

- NFT -

Neuroelectromagnetic
Forward Head Modeling Toolbox

Zeynep Akalin Acar

May 25, 2010

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

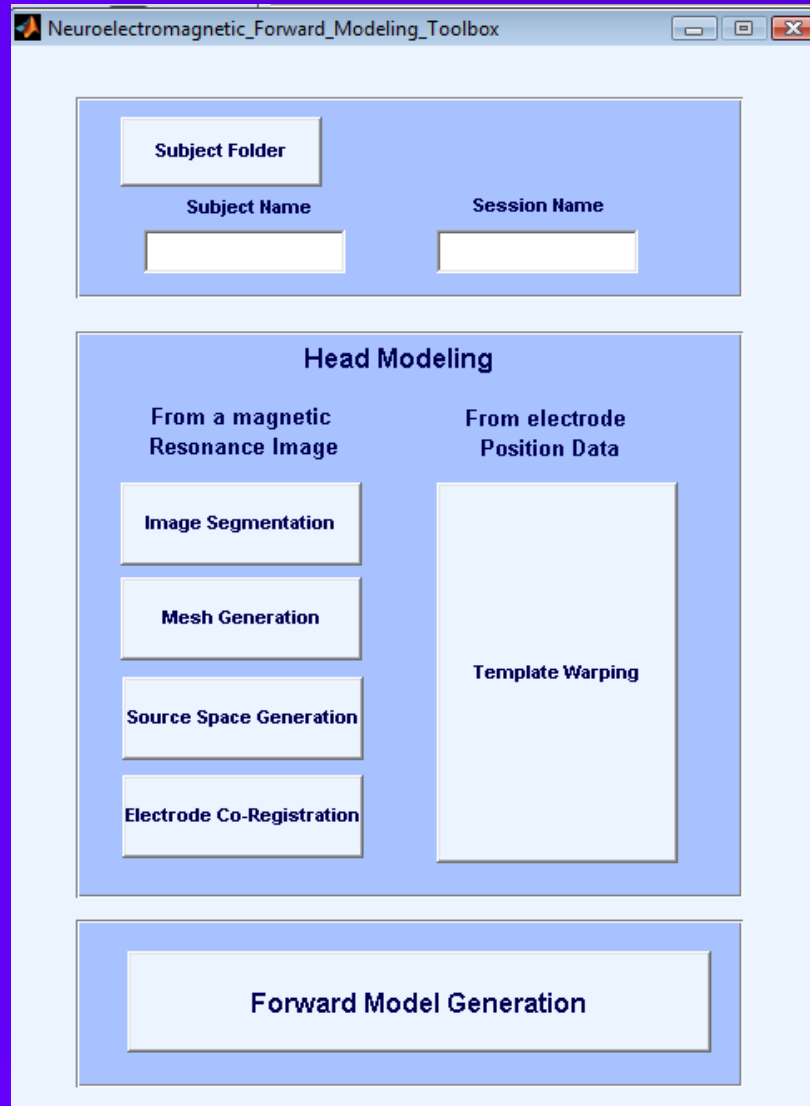
◆ T1 MR Images

- 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

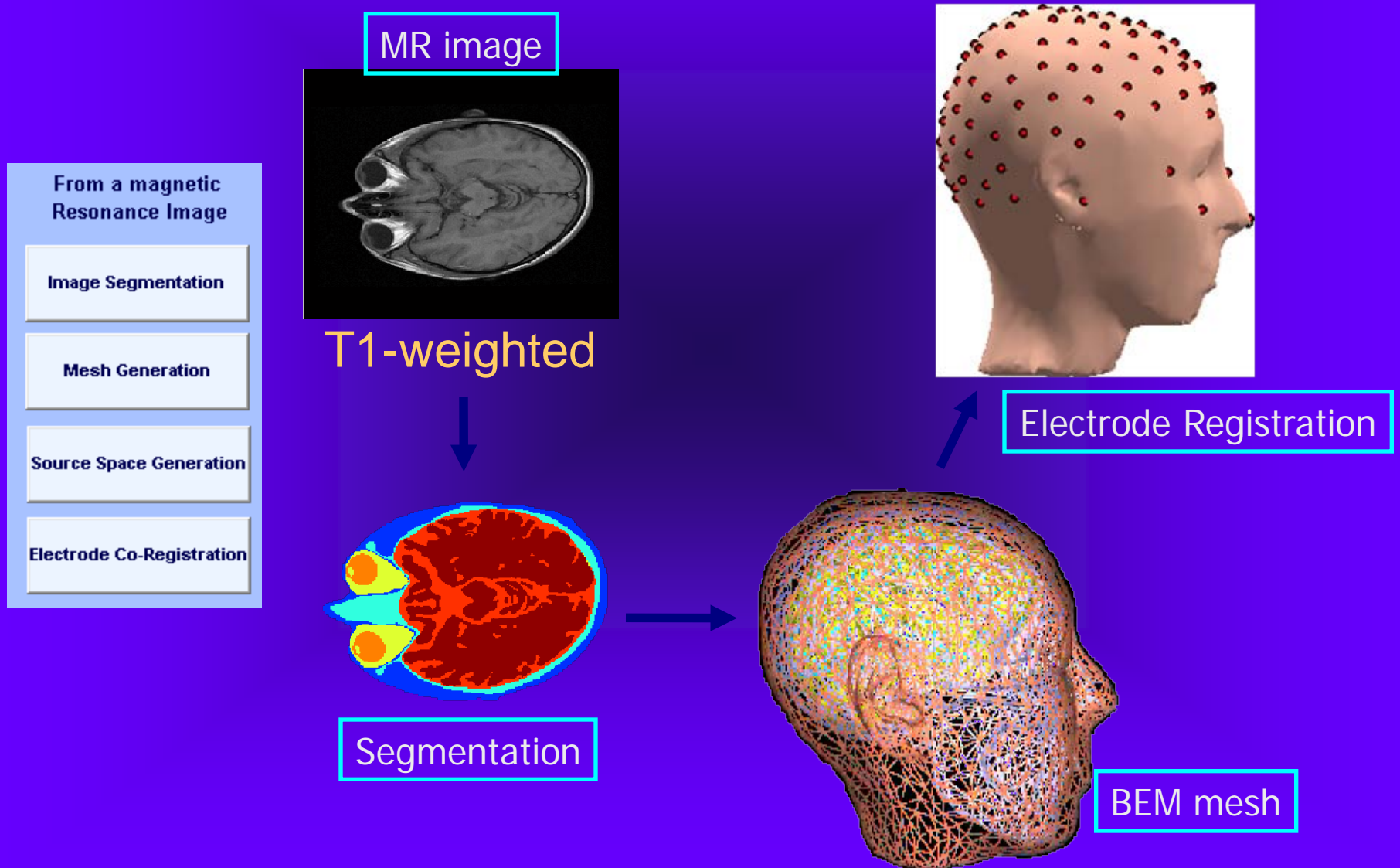
Subject Selection



A screenshot of a software interface for subject selection. The interface is contained within a light blue rectangular box with a thin white border. At the top left, there is a white rectangular button labeled "Subject Folder". Below this button, the text "Subject Name" is centered above a white rectangular input field. To the right of the "Subject Name" field, the text "Session Name" is centered above another white rectangular input field.

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

Head Modeling from MR Images



Preparing MR image for segmentation

Using FREESURFER:

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

Image Segmentation

Head Modeling Toolbox: Segmentation

File

From a magnetic Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registration

Coronal view

Axial view

Sagittal view

Display Image

- MR image
- Filtered image
- Scalp mask
- Brain mask
- Outer skull mask
- Inner skull mask

Save Results

Output Folder: C:\Users\Zeynep\Documents\Post-doc\Toolbox\Subject_Zeynep

Filtered Image Segmentation

Image Segmentation

1. Anisotropic Filtering

5 Number of iterations

3 Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

66 Set + Lowest point of the cerebellum

White matter seed point

x y z

135 135 110 Set +

0.4 Fill level [0, 1] 0.4 Threshold [0, 1]

4. Outer Skull Segmentation

z

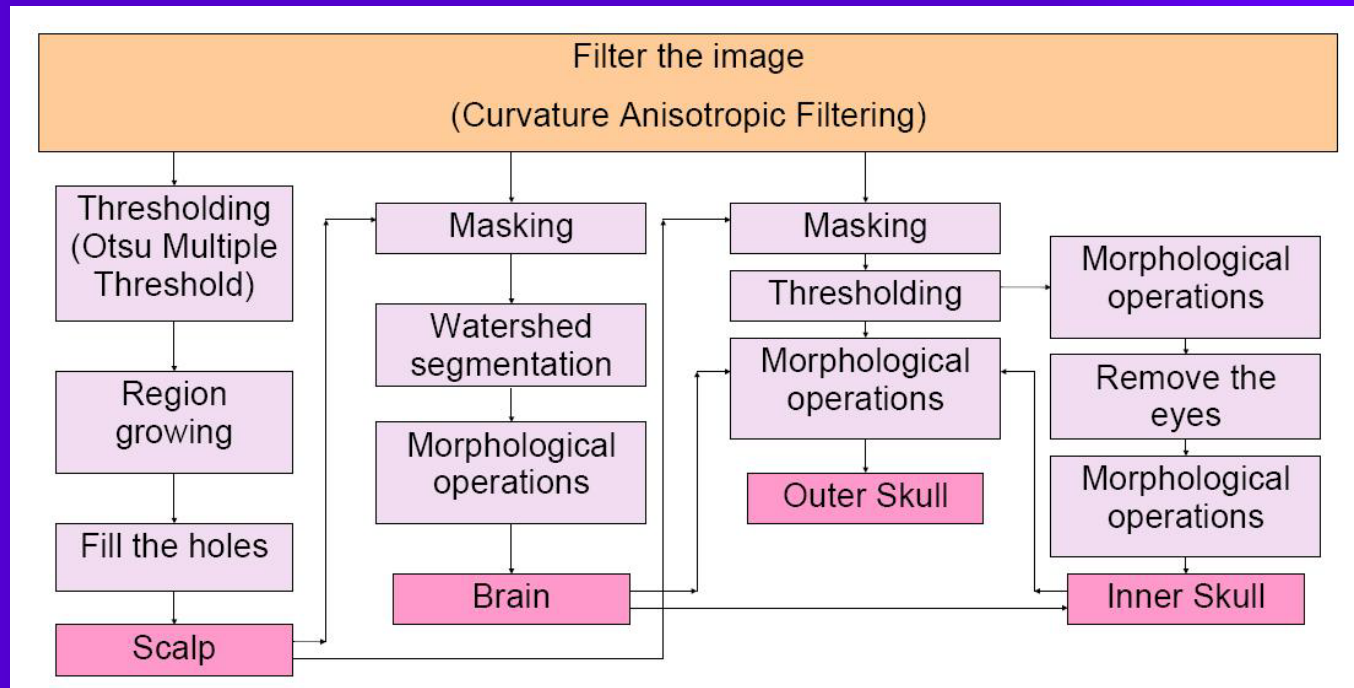
110 Set + Central eye location

5. Inner Skull Segmentation

< Prev Run Next >

◆ Interface for Segmentation of MR Images

Image Segmentation Flowchart



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

Mesh Generation

From a magnetic Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registration

The screenshot shows a software window titled "Head Modeling Toolbox: Mesh Generation". The interface includes several input fields and buttons:

- Load Segmentation:** A button with the file path `C:\Users\Zeynep\Documents\Post-doc\Toolbox\Subject_Zeynep\zeynep_segments` next to it.
- Output Folder:** A button with the file path `C:\Users\Zeynep\Documents\Post-doc\Toolbox\Subject_Zeynep` next to it.
- # of layers:** A text input field containing the value `4`.
- Mesh name:** A text input field containing the value `zeynep`.
- Local mesh refinement:** A checkbox that is currently unchecked.
- Edge length/Distance between meshes:** A text input field containing the value `2.0`.
- Start Mesh Generation:** A large button to initiate the process.
- Status:** A label at the bottom of the main panel.

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

Source Space Generation

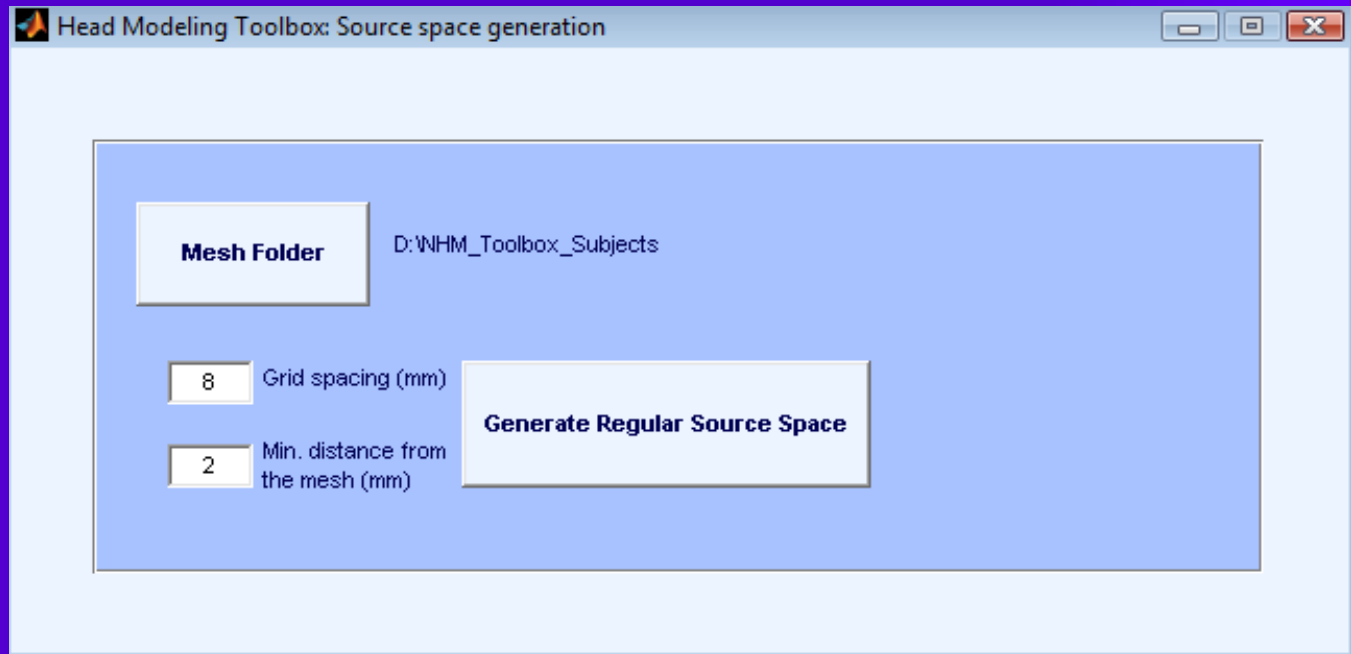
From a magnetic Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registration



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

Electrode Co-Registration

From a magnetic Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registration

Head Modeling Toolbox: Electrode Co-Registration

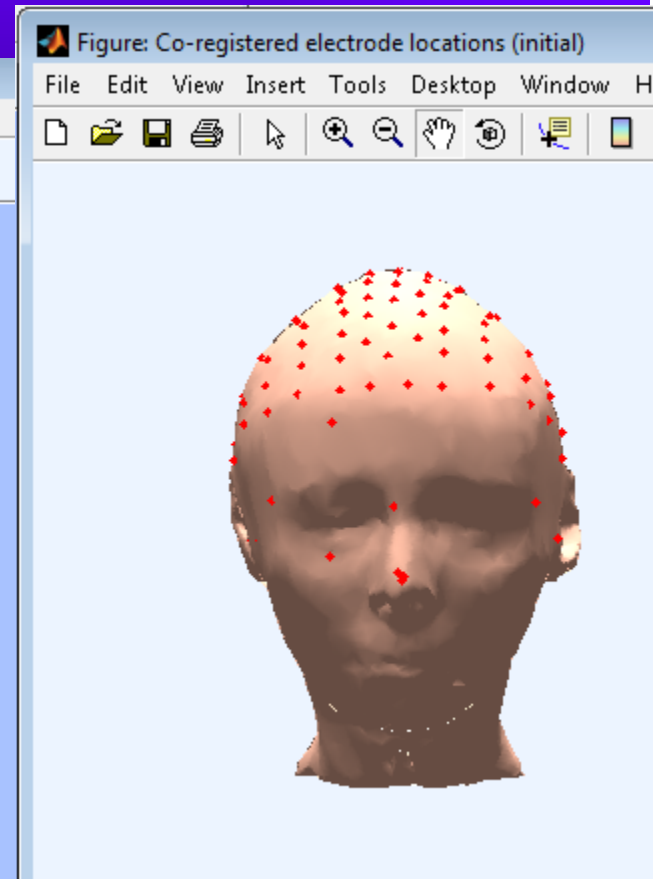
Load sensor locations Electrode file name

Mesh Folder D:\NHM_Toolbox_Subjects

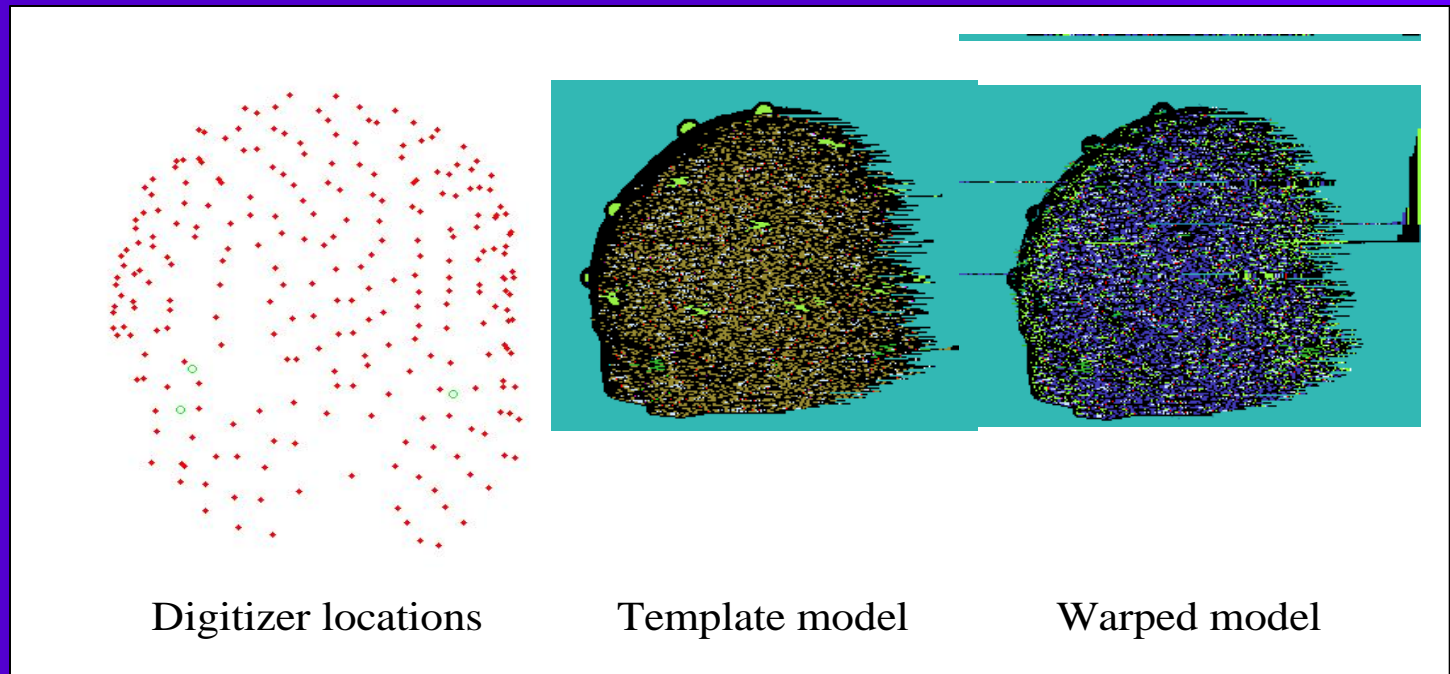
Initial co-registration Translation
Rotation

Complete co-registration Translation
Rotation

Save initial reg. Save complete reg.



Head Modeling from Electrode Position Data

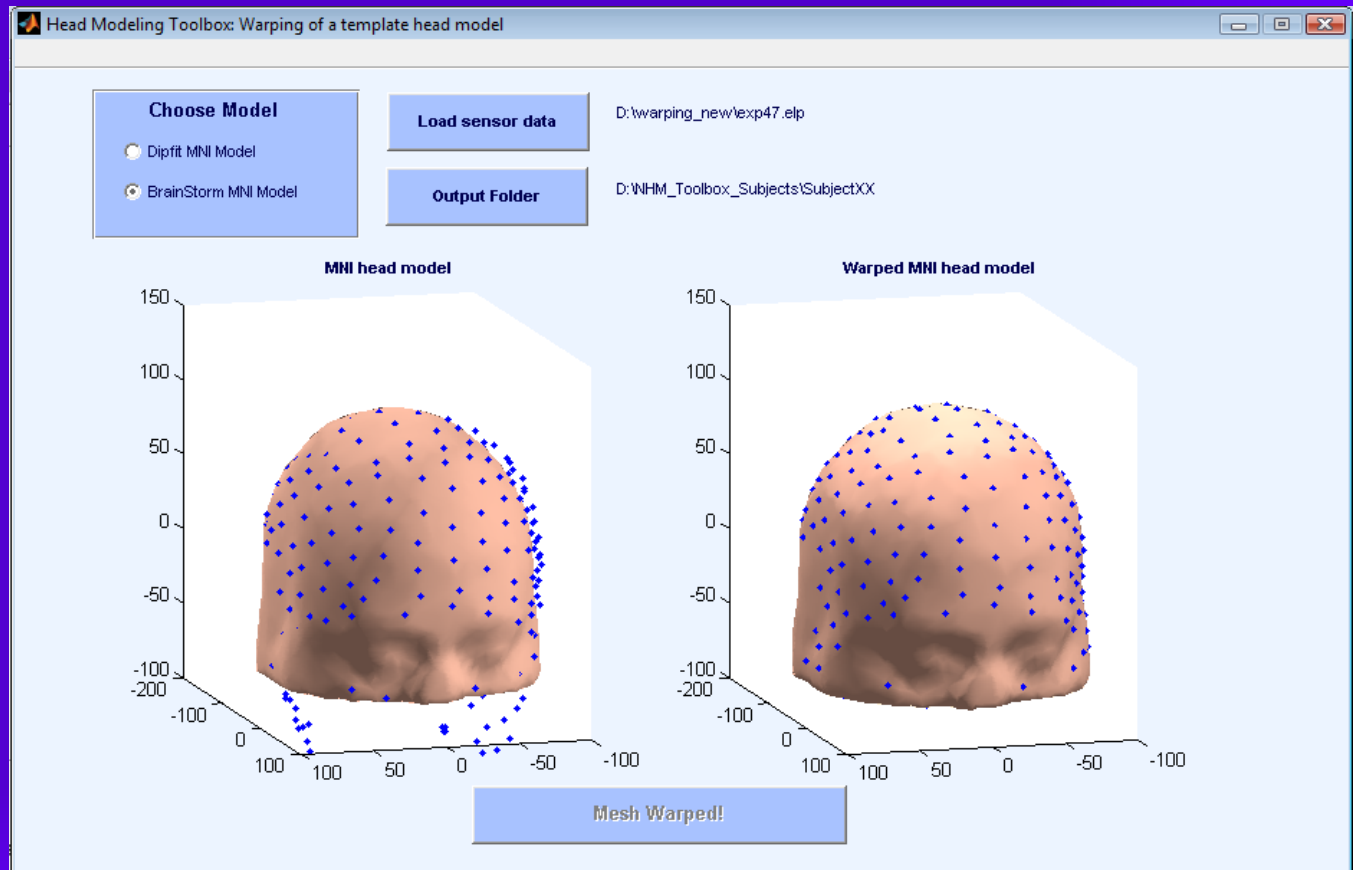


- ◆ Warp a template mesh to electrode positions
 - When no MR images are available
 - Non-rigid thin-plate spline warping

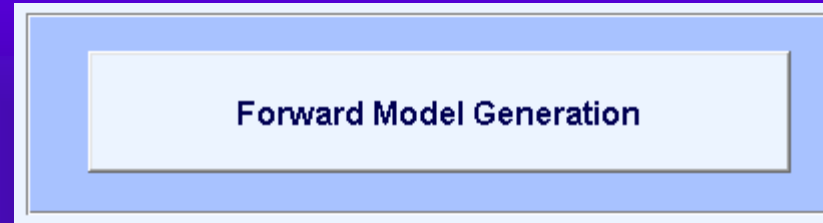
Template Warping

**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 Model Generation

Forward Problem Solution

File

BEM Mesh Info

Mesh Name

Number of Layers

Number of Nodes

Number of Elements

Number of Nodes/Element

BEM Model

Model Name

Enter conductivity values:

Scalp Skull

Brain

Modified (Isolated Problem Approach)

No Model

Session

Session Name

Load Sensors

Mesh Node List

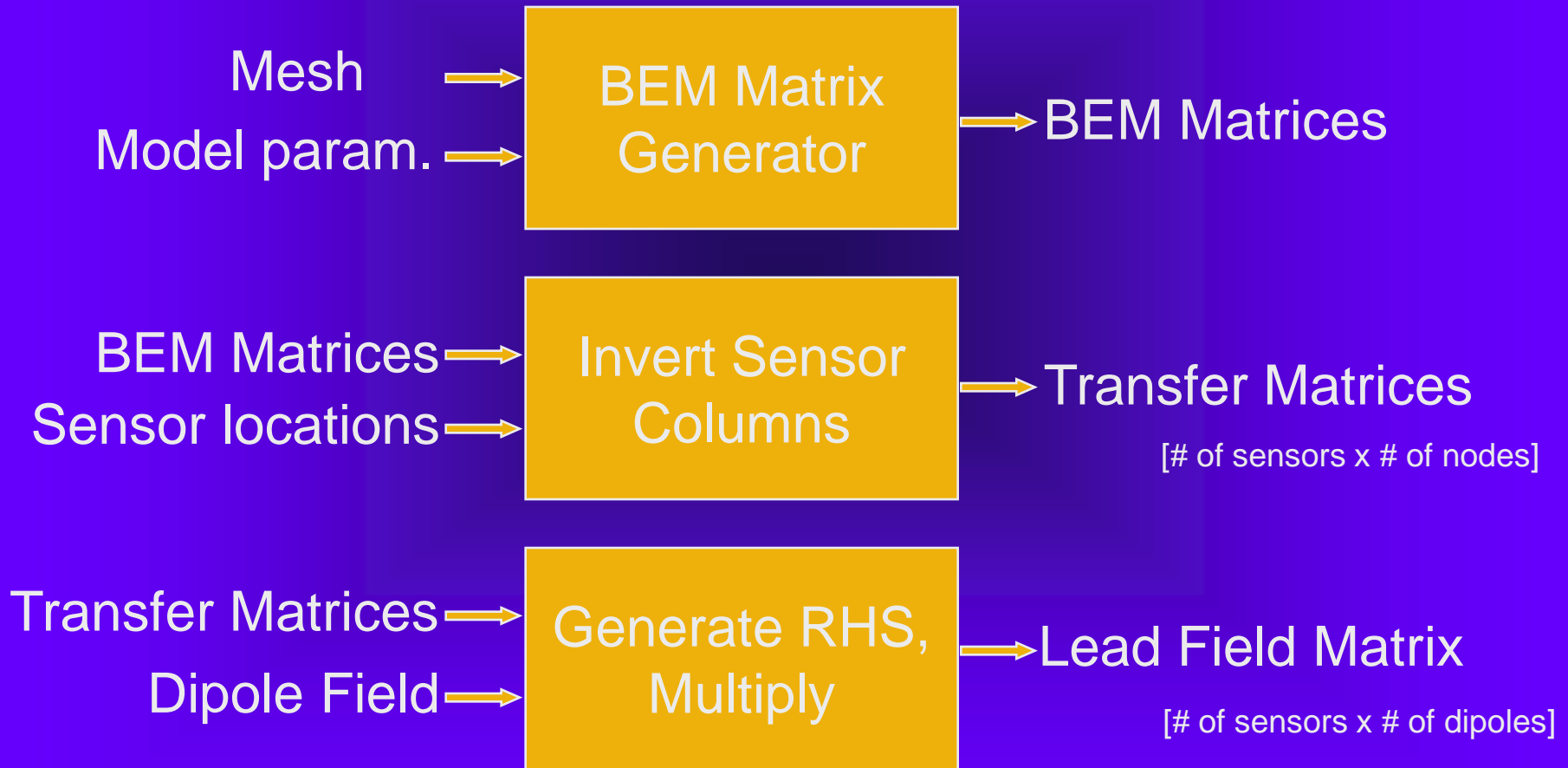
Mesh Coordinates

No Session

Forward Problem Solution

For Dipole

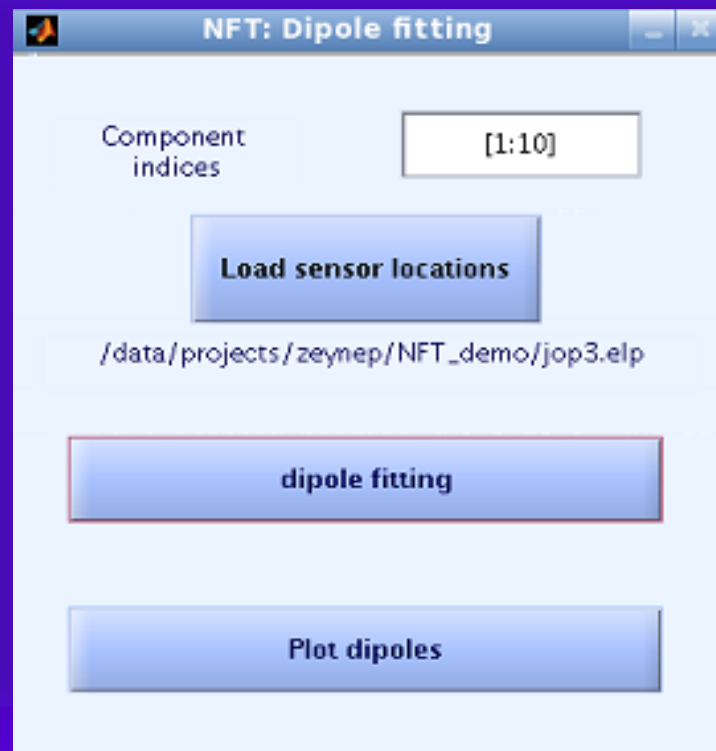
Forward Problem Solution



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	E _{mean}	E _{min}	E _{max}
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

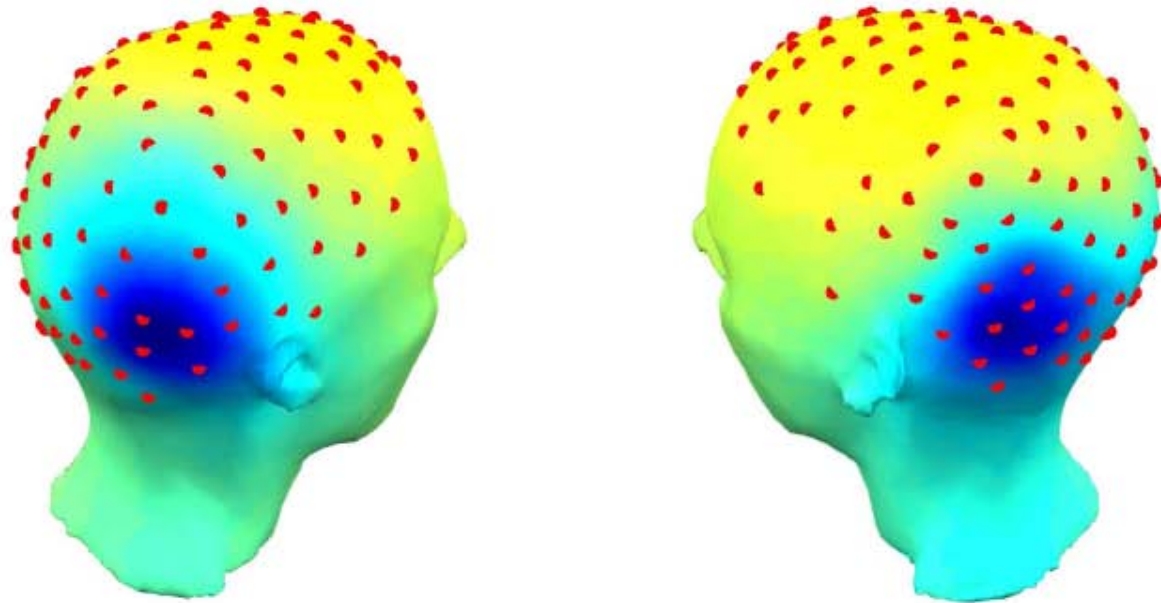
Localization
error (mm)

Compared
with Mesh 4_2

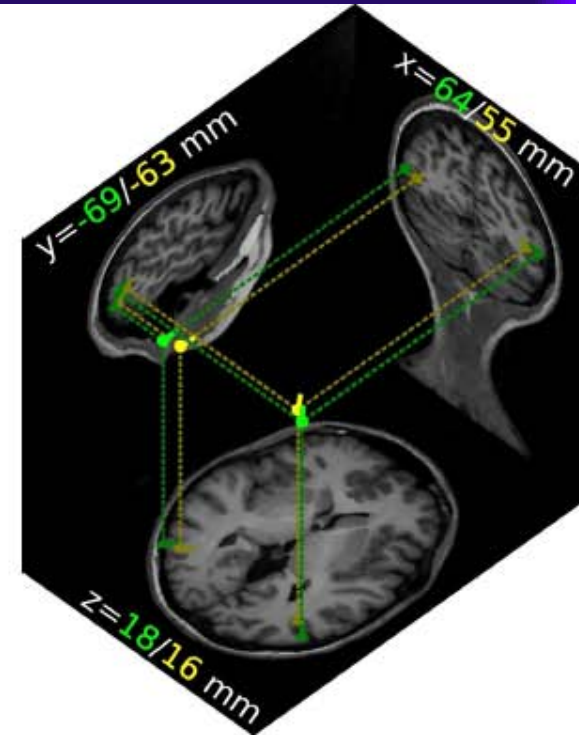
Source localization comparisons

- ◆ 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

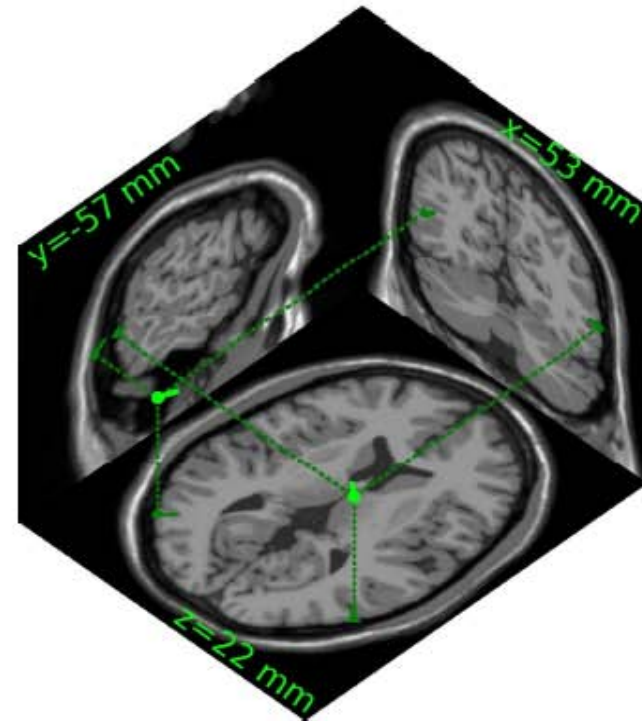
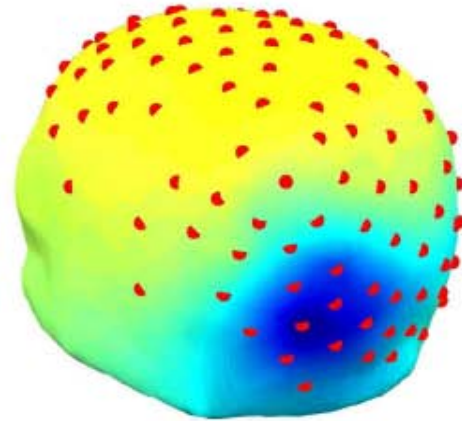
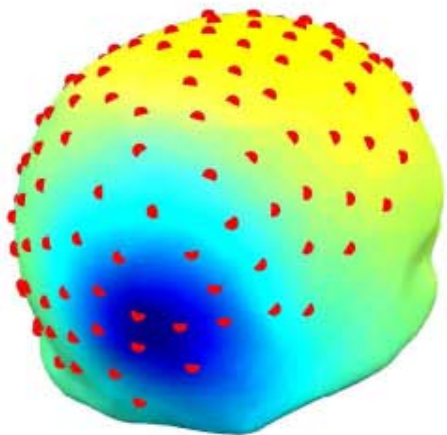


Scalp maps of 2 components



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

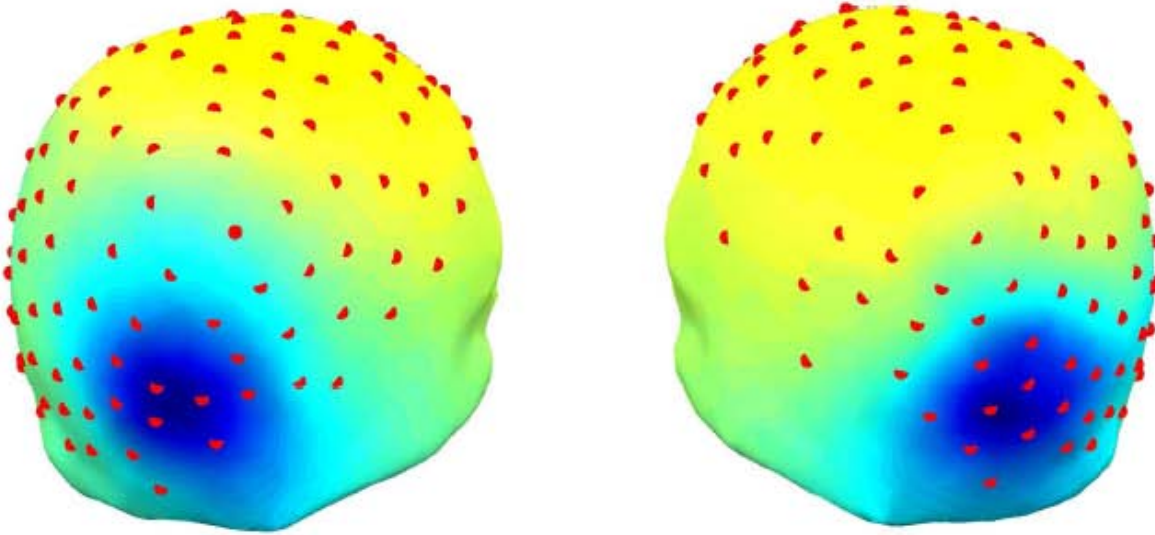
Warped MNI head model



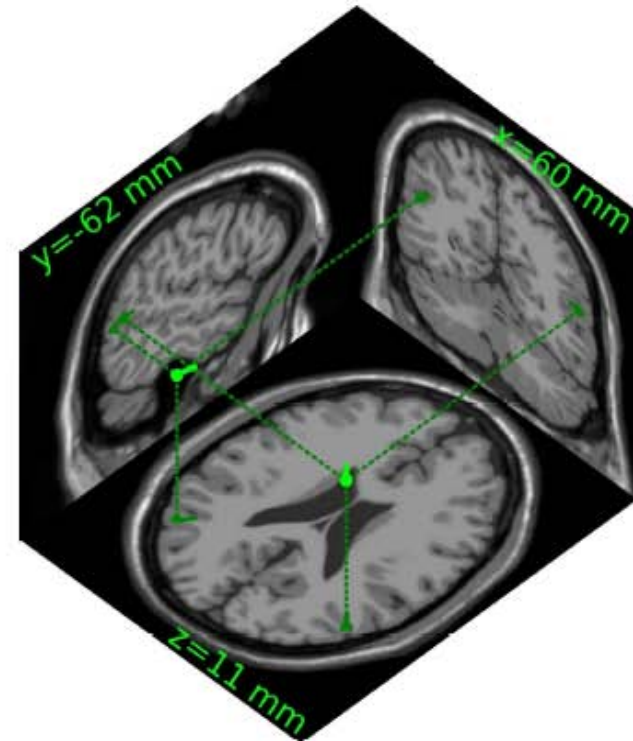
Scalp maps of 2 components

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

Neuroelectromagnetic Forward Head Modeling Toolbox[☆]

Zeynep Akalin Acar*, Scott Makeig

Swartz Center for Computational Neuroscience, Institute for Neural Computation, University of California San Diego 0961, La Jolla, CA 92093-0961, United States

ARTICLE INFO	ABSTRACT
<p><i>Article history:</i> Received 10 September 2009 Received in revised form 28 April 2010 Accepted 29 April 2010</p> <hr/> <p><i>Keyword:</i></p>	<p>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</p>

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.