

NFT

Neuroelectromagnetic Forward Head Modeling Toolbox

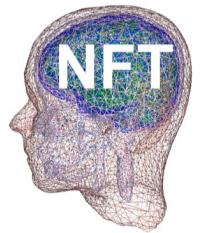
Zeynep AKALIN ACAR

14th EEGLAB Workshop, Mallorca

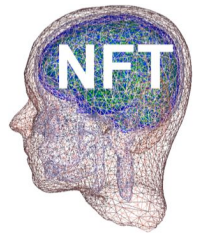
September, 2011



NFT

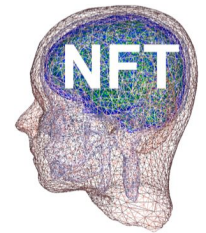


- ◆ A complete framework for accurate forward problem solution.
- ◆ Easy-to-use MATLAB environment with GUI and command-line functions.
- ◆ Ability to use available subject information
 - T1-weighted 3D MR images
 - Digitized sensor (electrode) locations



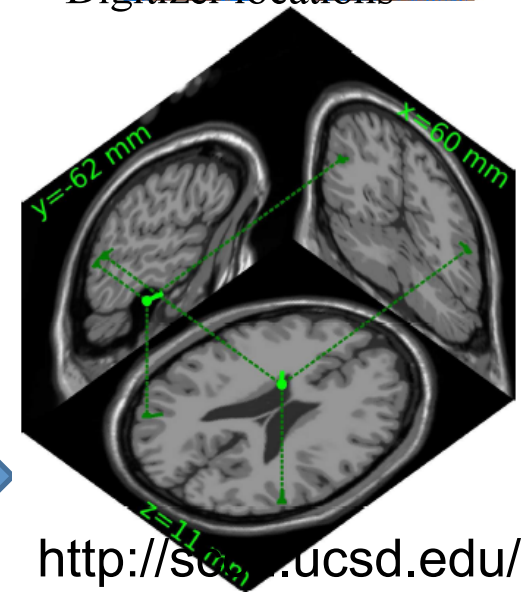
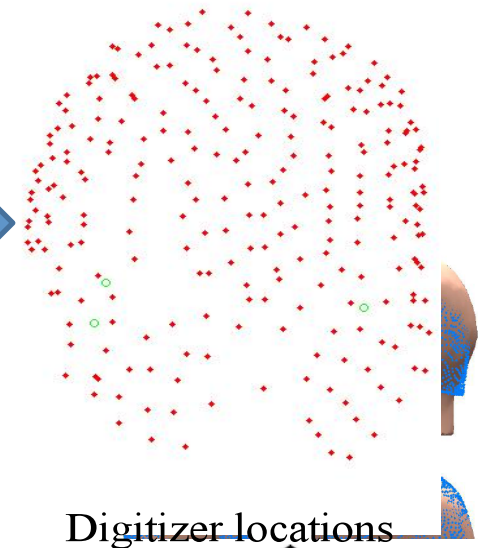
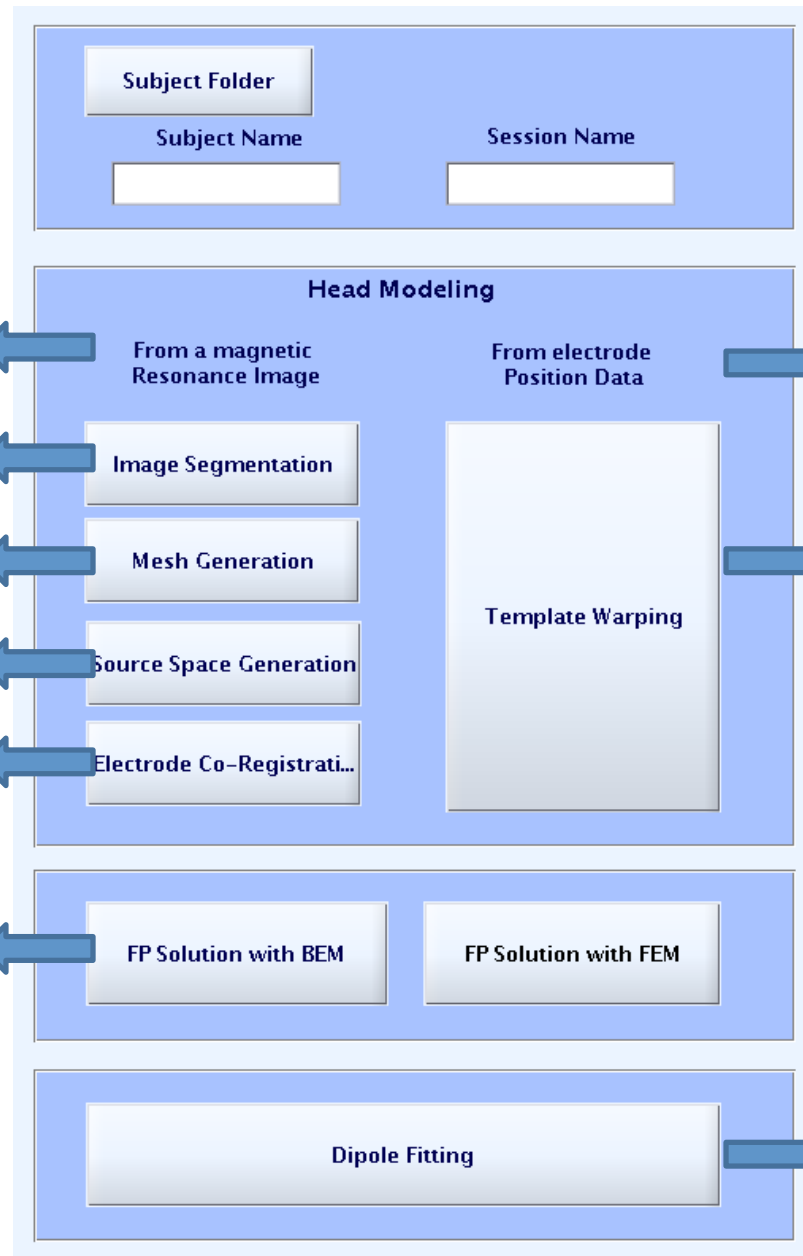
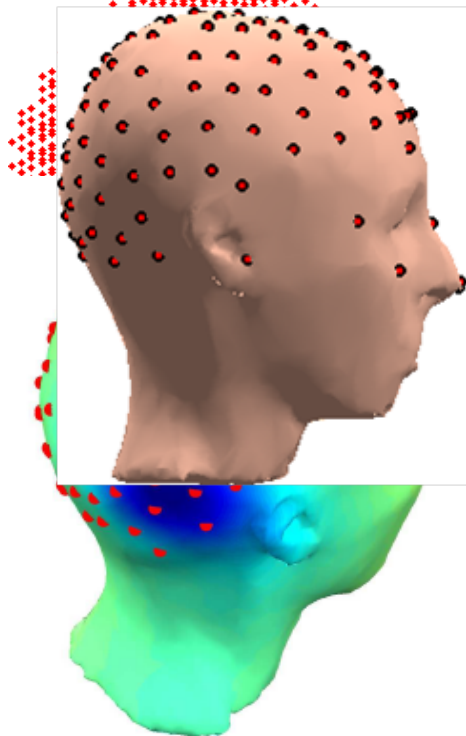
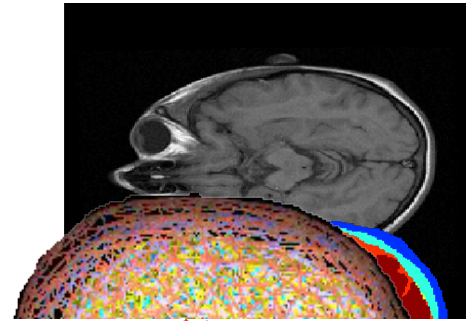
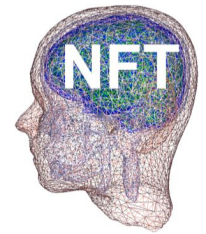
Comparison with Dipfit

- ◆ The realistic model in Dipfit is a three-layer MNI head model represented with 3000 vertices.
 - The forward matrices are pre-calculated, so there is no need for FP calculations.
- ◆ NFT generates subject-specific models.
 - NFT does model generation and forward problem calculations.
 - More accurate.



Starting NFT

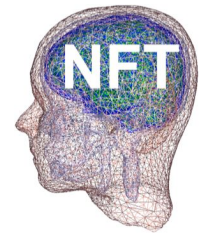
- ◆ To start from EEGLAB
EEGLAB -> Tools -> NFT
- ◆ To start as a standalone toolbox
addpath NFT directory
Type 'NFT' in Matlab



Subject Selection

Subject Folder	
Subject Name	Session Name
<input type="text"/>	<input type="text"/>

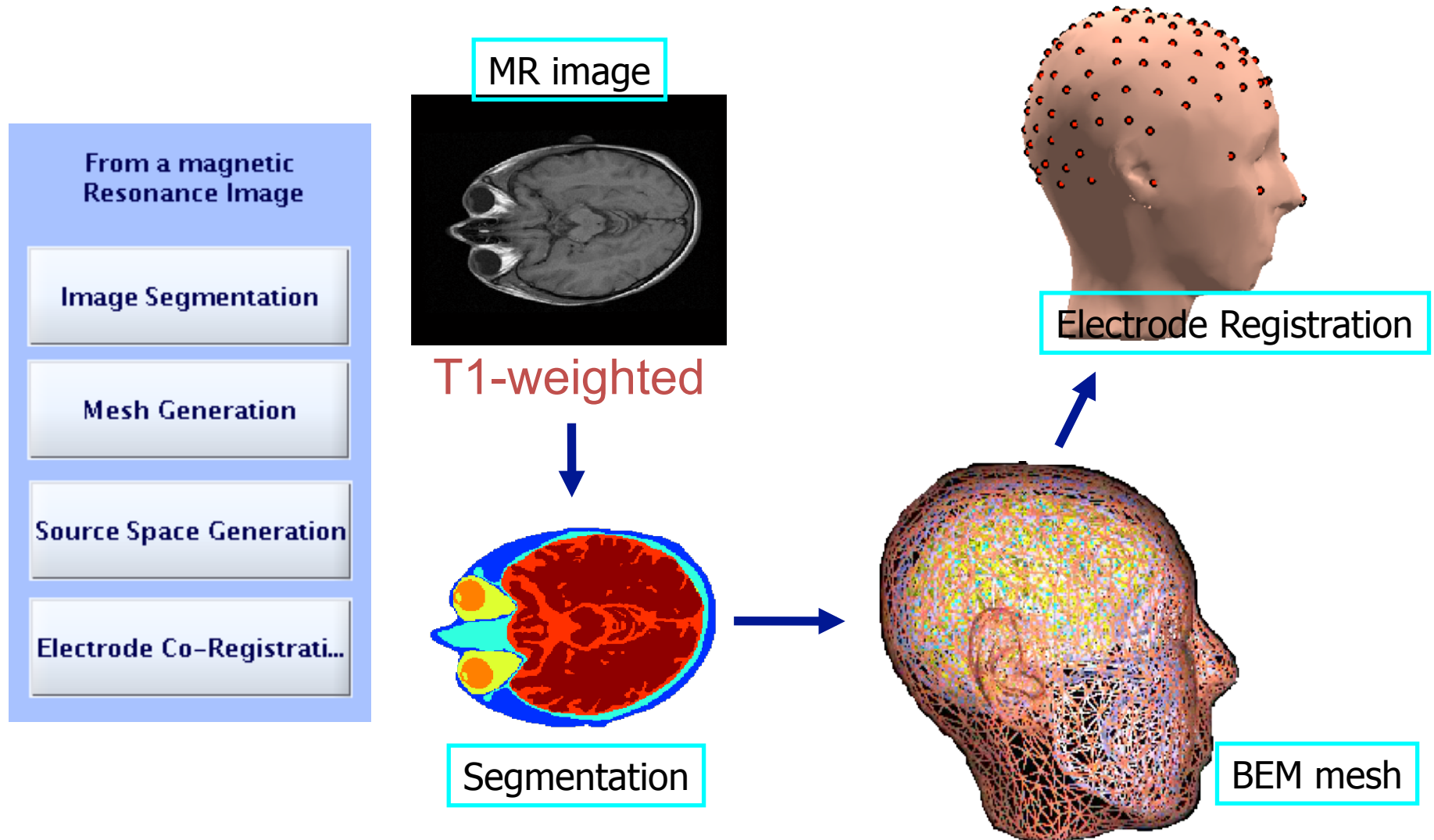
- ◆ Select subject folder
- ◆ Specify subject name
- ◆ Specify session name

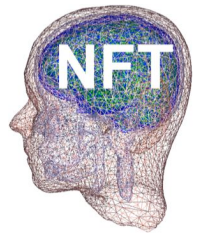


Subject Selection

Subject Folder	/data/projects/zeynep/common/home_zeynep/jo/deneme/dene_real	
Subject Name	Session Name	
SubjectA	sesNov20_10	

Head modeling from MR images

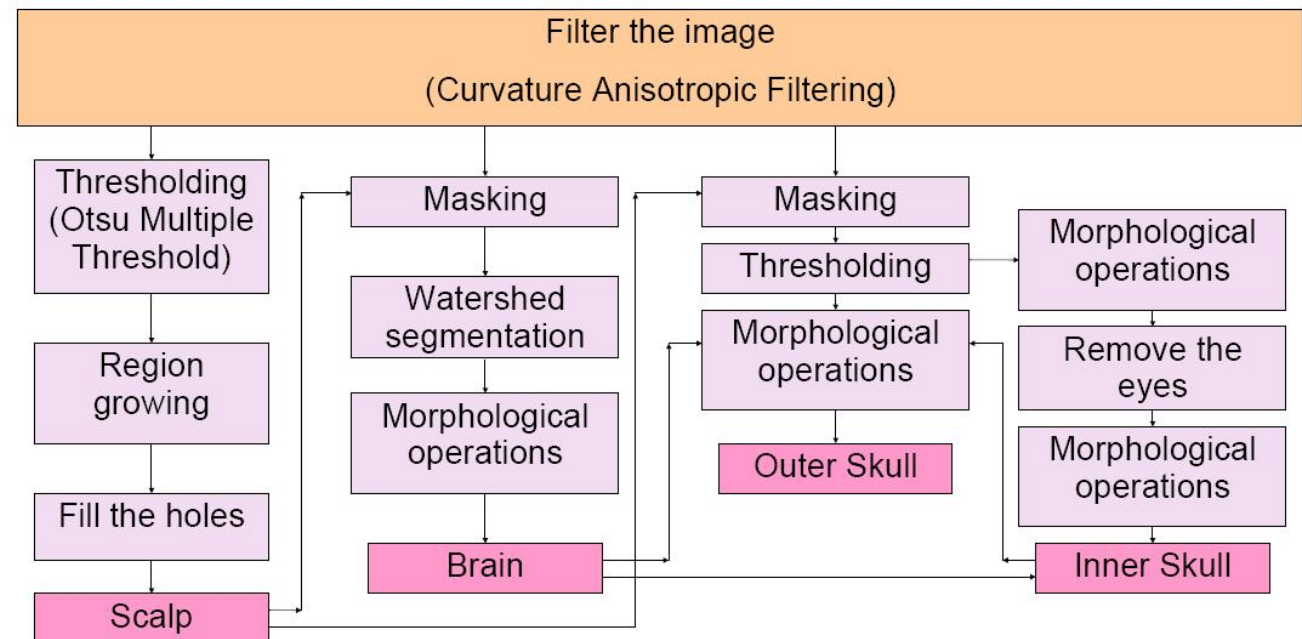
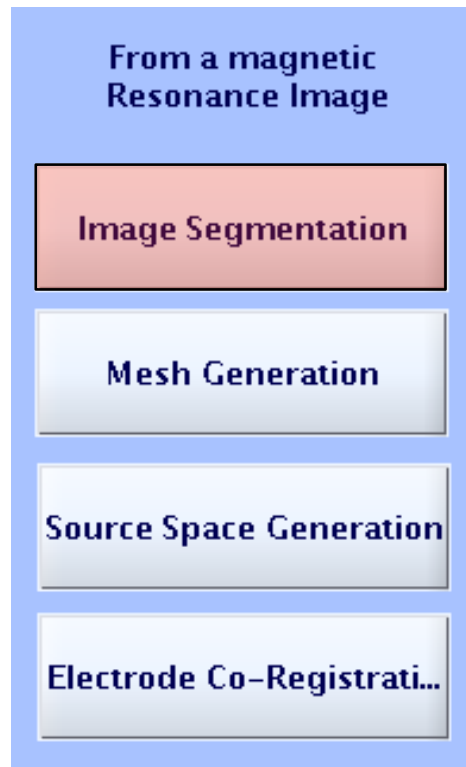




Preparing the MR Image

- ◆ Using FreeSurfer
 - Inhomogeneity correction
 - Convert to 1x1x1 volume
 - Arrange direction of the image
 - Save in analyze format

Image Segmentation



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

Image Segmentation

NFT: MR segmentation

File

(x,y,z)=

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: /data/projects/zeynep/comm on/home zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x White matter seed point

y White matter seed point

z Center of one eye

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Image Segmentation

Load image

NFT: MR segmentation

File

- Open ...
- Close

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: /data/projects/zeynep/comm on/home zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x White matter seed point

y White matter seed point

z White matter seed point

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Segmentation

Select an image in analyze format

The screenshot displays the 'NFT: MR segmentation' software interface. The main window features three viewports labeled '(x,y,z)=', 'Coronal view', and 'Sagittal view'. A 'Select File to Open' dialog box is centered, showing a file list with 't3test001.hdr' selected. The right panel, titled 'Image Segmentation', contains the following settings:

- Swap L/R
- 1. Anisotropic Filtering**
 - Number of iterations: 5
 - Image diffusion: 3
- 2. Scalp Segmentation**
- 3. Brain Segmentation**
 - Cerebellar low point: 66
 - x: 135
 - y: 135 White matter seed point
 - z: 110
 - Fill level: 0.4 [0, 1] Threshold: 0.4 [0, 1]
- 4. Outer Skull Segmentation**
 - z: 110 Center of one eye
- 5. Inner Skull Segmentation**

At the bottom, the 'Save Results' section shows:

- Output Folder: /data/projects/zeynep/comm on/home zevneb/io/deneme
- Buttons: Filtered Image, Segmentation

Segmentation

Run filtering

NFT: MR segmentation

File

(x,y,z)= (128, 128, 128)

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 /data/projects/zeynep/comm
on/home zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

Swap L/R Check inhomogeneity

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Set Cerebellar low point

x

y Set White matter seed point

z

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

4. Outer Skull Segmentation

z Set Center of one eye

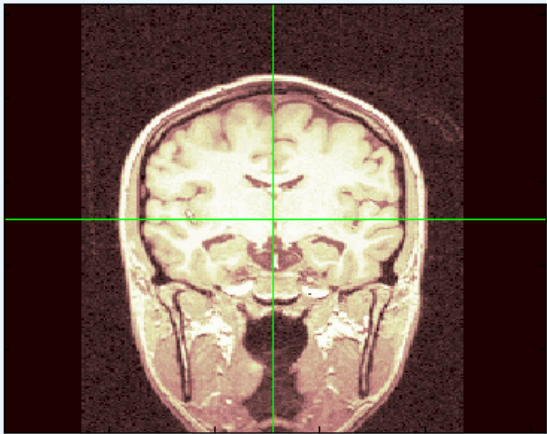
5. Inner Skull Segmentation

Segmentation

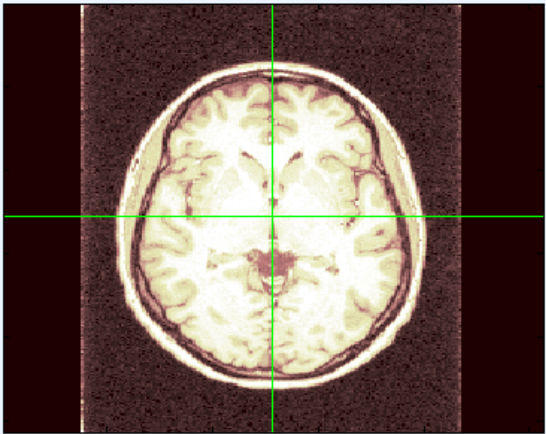
NFT: MR segmentation

File

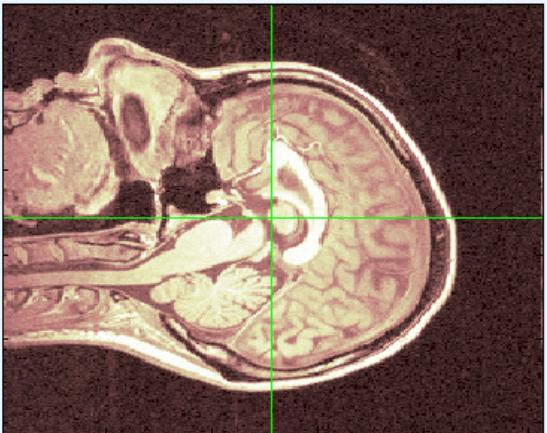
(x,y,z)= (128, 128, 128)



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 /data/projects/zeynep/comm on/home zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

Swap L/R Check inhomogeneity

1. Anisotropic Filtering

Number of iterations:

Image diffusion:

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point: Set

White matter seed point: Set

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

4. Outer Skull Segmentation

Center of one eye: Set

5. Inner Skull Segmentation

< Prev Run Next >

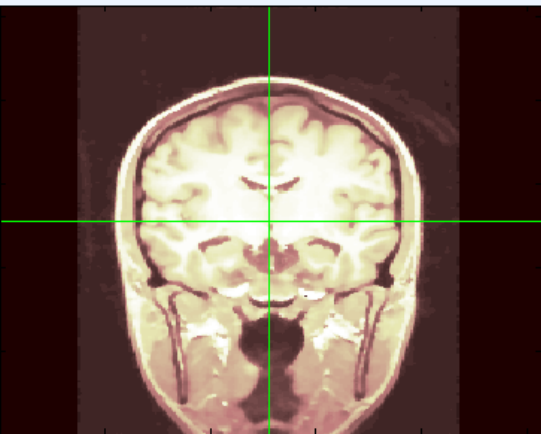
Image is filtered!

Segmentation

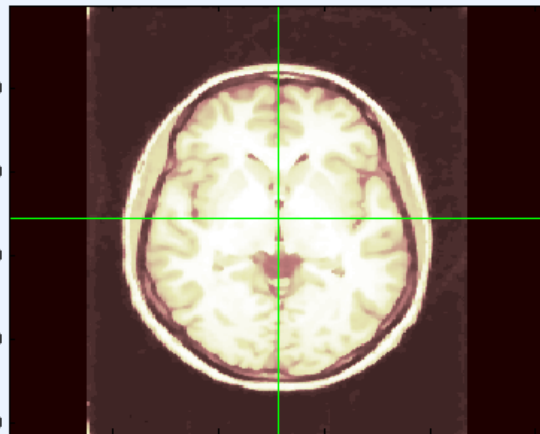
View filtered image

NFT: MR segmentation

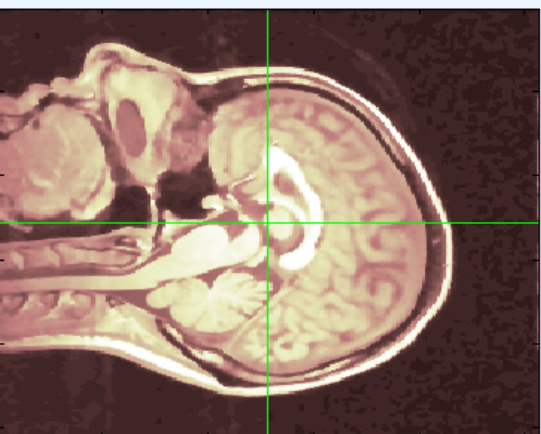
(x,y,z)= (128, 128, 128)



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 /data/projects/zeynep/comm
on/home_zevneb/io/deneme

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

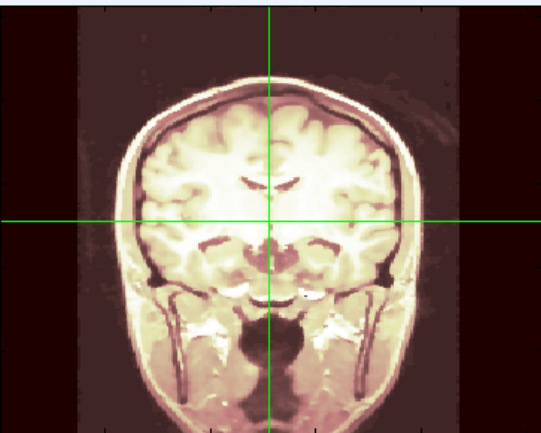
Image is filtered!

Segmentation

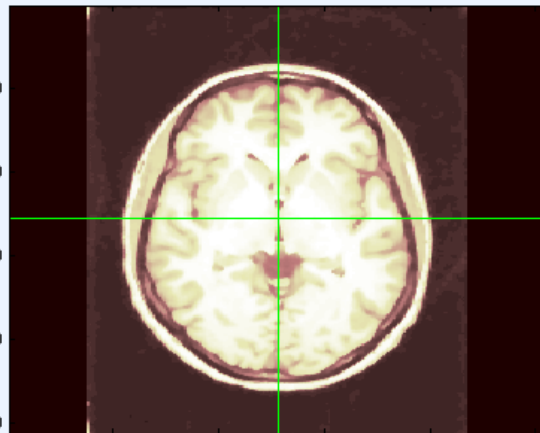
Click 'Next' for scalp segmentation

NFT: MR segmentation

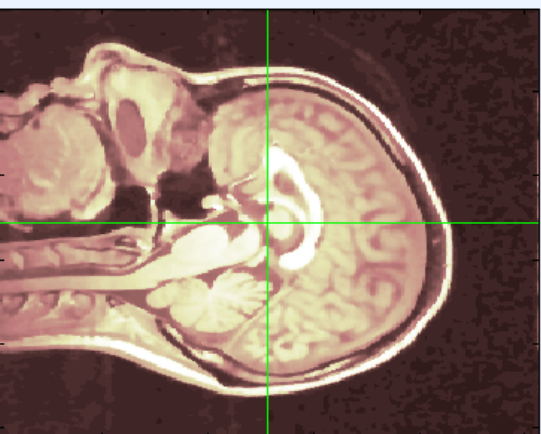
(x,y,z)= (128, 128, 128)



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

/data/projects/zeynep/comm
on/home_zevneb/io/deneme

Filtered Image

Segmentation

Image Segmentation

Swap L/R Check inhomogeneity

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Set Cerebellar low point

x

y Set White matter seed point

z

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

4. Outer Skull Segmentation

z Set Center of one eye

5. Inner Skull Segmentation

< Prev

Run

Next >

Image is filtered!

Segmentation

Click 'Run' for scalp segmentation

NFT: MR segmentation

(x,y,z)= (128, 128, 128)

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 /data/projects/zeynep/comm
on/home zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

Swap L/R Check inhomogeneity

1. Anisotropic Filtering

Number of iterations:

Image diffusion:

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point: Set

White matter seed point: Set

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

4. Outer Skull Segmentation

Center of one eye: Set

5. Inner Skull Segmentation

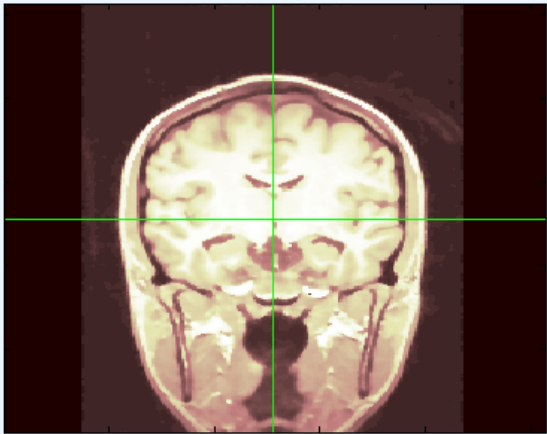
Segmenting scalp...

Image Segmentation

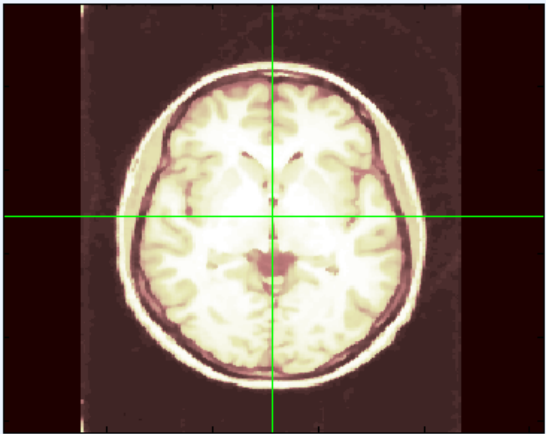
NFT: MR segmentation

File

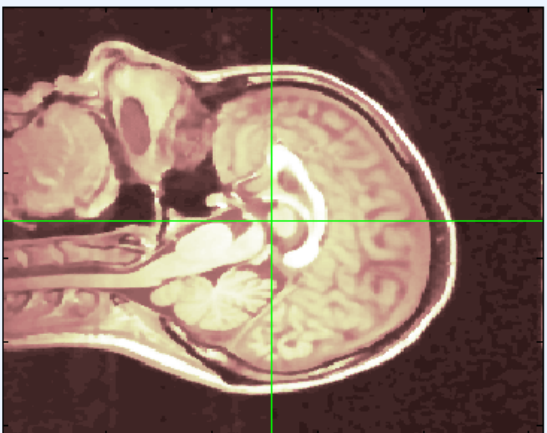
(x,y,z)= (128, 128, 128)



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 /data/projects/zeynep/comm
on/home zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

Swap L/R Check inhomogeneity

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

White matter seed point

Set

z

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

4. Outer Skull Segmentation

Center of one eye

z

Set

5. Inner Skull Segmentation

Scalp segmented!

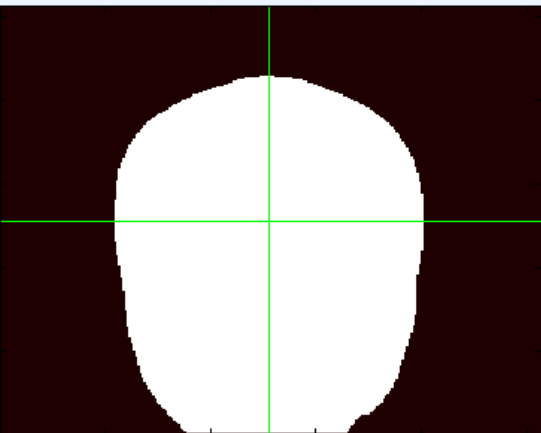
Segmentation

View scalp mask

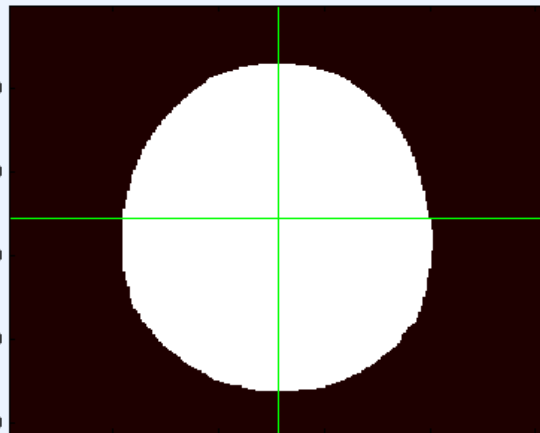
NFT: MR segmentation

File

(x,y,z)= (128, 128, 128)



Coronal view



Axial view

Display Image

MR image

Filtered image

Scalp mask

Brain mask

Outer skull mask

Inner skull mask

Save Results

Output Folder /data/projects/zeynep/comm
on/home_zevneb/io/deneme

Filtered Image Segmentation

Image Segmentation

Swap L/R Check inhomogeneity

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

White matter seed point

Set

z

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

4. Outer Skull Segmentation

Center of one eye

Set

5. Inner Skull Segmentation

Scalp segmented!

Segmentation

Click 'Next' for brain segmentation

NFT: MR segmentation

(x,y,z)= (128, 128, 128)

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: /data/projects/zeynep/comm on/home zevneb/io/deneme

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Scalp segmented!

Segmentation

Selection of cerebellar low point

NFT: MR segmentation

(x,y,z)= (128, 172, 67)

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Scalp segmented!

Display Image

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

Save Results

/data/projects/zeynep/comm on/home zevneb/io/deneme

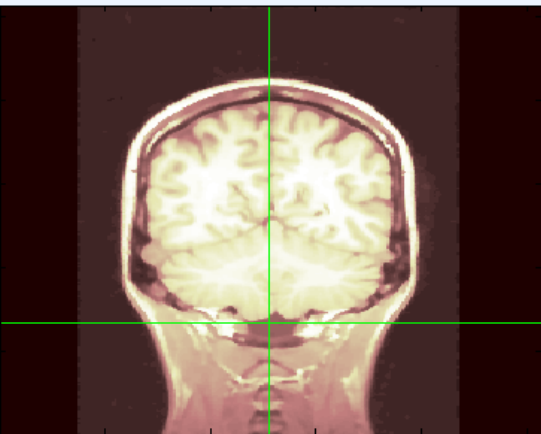
Segmentation

Click 'Set'

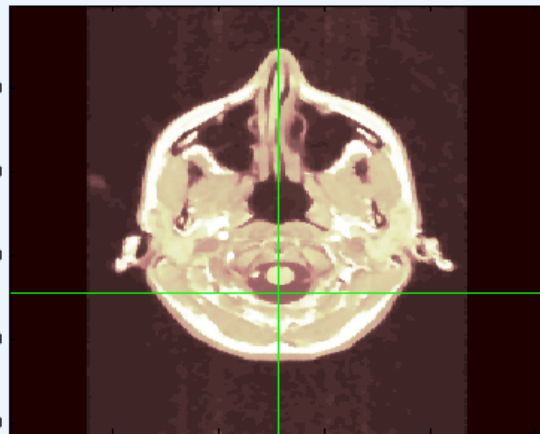
NFT: MR segmentation

File

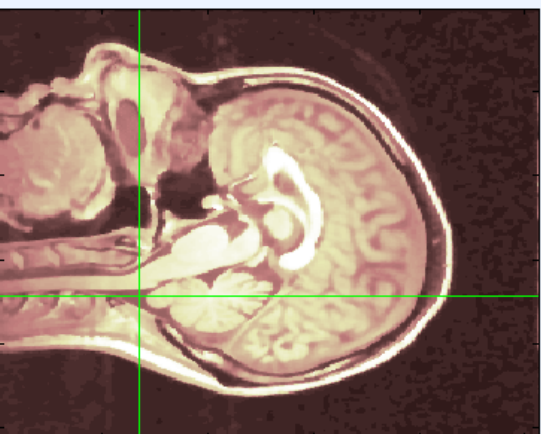
(x,y,z)= (128, 172, 67)



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 /data/projects/zeynep/comm on/home zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

Swap L/R Check inhomogeneity

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Scalp segmented!

Segmentation

Selection of a WM point

NFT: MR segmentation

File

(x,y,z)= (150, 172, 158)

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 /data/projects/zeynep/comm
on/home_zevneb/io/deneme

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Scalp segmented!

Segmentation

Click 'Set'

NFT: MR segmentation

File

(x,y,z)= (150, 172, 158)

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 /data/projects/zeynep/comm
on/home_zevneb/io/deneme

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Scalp segmented!

Segmentation

Click 'Run' for brain segmentation

File NFT: MR segmentation

(x,y,z)= (150, 172, 158)

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 /data/projects/zeynep/comm
on/home_zevneb/io/deneme

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Brain segmented!

Segmentation

Change thresholds if there is need

NFT: MR segmentation

(x,y,z) = (150, 172, 158)

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x White matter seed point

y White matter seed point

z White matter seed point

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Segmenting brain...

Display Image

MR image

Filtered image

Scalp mask

Brain mask

Outer skull mask

Inner skull mask

Save Results

Output Folder /data/projects/zeynep/comm on/home_zevneb/io/deneme

Segmentation

View brain mask

NFT: MR segmentation

File

(x,y,z) = (150, 172, 158)

70
200
150
100
50

50 100 150 200 250

x

Coronal view

y
50
100
150
200
250

50 100 150 200 250

x

Axial view

y
50
100
150
200
250

50 100 150 200 250

z

Sagittal view

Display Image

MR image

Filtered image

Scalp mask

Brain mask

Outer skull mask

Inner skull mask

Save Results

Output Folder /data/projects/zeynep/comm
on/home_zevneb/io/deneme

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Brain segmented!

Segmentation

Click 'Next' for skull segmentation

File
NFT: MR segmentation

(x,y,z) = (150, 172, 158)

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 /data/projects/zeynep/comm
on/home_zevneb/io/deneme

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Brain segmented!

Segmentation

Select a slice for eyes

NFT: MR segmentation

File

(x,y,z)= (150, 67, 95)

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 /data/projects/zeynep/comm
on/home_zevneb/io/deneme

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Brain segmented!

Segmentation

Click 'Set'

NFT: MR segmentation

File

(x,y,z)= (150, 67, 95)

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 /data/projects/zeynep/comm
on/home_zeynep/io/deneme

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Brain segmented!

Segmentation

Click 'Run' for skull segmentation

NFT: MR segmentation

(x,y,z)= (150, 67, 95)

Coronal view

Axial view

Display Image

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

Save Results

Output Folder /data/projects/zeynep/comm
on/home_zevneb/io/deneme

Filtered Image Segmentation

Image Segmentation

Swap L/R Check inhomogeneity

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Set Cerebellar low point

x

y Set White matter seed point

z

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

4. Outer Skull Segmentation

z Set Center of one eye

5. Inner Skull Segmentation

Segmenting skull...

Segmentation

Click on the eyes

Figure 2

File Edit View Insert Tools Desktop Window Help

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Segmenting skull...

Brain mask

Outer skull mask

Inner skull mask

Save Results

/data/projects/zeynep/comm on/home zeynep/io/deneme

(x,y,z)= (150, 67, 95)

Coronal view

Sagittal view

Segmentation

NFT: MR segmentation

Figure 2

(x,y,z)= (150, 67, 95)

Coronal view

Sagittal view

Brain mask
Outer skull mask
Inner skull mask

Save Results

Output Folder /data/projects/zeynep/comm on/home zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

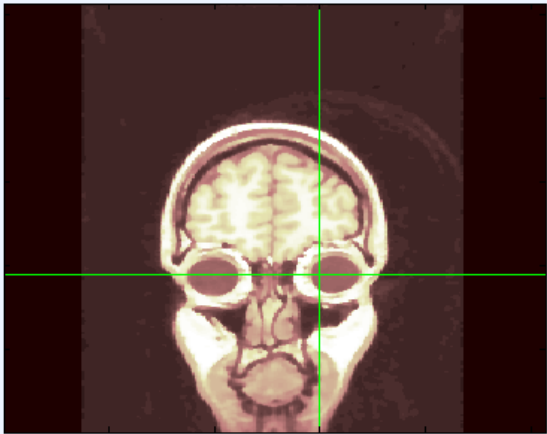
Segmenting skull...

Segmentation

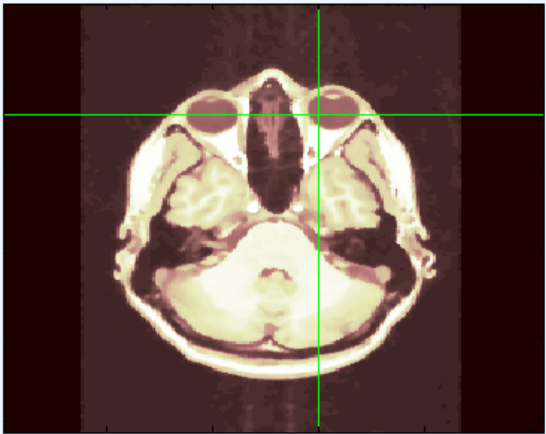
NFT: MR segmentation

File

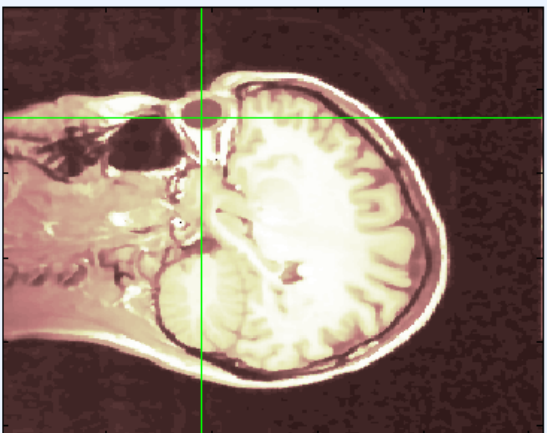
(x,y,z)= (150, 67, 95)



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 /data/projects/zeynep/comm on/home zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

Swap L/R Check inhomogeneity

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

White matter seed point

Set

z

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

4. Outer Skull Segmentation

Center of one eye

z

5. Inner Skull Segmentation

< Prev Run Next >

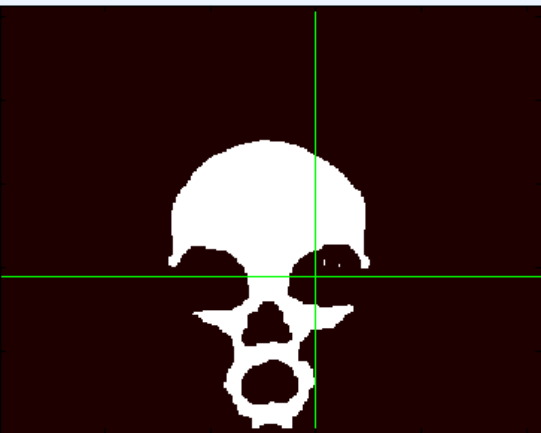
Skull segmented!

Segmentation

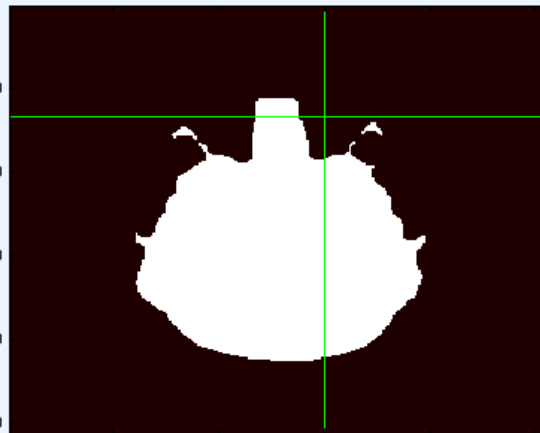
View skull segmentation

File
NFT: MR segmentation

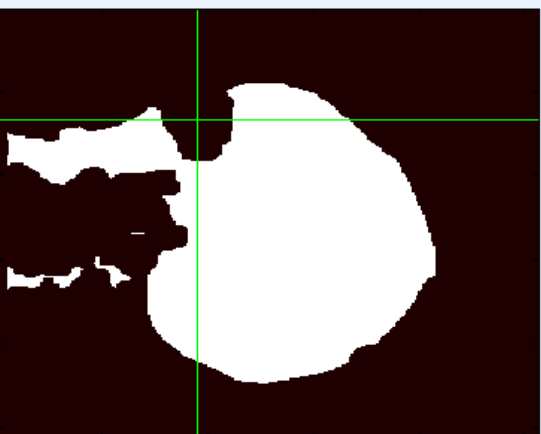
(x,y,z)= (150, 67, 95)



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: /data/projects/zeynep/comm on/home zeynep/io/deneme

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Skull segmented!

Segmentation

Click 'Next' for CSF segmentation

NFT: MR segmentation

File

(x,y,z)= (150, 67, 95)

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 /data/projects/zeynep/comm
on/home_zevneb/io/deneme

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

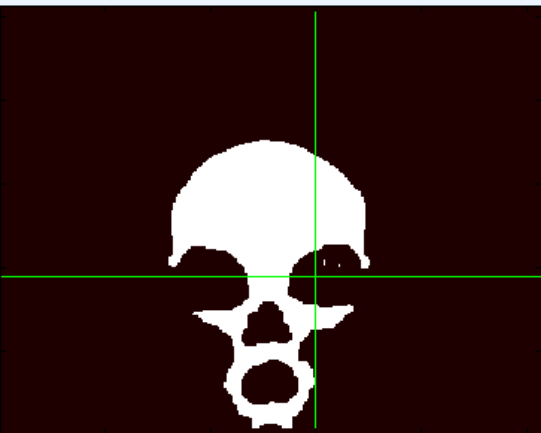
Skull segmented!

Segmentation

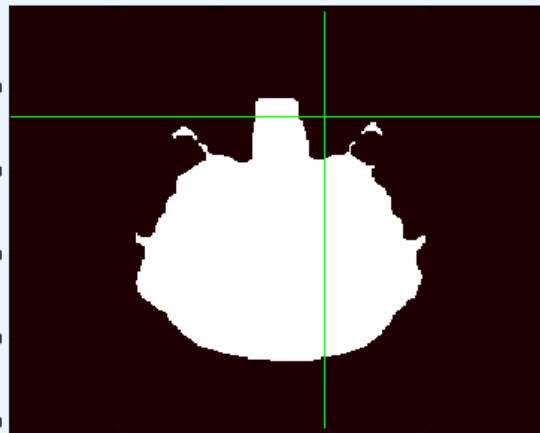
Click 'Run' for CSF segmentation

File NFT: MR segmentation

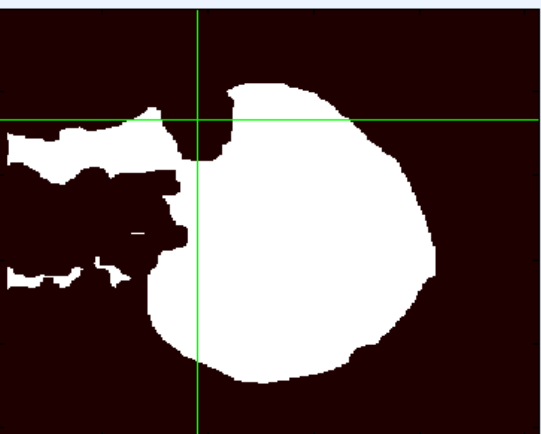
(x,y,z)= (150, 67, 95)



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: /data/projects/zeynep/comm
on/home_zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Segmenting CSF...

Segmentation

NFT: MR segmentation

File

(x,y,z)= (150, 67, 95)

Coronal view

Axial view

Display Image

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

Save Results

Output Folder /data/projects/zeynep/comm
on/home_zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

Swap L/R Check inhomogeneity

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

White matter seed point

Set

z

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

4. Outer Skull Segmentation

Center of one eye

z

5. Inner Skull Segmentation

Segmentation complete!

Sagittal view

Segmentation

View CSF segmentation

NFT: MR segmentation

(x,y,z) = (150, 160, 139)

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 /data/projects/zeynep/comm
on/home_zevneb/io/deneme

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Segmentation complete!

Segmentation

Save filtered image

NFT: MR segmentation

File

(x,y,z)= (150, 160, 139)

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 /data/projects/zeynep/comm on/home zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

Swap L/R Check inhomogeneity

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

White matter seed point

Set

z

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

4. Outer Skull Segmentation

Center of one eye

Set

5. Inner Skull Segmentation

Saving filtered image as SubjectA_filtered.mat

Segmentation

NFT: MR segmentation

File

(x,y,z) = (150, 160, 139)

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 /data/projects/zeynep/comm
on/home_zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

Swap L/R Check inhomogeneity

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

White matter seed point

Set

z

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

4. Outer Skull Segmentation

Center of one eye

Set

5. Inner Skull Segmentation

Filtered image saved as SubjectA_filtered.mat

Segmentation

Save segmentation

NFT: MR segmentation

File

(x,y,z) = (150, 160, 139)

70
200
150
100
50

50 100 150 200 250

x

Coronal view

y
50
100
150
200
250

50 100 150 200 250

x

Axial view

y
50
100
150
200
250

50 100 150 200 250

z

Sagittal view

Display Image

MR image

Filtered image

Scalp mask

Brain mask

Outer skull mask

Inner skull mask

Save Results

Output Folder /data/projects/zeynep/comm
on/home_zevneb/io/deneme

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Saving segmentation as SubjectA_segments.mat

Segmentation

NFT: MR segmentation

File

(x,y,z) = (150, 160, 139)

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: /data/projects/zeynep/comm
on/home_zevneb/io/deneme

Image Segmentation

Swap L/R

1. Anisotropic Filtering

Number of iterations

Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point

x

y White matter seed point

z

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

4. Outer Skull Segmentation

z Center of one eye

5. Inner Skull Segmentation

Segmentation saved as SubjectA_segments.mat

Image Segmentation

```
Command Window
New to MATLAB? Watch this Video, see Demos, or read Getting Started.

>> dir SubjectA*

SubjectA_mri.mat      SubjectA_segments.mat

>> load SubjectA_mri
>> mri

mri =

    dim: [256 256 256]
   xgrid: [1x256 double]
   ygrid: [1x256 double]
   zgrid: [1x256 double]
 anatomy: [256x256x256 double]
 transform: [4x4 double]
    hdr: []

>> load SubjectA_segments
>> Segm

Segm =

    scalpmask: [256x256x256 logical]
    brainmask: [256x256x256 logical]
    outerskullmask: [256x256x256 logical]
    innerskullmask: [256x256x256 logical]

fx >> |
```

Mesh Generation

From a magnetic
Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registrati...

NFT: Mesh generation

Load Segmentation /data/projects/zeynep/common/home_zeynep/jo/deneme/d
ene_real/SubjectA_segments

Output Folder /data/projects/zeynep/common/home_zeynep/jo/deneme/de
ne real

4 # of layers Mesh name: SubjectA

Linear Quadratic

7000 Number of nodes per layer

Local mesh refinement

2.1 Edge length/
Distance between meshes

Start Mesh Generation

Status

Generate linear FEM mesh

Generate quadratic FEM mesh

Generate Mesh for a 3 or 4 layer head model

Source Space Generation

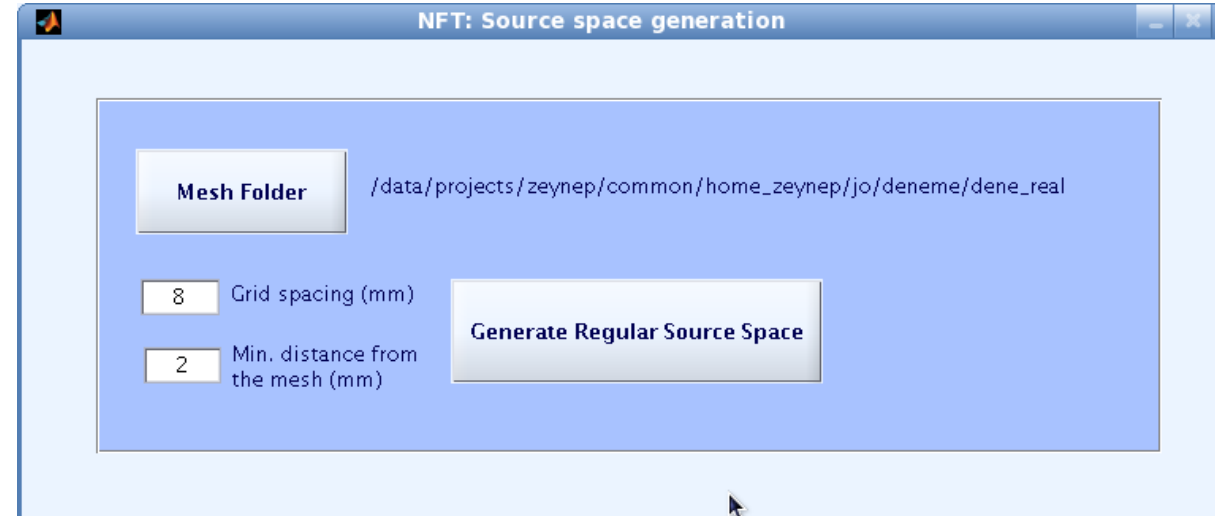
From a magnetic
Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registrati...



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

Source Space Generation

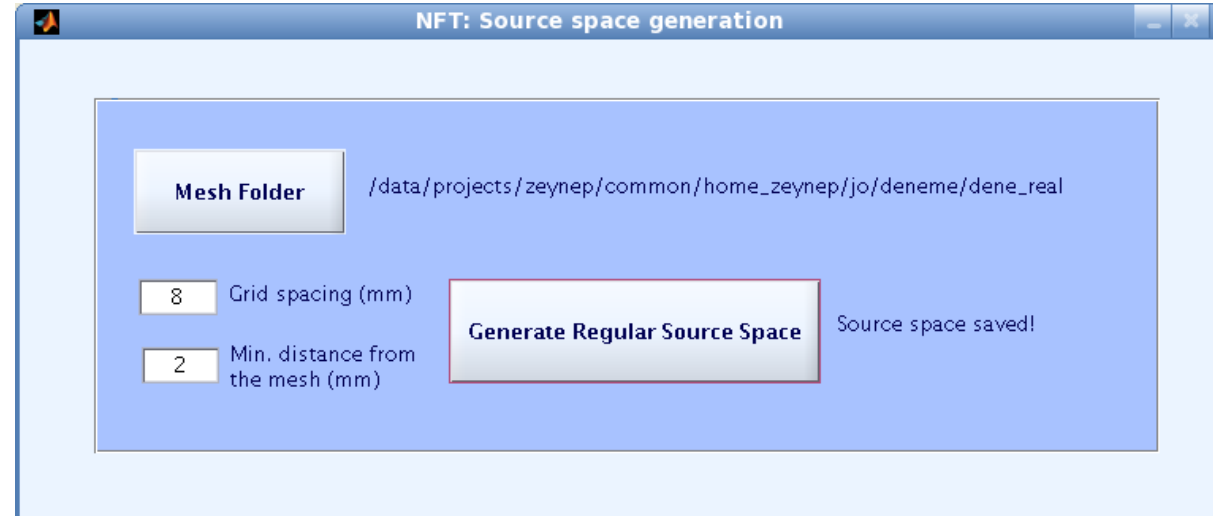
From a magnetic
Resonance Image

Image Segmentation

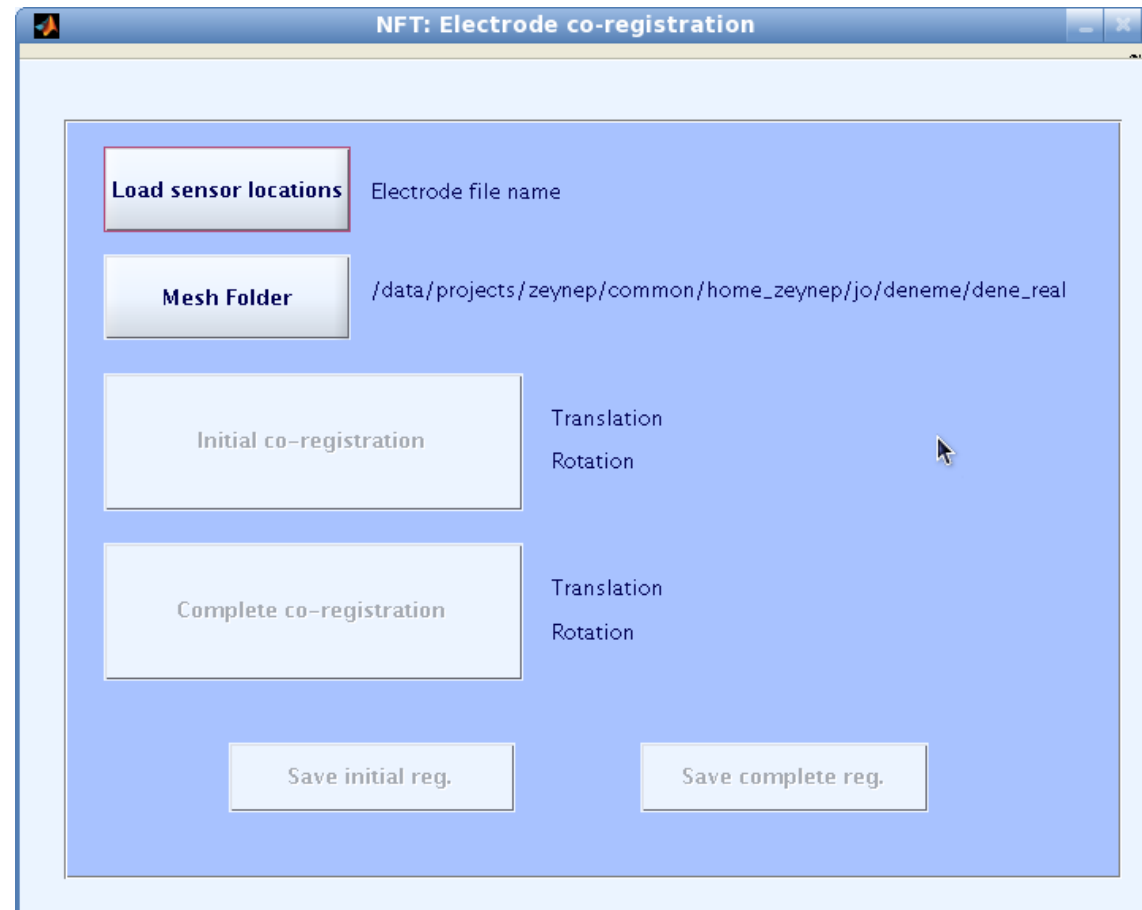
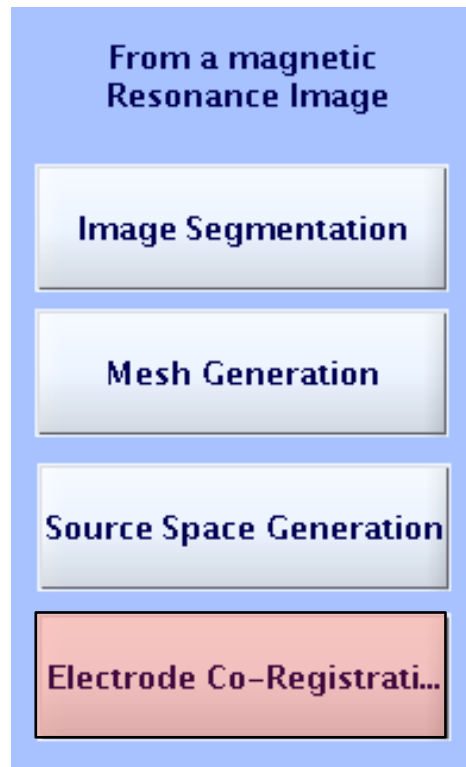
Mesh Generation

Source Space Generation

Electrode Co-Registrati...



Electrode Co-registration



Electrode Co-registration

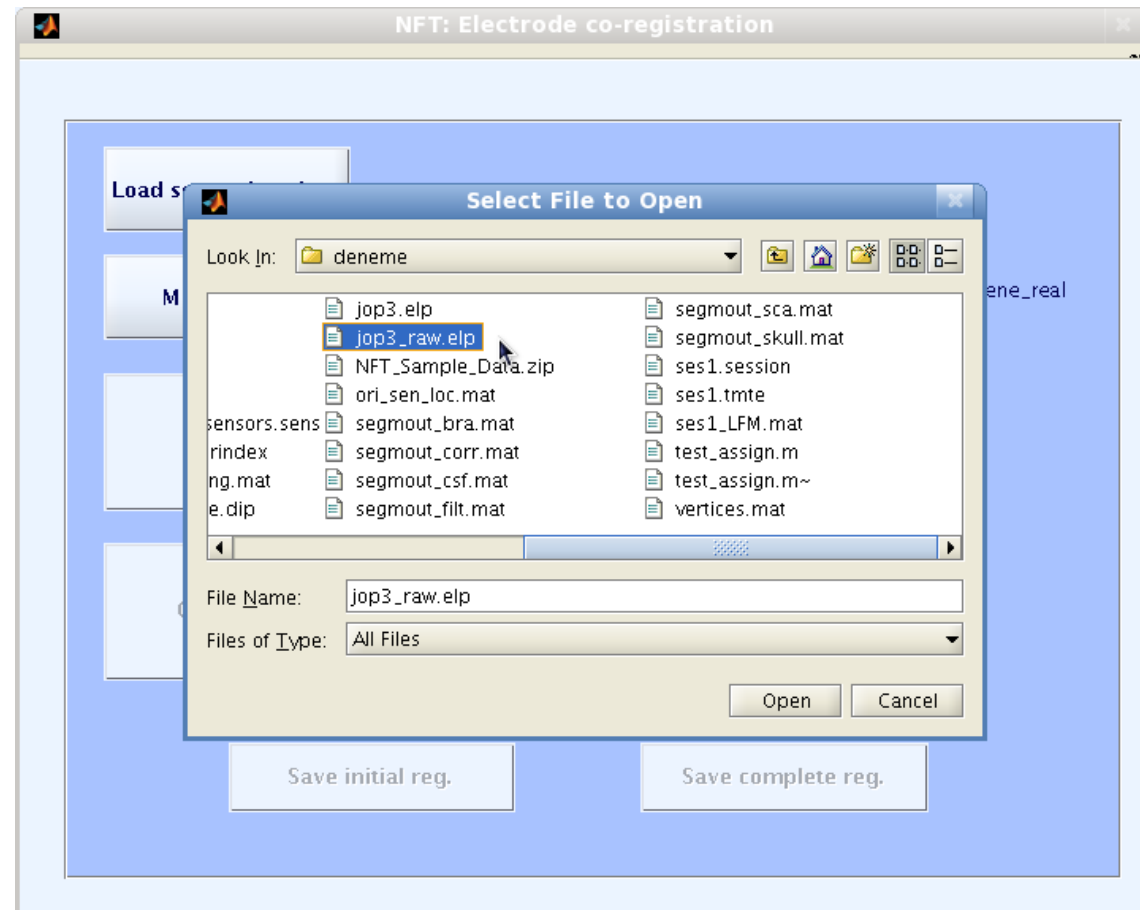
From a magnetic
Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registrati...



Electrode Co-registration

From a magnetic Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registrati...

coregister()

File Edit View Insert Tools Desktop Window Help

Labels on
Electrodes
Labels on
Electrodes
Mesh off

Help me
Funct. help

Move right (mm)	0	Pitch (rad)	0	Resize {x}	1	Align fiducials
Move front (mm)	0	Roll (rad)	0	Resize {y}	1	Warp montage
Move up (mm)	0	Yaw (rad)	0	Resize {z}	1	Cancel Ok

Electrode Co-registration

From a magnetic
Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registrati...

coregister()

File Edit View Insert Tools Desktop Window Help

Labels on
Electrodes
Labels on
Electrodes
Mesh off

Help me
Funct. help

Move right (mm) 0 Pitch (rad) 0 Resize (x) 1 Align fiducials
 Move front (mm) 2 Roll (rad) 0.25 Resize (y) 1 Warp montage
 Move up (mm) 5 Yaw (rad) -1.571 Resize (z) 1 Cancel Ok

Electrode Co-registration

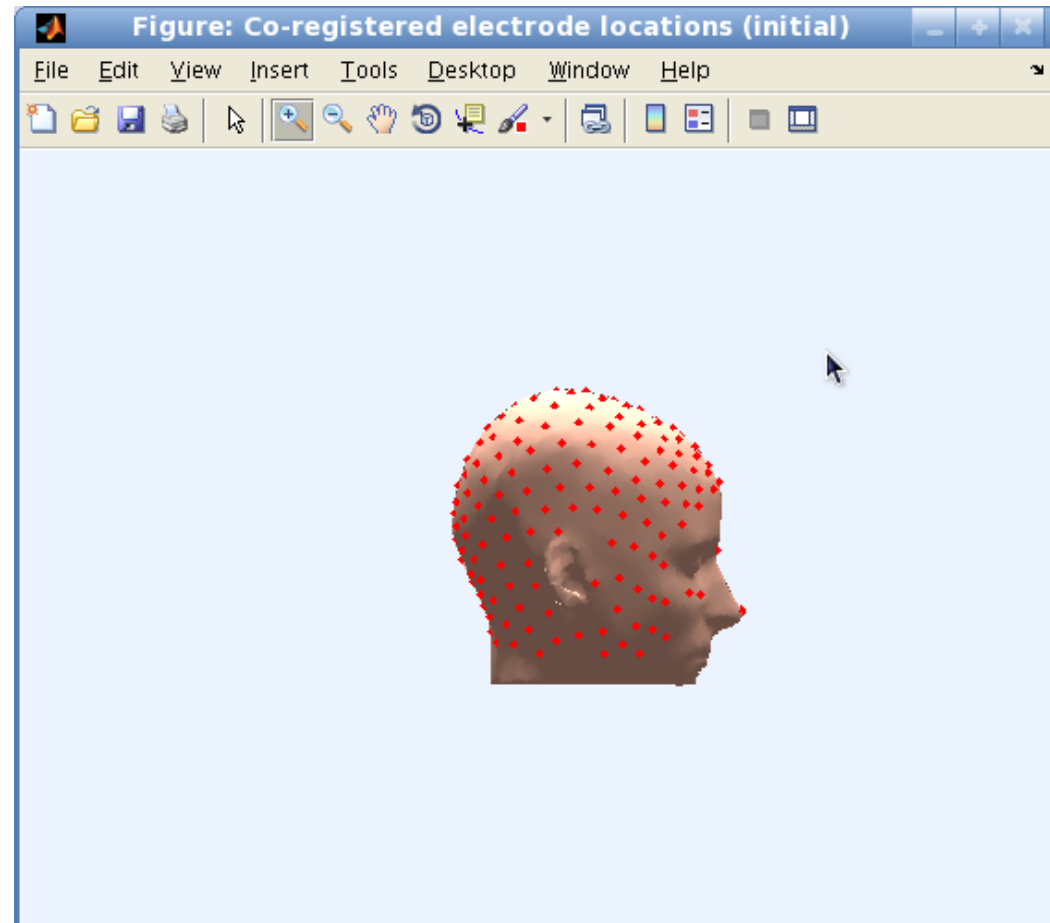
From a magnetic
Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registrati...



Electrode Co-registration

From a magnetic Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registrati...

NFT: Electrode co-registration

Load sensor locations /data/projects/zeynep/common/home_zeynep/jo/deneme/jop3_raw.el

Mesh Folder /data/projects/zeynep/common/home_zeynep/jo/deneme/dene_real

Initial co-registration Translation 0 2 5
Rotation 0 0.25 -1.5708

Complete co-registration Translation
Rotation

Save initial reg. Save complete reg.

Computing translation and rotation parameters...

Electrode Co-registration

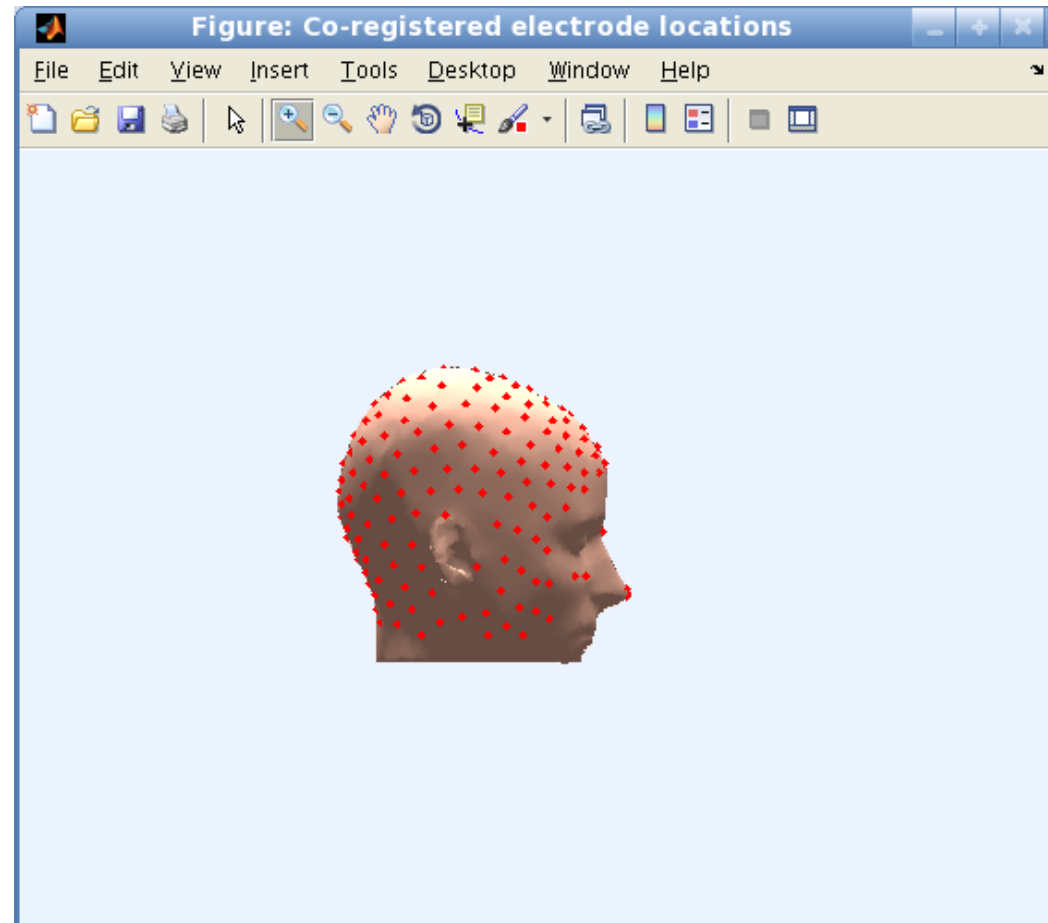
From a magnetic
Resonance Image

Image Segmentation

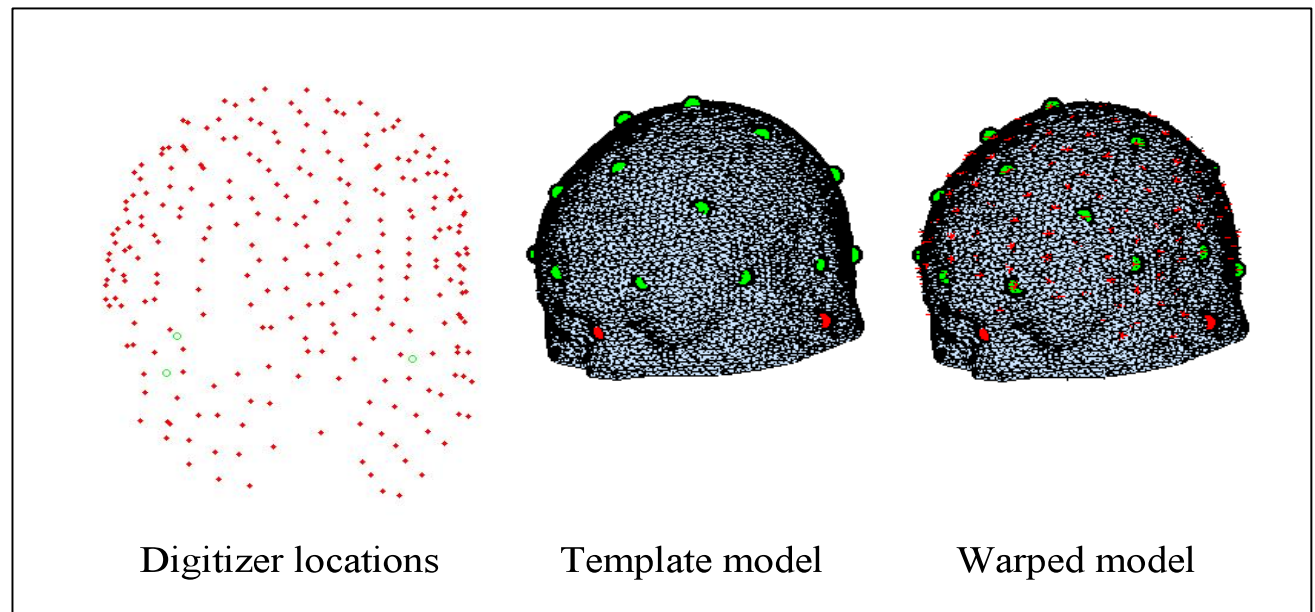
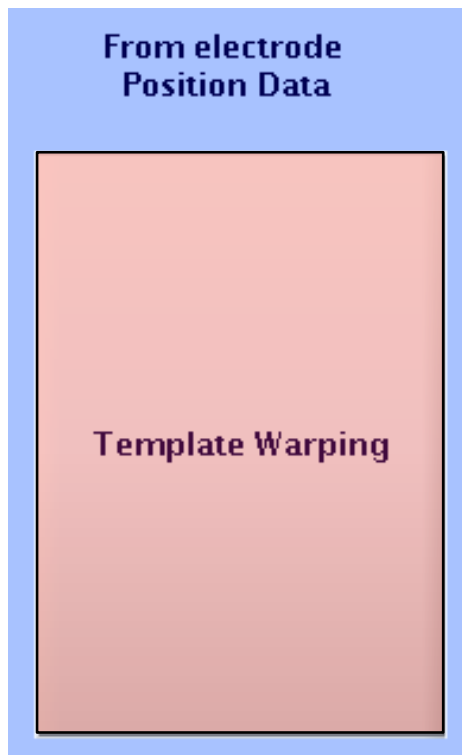
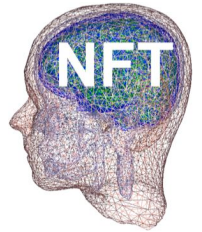
Mesh Generation

Source Space Generation

Electrode Co-Registrati...



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

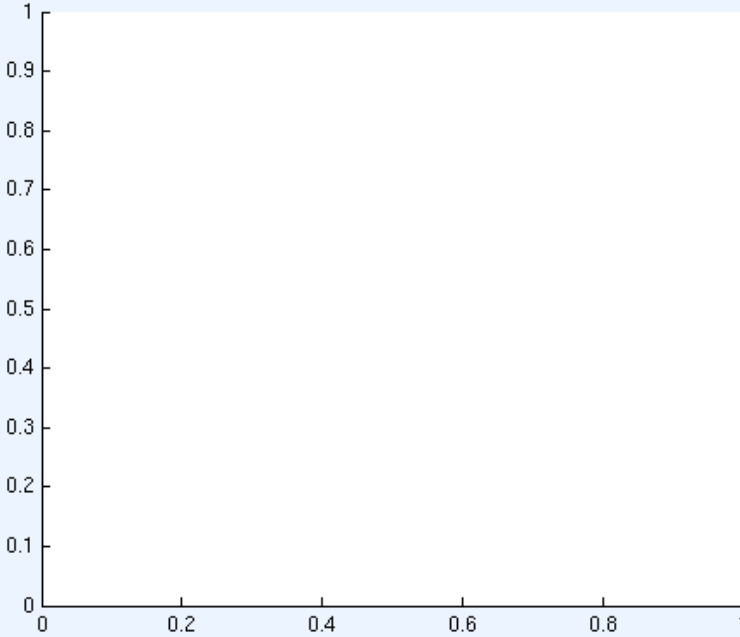
NFT: Template head model warping

of layers (3 or 4)

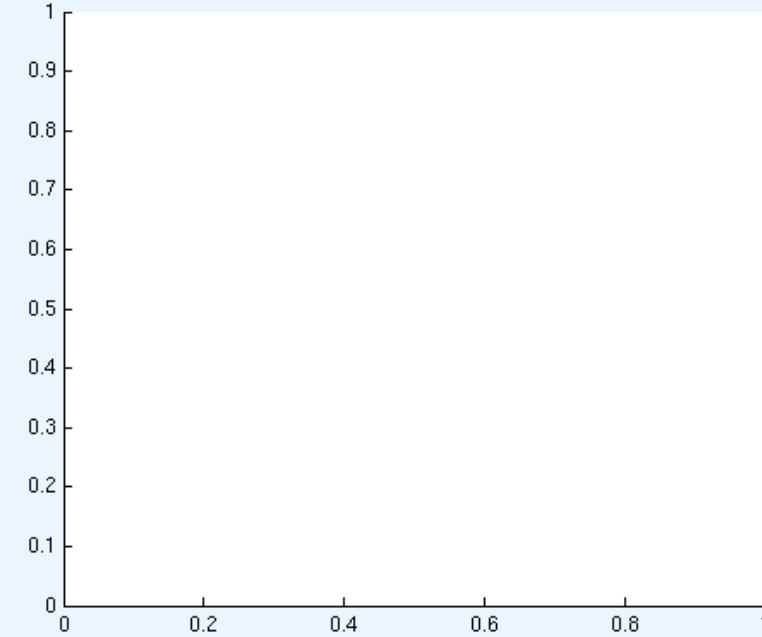
Load sensor data

Output Folder /data/projects/zeynep/common/home_zeynep/jo/dene
me/dene_mni

MNI head model



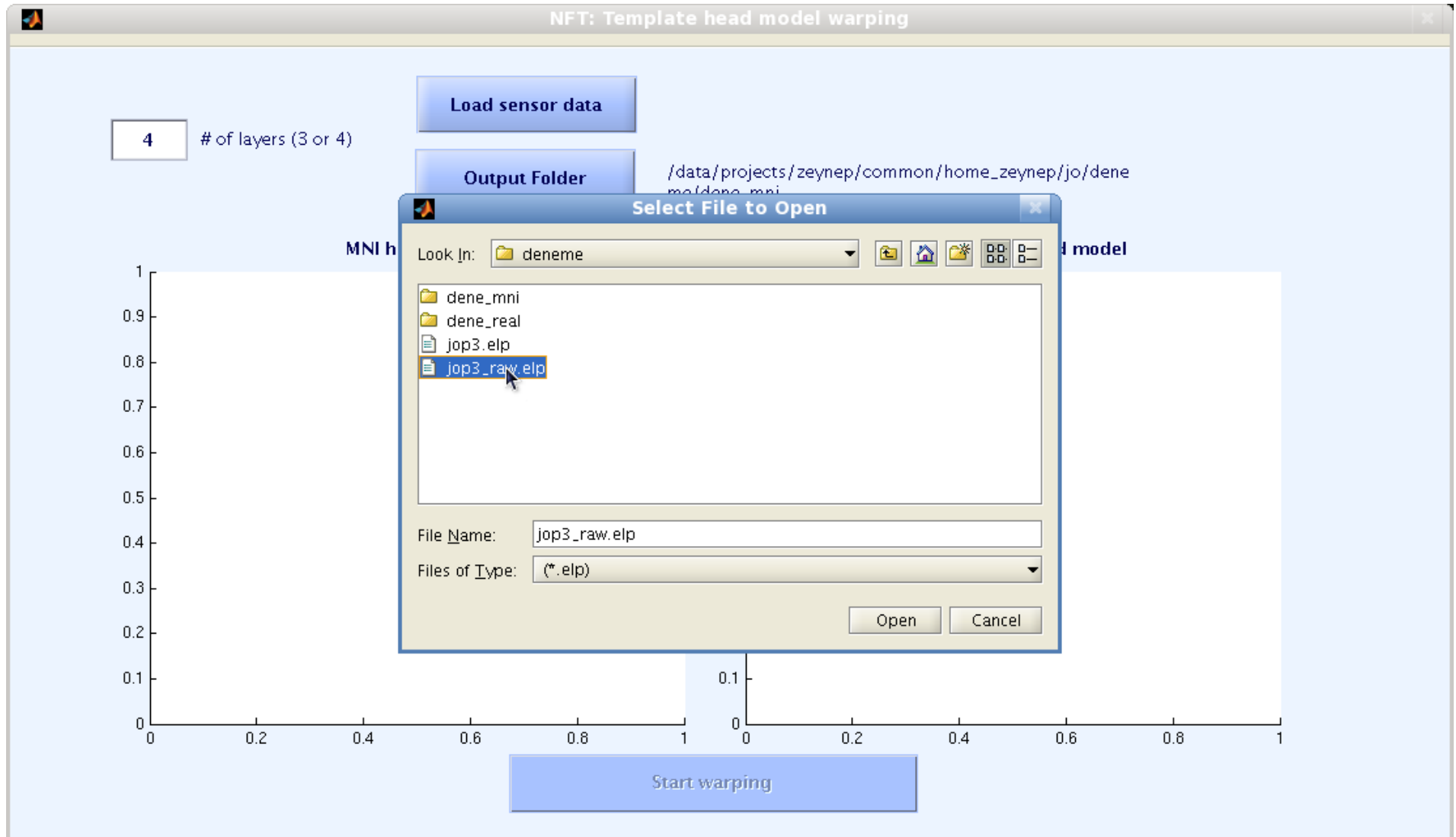
Warped MNI head model



Start warping

The interface displays two side-by-side coordinate systems, each with x and y axes ranging from 0 to 1. The left plot is titled 'MNI head model' and the right plot is titled 'Warped MNI head model'. Both plots are currently empty, indicating that the warping process has not yet been executed.

Template Warping



4 # of layers (3 or 4)

Load sensor data

Output Folder /data/projects/zeynep/common/home_zeynep/jo/dene

Select File to Open

Look In: dene

- dene_mni
- dene_real
- jop3.elp
- jop3_raw.elp**

File Name: jop3_raw.elp

Files of Type: (*.elp)

Start warping

Template Warping

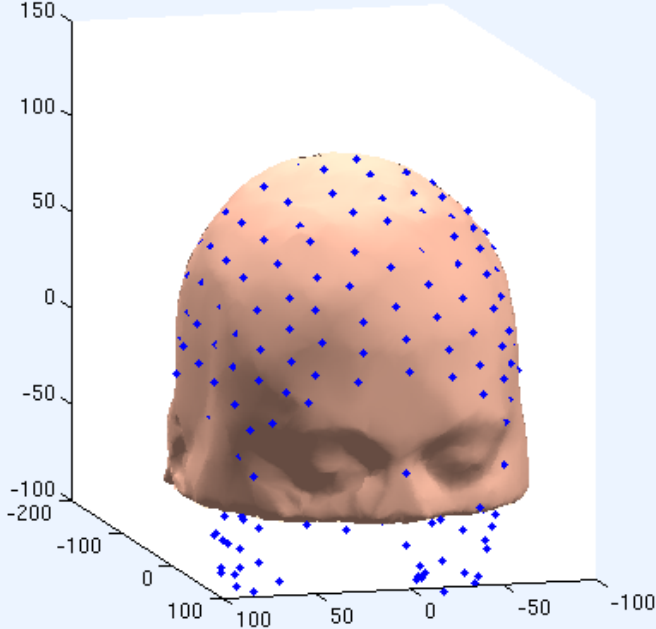
NFT: Template head model warping

of layers (3 or 4)

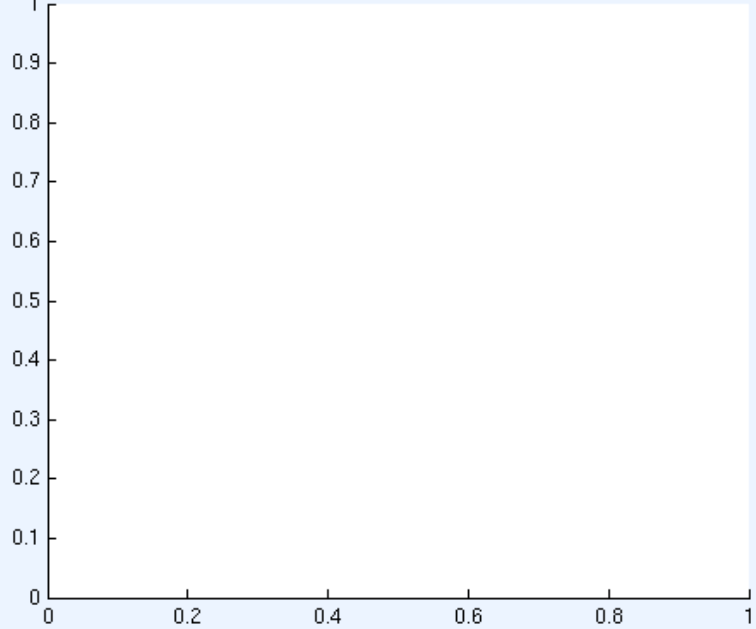
Load sensor data /data/projects/zeynep/common/home_zeynep/jo/dene
me/jop3_raw.elp

Output Folder /data/projects/zeynep/common/home_zeynep/jo/dene
me/dene_mni

MNI head model



Warped MNI head model



Start Warping

Template Warping

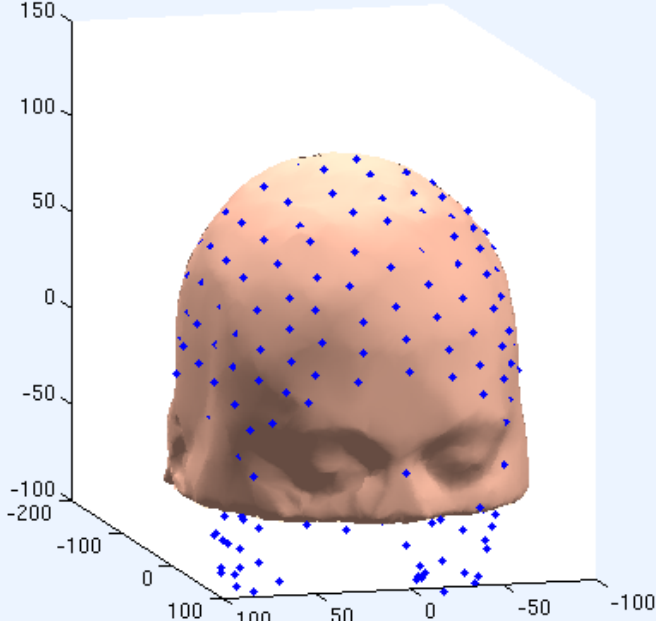
NFT: Template head model warping

of layers (3 or 4)

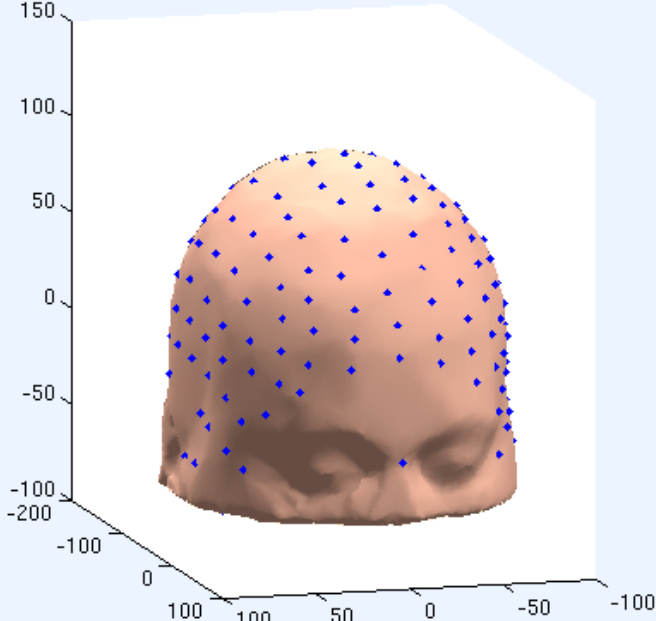
Load sensor data /data/projects/zeynep/common/home_zeynep/jo/dene
me/jop3_raw.elp

Output Folder /data/projects/zeynep/common/home_zeynep/jo/dene
me/dene_mni

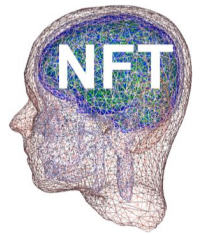
MNI head model



Warped MNI head model



Mesh Warper!



Forward Problem Solver

- ◆ MATLAB interface to numerical solvers
- ◆ Boundary Element Method or Finite Element Method
 - EEG Only (for now)
 - Interfaces to the Matrix generator executable written in C++
- ◆ Other computation done in MATLAB
- ◆ Generated matrices are stored on disk for future use.

Forward Problem Solution with BEM

Forward Model Generation

NFT: Forward problem solution

File

BEM Mesh Info

SubjectA Mesh Name

Show Mesh

4 Number of Layers

13724 Number of Nodes

27476 Number of Elements

3 Number of Nodes/Element

BEM Model

SubjectA Model Name

Enter conductivity values:

0.33 Scalp 0.0042 Skull

0.33 Brain 1.79 CSF

Modified (Isolated Problem Approach)

Create Model

Value Changed!

Session

sesNov20_10 Session Name

Load Sensors

Mesh Coordinates **Load**

Mesh Node List **Show Sensors**

Generate transfer matrix

Value Changed!

Forward Problem Solution

Load Source Space

Compute Lead Field Matrix

Plot Potential Distribution

For Dipole

Forward Problem Solution with BEM

Forward Model Generation

NFT: Forward problem solution

File

BEM Mesh Info

SubjectA Mesh Name

Show Mesh

4 Number of Layers

13724 Number of Nodes

27476 Number of Elements

3 Number of Nodes/Element

BEM Model

SubjectA Model Name

Enter conductivity values:

0.33 Scalp 0.0042 Skull

0.33 Brain 1.79 CSF

Modified (Isolated Problem Approach)

Create Model

Generating matrices...

Session

sesNov20_10 Session Name

Load Sensors

Mesh Coordinates Mesh Node List

Load Show Sensors

Generate transfer matrix

Value Changed!

Forward Problem Solution

Load Source Space

Compute Lead Field Matrix

Plot Potential Distribution

For Dipole

Forward Problem Solution with BEM

Forward Model Generation

NFT: Forward problem solution

File

BEM Mesh Info

SubjectA Mesh Name

Show Mesh

4 Number of Layers

13724 Number of Nodes

27476 Number of Elements

3 Number of Nodes/Element

BEM Model

SubjectA Model Name

Enter conductivity values:

0.33 Scalp 0.0042 Skull

0.33 Brain 1.79 CSF

Modified (Isolated Problem Approach)

Create Model

BEM Model Created

Session

sesNov20_10 Session Name

Load Sensors

Mesh Coordinates **Load**

Mesh Node List **Show Sensors**

Generate transfer matrix

Value Changed!

Forward Problem Solution

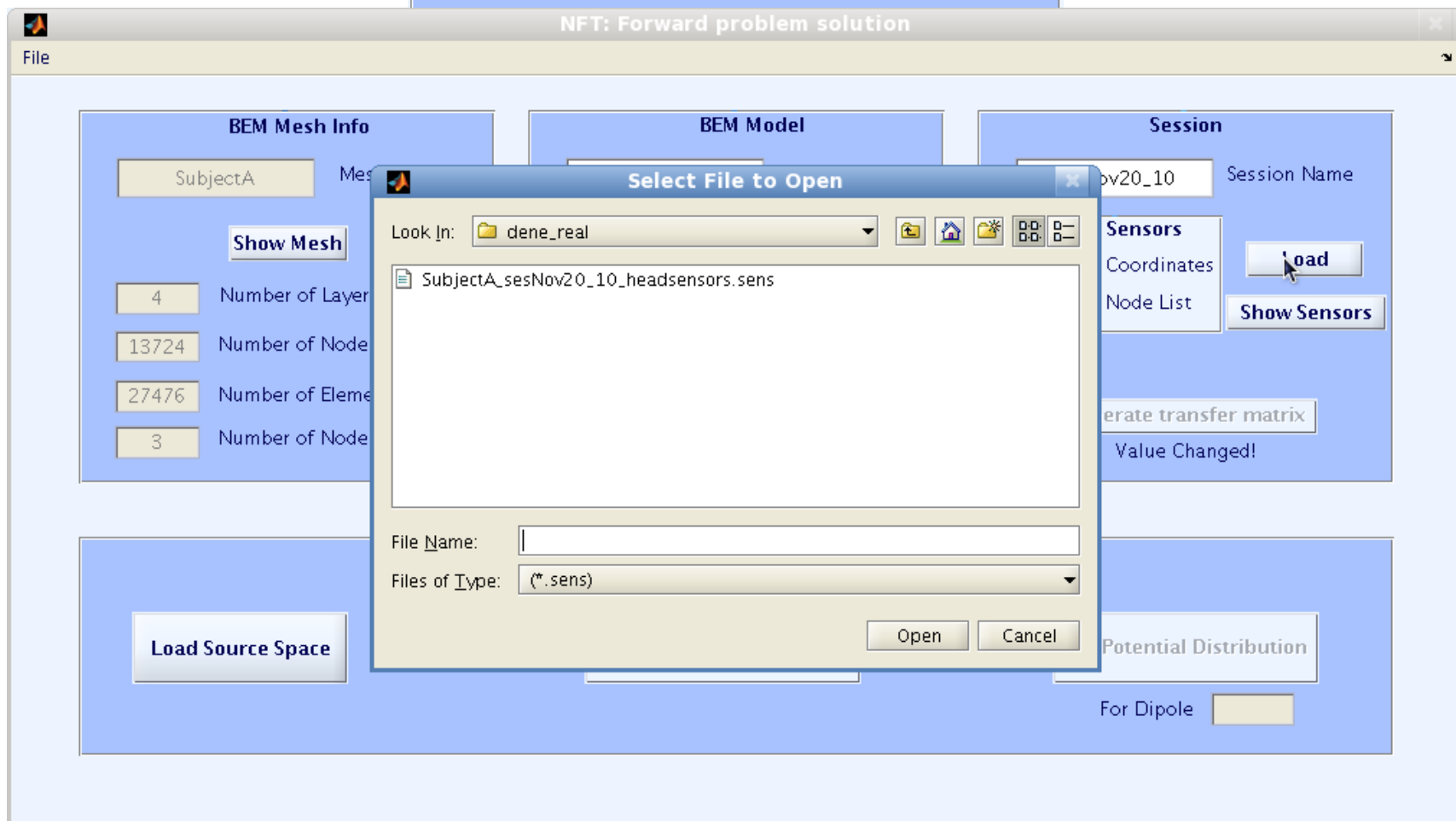
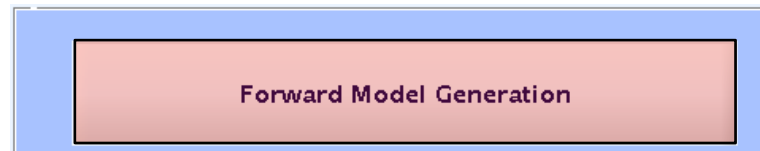
Load Source Space

Compute Lead Field Matrix

Plot Potential Distribution

For Dipole

Forward Problem Solution with BEM



NFT: Forward problem solution

File

BEM Mesh Info

SubjectA Mesh

Show Mesh

4 Number of Layers

13724 Number of Nodes

27476 Number of Elements

3 Number of Nodes

Load Source Space

BEM Model

Session

Nov20_10 Session Name

Sensors

Coordinates

Node List

Load

Show Sensors

Generate transfer matrix

Value Changed!

Potential Distribution

For Dipole

Select File to Open

Look In: dene_real

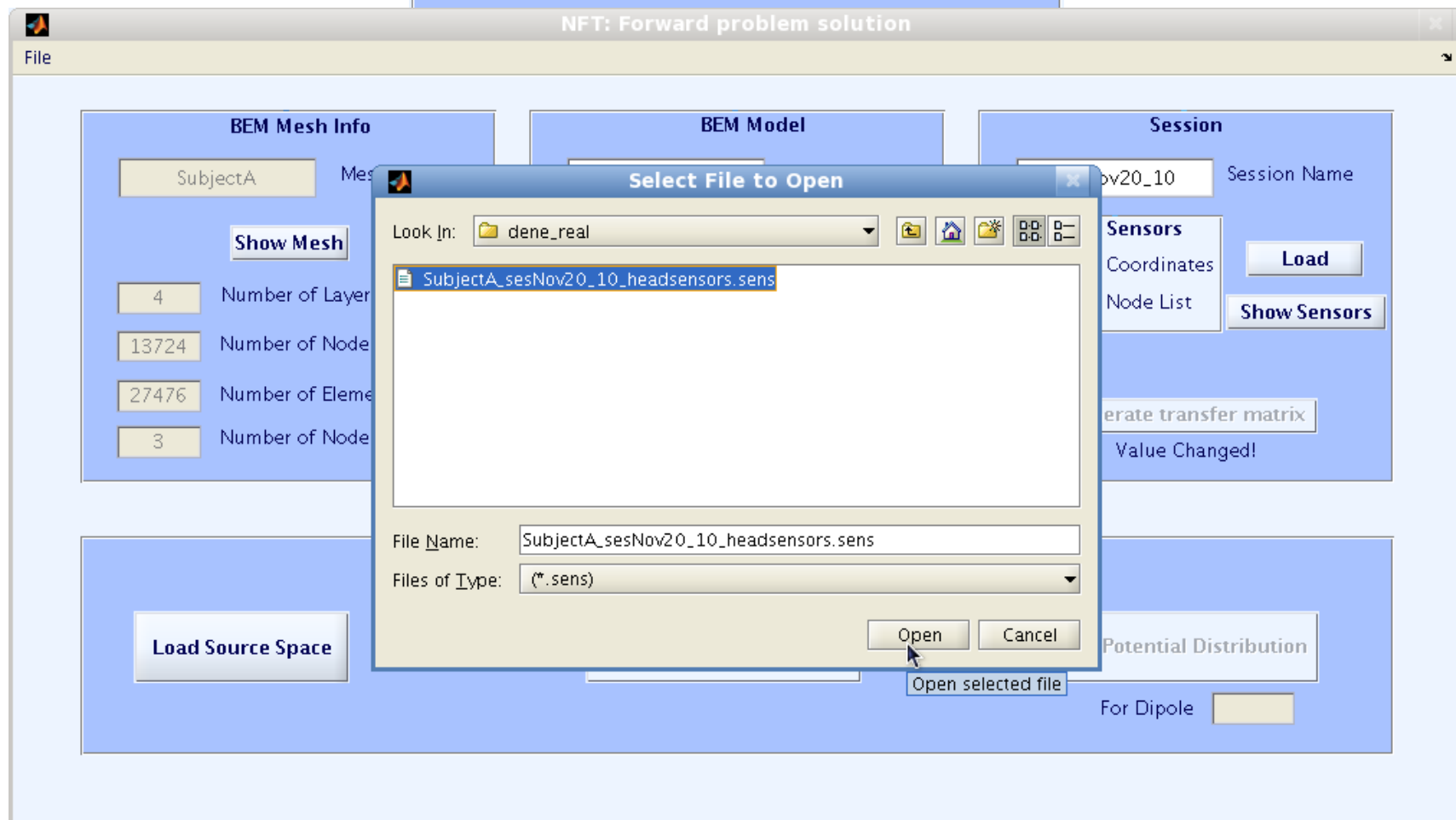
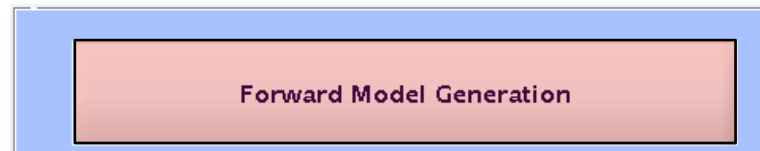
SubjectA_sesNov20_10_head sensors.sens

File Name:

Files of Type: (*.sens)

Open Cancel

Forward Problem Solution with BEM



NFT: Forward problem solution

File

BEM Mesh Info

SubjectA Mesh

Show Mesh

4 Number of Layers

13724 Number of Nodes

27476 Number of Elements

3 Number of Nodes

Load Source Space

BEM Model

Session

Nov20_10 Session Name

Sensors

Coordinates Load

Node List Show Sensors

Generate transfer matrix

Value Changed!

Potential Distribution

For Dipole

Select File to Open

Look In: dene_real

SubjectA_sesNov20_10_headensors.sens

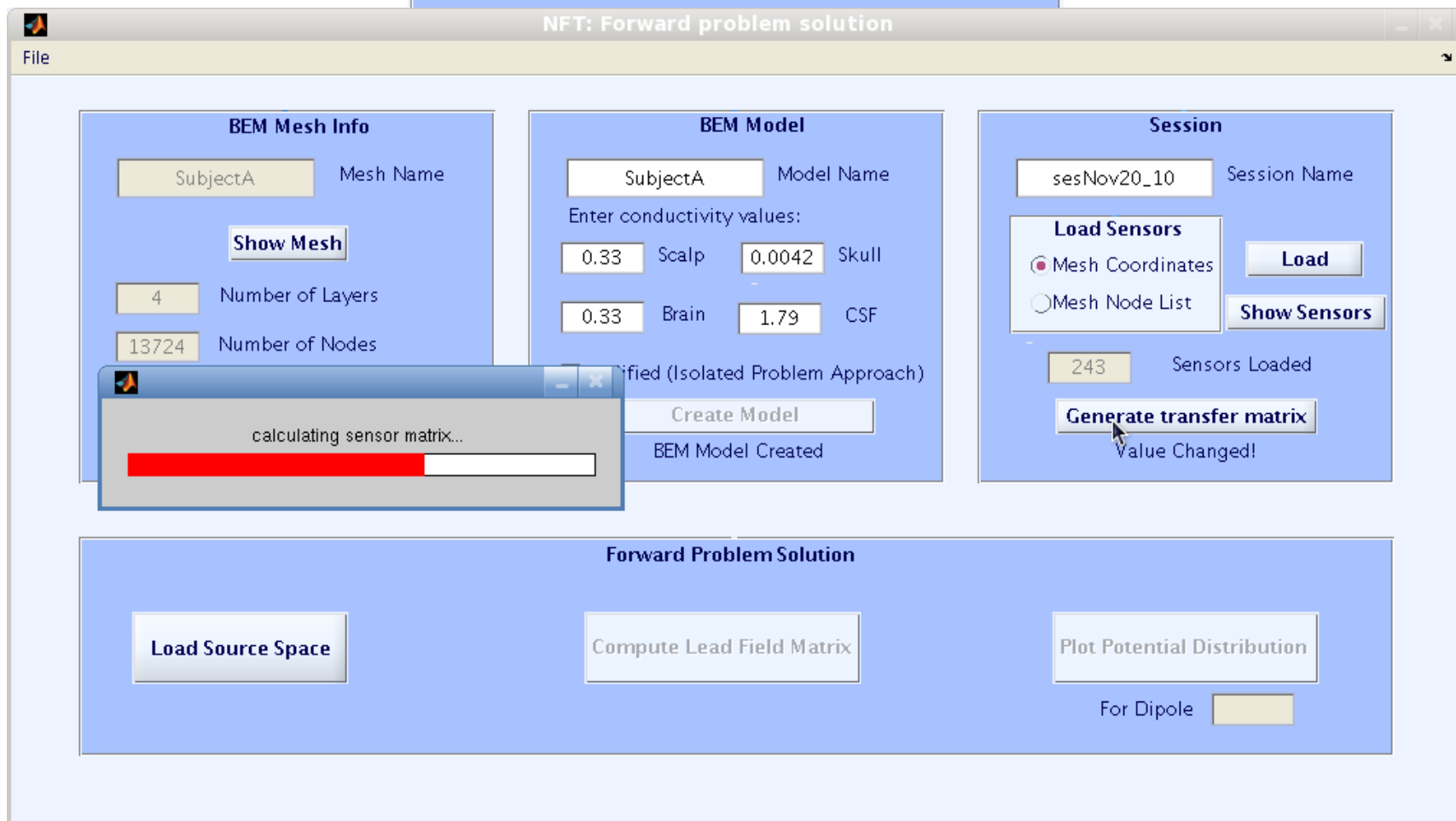
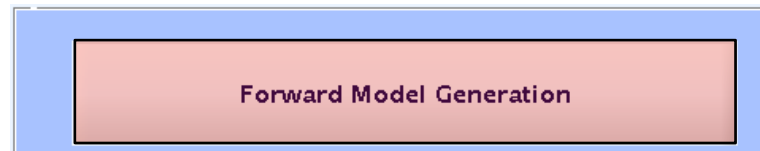
File Name: SubjectA_sesNov20_10_headensors.sens

Files of Type: (*.sens)

Open Cancel

Open selected file

Forward Problem Solution with BEM



NFT: Forward problem solution

File

BEM Mesh Info

SubjectA Mesh Name

Show Mesh

4 Number of Layers

13724 Number of Nodes

BEM Model

SubjectA Model Name

Enter conductivity values:

0.33 Scalp 0.0042 Skull

0.33 Brain 1.79 CSF

Unified (Isolated Problem Approach)

Create Model

BEM Model Created

Session

sesNov20_10 Session Name

Load Sensors

Mesh Coordinates **Load**

Mesh Node List **Show Sensors**

243 Sensors Loaded

Generate transfer matrix

Value Changed!

Forward Problem Solution

Load Source Space

Compute Lead Field Matrix

Plot Potential Distribution

For Dipole

calculating sensor matrix...

Forward Problem Solution with BEM

Forward Model Generation

NFT: Forward problem solution

File

BEM Mesh Info

SubjectA Mesh Name

Show Mesh

4 Number of Layers

13724 Number of Nodes

27476 Number of Elements

3 Number of Nodes/Element

BEM Model

SubjectA Model Name

Enter conductivity values:

0.33 Scalp 0.0042 Skull

0.33 Brain 1.79 CSF

Modified (Isolated Problem Approach)

Create Model

BEM Model Loaded

Session

sesNov20_10 Session Name

Load Sensors

Mesh Coordinates **Load**

Mesh Node List **Show Sensors**

243 Sensors Loaded

Generate transfer matrix

Session Loaded

Forward Problem Solution

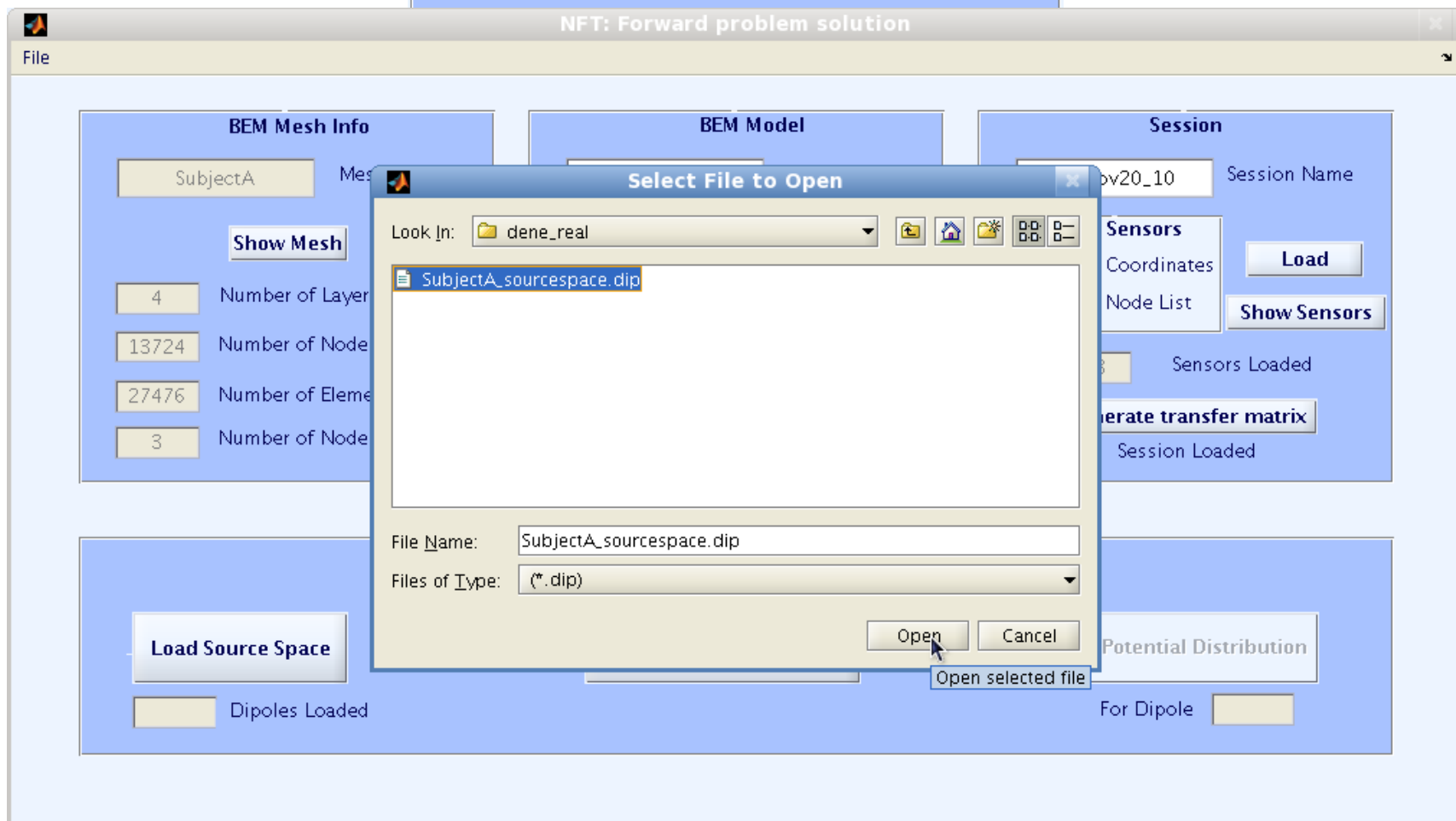
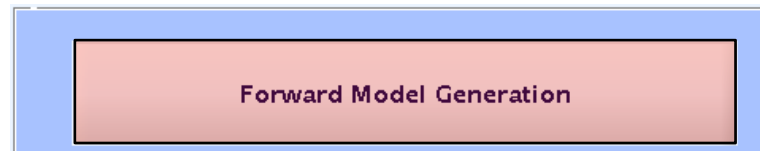
Load Source Space

Compute Lead Field Matrix

Plot Potential Distribution

For Dipole

Forward Problem Solution with BEM



NFT: Forward problem solution

File

BEM Mesh Info

SubjectA Mesh

Show Mesh

4 Number of Layers

13724 Number of Nodes

27476 Number of Elements

3 Number of Nodes

Load Source Space

Dipoles Loaded

BEM Model

Session

ov20_10 Session Name

Sensors

Coordinates

Node List

Sensors Loaded

Generate transfer matrix

Session Loaded

Potential Distribution

For Dipole

Select File to Open

Look In: dene_real

SubjectA_sourcepace.dip

File Name: SubjectA_sourcepace.dip

Files of Type: (*.dip)

Open Cancel

Open selected file

Forward Problem Solution with BEM

Forward Model Generation

NFT: Forward problem solution

File

BEM Mesh Info

SubjectA Mesh Name

Show Mesh

4 Number of Layers

13724 Number of Nodes

27476 Number of Elements

3 Number of Nodes/Element

BEM Model

SubjectA Model Name

Enter conductivity values:

0.33 Scalp 0.0042 Skull

0.33 Brain 1.79 CSF

Modified (Isolated Problem Approach)

Create Model

BEM Model Loaded

Session

sesNov20_10 Session Name

Load Sensors

Mesh Coordinates Mesh Node List

Load

Show Sensors

243 Sensors Loaded

Generate transfer matrix

Session Loaded

Forward Problem Solution

Load Source Space

6447 Dipoles Loaded

Compute Lead Field Matrix

Computing...

Plot Potential Distribution

For Dipole

Forward Problem Solution with BEM

Forward Model Generation

NFT: Forward problem solution

File

BEM Mesh Info

SubjectA Mesh Name

Show Mesh

4 Number of Layers

13724 Number of Nodes

27476 Number of Elements

3 Number of Nodes/Element

BEM Model

SubjectA Model Name

Enter conductivity values:

0.33 Scalp 0.0042 Skull

0.33 Brain 1.79 CSF

Modified (Isolated Problem Approach)

Create Model

BEM Model Loaded

Session

sesNov20_10 Session Name

Load Sensors

Mesh Coordinates Mesh Node List

Load

Show Sensors

243 Sensors Loaded

Generate transfer matrix

Session Loaded

Forward Problem Solution

Load Source Space

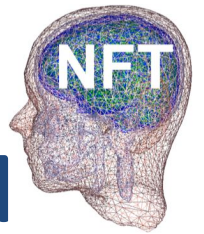
6447 Dipoles Loaded

Compute Lead Field Matrix

LFM Computed

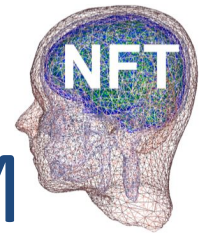
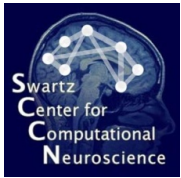
Plot Potential Distribution

For Dipole



Forward Problem Solution with FEM

- ◆ Tetgen for mesh generation
 - Uses BEM meshes as boundaries
- ◆ METU-FEM to generate transfer matrix
 - Compiled from source
 - Requires PETSc for matrix operations
- ◆ metufem .mex file for forward solutions in MATLAB
- ◆ Instructions available under README.FEM file.



Forward Problem Solution with FEM

NFT: Forward problem solution

File

FEM Mesh Info

SubjectA.1.msh Mesh Name

Show Mesh

4 Number of Layers

185656 Number of Nodes

4 Number of Nodes/Element

FEM Session

sesNov20_10 Session Name

Enter conductivity values:

0.33 Scalp 0.0132 Skull

0.33 Brain 1.79 CSF

Load sensors 243 Sensors Loaded

Create Session

No Session

Forward Problem Solution

Load Source Space

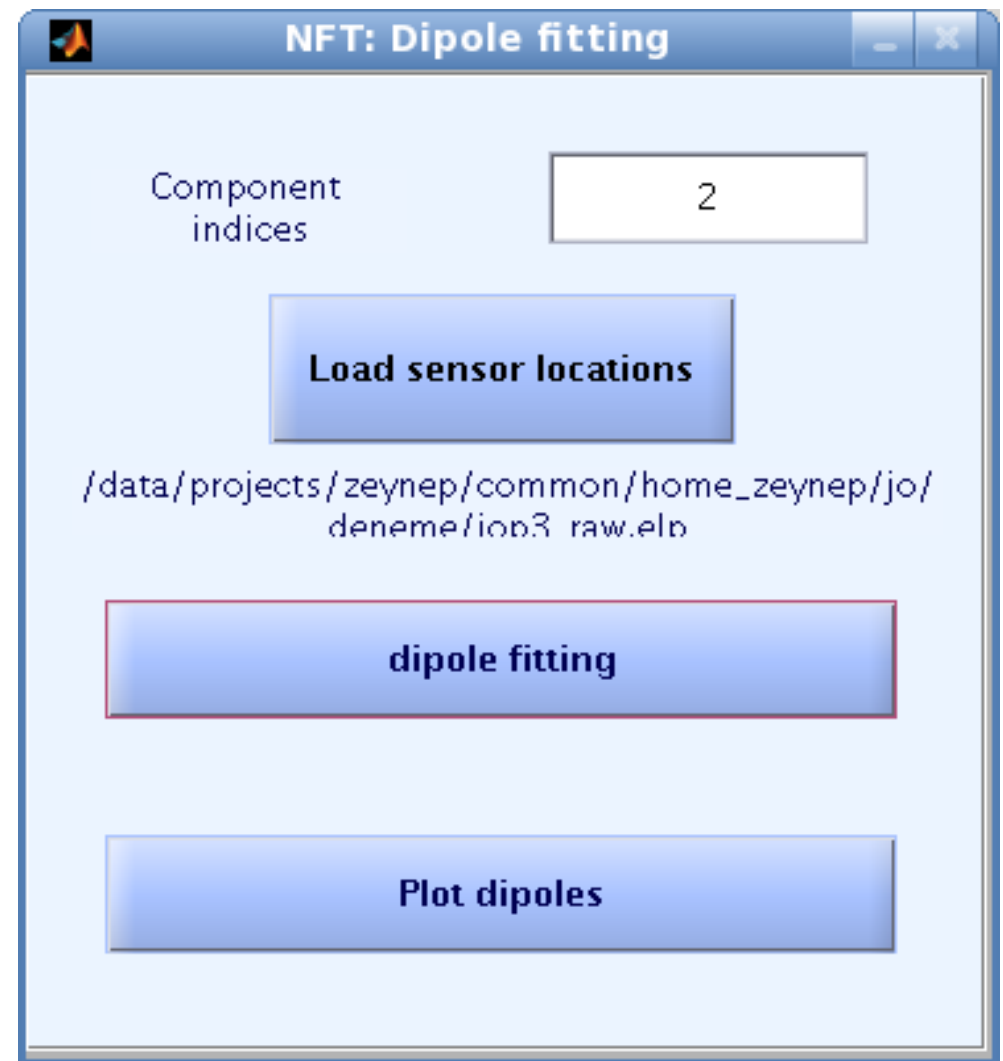
6447 Dipoles Loaded

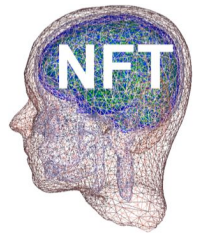
Compute Lead Field Matrix

Dipole Fitting

Dipole Fitting

- ◆ Requires EEGLAB integration to access Component indices.
- ◆ Uses FieldTrip in EEGLAB for dipole fitting.



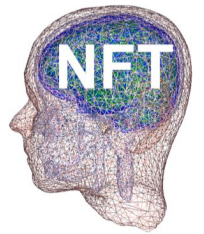


Output

- ◆ Dipole source localization is saved in EEG structure, under EEG.etc.nft.
- ◆ After source localization with NFT, you can continue using EEGLAB;
`EEG.dipfit.model = EEG.etc.nft.model;`



NFT download and reference



- ◆ <http://www.sccn.ucsd.edu/nft>
- ◆ Akalin Acar Z, Makeig S, Neuroelectromagnetic Forward Head Modeling Toolbox, J. of Neuroscience Methods, vol 190(2), 258-270, 2010.