



# 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

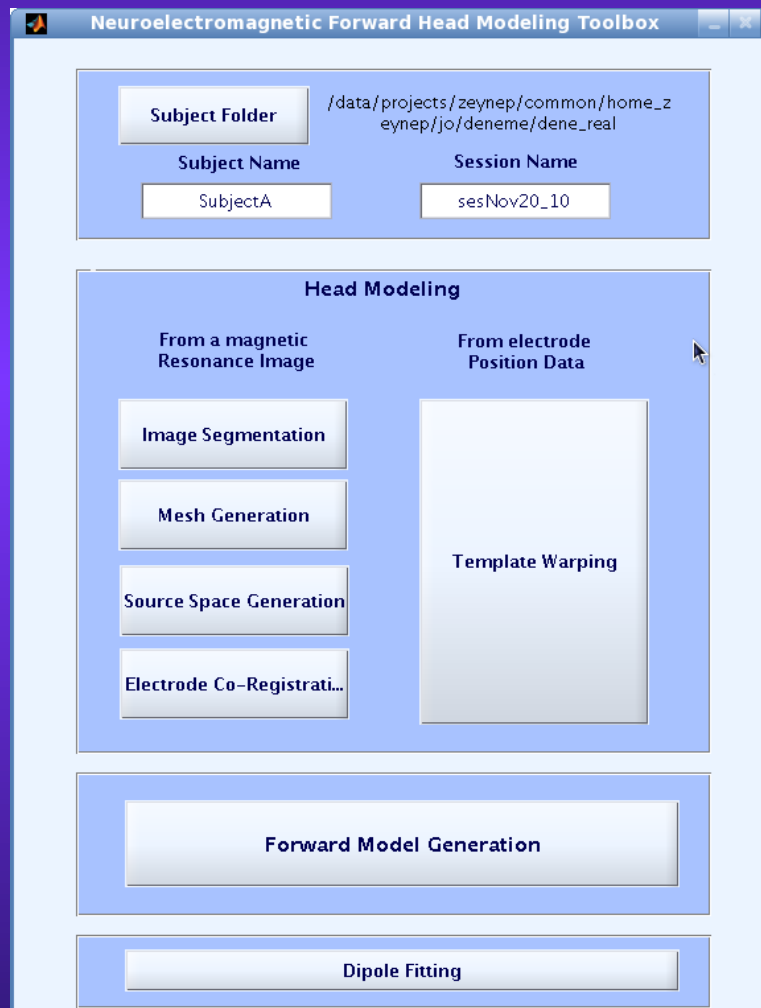
## T1 MR Images

- ◆ 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 sensors
- ◆ Warp Template to sensors
- ◆ Generate forward model
- ◆ Generate LFM for sensors

# NFT Main Menu



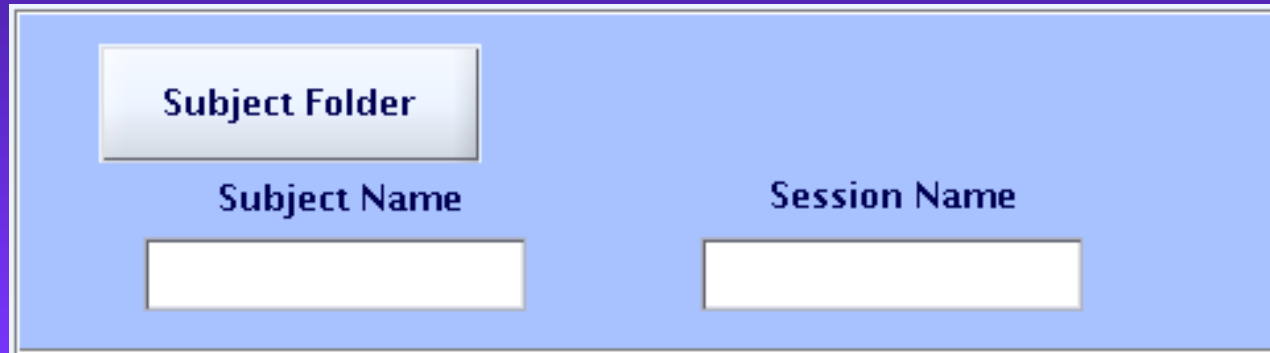
Subject Selection

Head Modeling

Forward Model Generation

Source Localization

# Subject Selection



A screenshot of a 'Subject Selection' form. The form is a light blue rectangle with a thin white border. Inside, there are three main components: a 'Subject Folder' button at the top left, a 'Subject Name' text input field at the bottom left, and a 'Session Name' text input field at the bottom right. The 'Subject Folder' button is a light blue rectangle with a white border and a slight 3D effect. The 'Subject Name' and 'Session Name' fields are white rectangles with light blue borders.

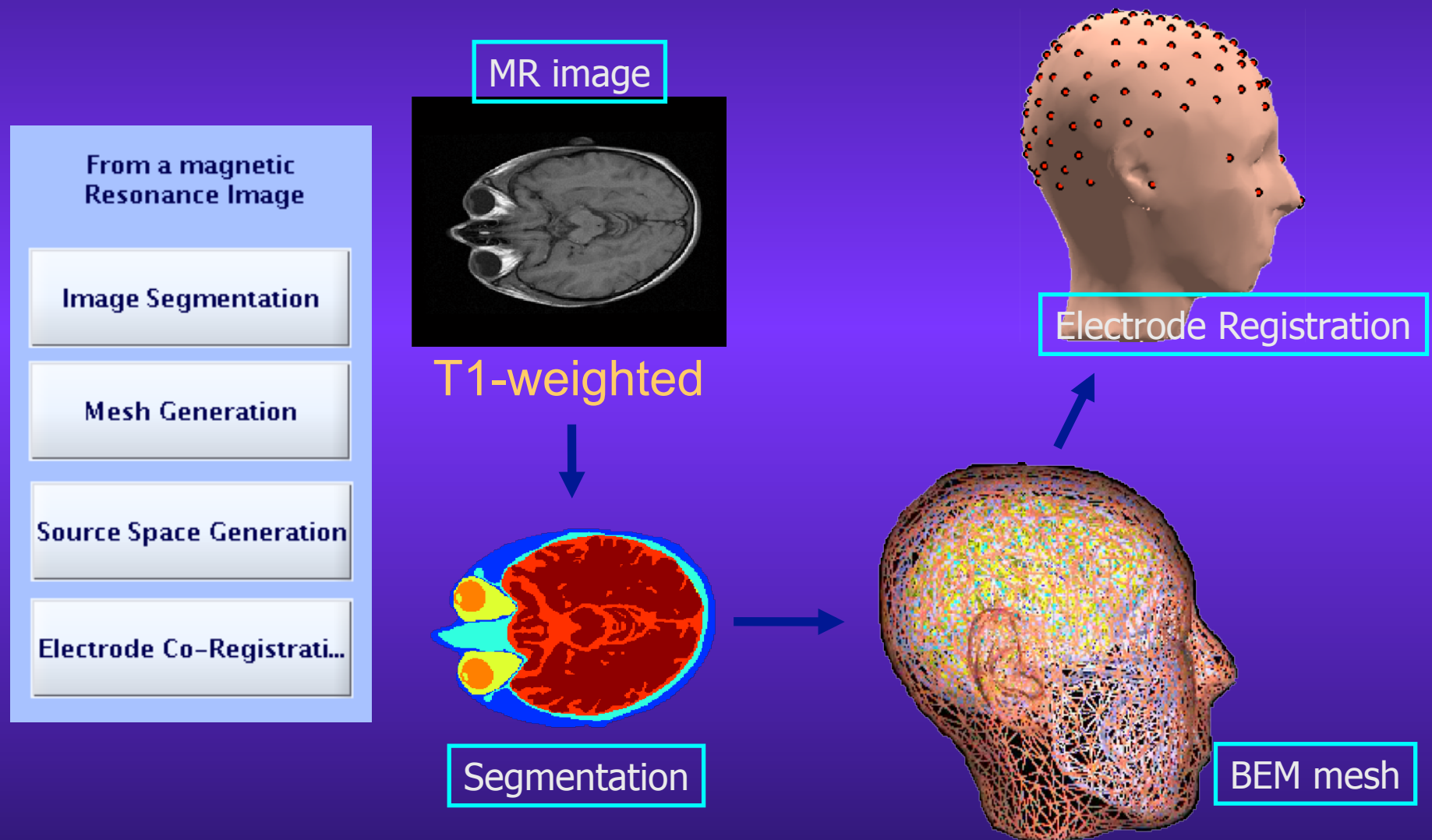
<b>Subject Folder</b>	
<b>Subject Name</b>	<b>Session Name</b>
<input type="text"/>	<input type="text"/>

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

# Subject Selection

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

# Head Modeling from MR Images



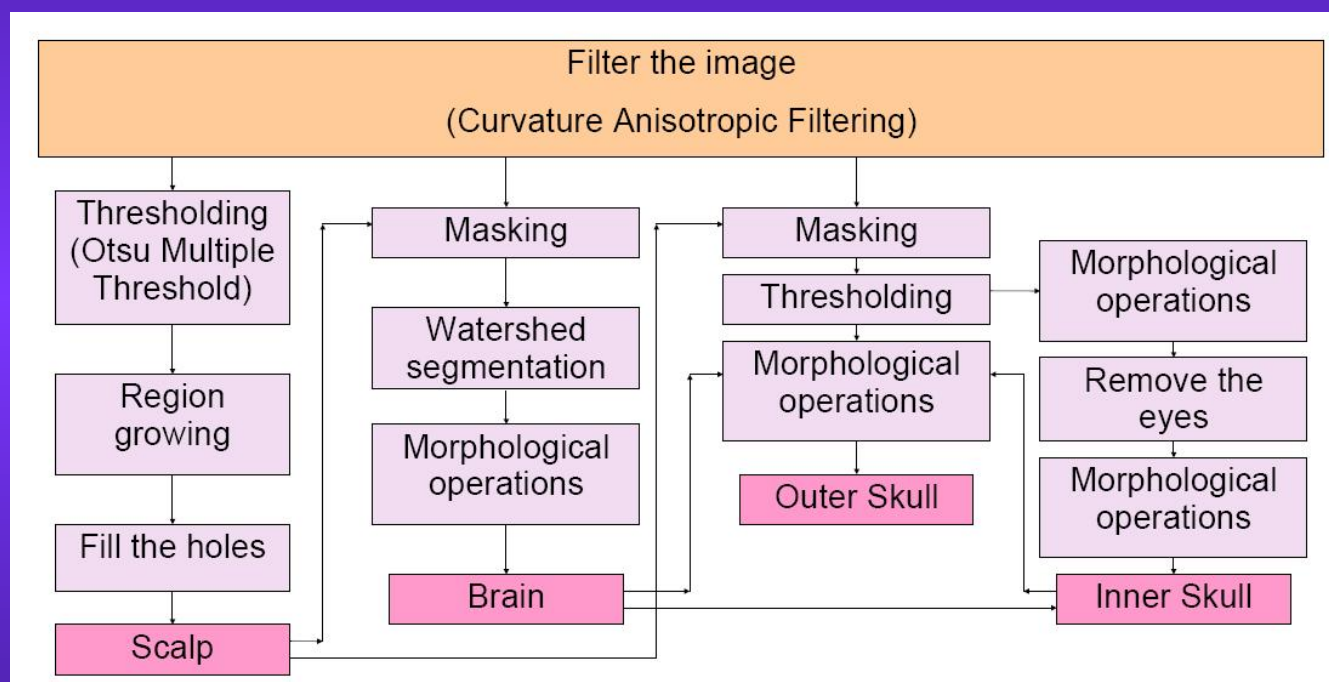
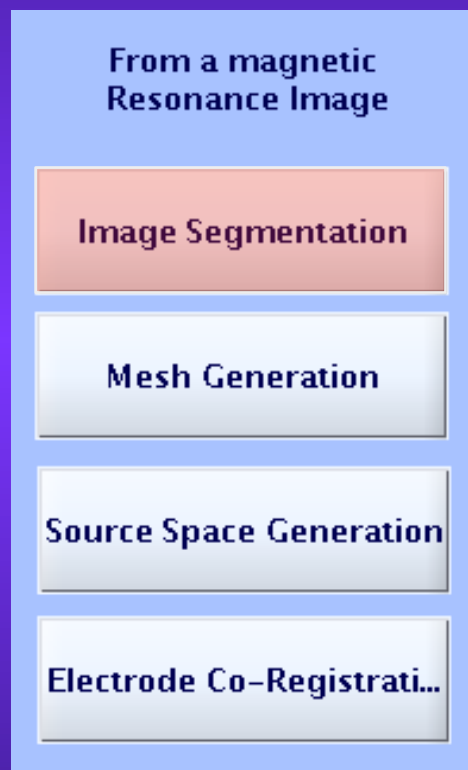


# Preparing the MR Image

## ◆ Using FreeSurfer

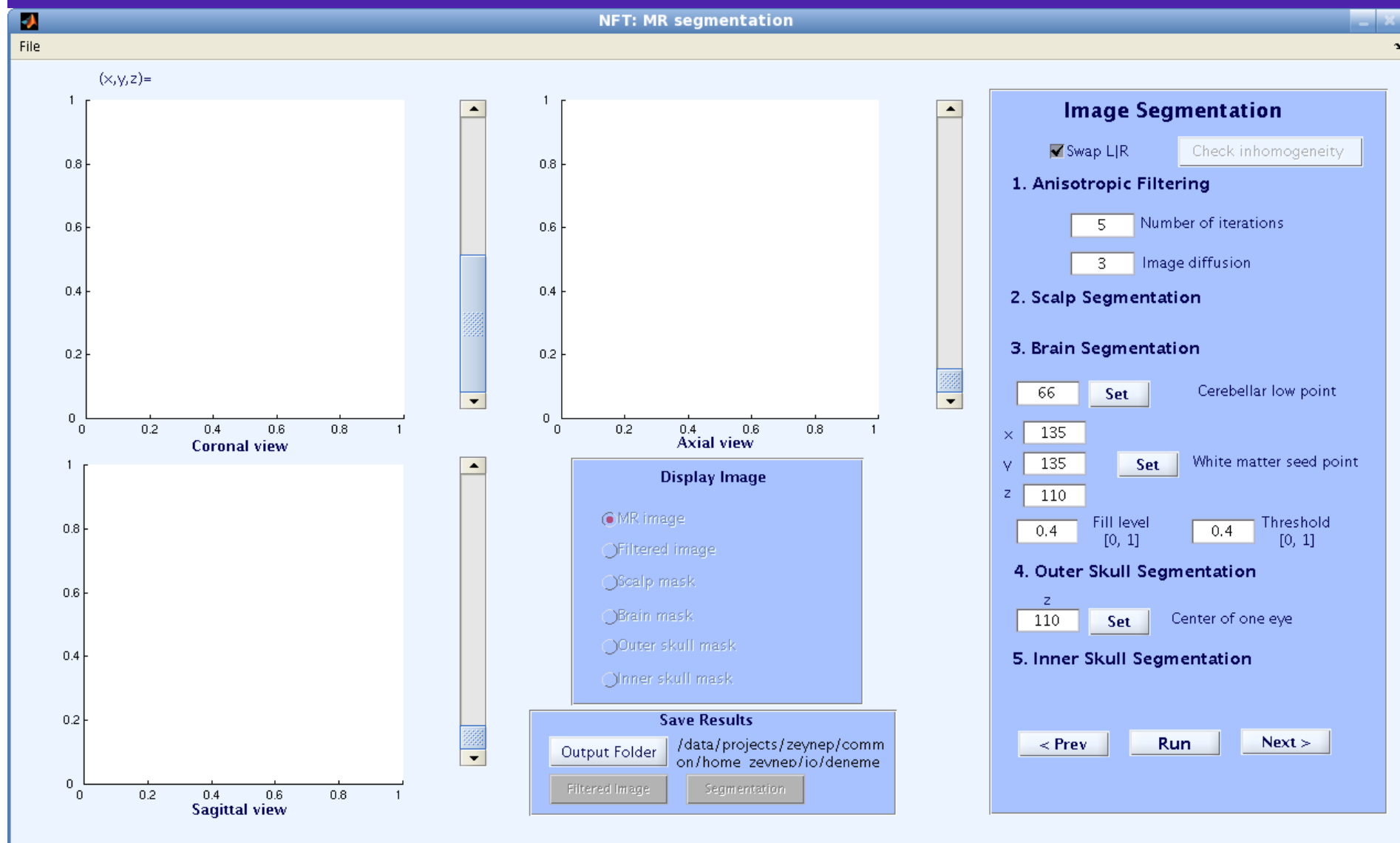
- Inhomogeneity correction
- Convert to 1x1x1 volume
- Arrange direction of the image
- Save in analyze format

# Image Segmentation

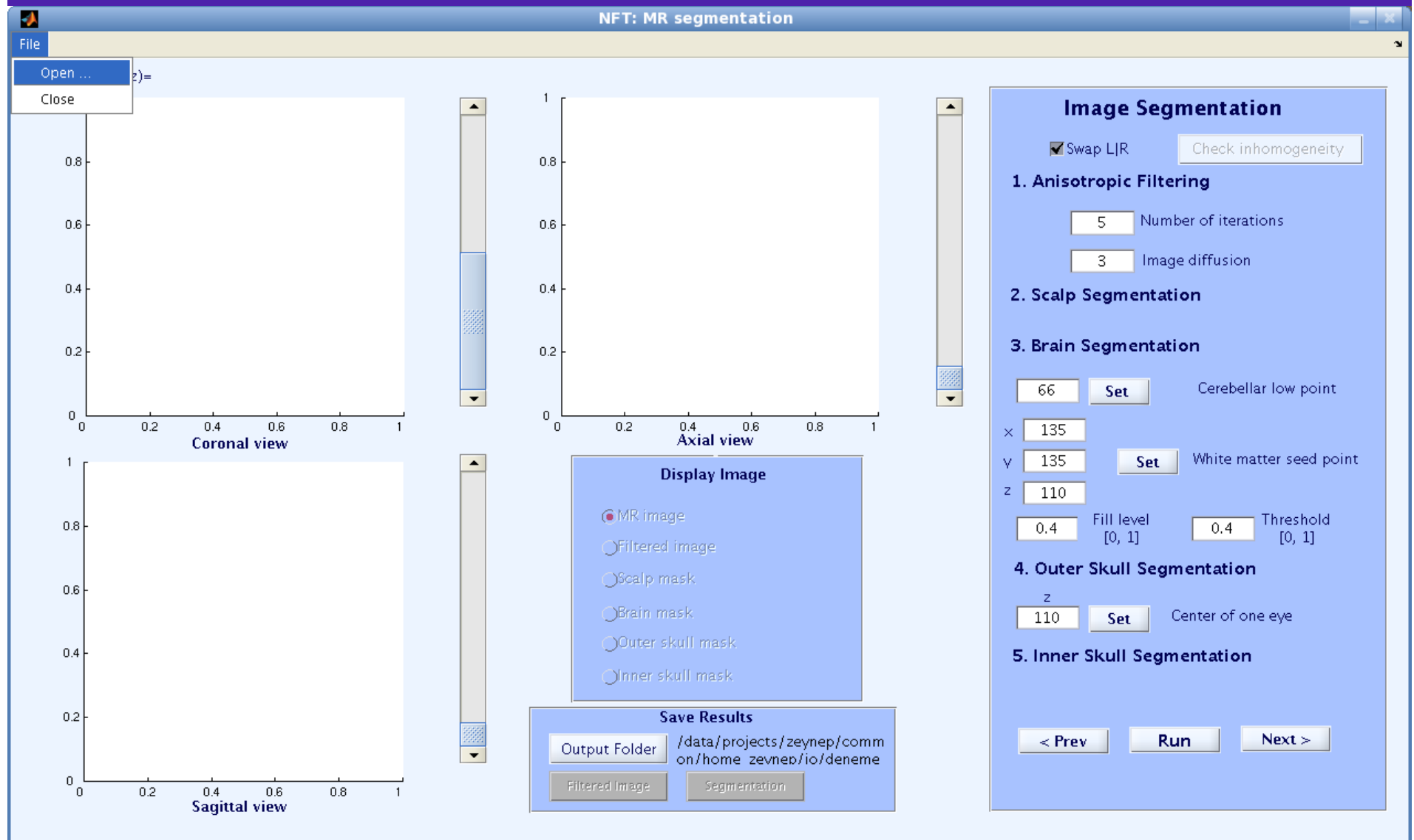


Classifies four tissues from T1-weighted images  
Scalp, Skull, CSF and Brain

# Image Segmentation

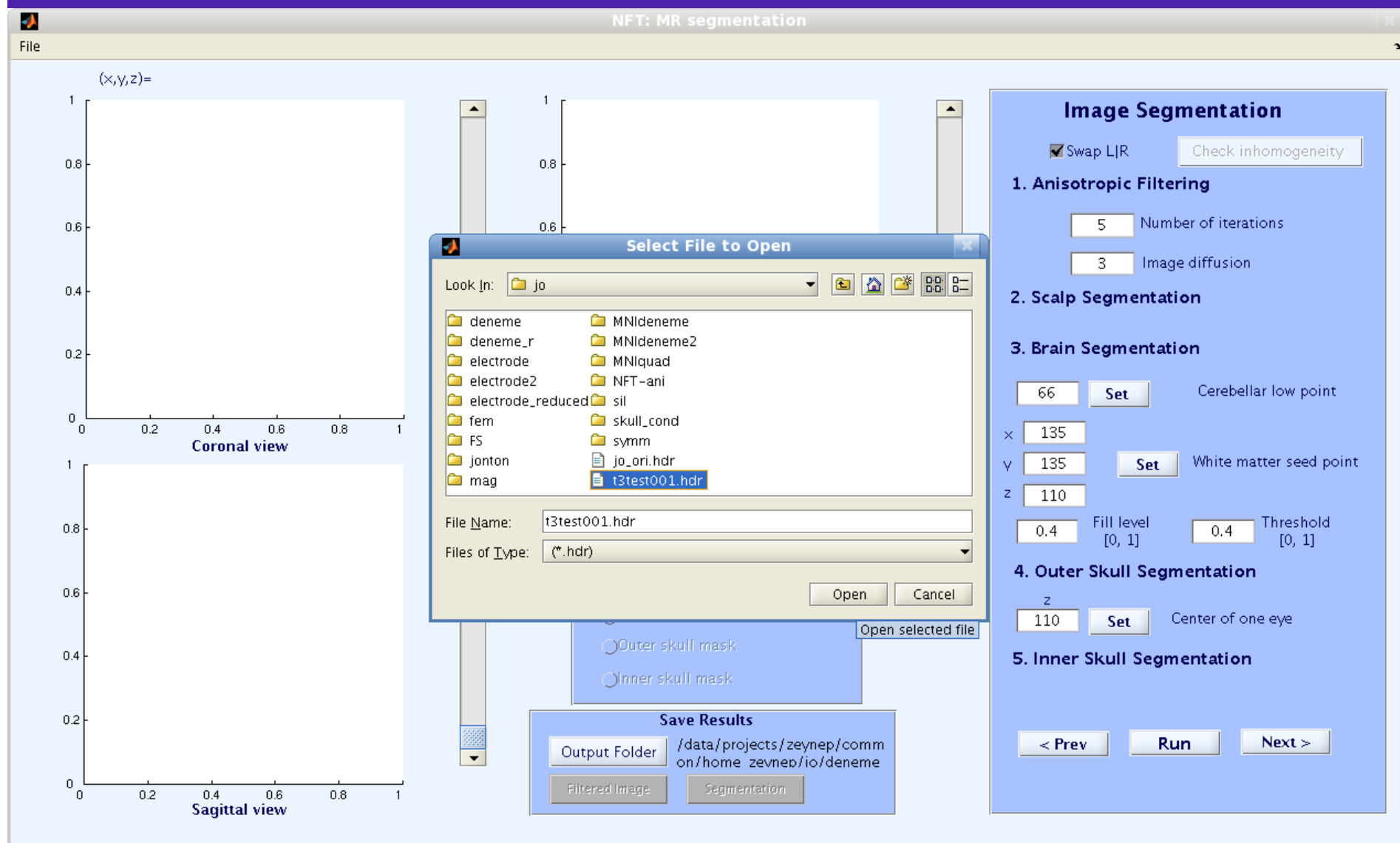


# Image Segmentation - load image



# Segmentation

Select an image in analyze format



# 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

1. Anisotropic Filtering

5 Number of iterations

3 Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

66  Cerebellar low point

x 135

y 135  White matter seed point

z 110

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

4. Outer Skull Segmentation

z 110  Center of one eye

5. Inner Skull Segmentation

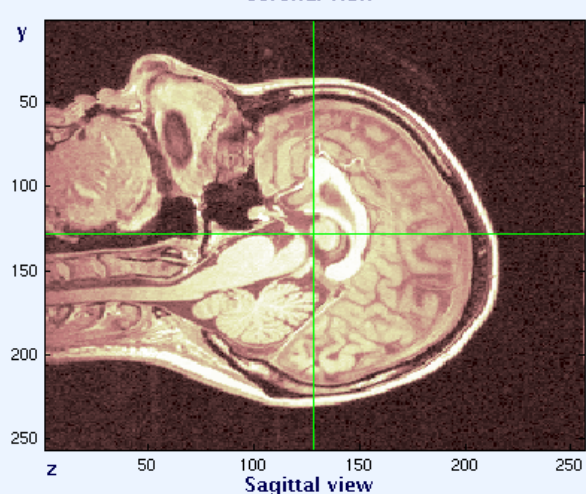
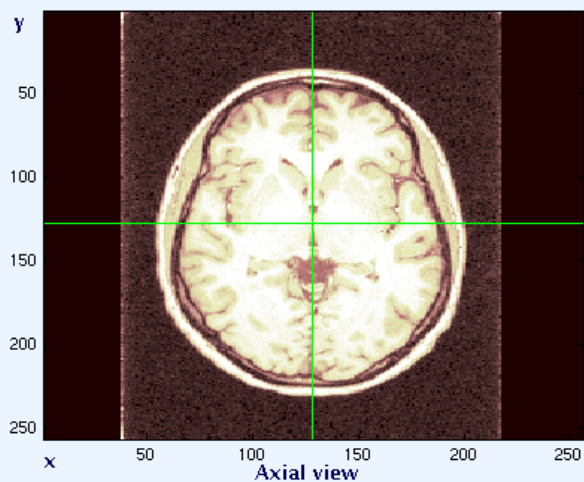
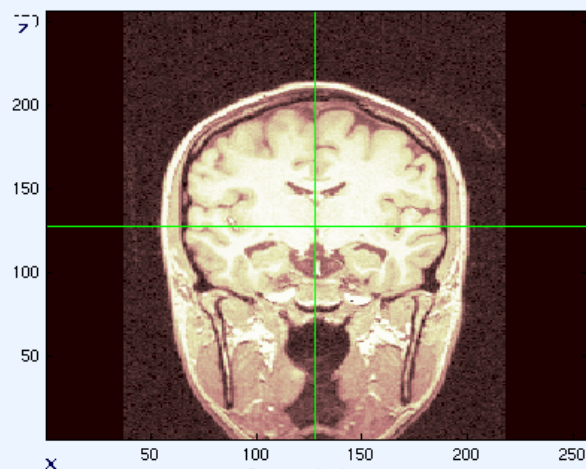
< Prev  Next >

# Segmentation

NFT: MR segmentation

File

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



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

5 Number of iterations

3 Image diffusion

## 2. Scalp Segmentation

## 3. Brain Segmentation

66 Set Cerebellar low point

x 135  
y 135 Set White matter seed point

z 110  
0.4 Fill level [0, 1] 0.4 Threshold [0, 1]

## 4. Outer Skull Segmentation

z 110 Set Center of one eye

## 5. Inner Skull Segmentation

< Prev Run Next >

Image is filtered!



# Segmentation

View filtered image

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

1. Anisotropic Filtering

5 Number of iterations

3 Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

66  Cerebellar low point

x 135

y 135  White matter seed point

z 110

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

4. Outer Skull Segmentation

z 110  Center of one eye

5. Inner Skull Segmentation

< Prev **Run** Next >

Image is filtered!



# Segmentation

Click 'Next' for scalp 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

1. Anisotropic Filtering

5 Number of iterations

3 Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

66  Cerebellar low point

x 135

y 135  White matter seed point

z 110

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

4. Outer Skull Segmentation

z 110  Center of one eye

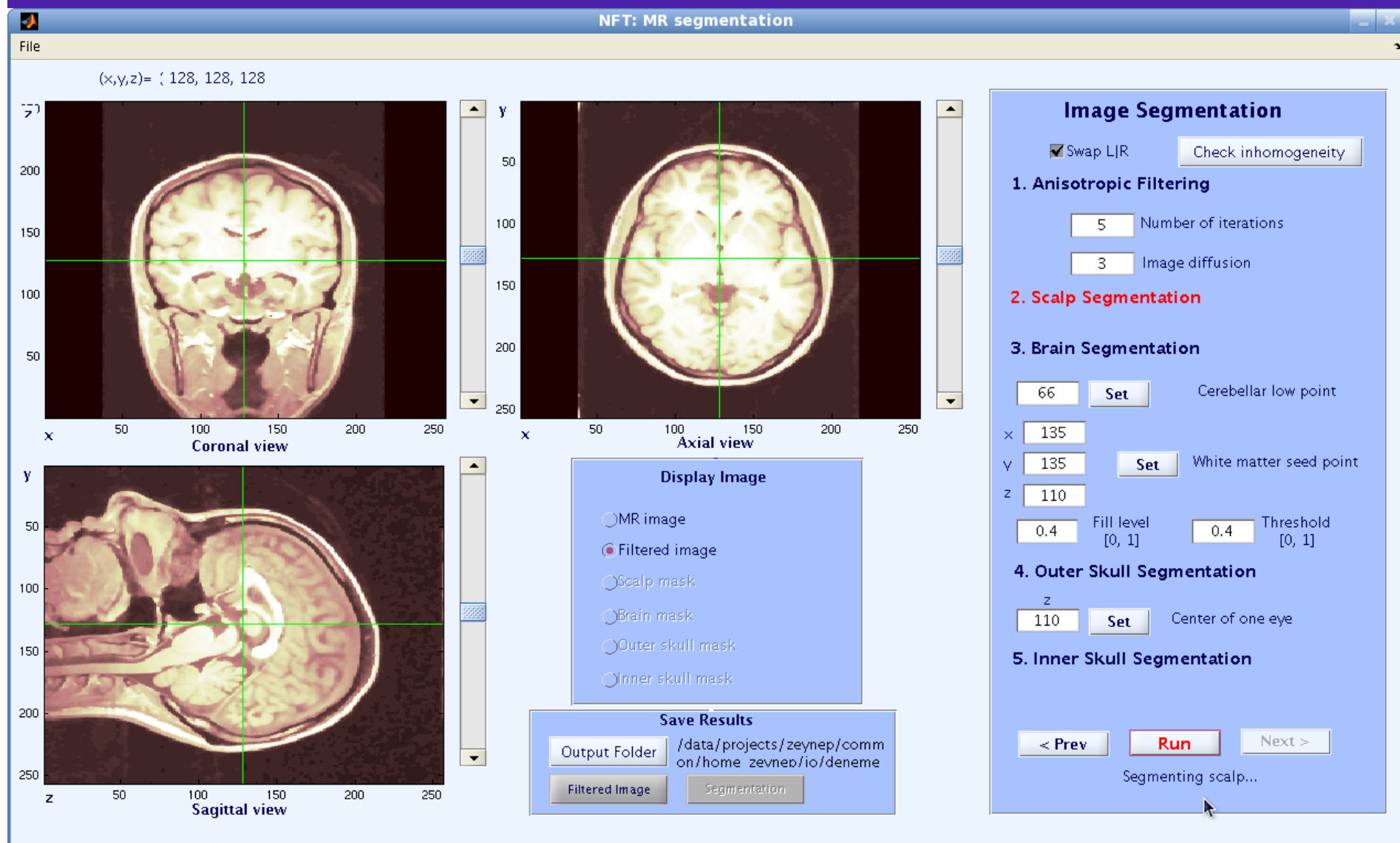
5. Inner Skull Segmentation

< Prev **Run** Next >

Image is filtered!

# Segmentation

Click 'Run' for scalp segmentation



# Image Segmentation

NFT: MR segmentation

File

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

70  
200  
150  
100  
50  
x 50 100 150 200 250  
Coronal view

y 50 100 150 200 250  
x 50 100 150 200 250  
Axial view

y 50 100 150 200 250  
z 50 100 150 200 250  
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

Scalp segmented!

# Segmentation

View scalp mask

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

1. Anisotropic Filtering

5 Number of iterations

3 Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

66  Cerebellar low point

x 135

y 135  White matter seed point

z 110

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

4. Outer Skull Segmentation

z 110  Center of one eye

5. Inner Skull Segmentation

< Prev **Run** Next >

Scalp segmented!

# Segmentation

Click 'Next' for brain 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

#### 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!

< Prev Run Next >

# Segmentation

Selection of cerebellar low point

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

1. Anisotropic Filtering

5 Number of iterations

3 Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

66  Cerebellar low point

x 135

y 135  White matter seed point

z 110

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

4. Outer Skull Segmentation

z 110  Center of one eye

5. Inner Skull Segmentation

< Prev Run Next >

Scalp segmented!



# 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

1. Anisotropic Filtering

5 Number of iterations

3 Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

67  Cerebellar low point

x 135

y 135  White matter seed point

z 110

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

4. Outer Skull Segmentation

z 110  Center of one eye

5. Inner Skull Segmentation

< Prev Run Next >

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 zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

☒ Swap L/R

1. Anisotropic Filtering

5 Number of iterations

3 Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

67  Cerebellar low point

x 135

y 135  White matter seed point

z 110

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

4. Outer Skull Segmentation

z 110  Center of one eye

5. Inner Skull Segmentation

< Prev **Run** Next >

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 zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

☒ Swap L/R

1. Anisotropic Filtering

5 Number of iterations

3 Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

67  Cerebellar low point

x 172

y 158  White matter seed point

z 150

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

4. Outer Skull Segmentation

z 110  Center of one eye

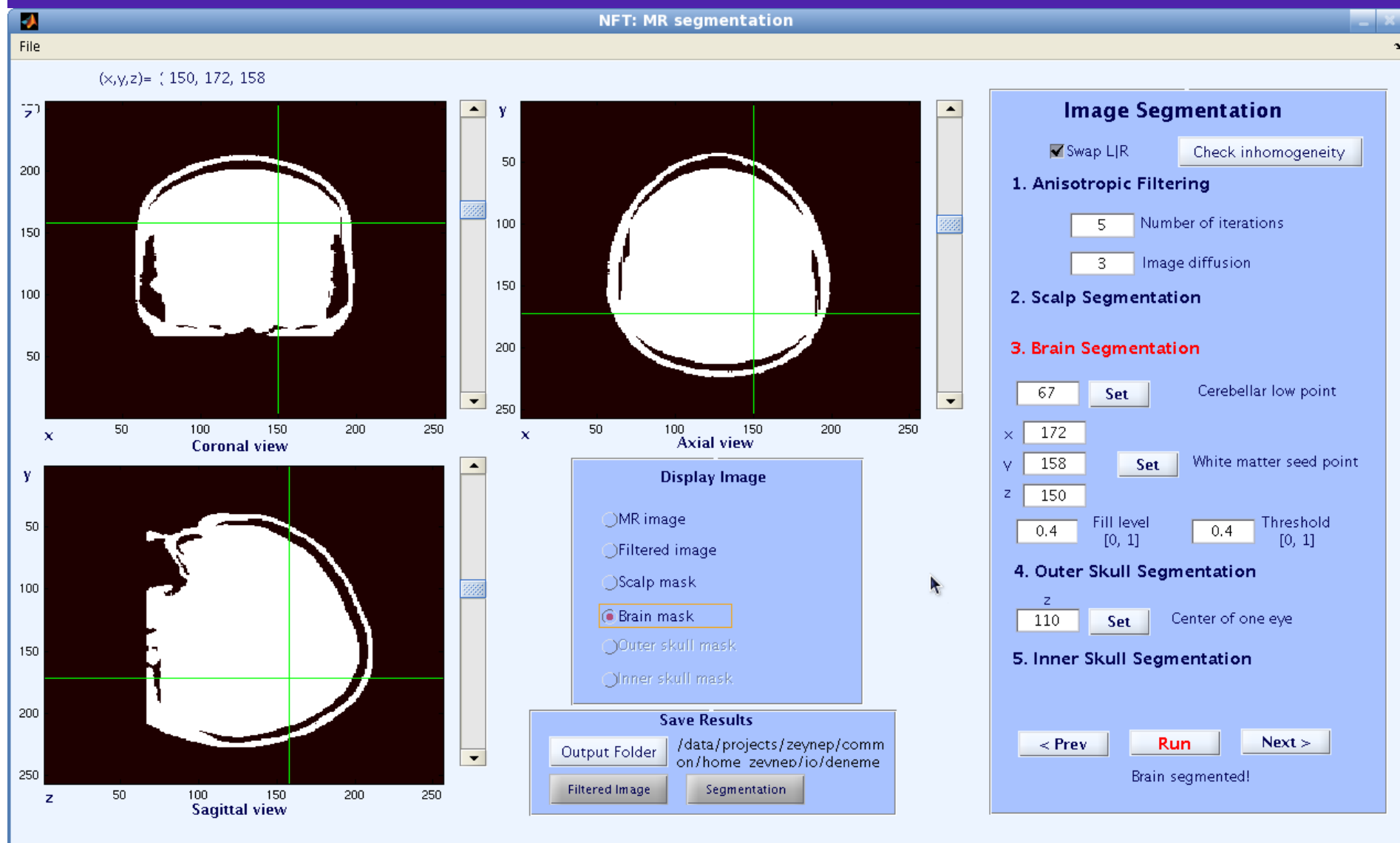
5. Inner Skull Segmentation

< Prev Run Next >

Scalp segmented!

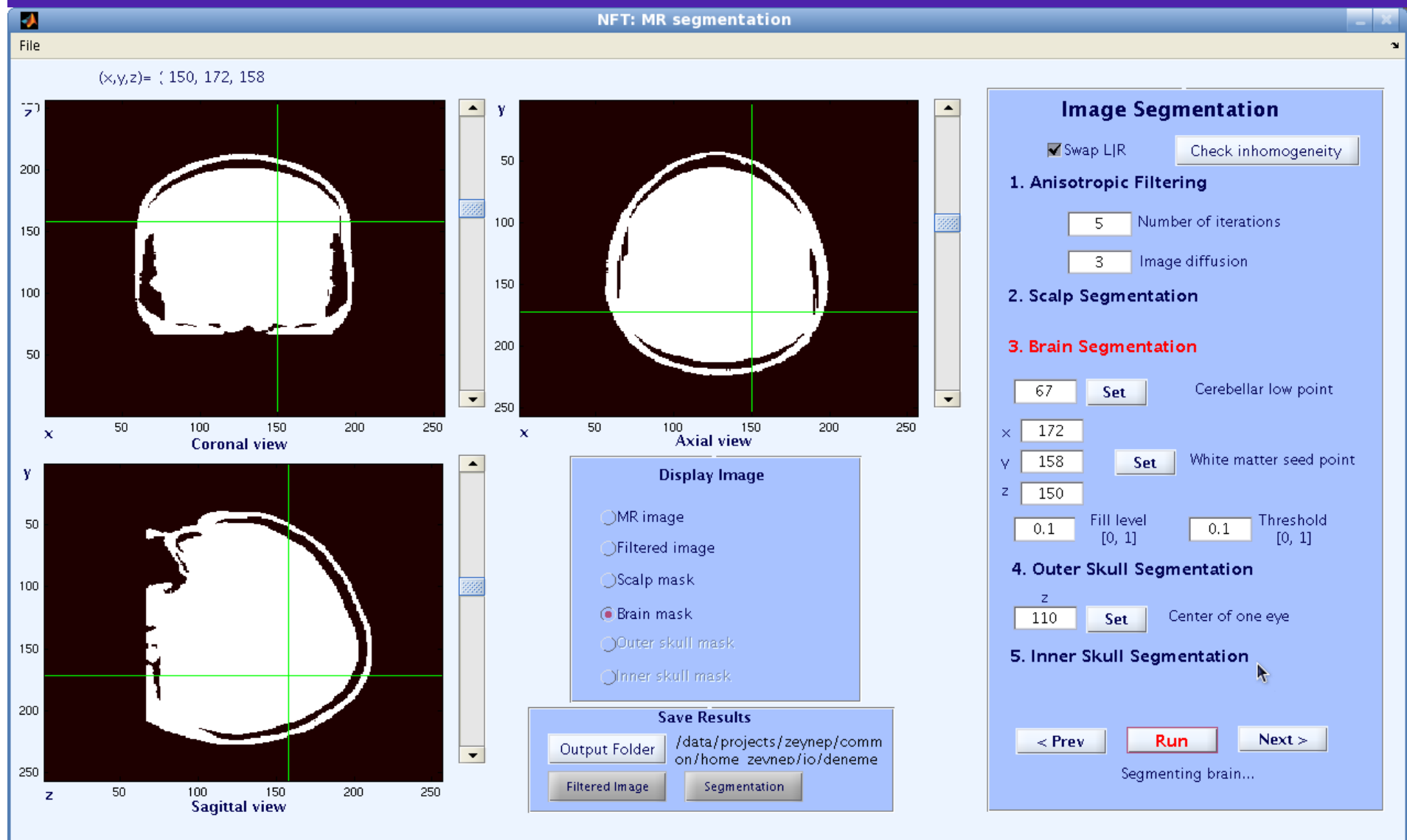
# Segmentation

Click 'Run' for brain segmentation



# Segmentation

Change thresholds if there is need



# Segmentation

View brain mask

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 zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

☒ Swap L/R

1. Anisotropic Filtering

5 Number of iterations

3 Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

67  Cerebellar low point

x 172

y 158  White matter seed point

z 150

0.1 Fill level [0, 1] 0.1 Threshold [0, 1]

4. Outer Skull Segmentation

z 110  Center of one eye

5. Inner Skull Segmentation

< Prev **Run** Next >

Brain segmented!

# Segmentation

Click 'Next' for skull segmentation

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 zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

☒ Swap L/R

1. Anisotropic Filtering

5 Number of iterations

3 Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

67  Cerebellar low point

x 172

y 158  White matter seed point

z 150

0.1 Fill level [0, 1] 0.1 Threshold [0, 1]

4. Outer Skull Segmentation

z 110  Center of one eye

5. Inner Skull Segmentation

< Prev **Run** Next >

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 zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

☒ Swap L/R

1. Anisotropic Filtering

5 Number of iterations

3 Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

67  Cerebellar low point

x 172

y 158  White matter seed point

z 150

0.1 Fill level [0, 1] 0.1 Threshold [0, 1]

4. Outer Skull Segmentation

z 110  Center of one eye

5. Inner Skull Segmentation

< Prev **Run** Next >

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

Filtered Image Segmentation

Image Segmentation

☒ Swap L/R

1. Anisotropic Filtering

5 Number of iterations

3 Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

67  Cerebellar low point

x 172

y 158  White matter seed point

z 150

0.1 Fill level [0, 1] 0.1 Threshold [0, 1]

4. Outer Skull Segmentation

z 95  Center of one eye

5. Inner Skull Segmentation

< Prev Run Next >

Brain segmented!

# Segmentation

Click 'Run' for 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

1. Anisotropic Filtering

5 Number of iterations

3 Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

67  Cerebellar low point

x 172

y 158  White matter seed point

z 150

0.1 Fill level [0, 1] 0.1 Threshold [0, 1]

4. Outer Skull Segmentation

z 95  Center of one eye

5. Inner Skull Segmentation

< Prev **Run** Next >

Segmenting skull...



# Segmentation

Click on the eyes

NFT: MR segmentation

File Edit View Insert Tools Desktop Window Help

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

Coronal view

Sagittal view

Figure 2

File Edit View Insert Tools Desktop Window Help

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

5 Number of iterations

3 Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

67 Set Cerebellar low point

x 172

y 158 Set White matter seed point

z 150

0.1 Fill level [0, 1] 0.1 Threshold [0, 1]

4. Outer Skull Segmentation

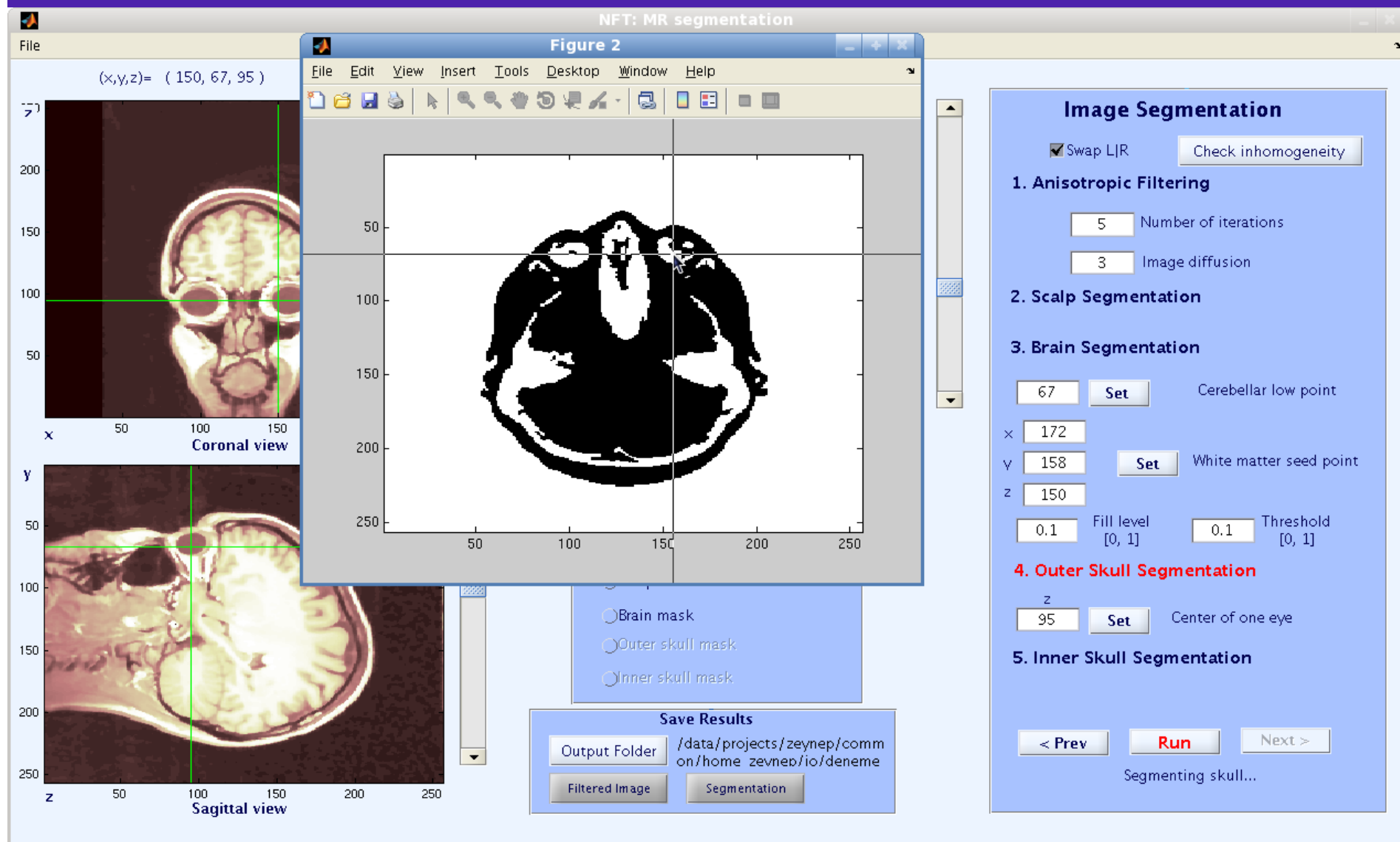
z 95 Set Center of one eye

5. Inner Skull Segmentation

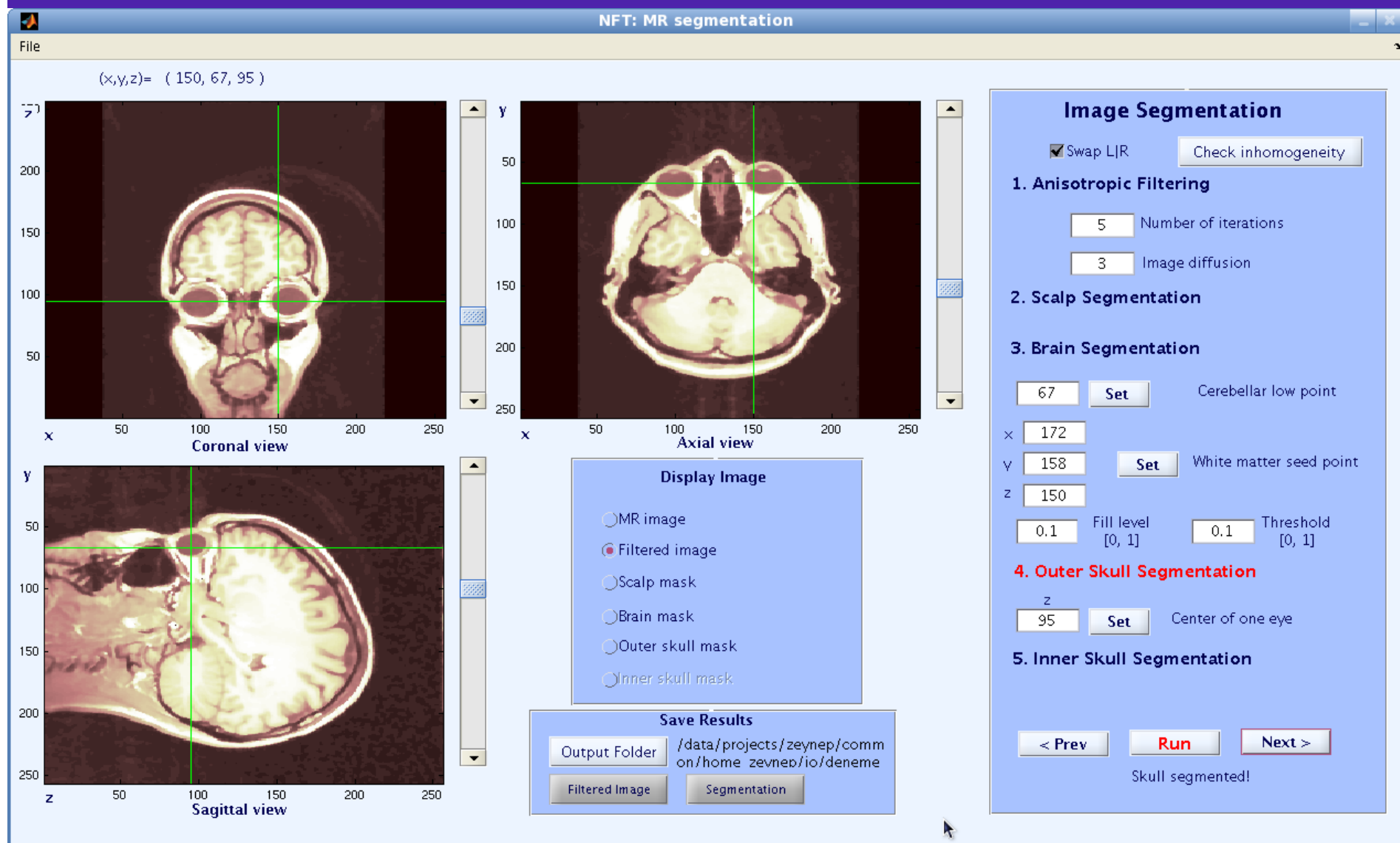
< Prev Run Next >

Segmenting skull...

# Segmentation



# Segmentation



# Segmentation

View 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

1. Anisotropic Filtering

5 Number of iterations

3 Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

67  Cerebellar low point

x 172

y 158  White matter seed point

z 150

0.1 Fill level [0, 1] 0.1 Threshold [0, 1]

4. Outer Skull Segmentation

z 95  Center of one eye

5. Inner Skull Segmentation

< Prev **Run** Next >

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 zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

☒ Swap L/R

1. Anisotropic Filtering

5 Number of iterations

3 Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

67  Cerebellar low point

x 172

y 158  White matter seed point

z 150

0.1 Fill level [0, 1] 0.1 Threshold [0, 1]

4. Outer Skull Segmentation

z 95  Center of one eye

5. Inner Skull Segmentation

< Prev **Run** Next >

Skull segmented!

# Segmentation

Click 'Run' 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 zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

☒ Swap L/R

1. Anisotropic Filtering

5 Number of iterations

3 Image diffusion

2. Scalp Segmentation

3. Brain Segmentation

67  Cerebellar low point

x 172

y 158  White matter seed point

z 150

0.1 Fill level [0, 1] 0.1 Threshold [0, 1]

4. Outer Skull Segmentation

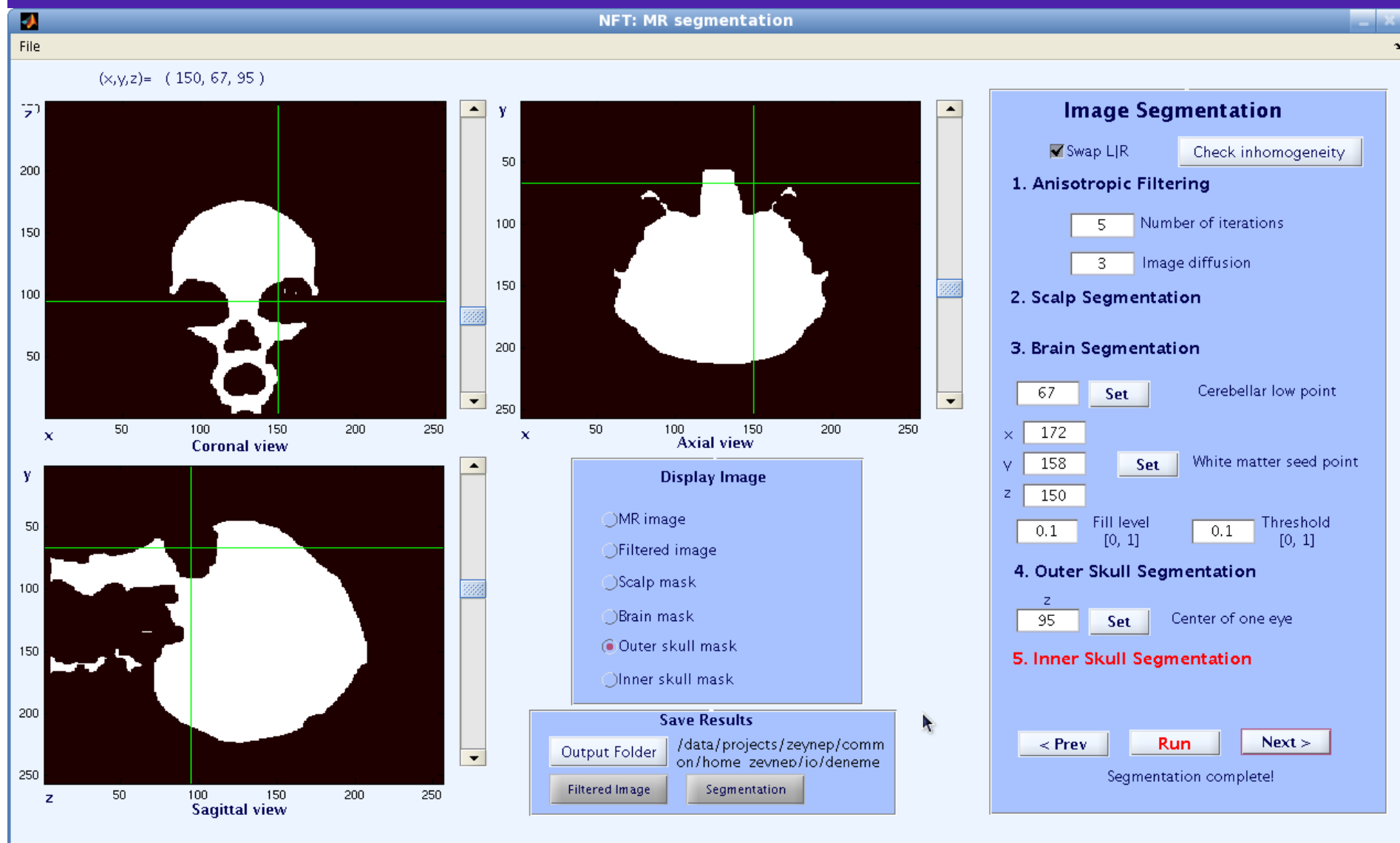
z 95  Center of one eye

5. Inner Skull Segmentation

< Prev **Run** Next >

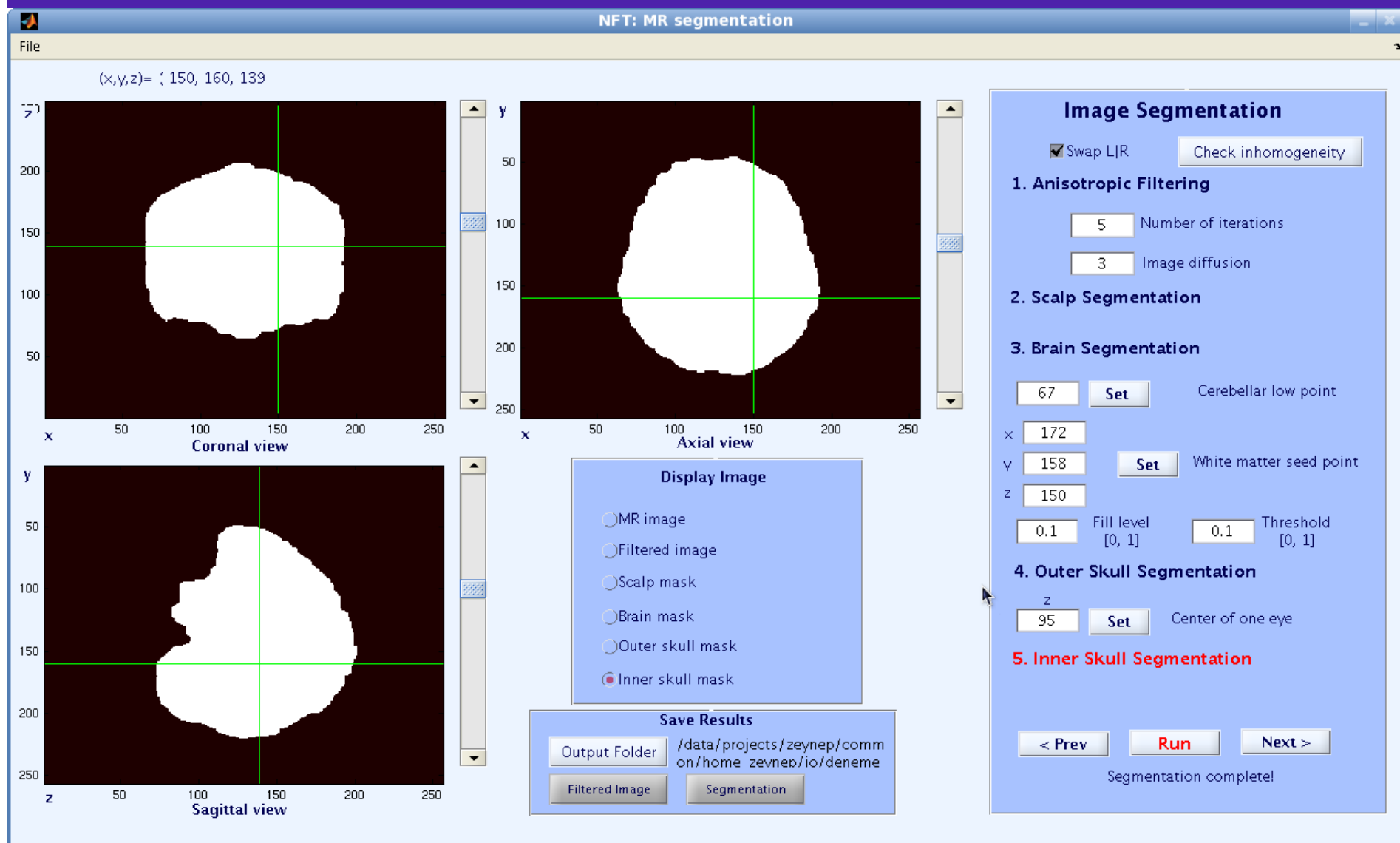
Segmenting CSF...

# Segmentation



# Segmentation

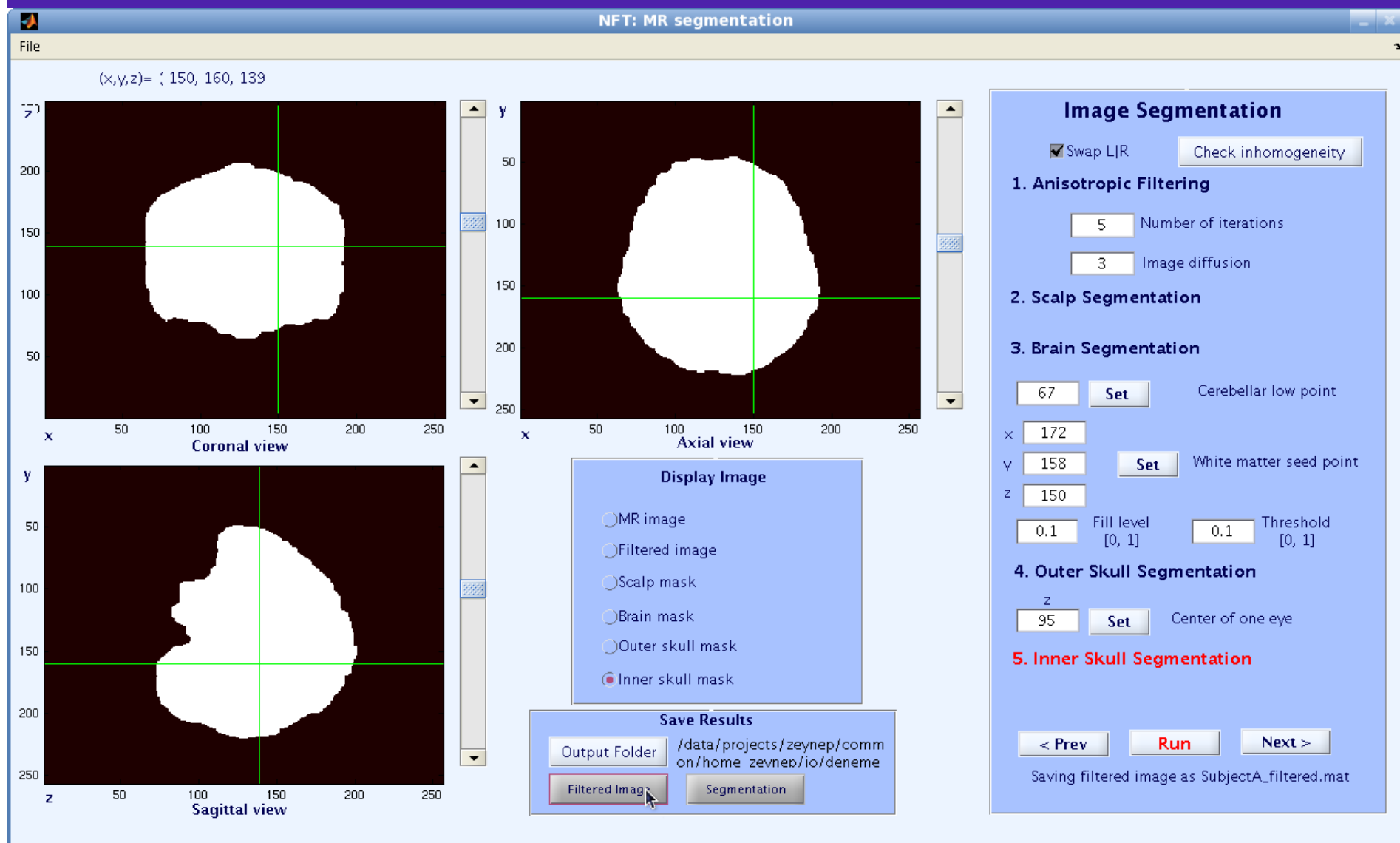
View CSF segmentation



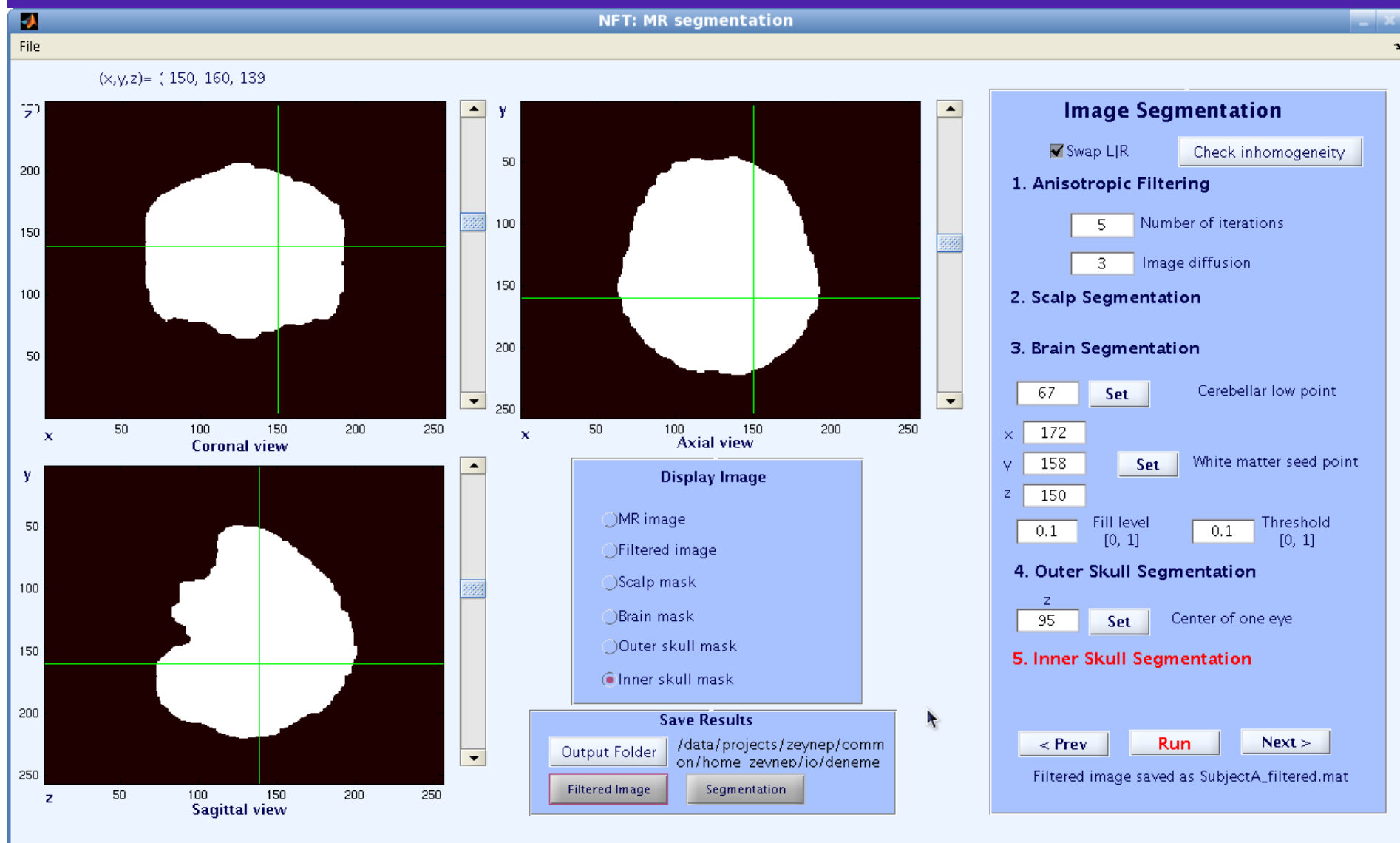


# Segmentation

Save filtered image

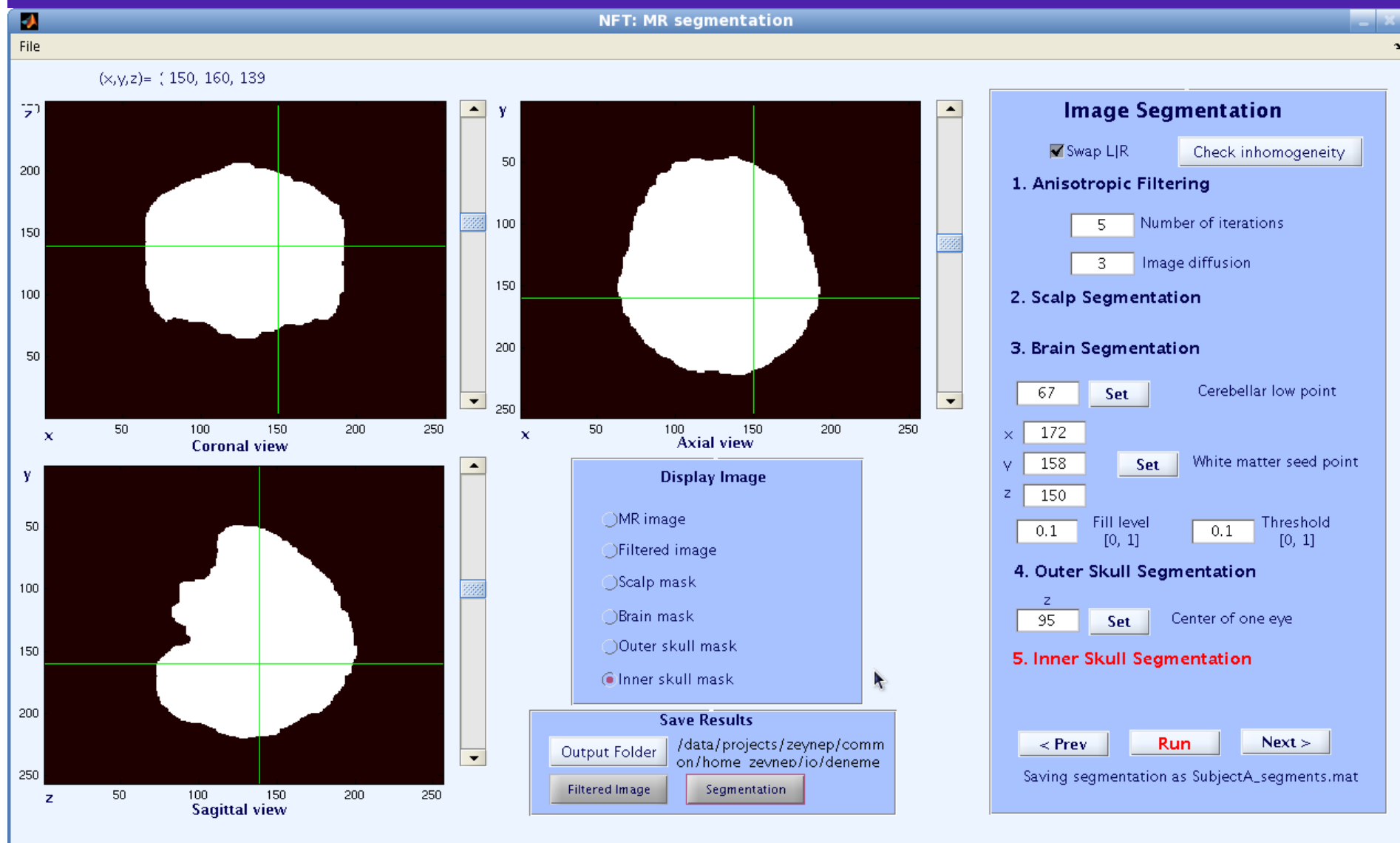


# Segmentation

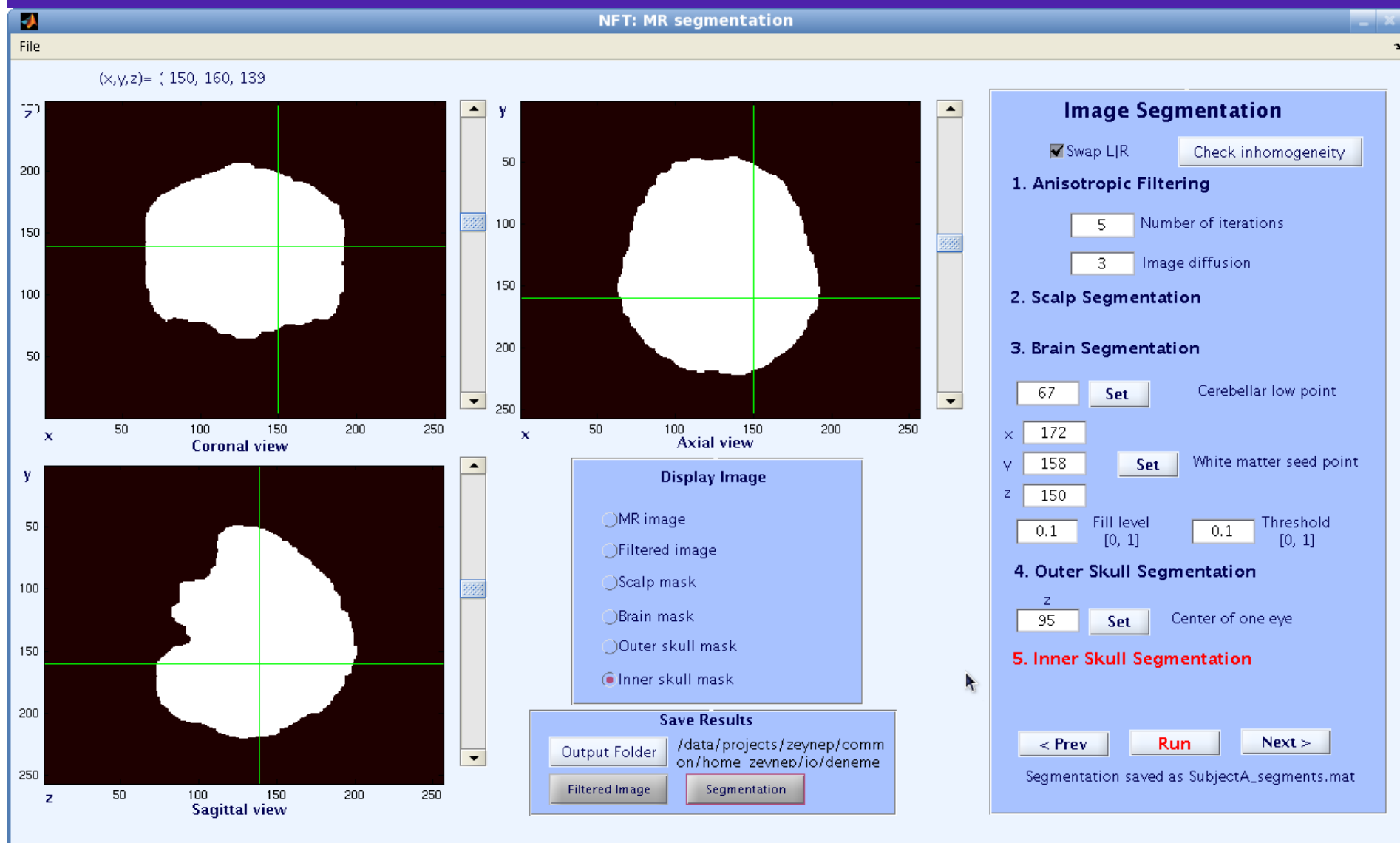


# Segmentation

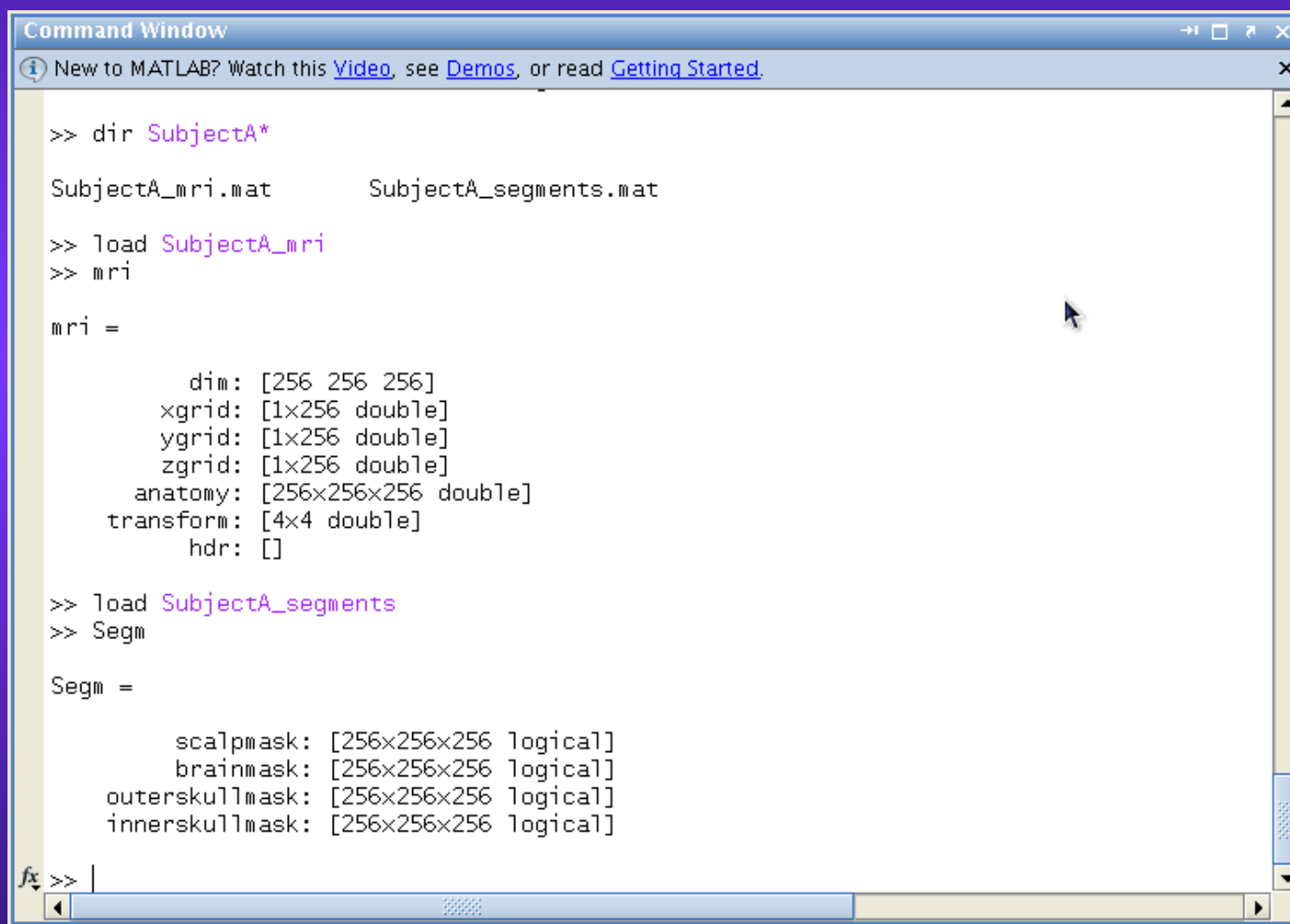
Save segmentation



# Segmentation



# 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]
```

# 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/dene\_real/SubjectA\_segments

Output Folder /data/projects/zeynep/common/home\_zeynep/jo/deneme/dene\_real

4 # of layers Mesh name: SubjectA

☒ Linear ☐ Quadratic 7000 Number of nodes per layer

☐ Local mesh refinement  
2.0 Edge length/  
Distance between meshes

Start Mesh Generation

Status

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

# Mesh Generation

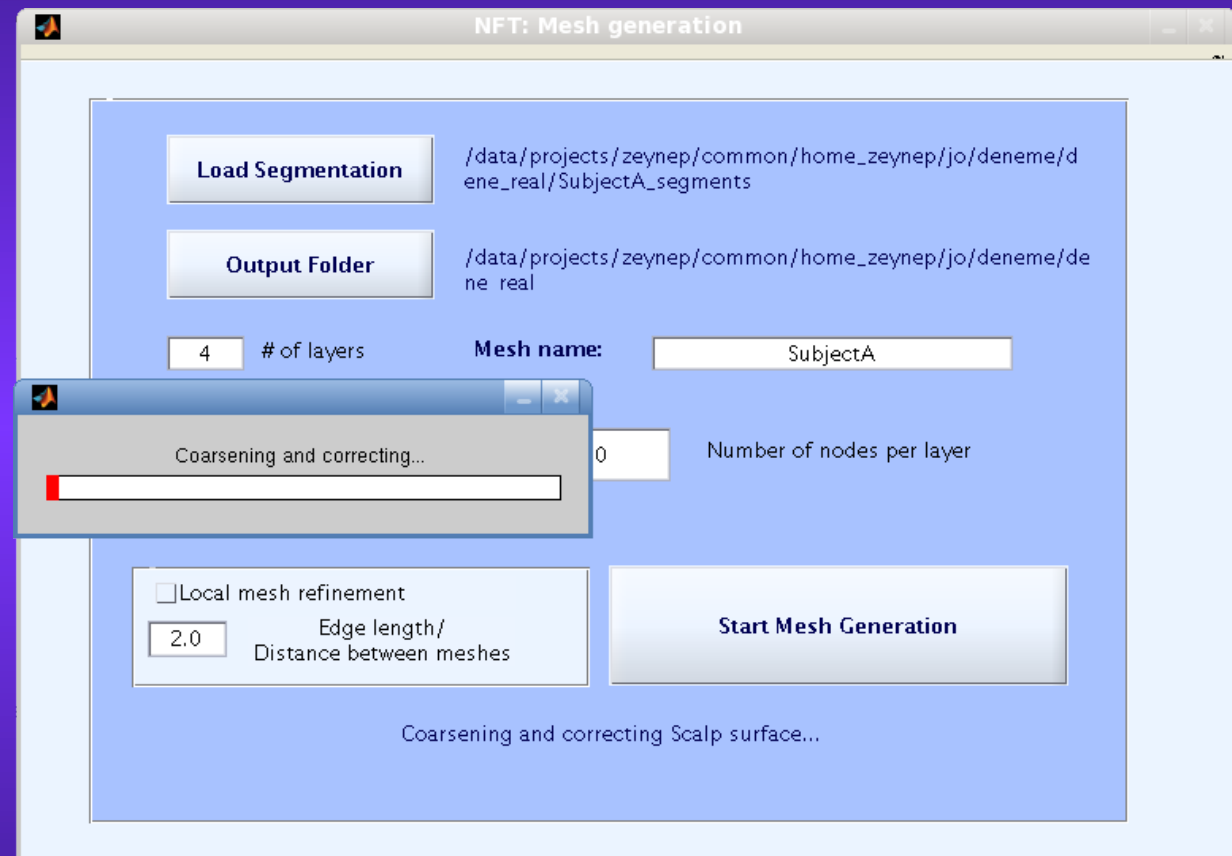
From a magnetic  
Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registrati...



# 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/dene\_real/SubjectA\_segments

Output Folder /data/projects/zeynep/common/home\_zeynep/jo/deneme/dene\_real

4 # of layers Mesh name: SubjectA

☒ Linear ☐ Quadratic 7000 Number of nodes per layer

☐ Local mesh refinement  
2.0 Edge length/  
Distance between meshes

Start Mesh Generation

Mesh saved!



# Source Space Generation

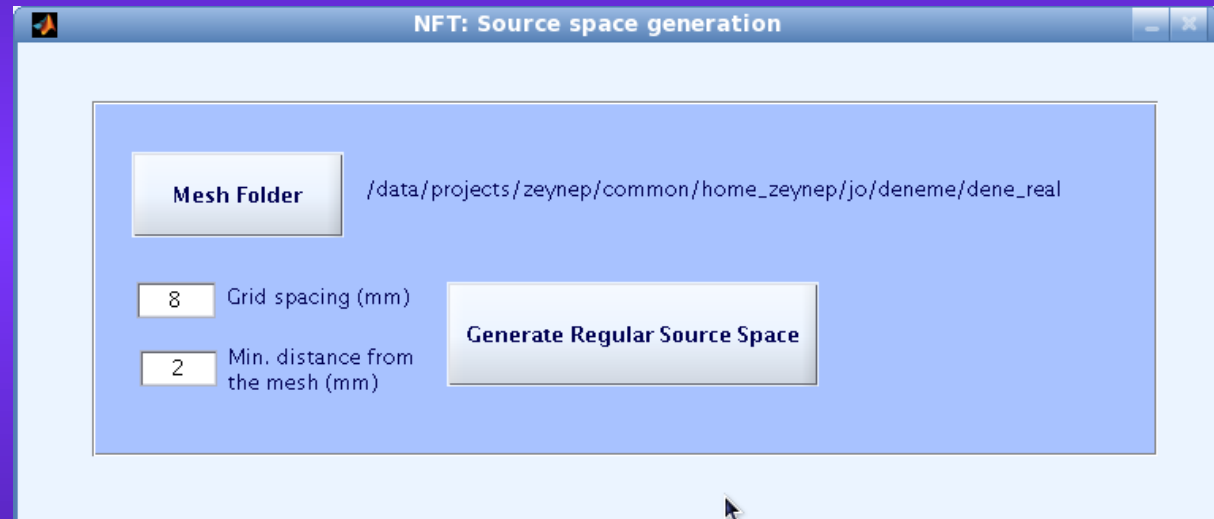
From a magnetic  
Resonance Image

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...

NFT: Source space generation

Mesh Folder

Grid spacing (mm)

Min. distance from the mesh (mm)

**Generate Regular Source Space** Source space saved!

# 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** Electrode file name

**Mesh Folder** /data/projects/zeynep/common/home\_zeynep/jo/deneme/dene\_real

**Initial co-registration** Translation  
Rotation

**Complete co-registration** Translation  
Rotation

Save initial reg. Save complete reg.

# Electrode Co-registration

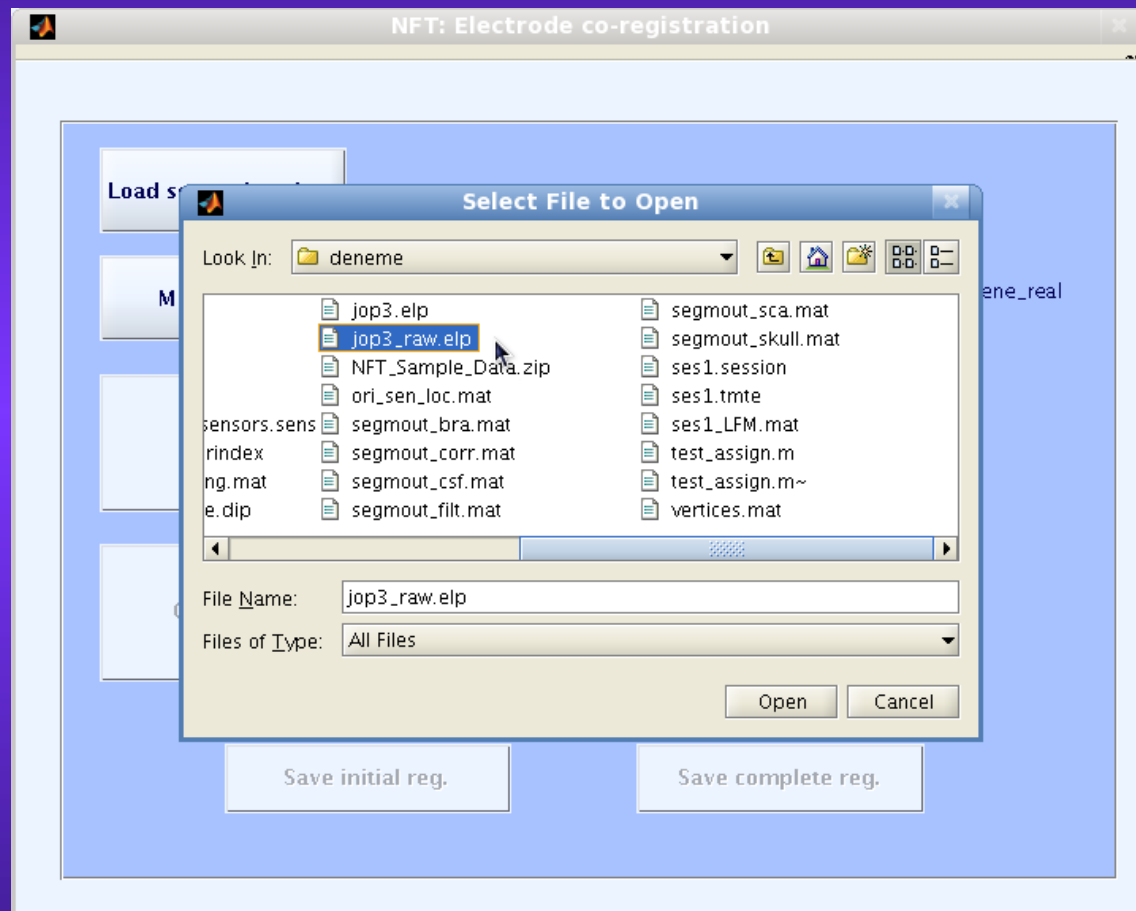
From a magnetic  
Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registrati...



# Electrode Co-registration

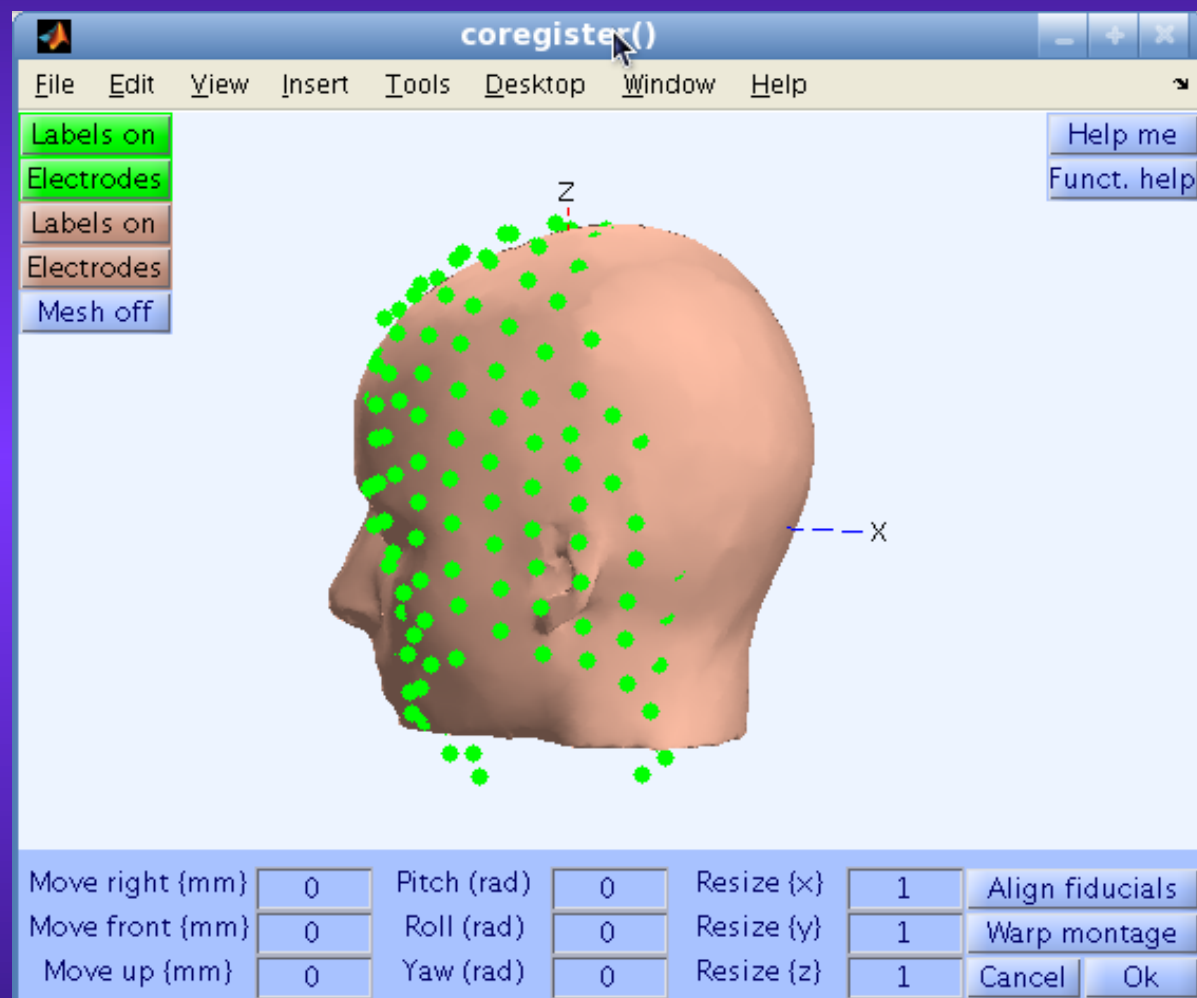
From a magnetic  
Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registrati...



# Electrode Co-registration

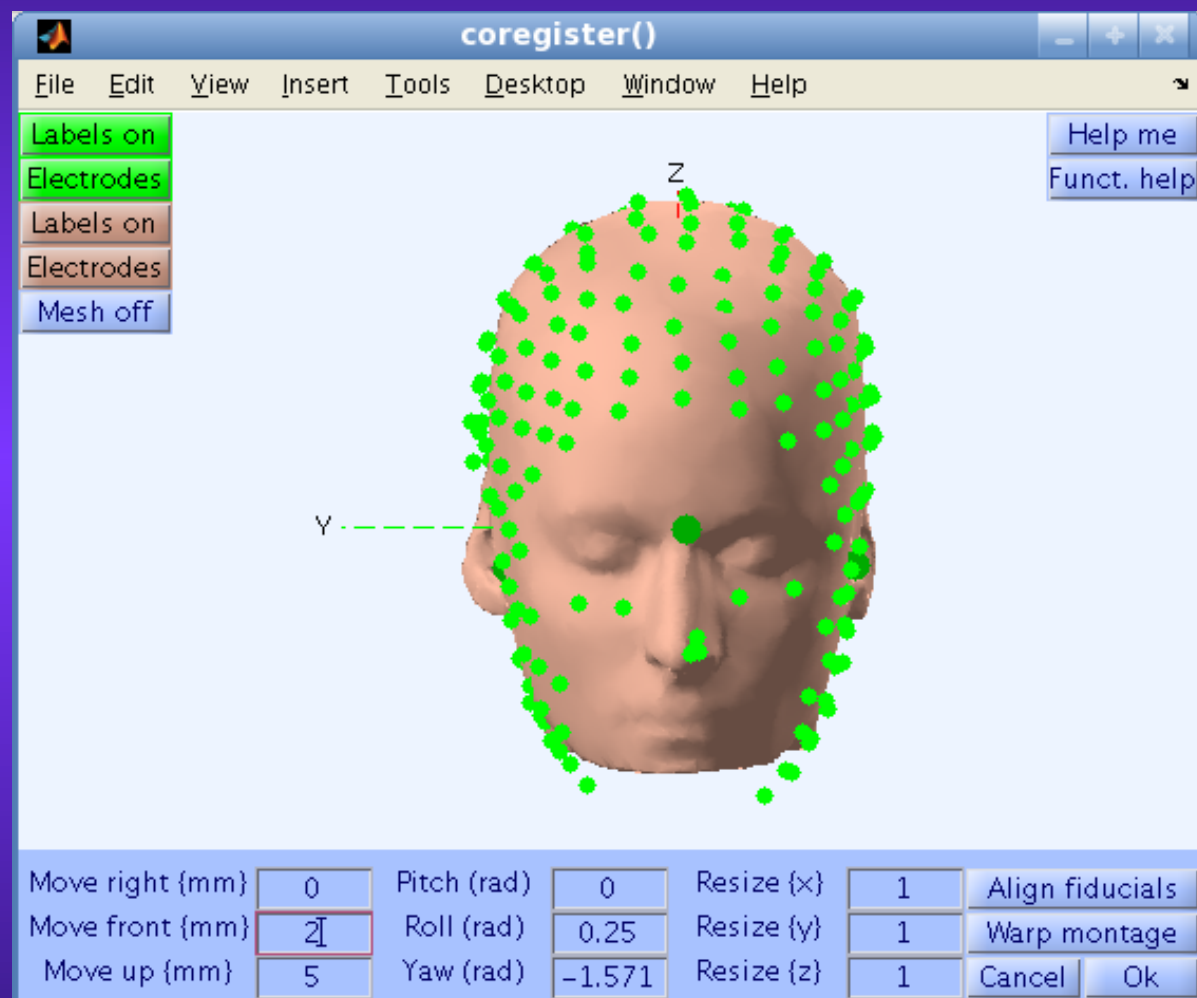
From a magnetic  
Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registrati...



# Electrode Co-registration

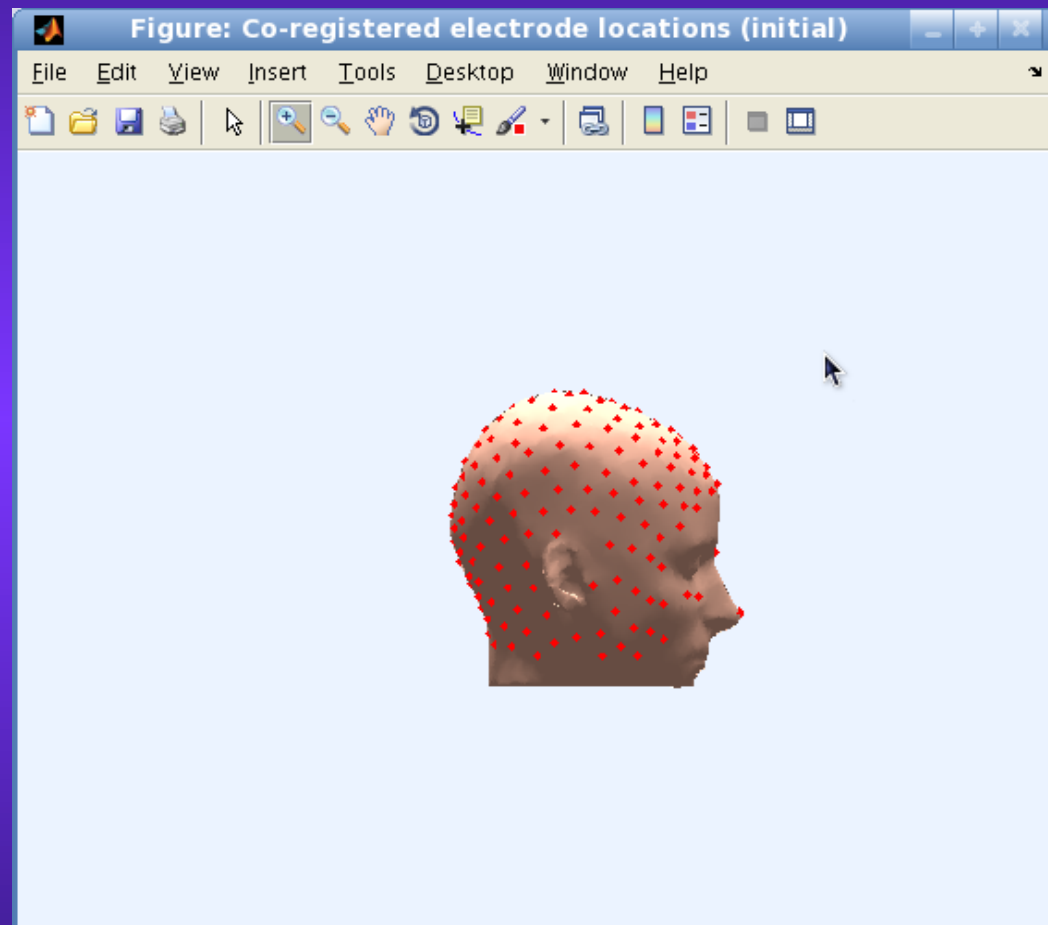
From a magnetic  
Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registrati...



# Electrode Co-registration

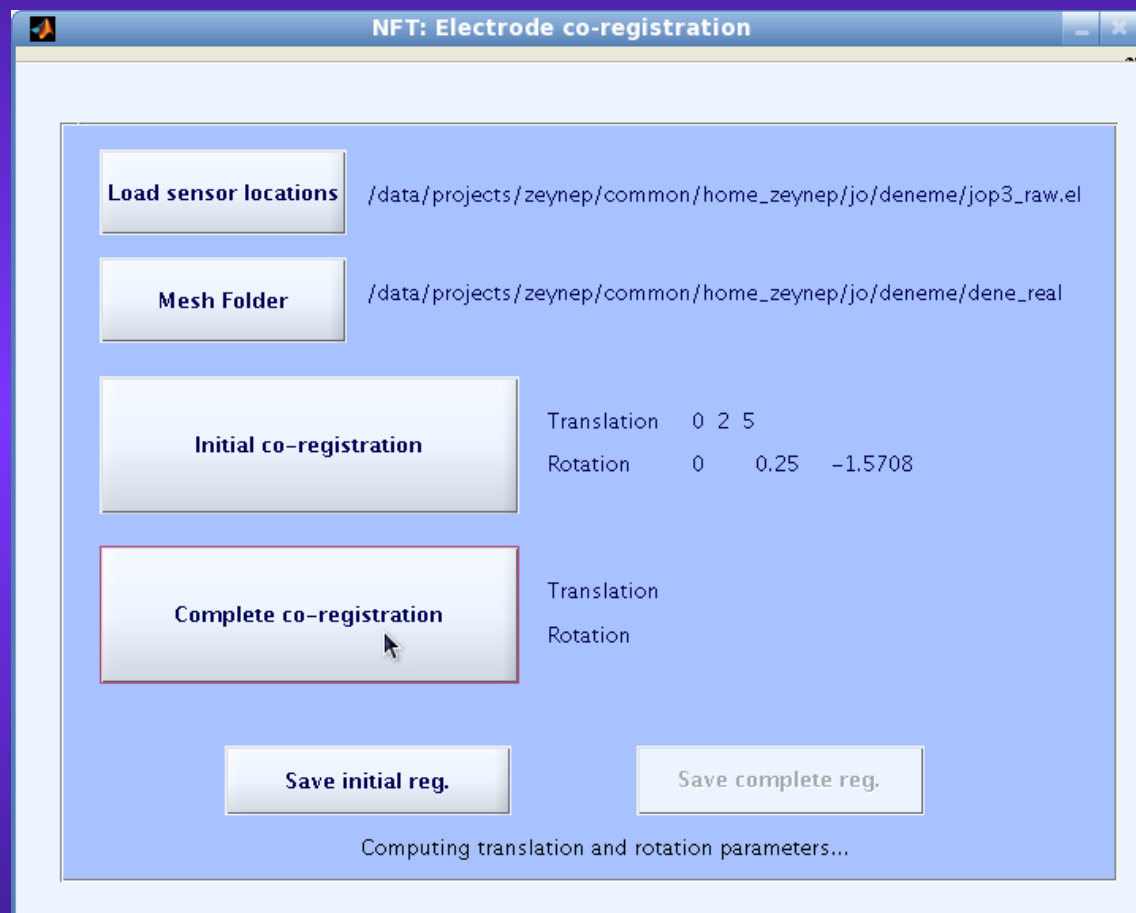
From a magnetic  
Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registrati...





# Electrode Co-registration

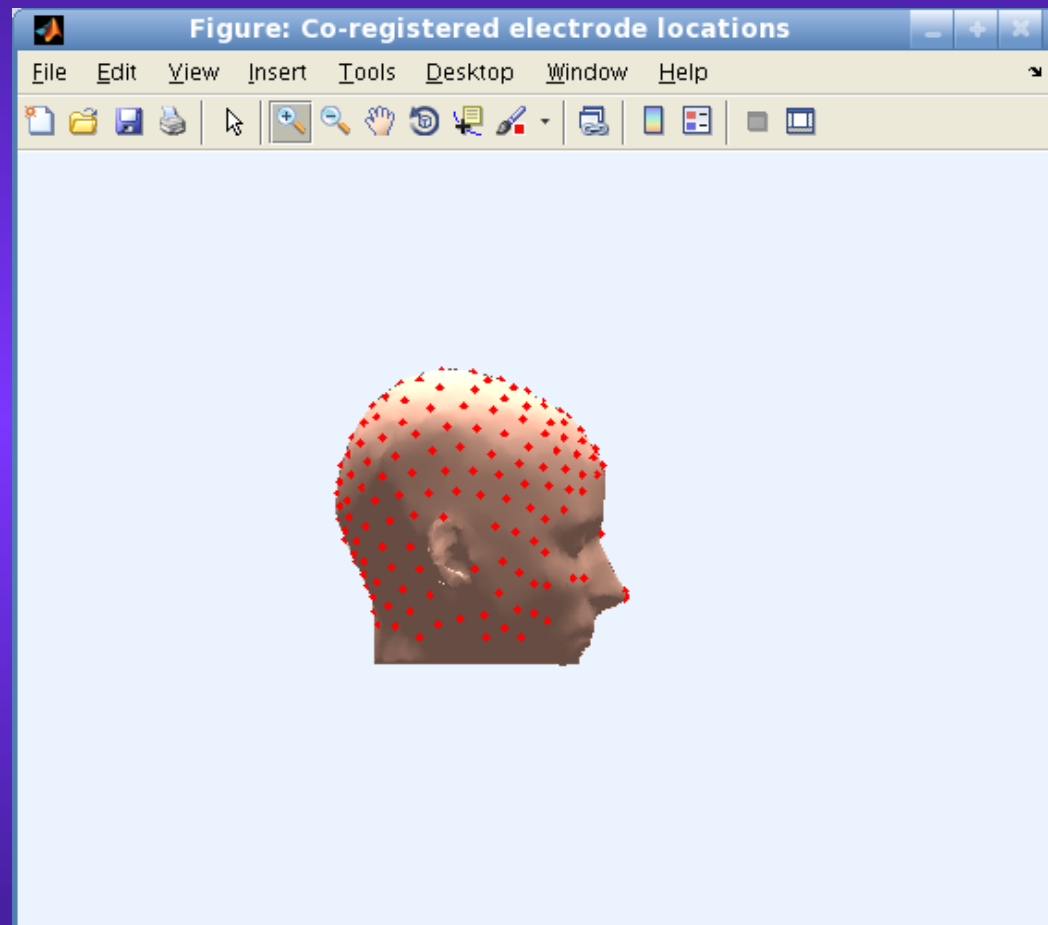
From a magnetic  
Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

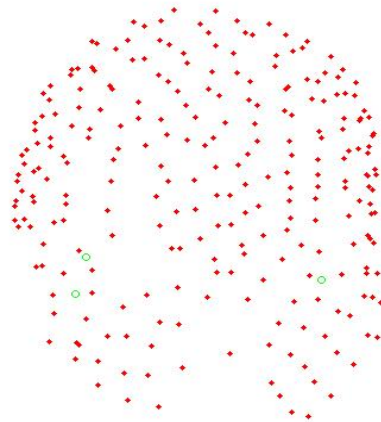
Electrode Co-Registrati...



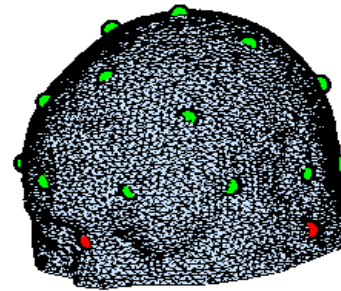
# Head Modeling from Electrode Position Data

From electrode  
Position Data

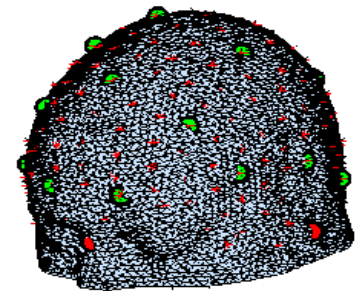
Template Warping



Digitizer locations



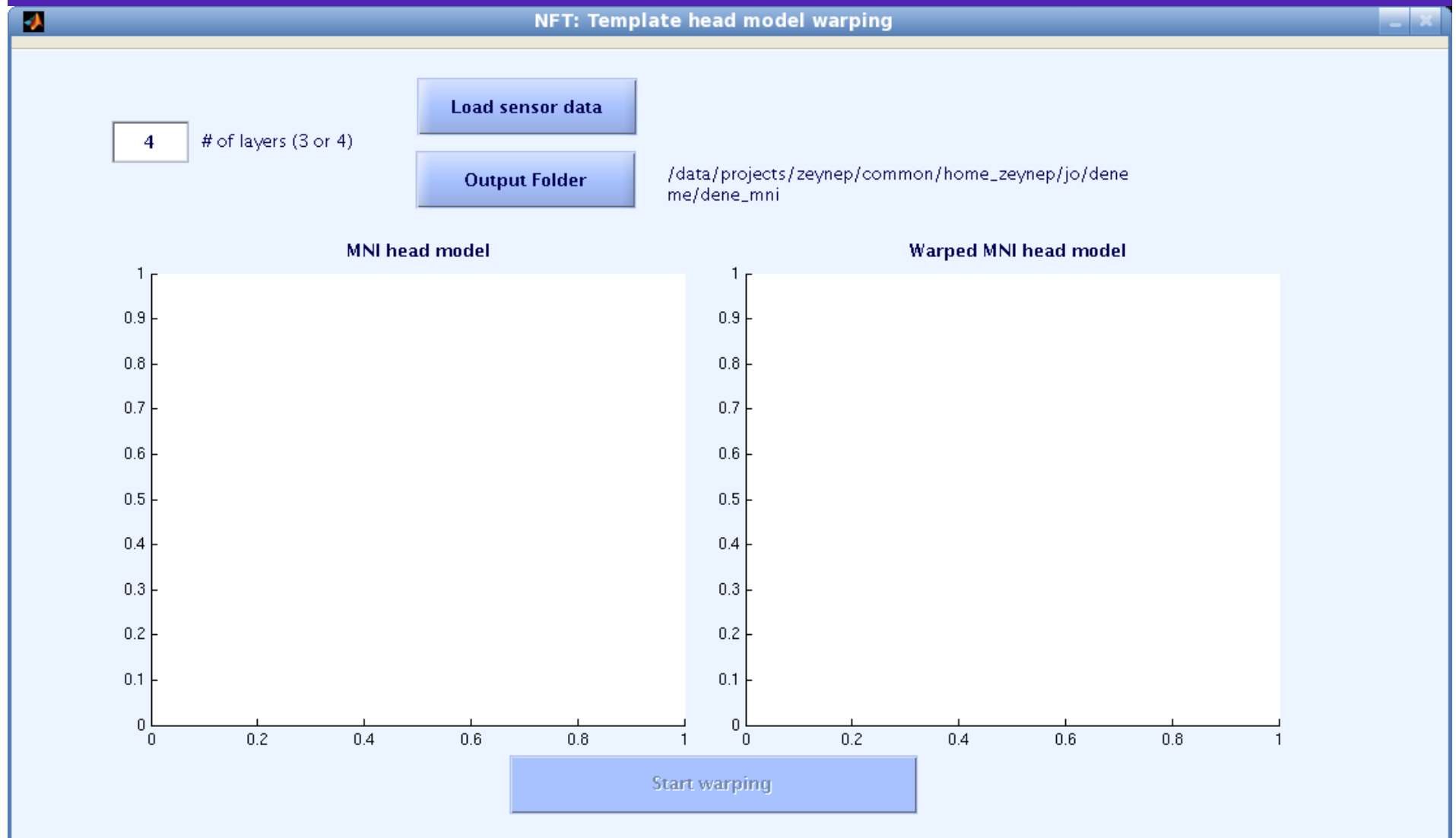
Template model



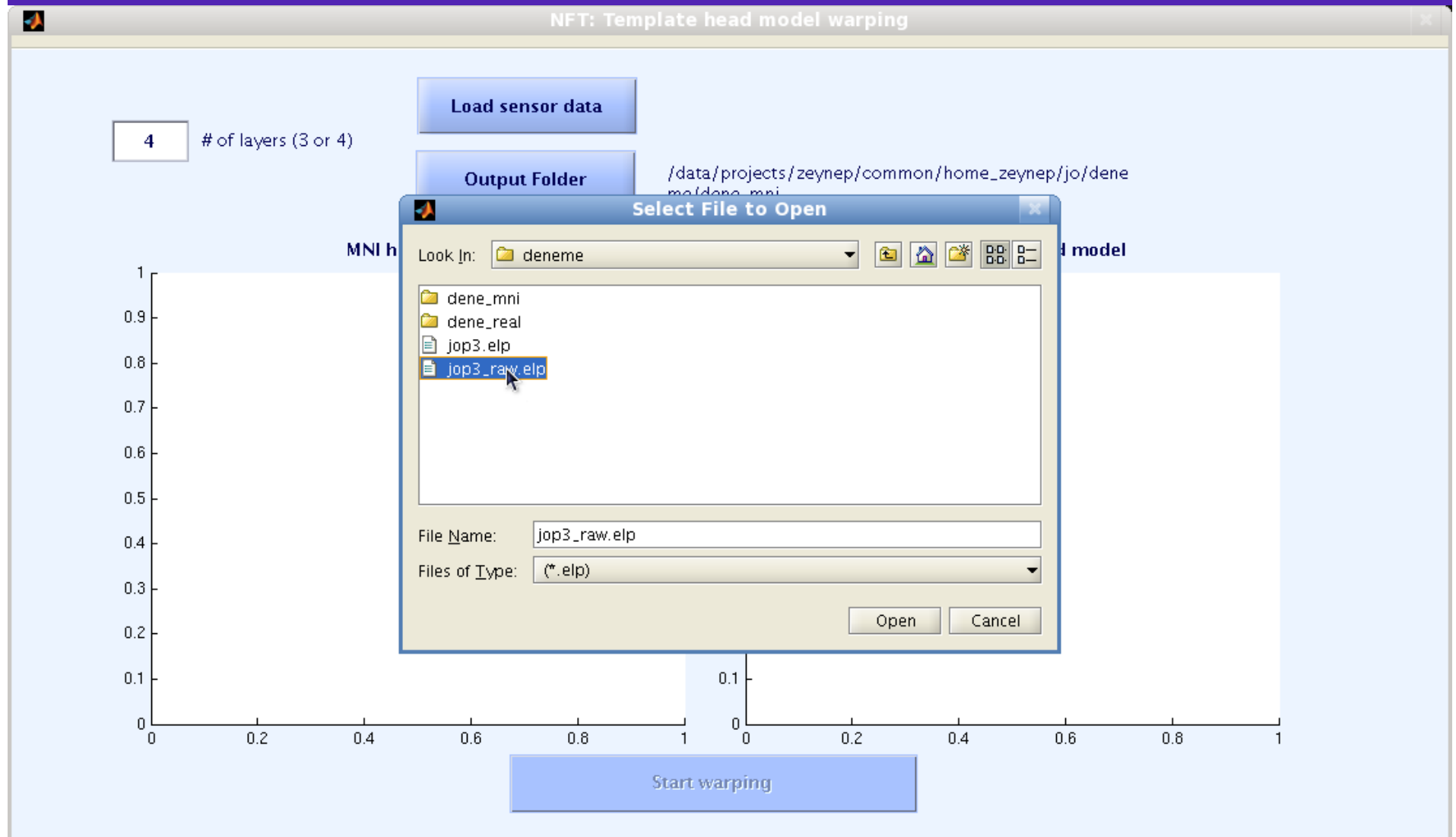
Warped model

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

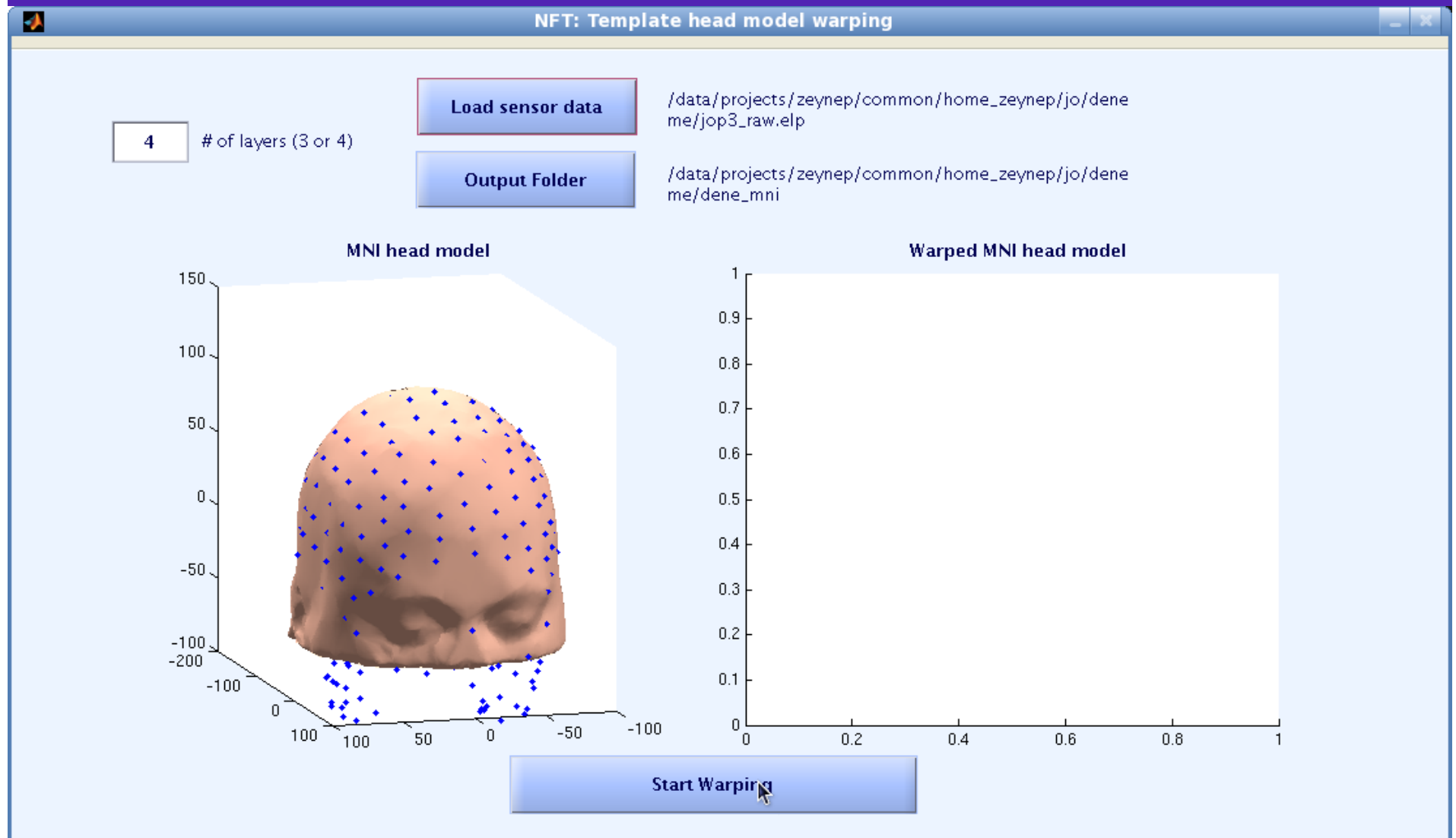
# Template Warping



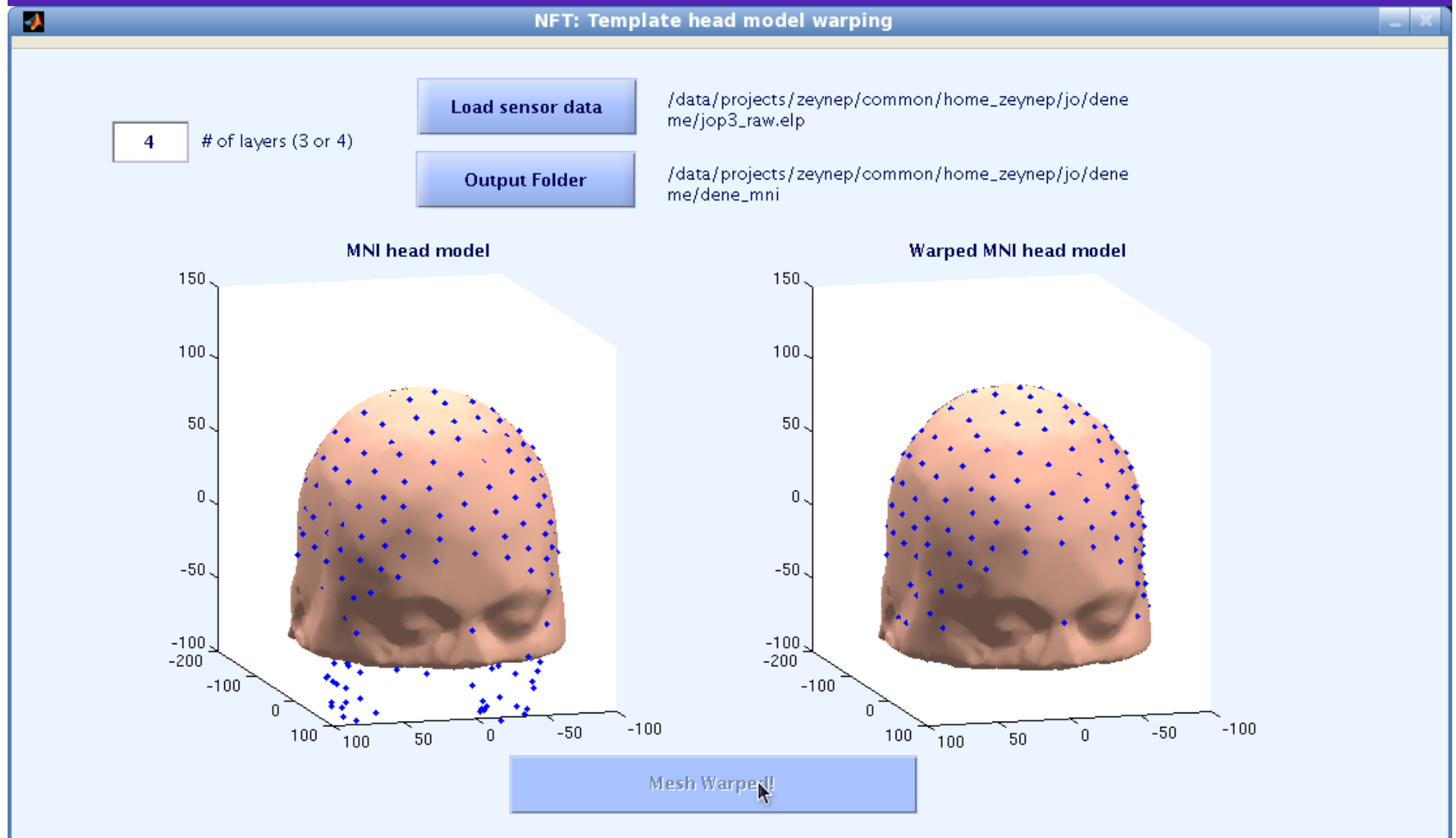
# Template Warping



# Template Warping



# 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

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 ☐ 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

## 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

## 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 ☐ Mesh Node List

Load

Show Sensors

Generate transfer matrix

Value Changed!

**Forward Problem Solution**

Load Source Space

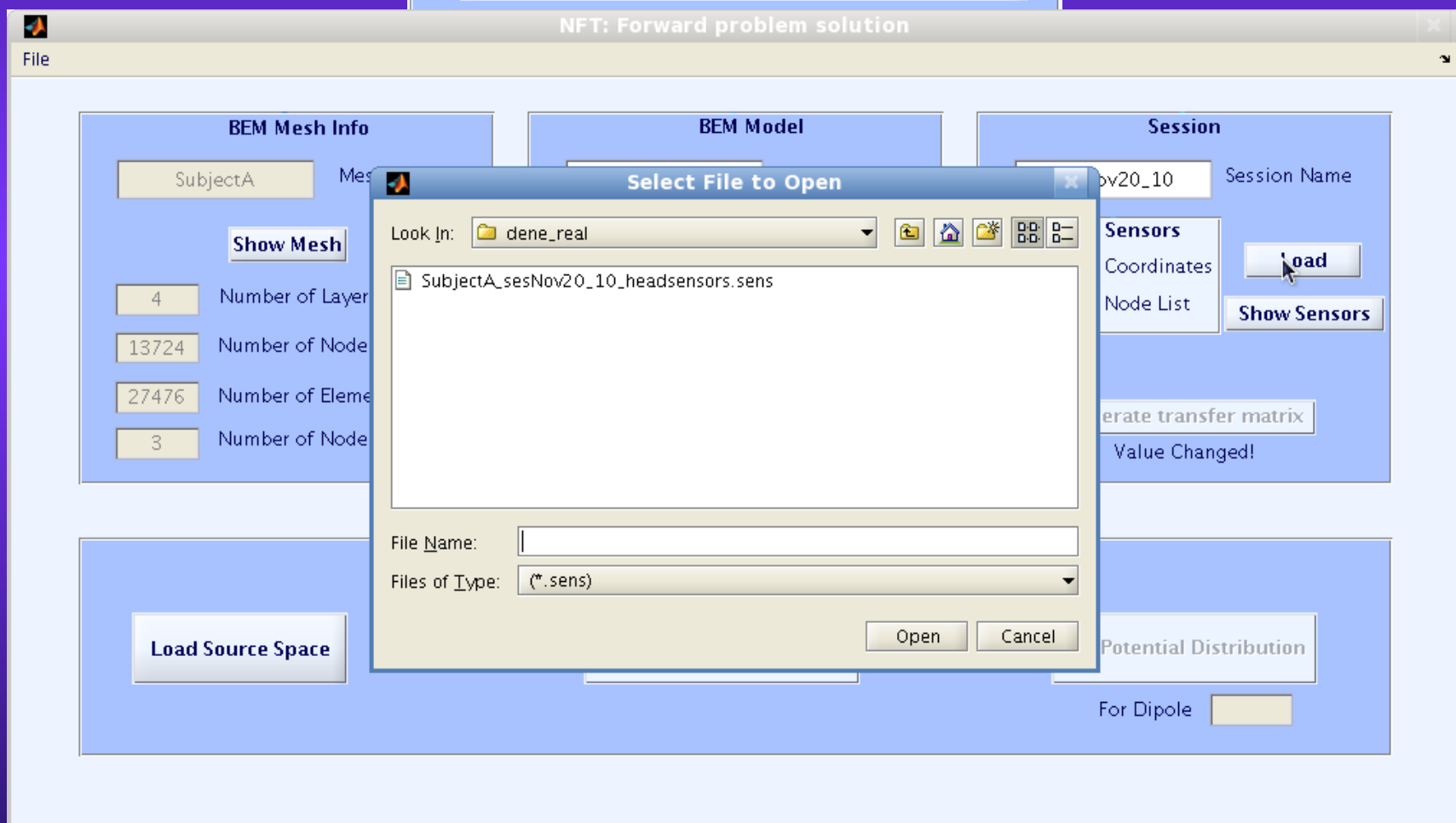
Compute Lead Field Matrix

Plot Potential Distribution

For Dipole

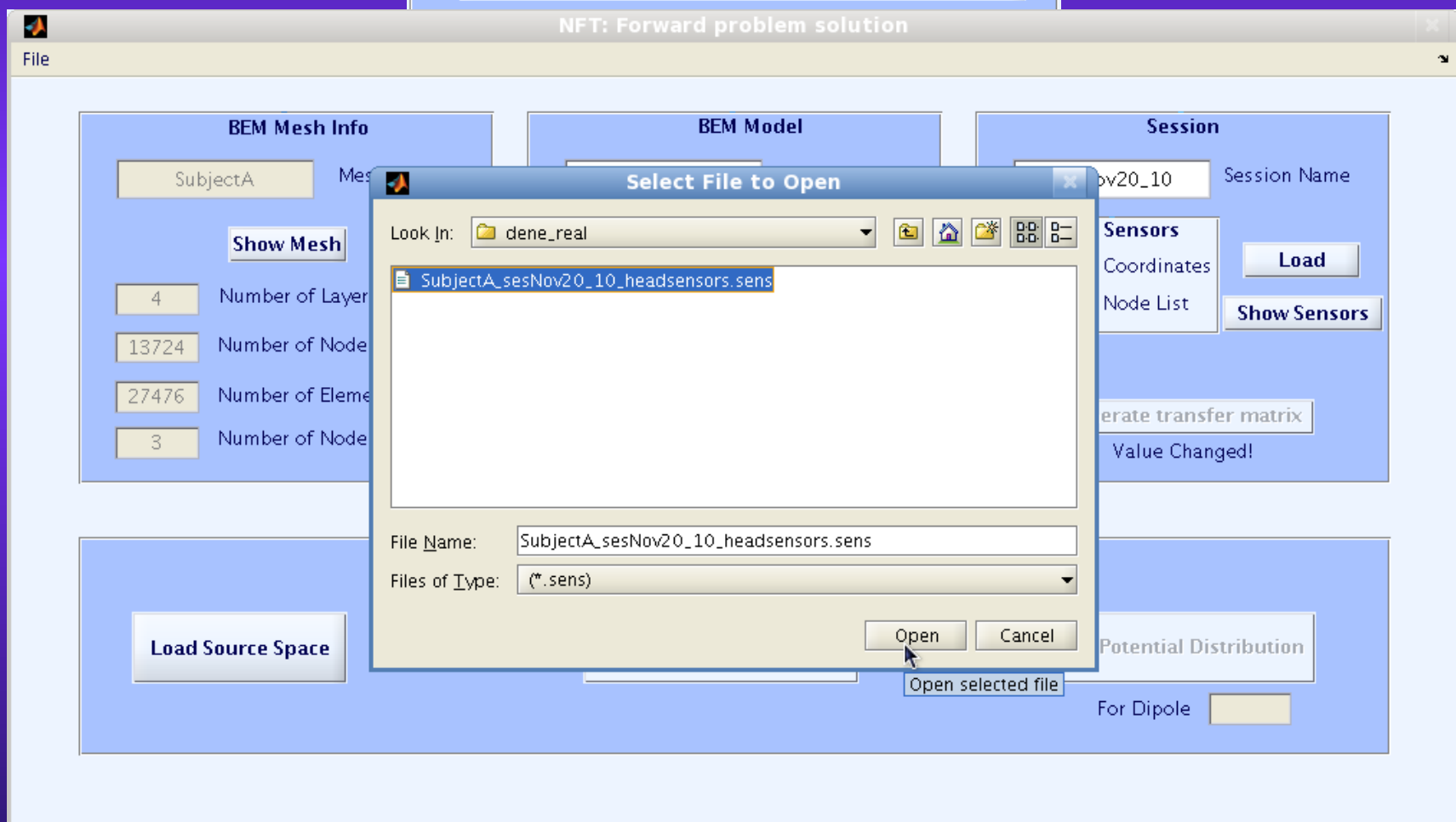
# Forward Problem Solution

Forward Model Generation



# Forward Problem Solution

Forward Model Generation



# Forward Problem Solution

Forward Model Generation

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 ☐ Mesh Node List

Load

Show Sensors

243 Sensors Loaded

Generate transfer matrix

Value Changed!

calculating sensor matrix...

**Forward Problem Solution**

Load Source Space

Compute Lead Field Matrix

Plot Potential Distribution

For Dipole

# Forward Problem Solution

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

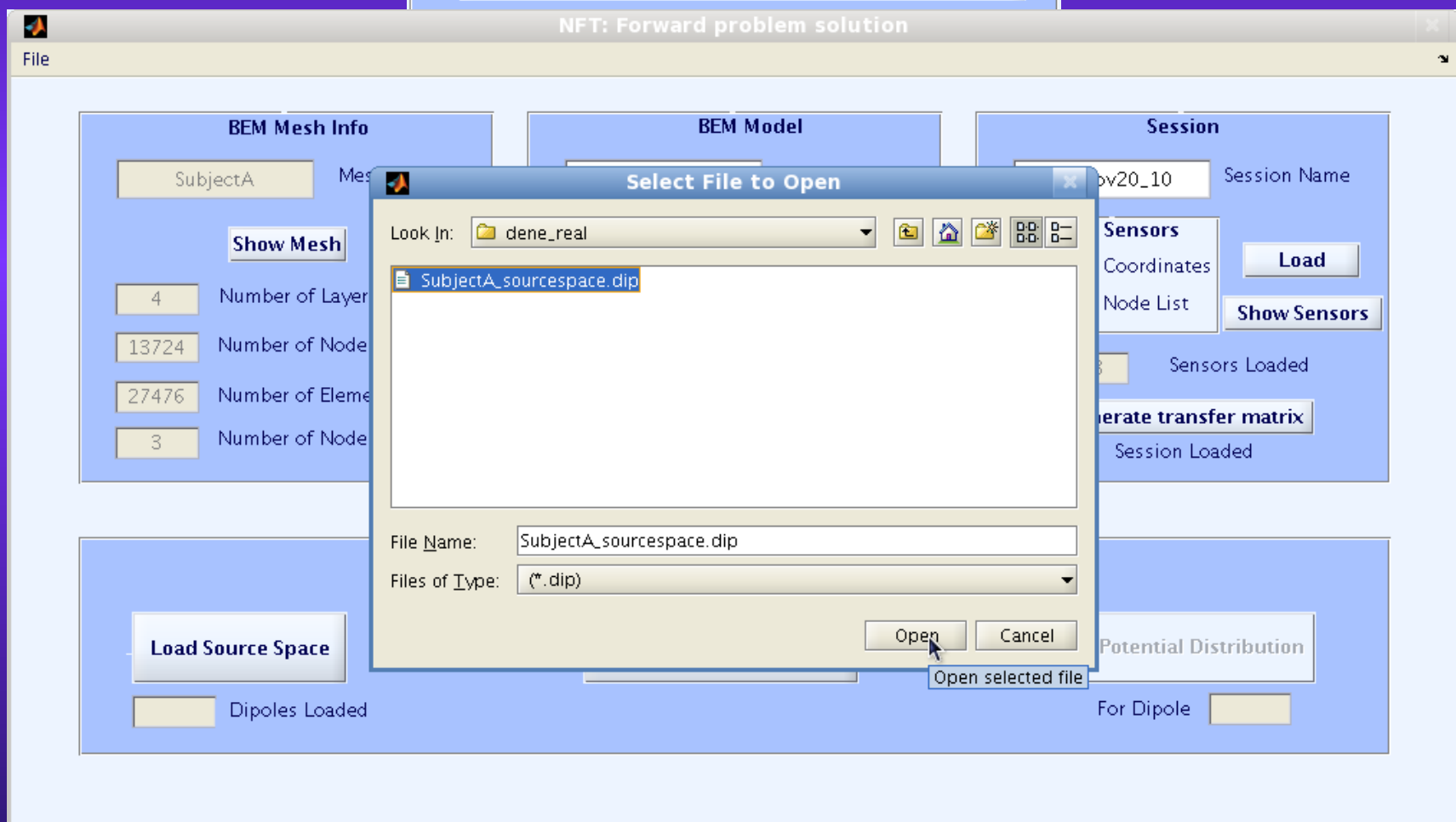
Compute Lead Field Matrix

Plot Potential Distribution

For Dipole

# Forward Problem Solution

Forward Model Generation



# Forward Problem Solution

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

## 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

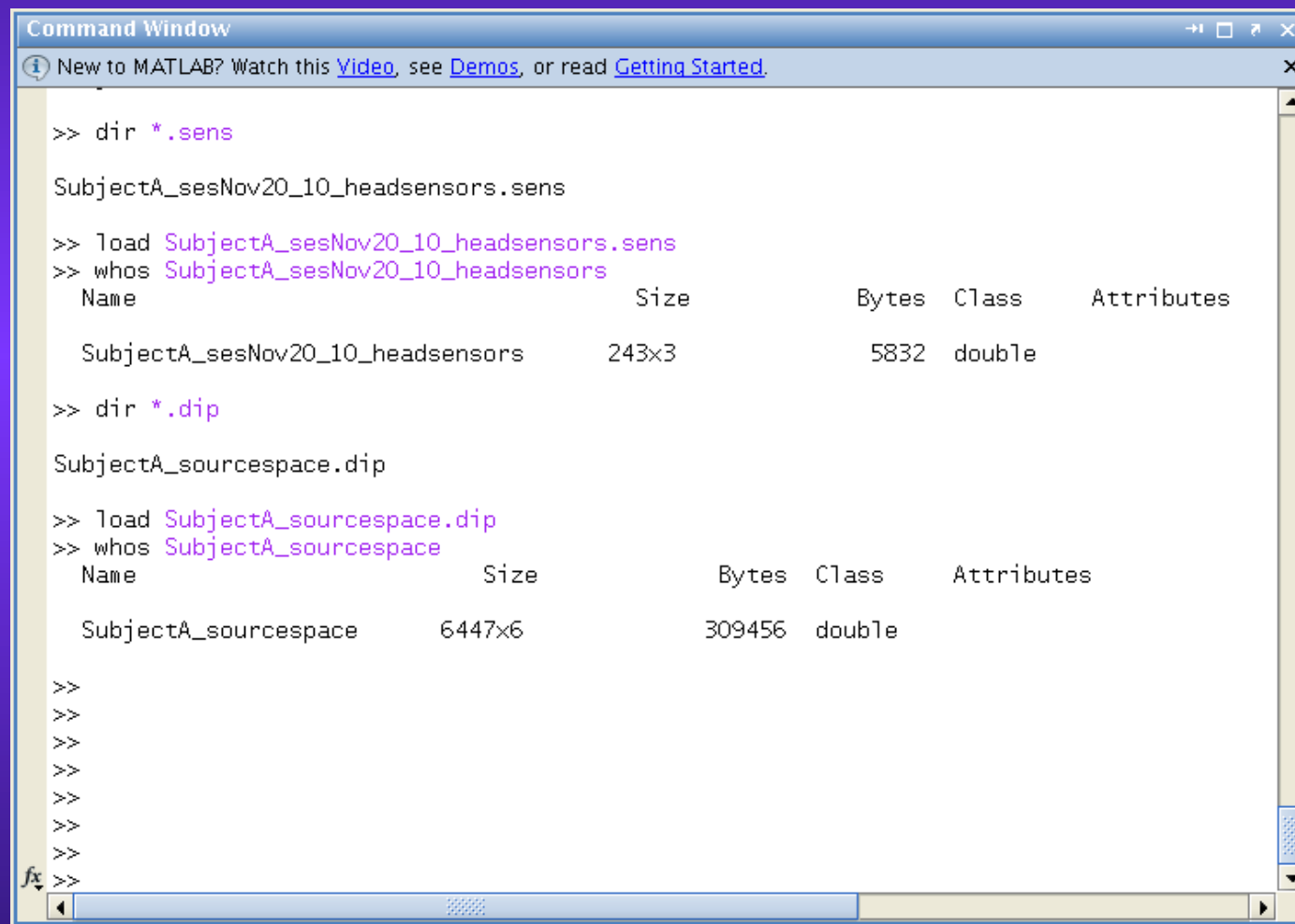
Compute Lead Field Matrix

LFM Computed

Plot Potential Distribution

For Dipole

# Forward Problem Solution



A screenshot of the MATLAB Command Window. The window title is "Command Window". At the top, there is a message: "New to MATLAB? Watch this [Video](#), see [Demos](#), or read [Getting Started](#)." Below this, the user has entered several commands. First, they used `dir *.sens` to list files, which returned `SubjectA_sesNov20_10_headsensensors.sens`. Then, they used `load SubjectA_sesNov20_10_headsensensors.sens` to load the file. This was followed by `whos SubjectA_sesNov20_10_headsensensors`, which displayed a table of the loaded variable. Next, they used `dir *.dip` to list files, which returned `SubjectA_sourcespace.dip`. Then, they used `load SubjectA_sourcespace.dip` to load the file. This was followed by `whos SubjectA_sourcespace`, which displayed another table of the loaded variable. Finally, there are several empty command lines indicated by `>>`.

```
>> dir *.sens

SubjectA_sesNov20_10_headsensensors.sens

>> load SubjectA_sesNov20_10_headsensensors.sens
>> whos SubjectA_sesNov20_10_headsensensors
  Name                                Size          Bytes  Class      Attributes
  SubjectA_sesNov20_10_headsensensors  243x3          5832   double

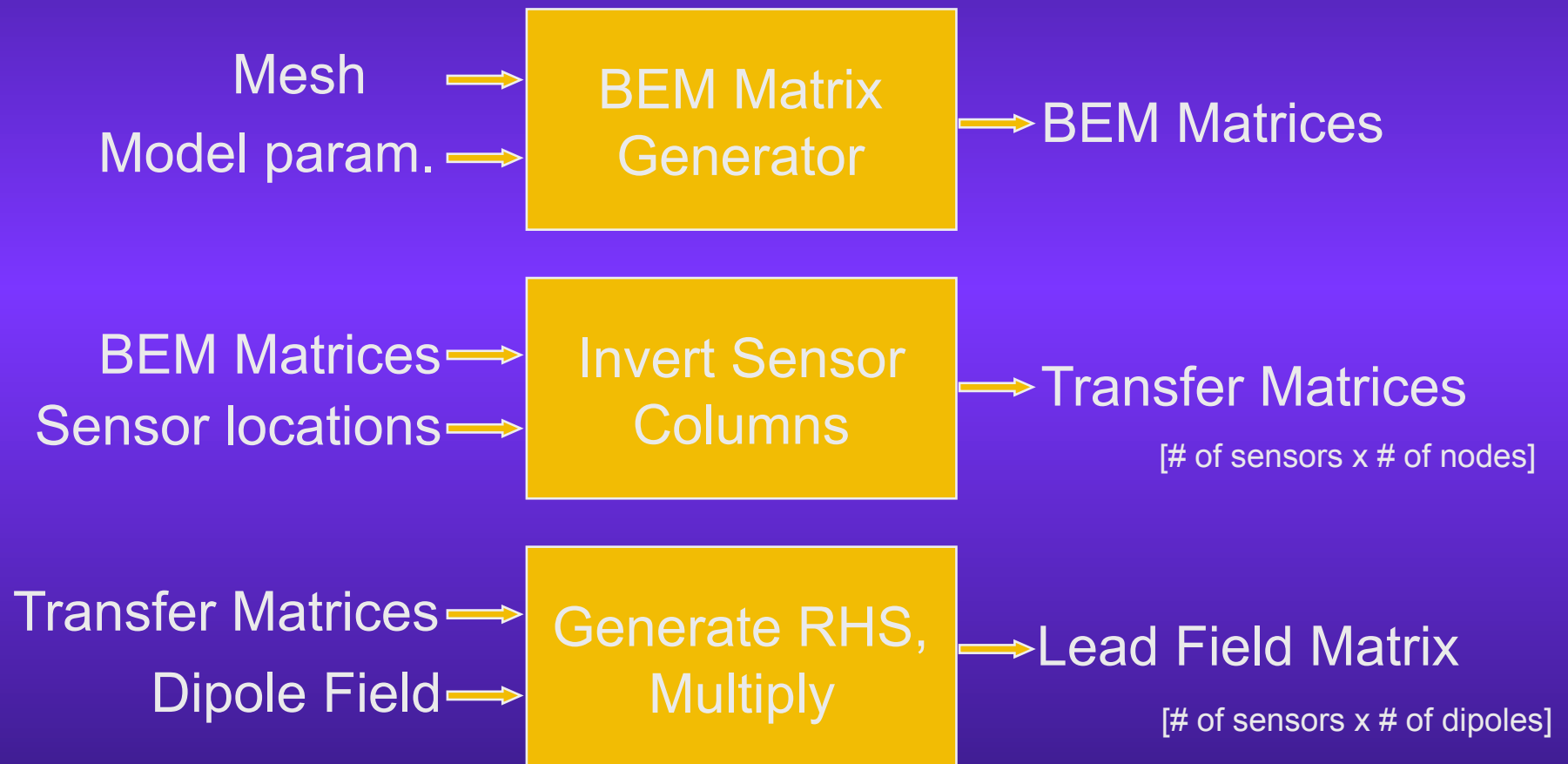
>> dir *.dip

SubjectA_sourcespace.dip

>> load SubjectA_sourcespace.dip
>> whos SubjectA_sourcespace
  Name                                Size          Bytes  Class      Attributes
  SubjectA_sourcespace                 6447x6        309456 double

>>
>>
>>
>>
>>
>>
>>
>>
```

# Forward Problem Solution



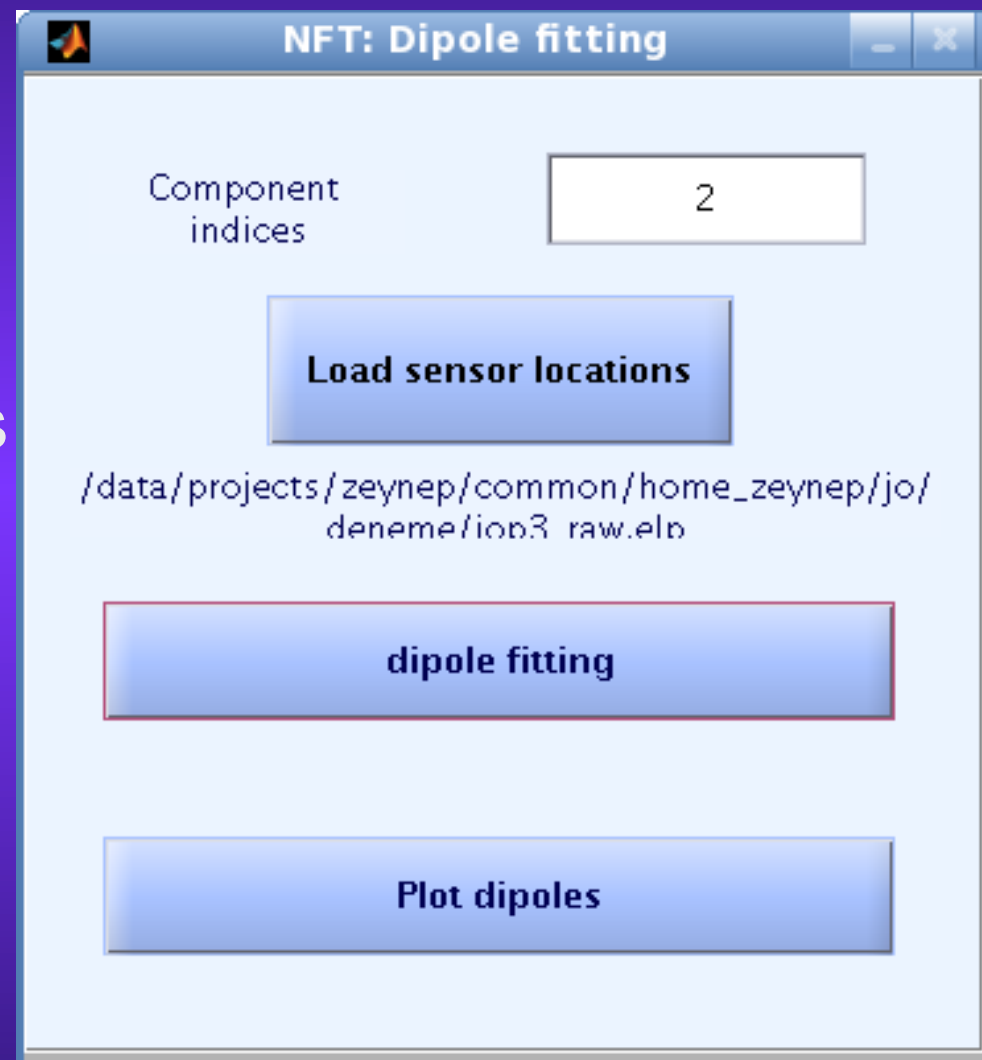
# Forward Problem Solver

- ◆ 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)

# Dipole Fitting

Dipole Fitting

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



# 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 <sub>mean</sub>	E <sub>min</sub>	E <sub>max</sub>
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 Comparison

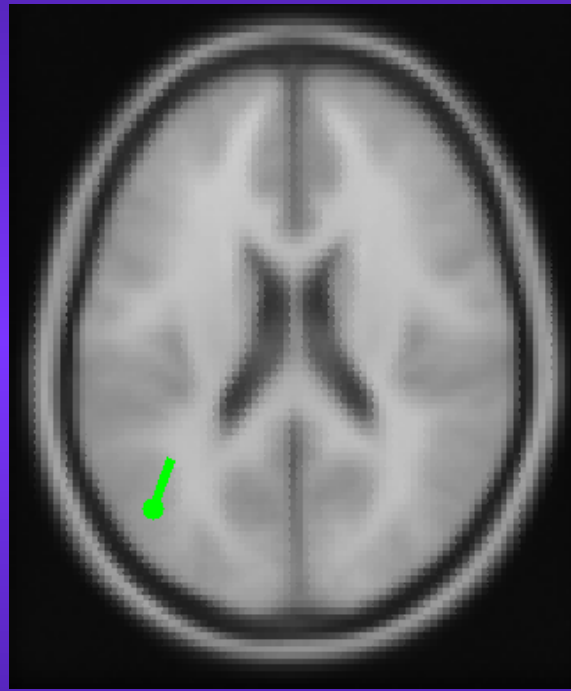
- ◆ BESA sources
- ◆ MNI head model – electrode co-registration and sources
- ◆ Warped MNI head model and electrode co-registration and sources
- ◆ Realistic head model and electrode co-registration
- ◆ Source localization with 4-layer realistic head model

# BESA

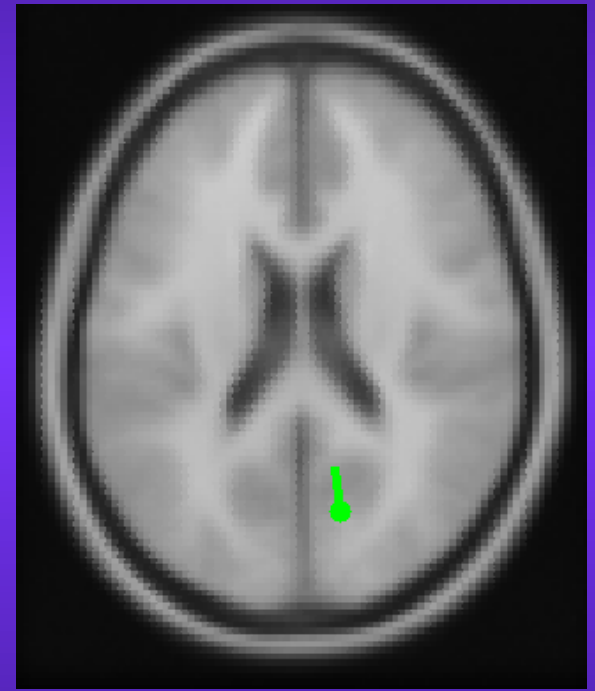


rv=0.0663

coord\_transform =[0 0 0 0 0 0 930 1050 969]



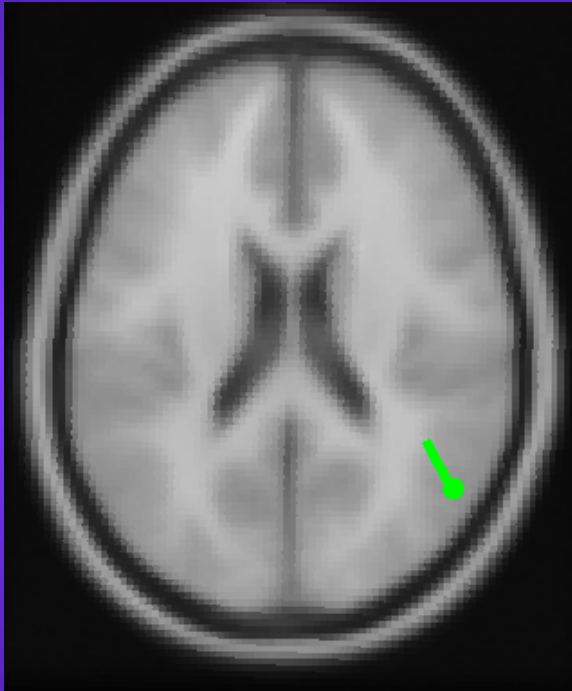
rv=0.0376



rv=0.0419



# MNI Source Localization

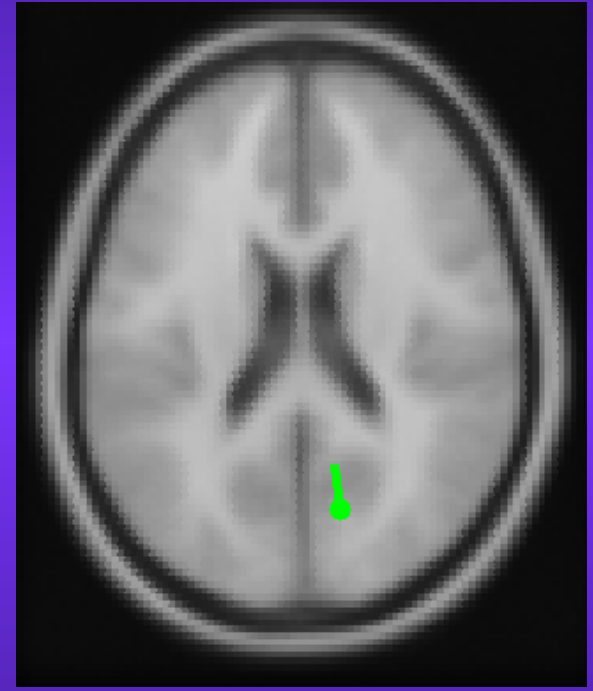


rv=0.0663

coord\_transform =[0 0 0 0 0 0 930 1050 969]

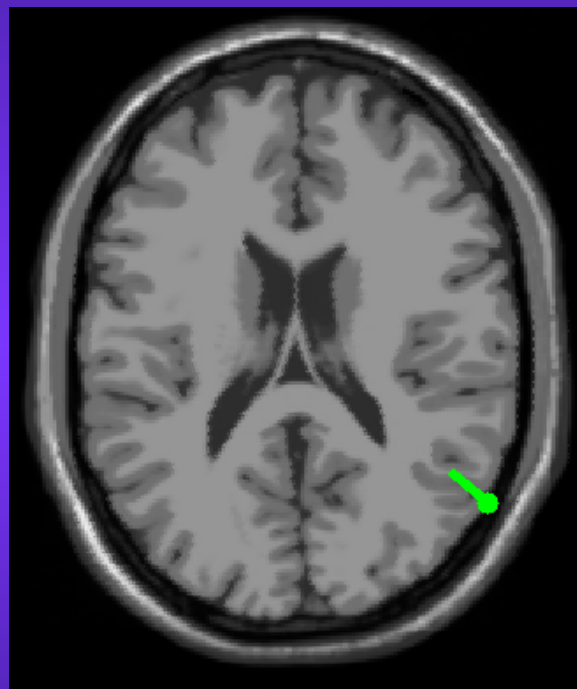


rv=0.0376

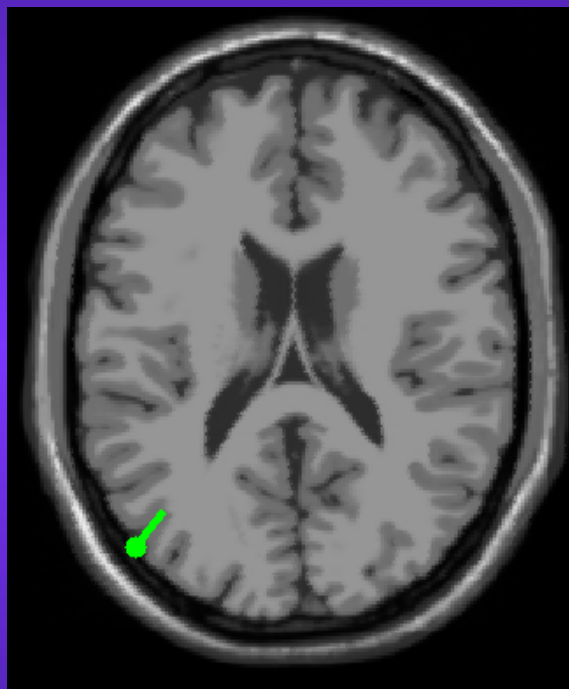


rv=0.0419

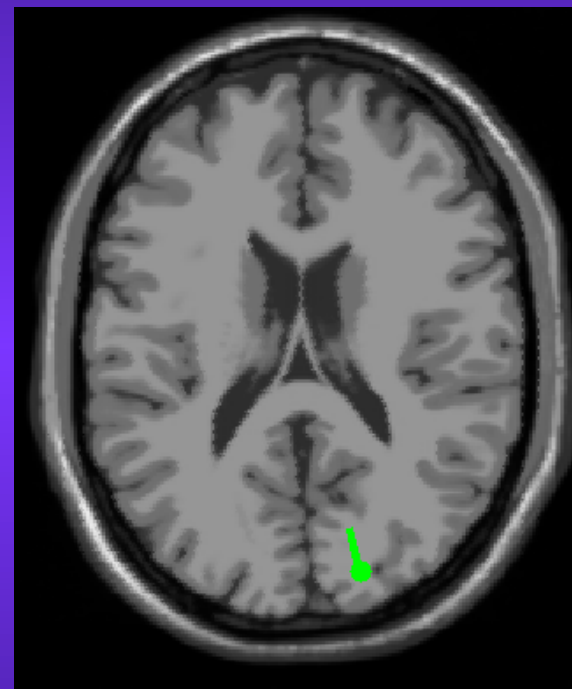
# Warped MNI sources



rv=0.0751  
pos=[60.4 -64.4 8.45]  
mom=[-53.1 43.9 -2.86]

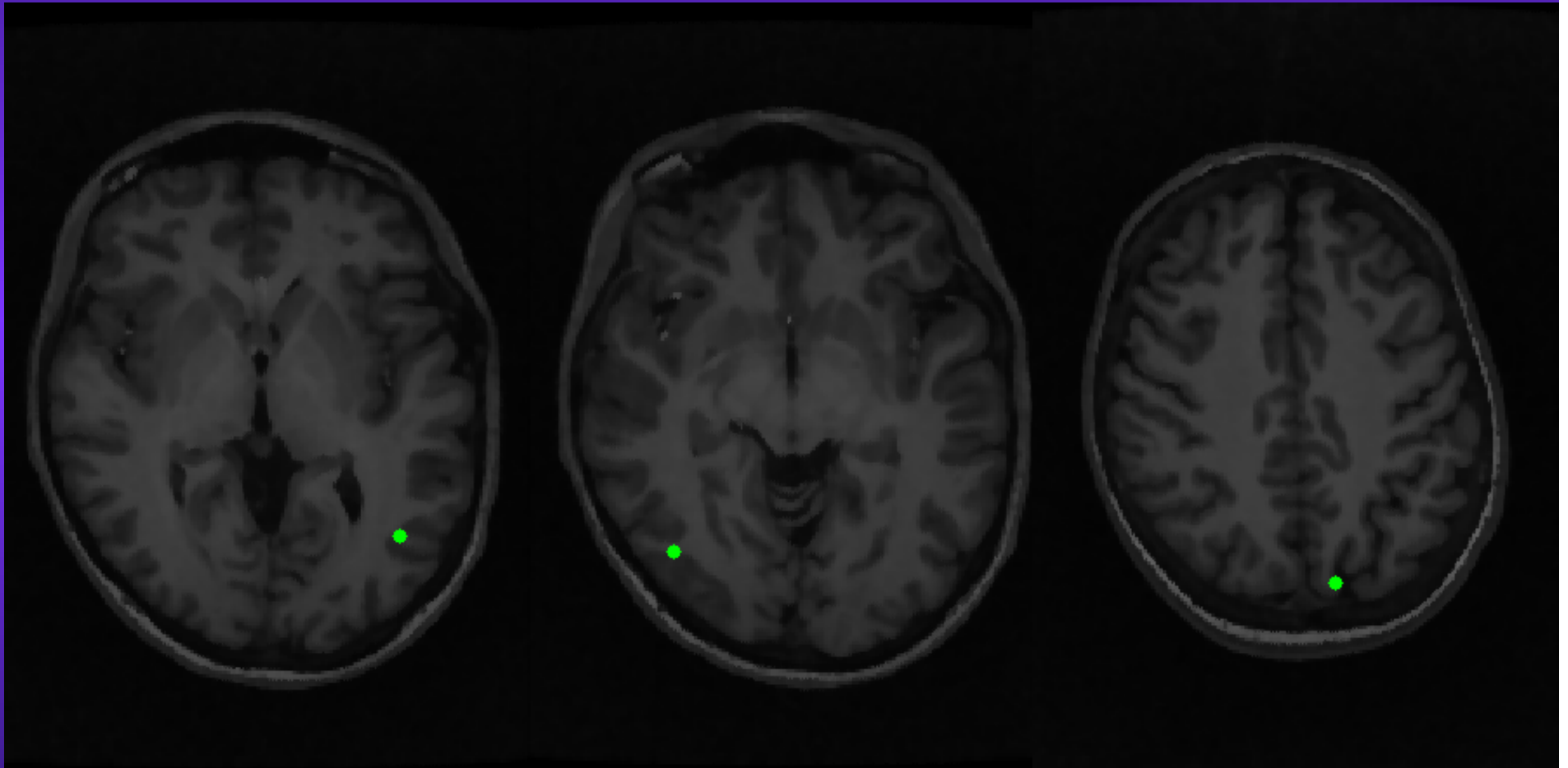


rv=0.0297  
pos=[-49.46 -78.44 5.69]  
mom=[19.3 24.0 11.13]



rv=0.1161  
pos=[17.0 -81.66 56.5]  
mom=[4.45 30.4 -9.74]

# Realistic 4-layer sources



# Future Functions

- ◆ Use T2-weighted and PD images in segmentation => better CSF segmentation.
- ◆ Finite Element Method.