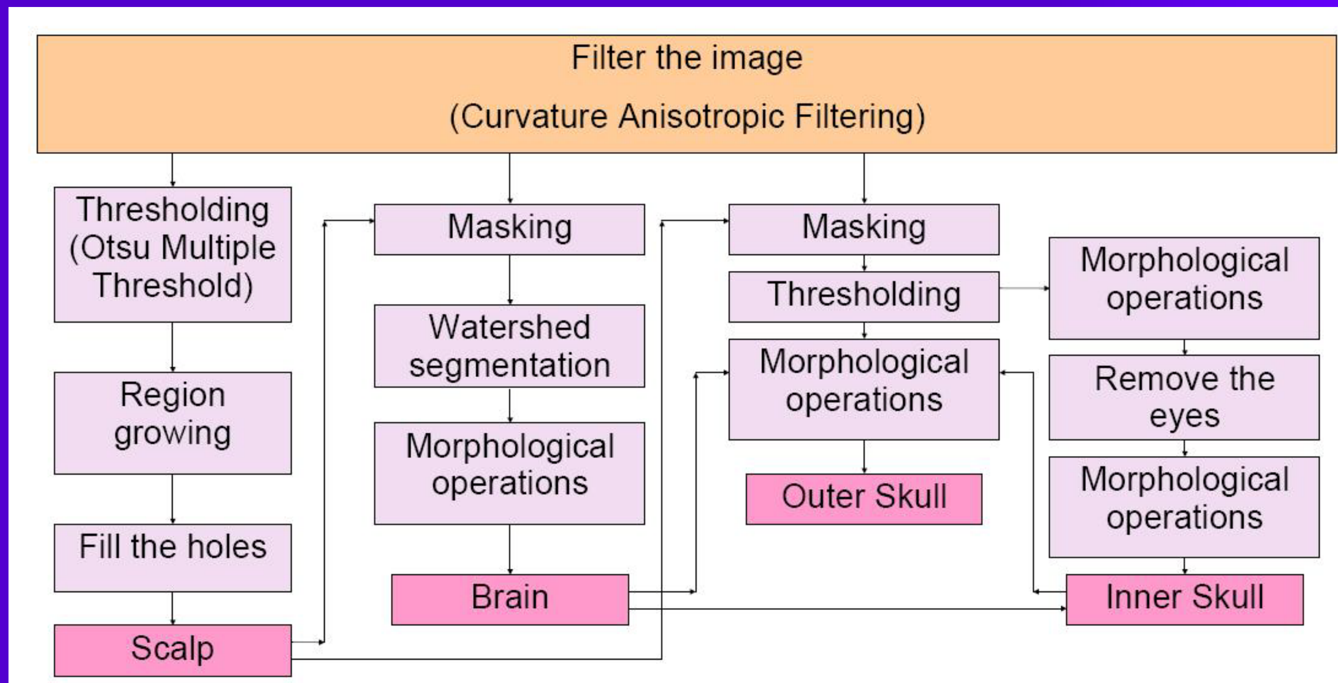


- Interface for Segmentation of MR Images

Image Segmentation Flowchart

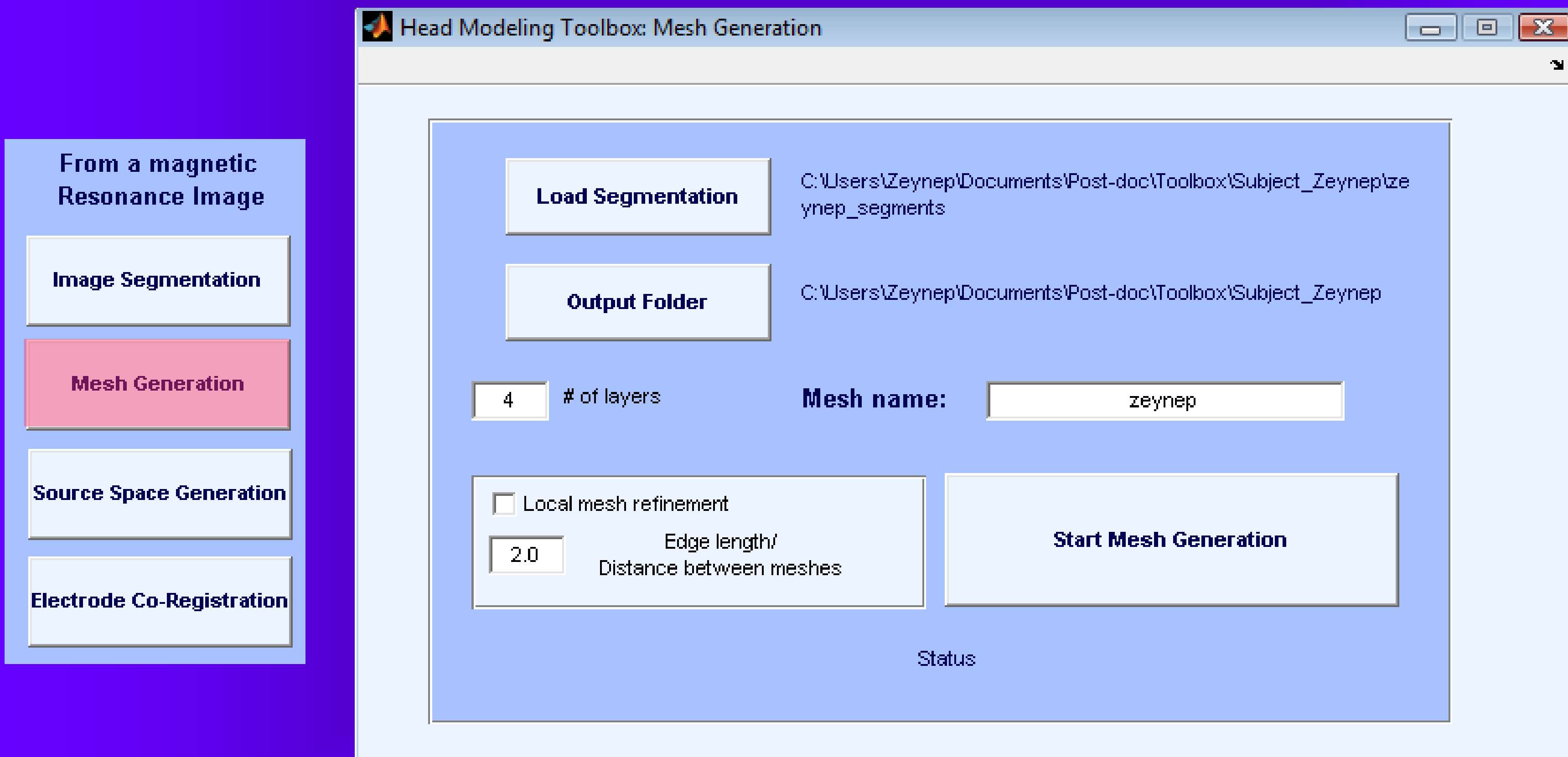
From a magnetic Resonance Image

- **Image Segmentation**
- **Mesh Generation**
- **Source Space Generation**
- **Electrode Co-Registration**



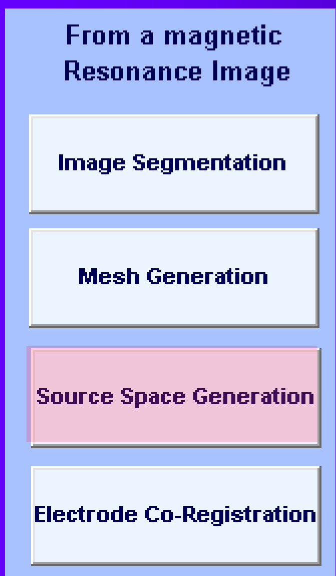
- Classifies four tissues from T1-weighted images
  - – Scalp, Skull, CSF and Brain

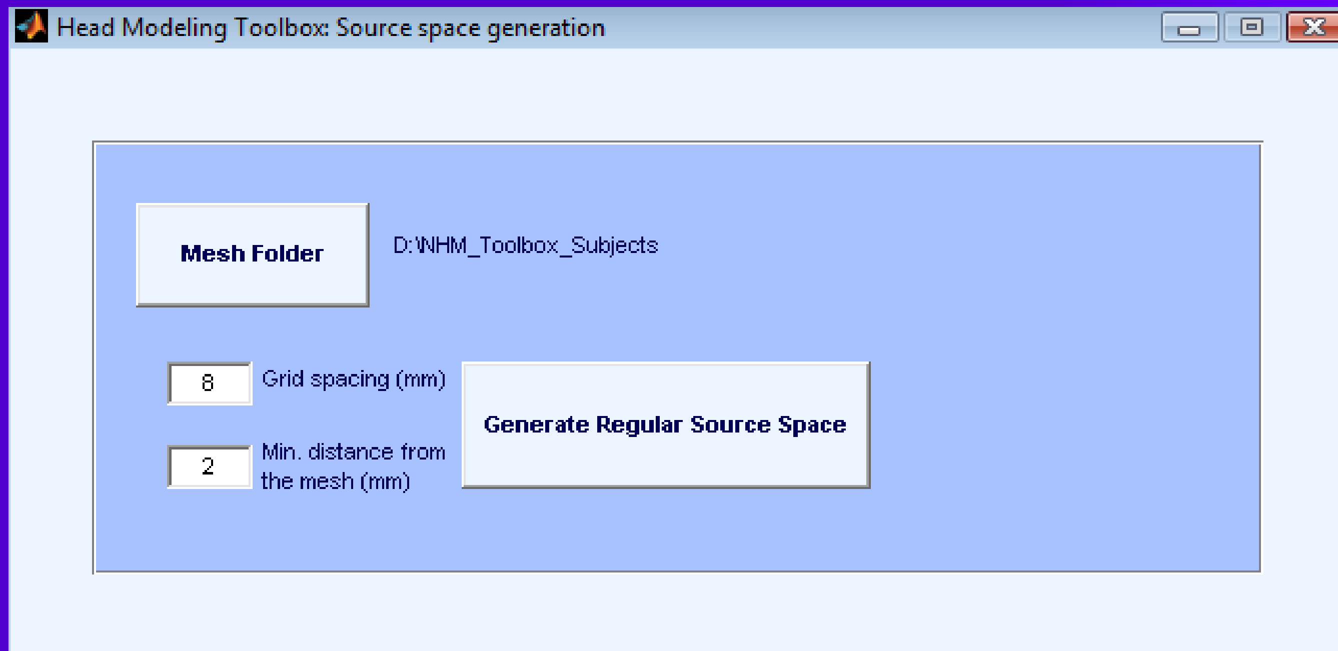
Mesh Generation



- Generate Mesh for a 3 or 4 layer head model
  - Triangulation, correction, coarsening, refinement

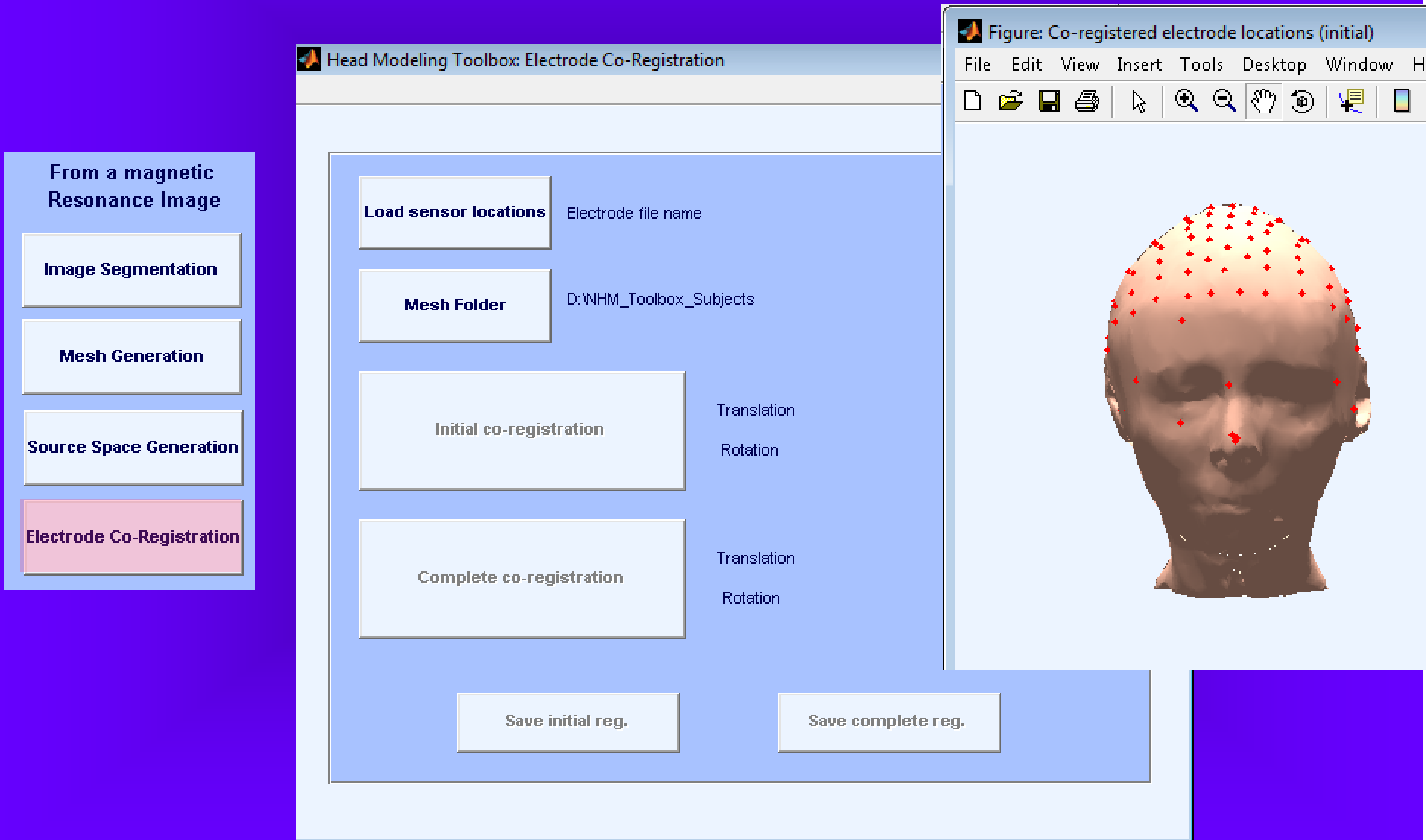
Source Space Generation





- Generate a simple source space
  - Regular Grid inside the brain
  - With a given spacing and distance to the mesh

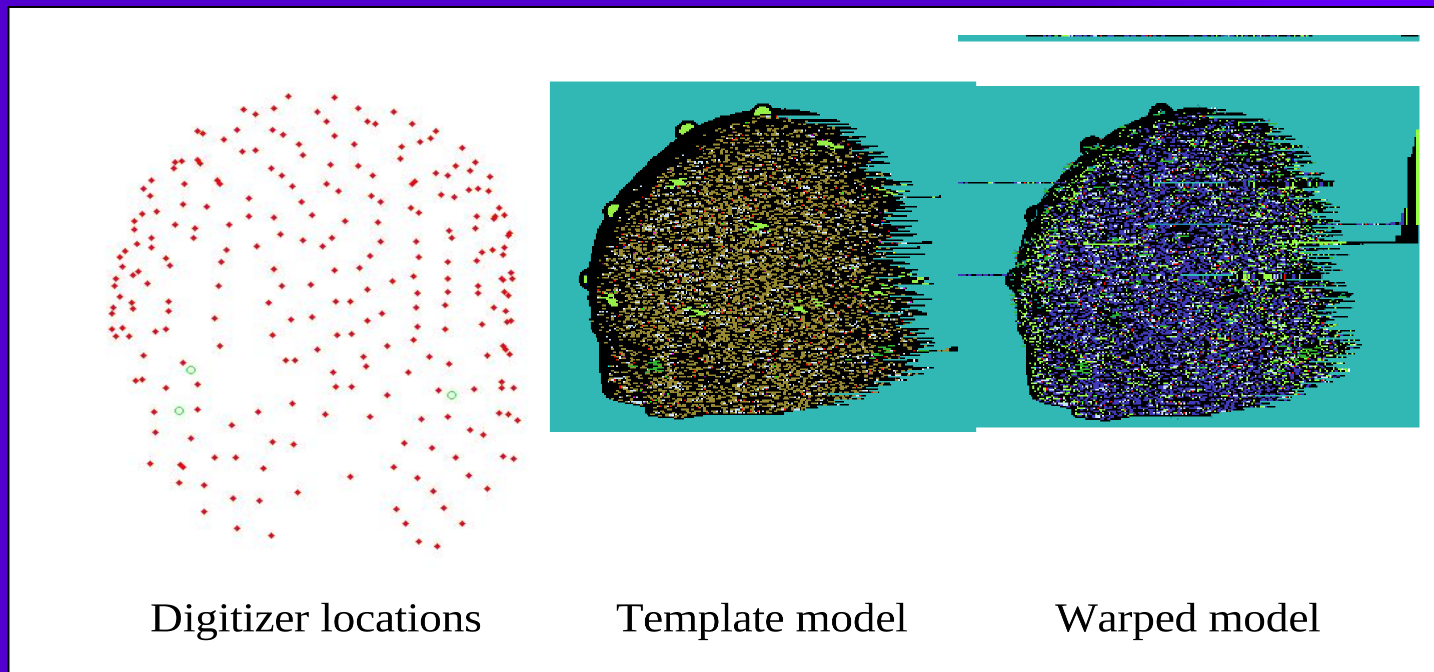
Electrode Co-Registration



Head Modeling from Electrode Position Data

From electrode Position Data

Template Warping

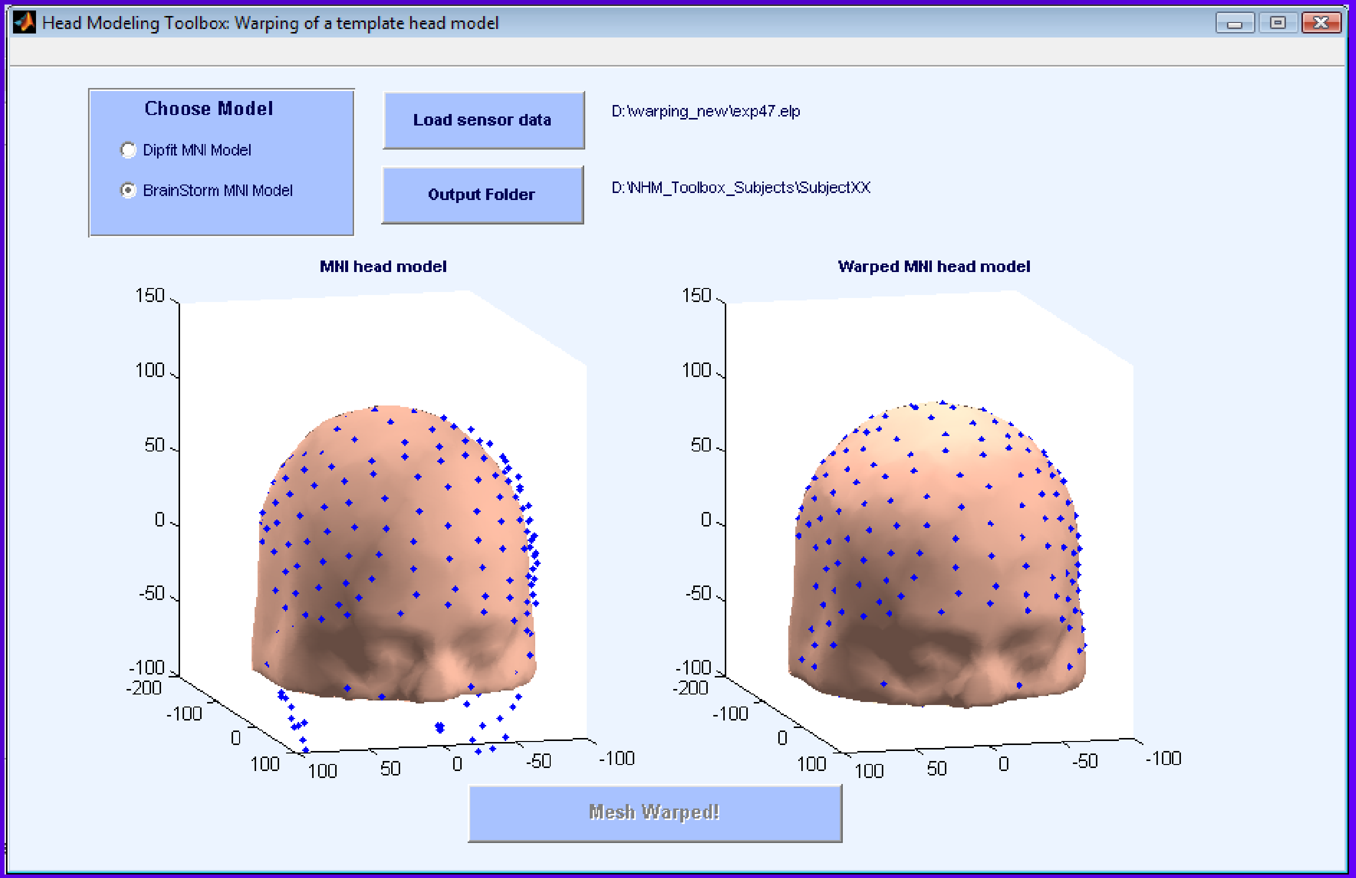


- Warp a template mesh to electrode positions
  - When no MR images are available
  - Non-rigid thin-plate spline warping

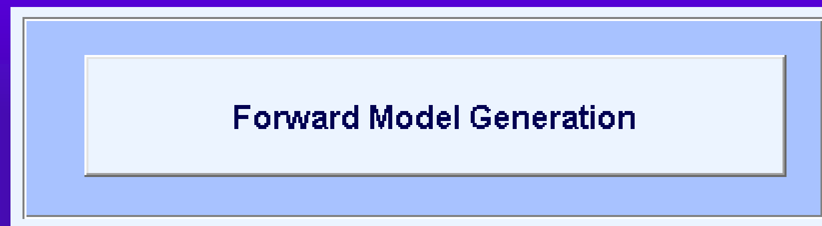
Template Warping

From electrode Position Data

Template Warping

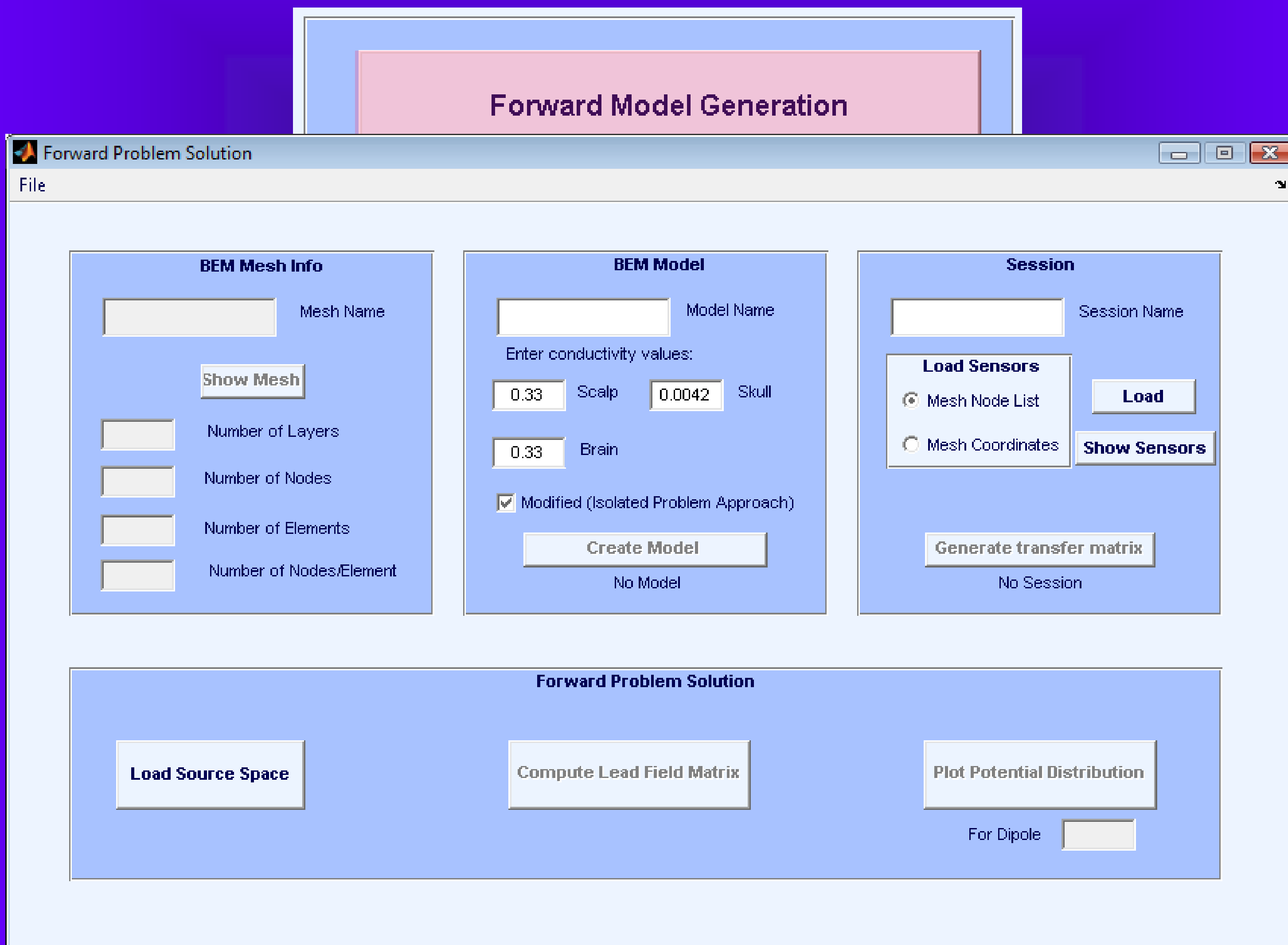


Forward Model Generation

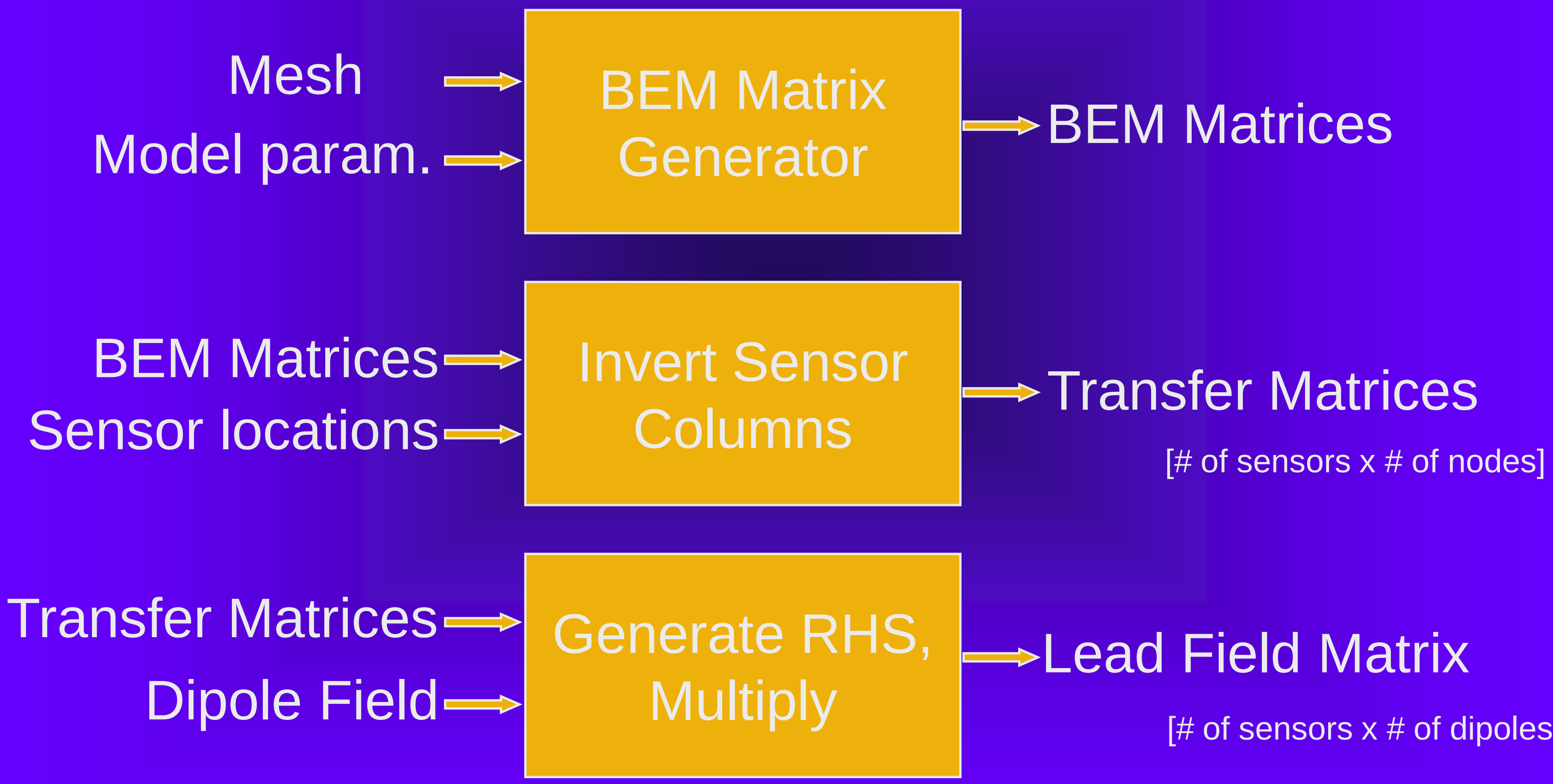


- Generates the Forward Model from Meshes
  - Uses the Boundary Element Method
- Three Structures
  - Mesh
  - Model (Mesh + Electrical Properties)
  - Session (Model + Sensors)

Forward Problem Solution



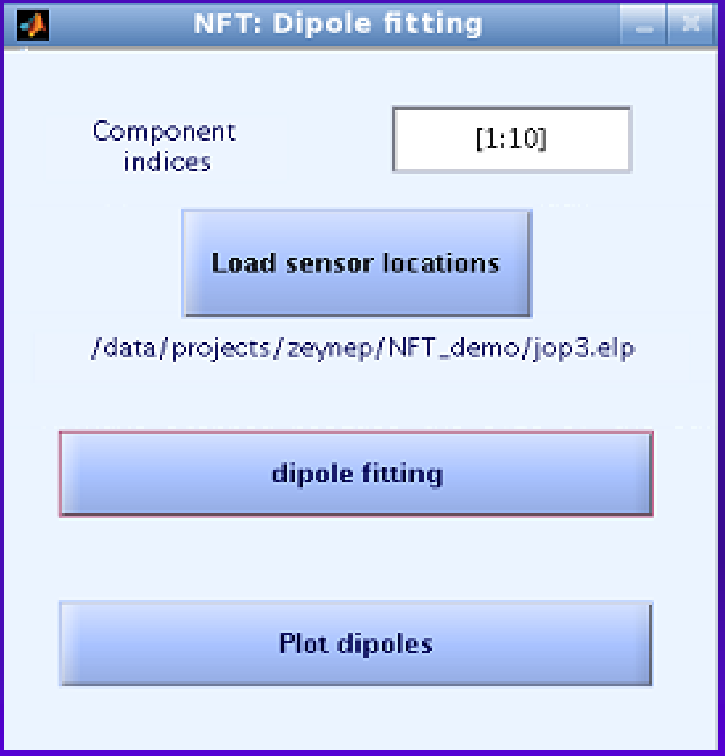
Forward Problem Solution



Forward Problem Solver

- MATLAB interface to numerical solvers
- Boundary Element Method
  - EEG Only (for now)
  - Supports IPA and Accelerated BEM
  - Interfaces to the Matrix generator executable written in C++
- Other computation done in MATLAB
- Generated matrices are stored on disk for future use.
- Other solvers under construction
  - Finite Element Method (FEM)
  - Analytic

Solution of inverse problem



Results on Mesh Complexity

Mesh Name	Layers	Nodes	Elements	LMR Ratio
Mesh 3	3	10337	20678	None
Mesh 3_1	3	12057	24118	2
Mesh 3_2	3	14769	29542	1.5
Mesh 4	4	13775	27550	None
Mesh 4_1	4	18499	36998	2
Mesh 4_2	4	20789	41578	1.6

Mesh Name	Emean	Emin	Emax
Mesh 3	17.1	7.11	23.67
Mesh 3_1	16.12	3.91	26.23
Mesh 3_2	16.9	4.07	29.31
Mesh 4	5.58	2.61	9.06
Mesh 4_1	0.86	0.23	1.8
Mesh 4_2	0	0	0

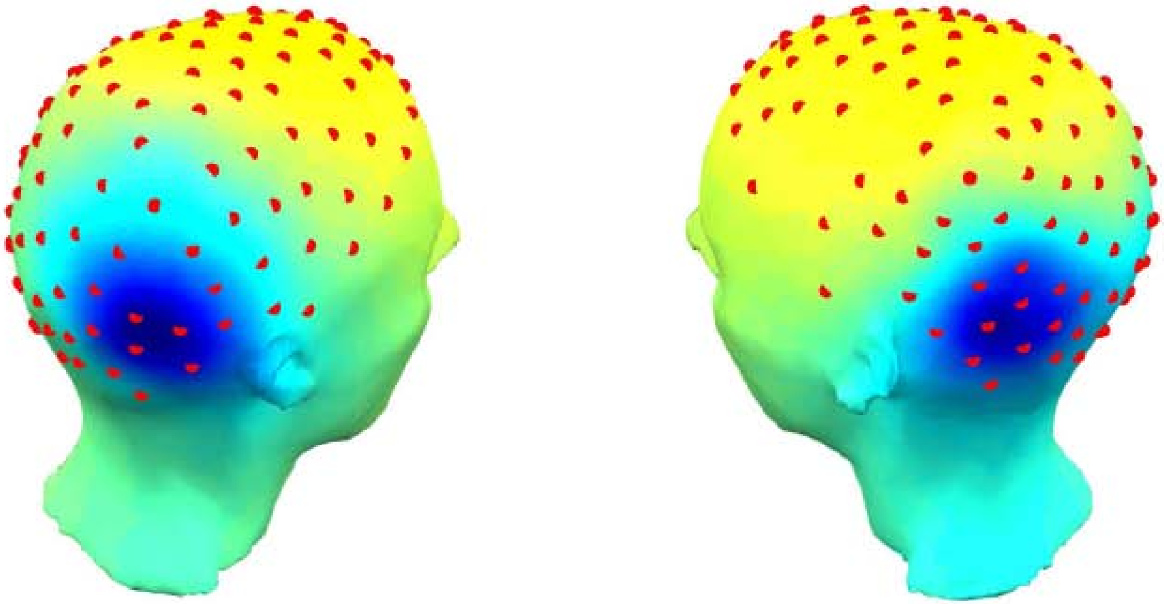
Localization error (mm)

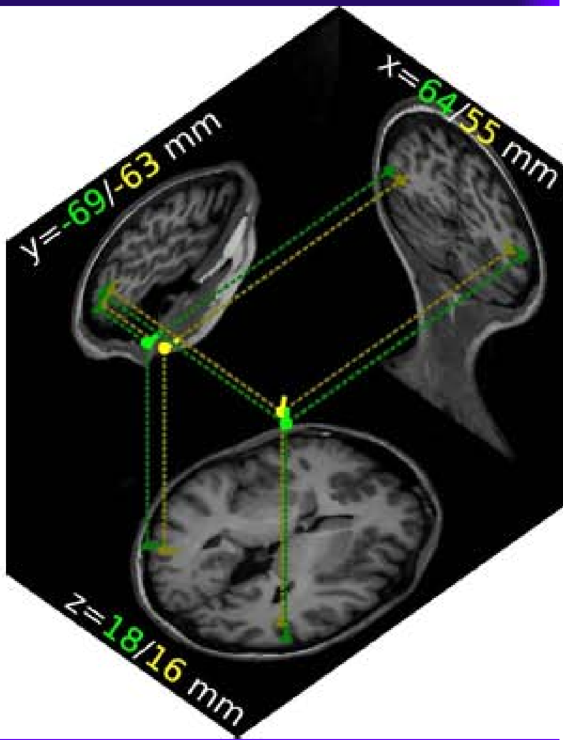
Compared with Mesh 4_2

Source localization comparisons

- MNI head model
- Warped MNI head model
- 4-layer MR-based realistic head model
- 3-layer MR-based realistic head model

3- and 4-layer MR-based realistic head model

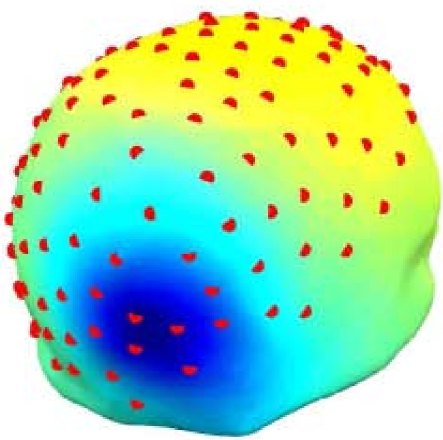


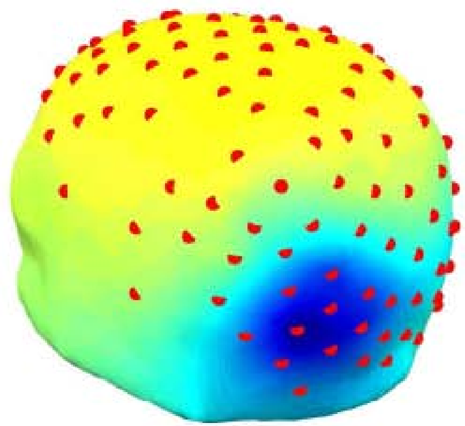


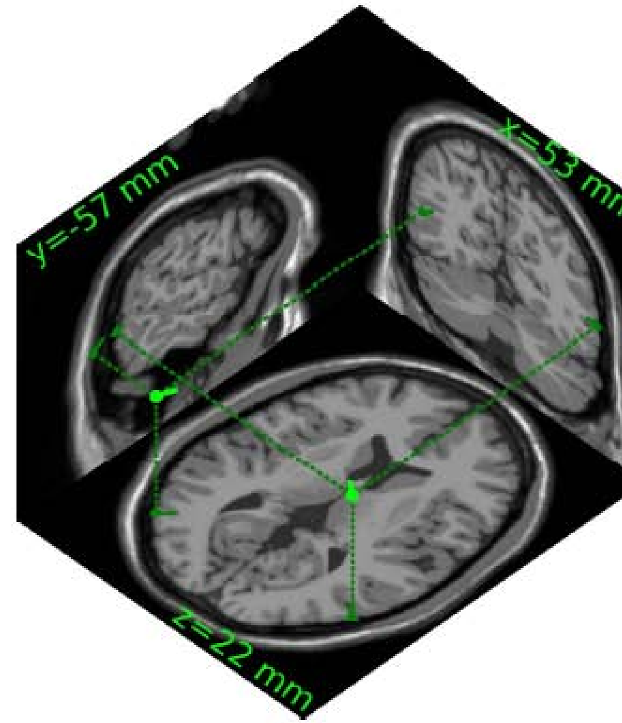
Scalp maps of 2 components

Sources of 2 components
green dipoles - 4-layer
yellow dipoles - 3-layer

Warped MNI head model



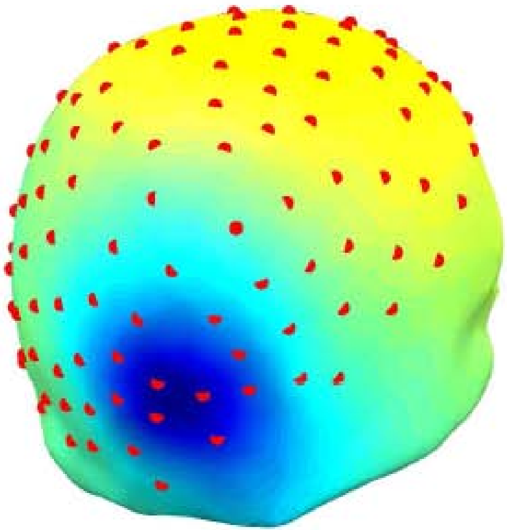


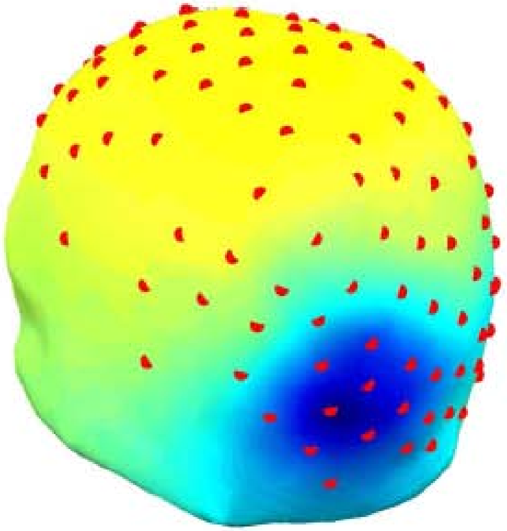


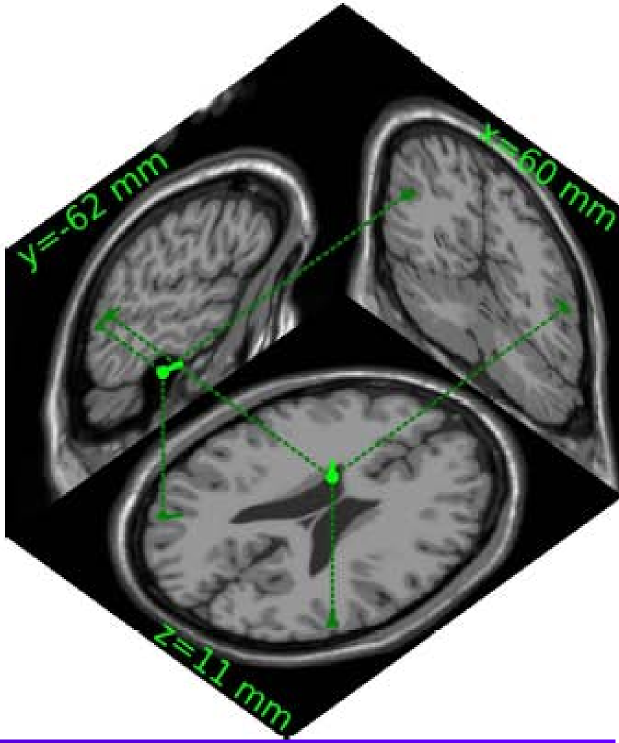
Scalp maps of 2 components

Sources of 2 components

MNI head model







Scalp maps of 2 components Sources of 2 components

Future Functions

- Magnetic field calculations.
- Analytical solutions for spherical models.
- Use of T2-weighted and PD images in segmentation => better CSF segmentation.
- 4-layer template head model.
- Finite Element Method.

NFT Download

www.sccn.ucsd.edu/nft

NFT Paper

Contents lists available at ScienceDirect

Journal of Neuroscience Methods

journal homepage: www.elsevier.com/locate/jneumeth

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JOURNAL OF NEUROSCIENCE METHODS

Neuroelectromagnetic Forward Head Modeling Toolbox☆

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A R T I C L E I N F O

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A B S T R A C T

This paper introduces a Neuroelectromagnetic Forward Head Modeling Toolbox (NFT) running under MATLAB (The Mathworks, Inc.) for generating realistic head models from available data (MRI and/or electrode locations) and for computing numerical solutions for the forward problem of electromagnetic source imaging. The NFT includes tools for segmenting scalp, skull, cerebrospinal fluid (CSF) and brain tissues from T1-weighted magnetic resonance (MR) images. The Boundary Element Method (BEM) is used for the numerical solution of the forward problem. After extracting segmented tissue volumes, surface

Estimated time to calculate results for each step...

1) Image Segmentation takes totally ~25 minutes.
The status of segmentation is written just below the 'prev run next' buttons.
It says 'segmenting scalp...', 'scalp segmented', etc.

2) Mesh Generation takes ~25 min
There are some waitbars in mesh generation and if there are not,
the status is written on the GUI.

3) Source space generation takes 2-3 minutes,
There is a waitbar.

4) Automatic coregistration takes ~20 minutes.
There is no waitbar and no messages, so you have to be patient.

5) Warping takes a couple of minutes, there are waitbars for this

6) Forward model generation take ~5-6 hours depending on the mesh.
Status of bem matrix generation is written on the 'model' module of the GUI.
There is a waitbar in the transfer matrix generation, and the status of
LFM generation is written on the GUI.