

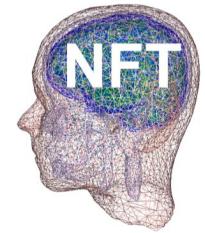
NFT

Neuroelectromagnetic Forward Head Modeling Toolbox

Zeynep AKALIN ACAR

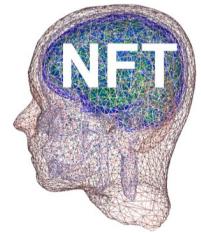
14th EEGLAB Workshop, Mallorca

September, 2011



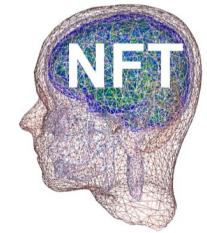
NFT

- ◆ 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



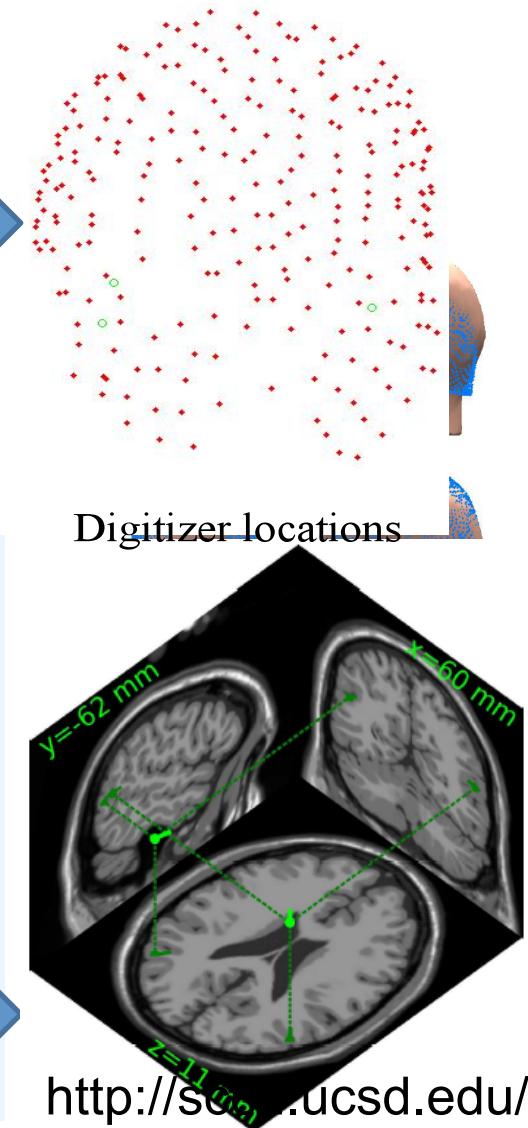
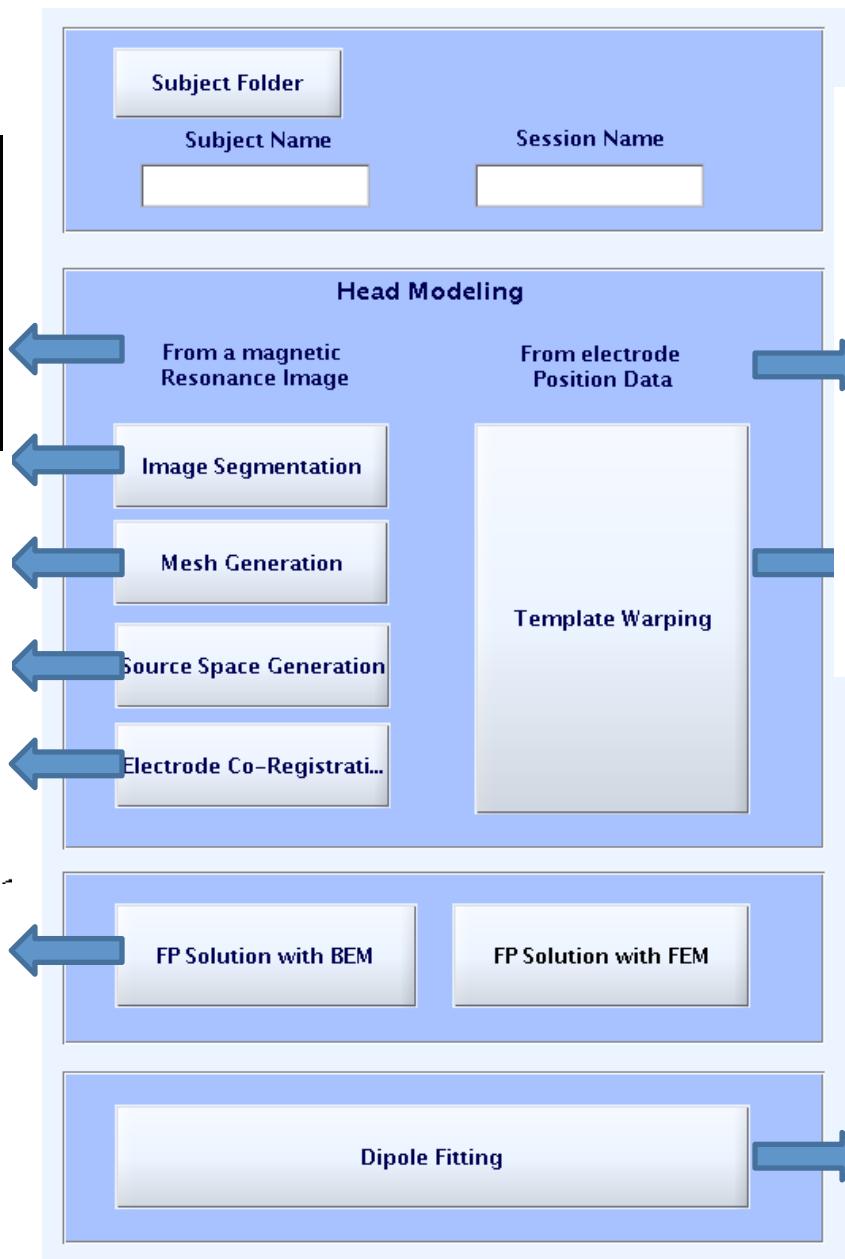
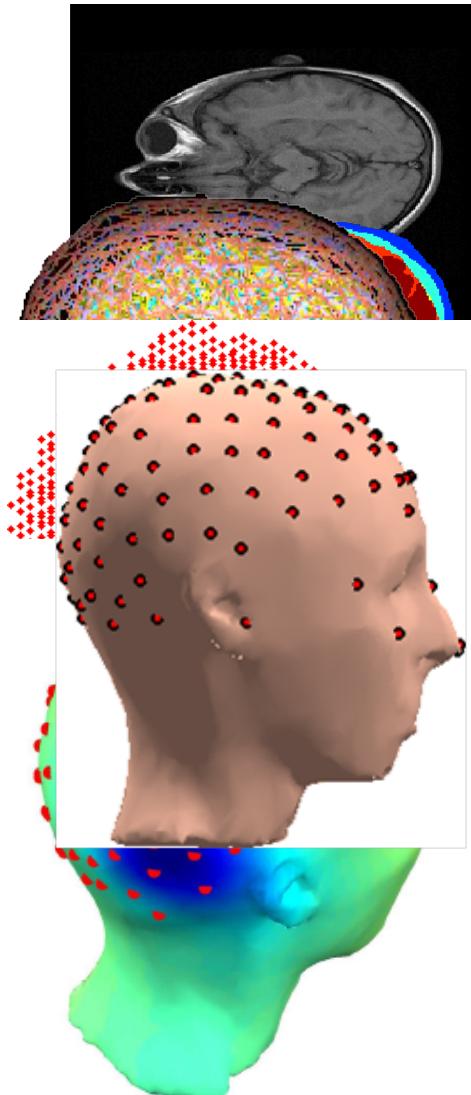
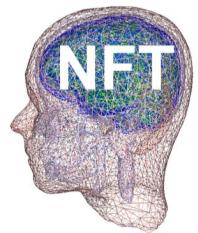
Comparison with Dipfit

- ◆ 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.

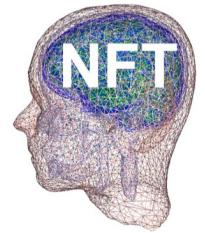


Starting NFT

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



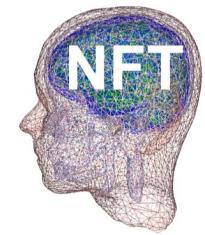
<http://scn.ucsd.edu/nft>



Subject Selection

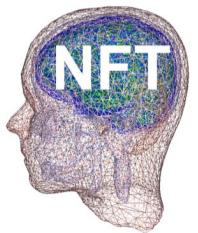
| | |
|-----------------------|----------------------|
| Subject Folder | |
| Subject Name | Session Name |
| <input type="text"/> | <input type="text"/> |

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

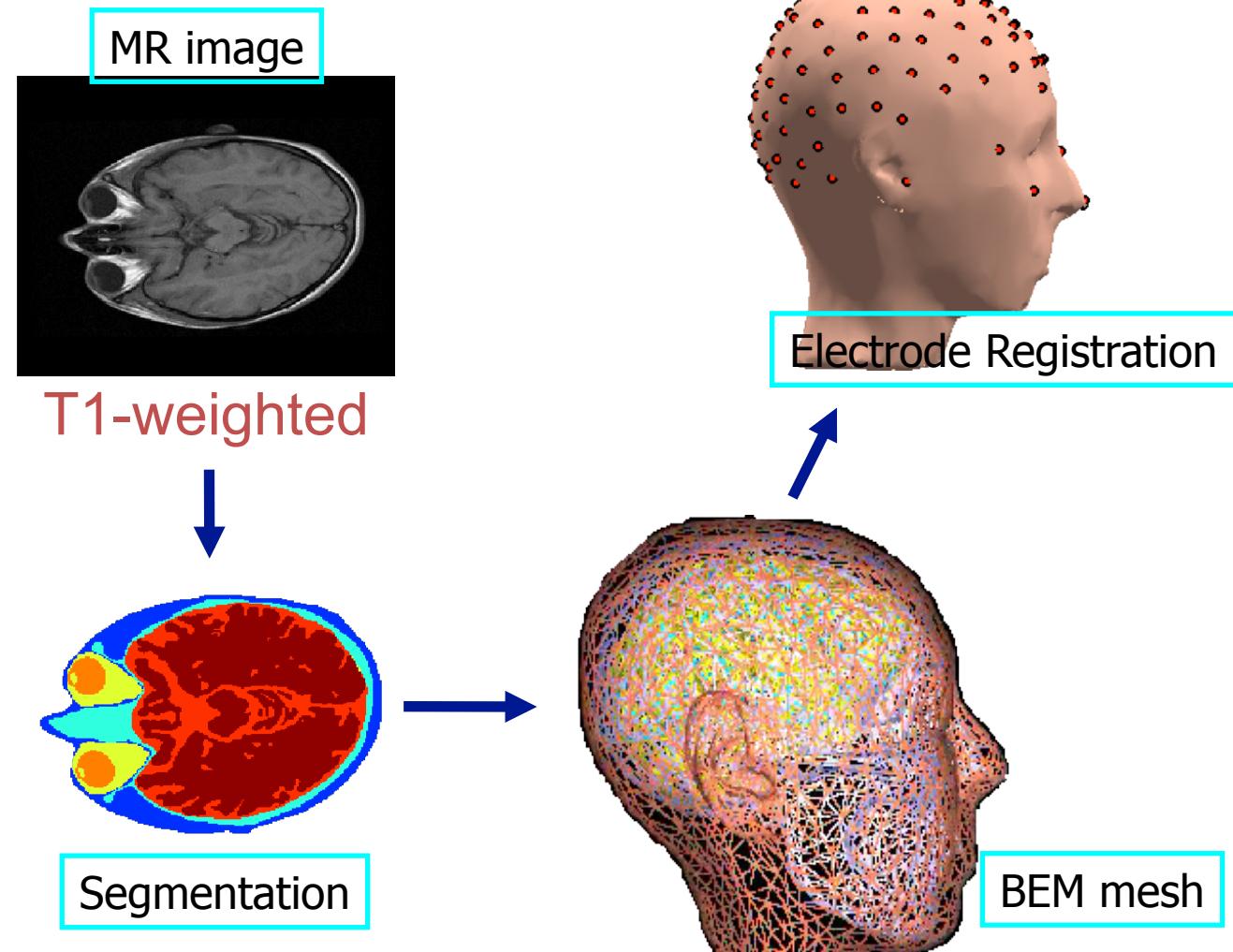
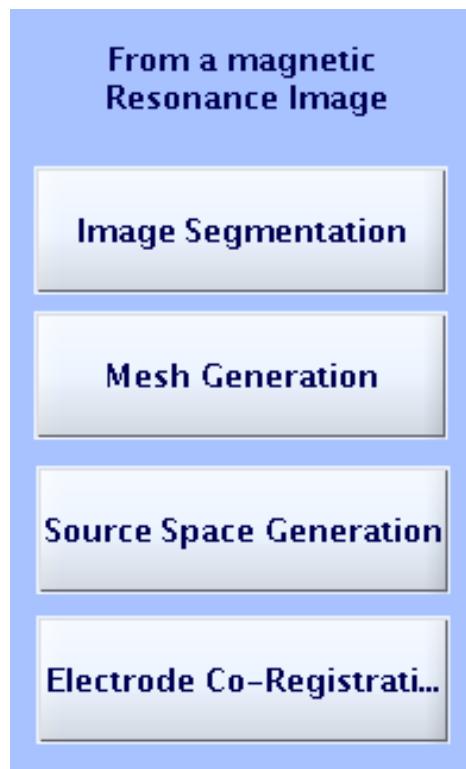


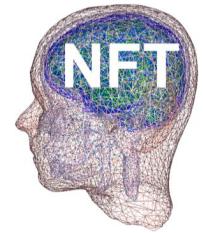
Subject Selection

| | | |
|-----------------------|--|--|
| Subject Folder | /data/projects/zeynep/common/home_z eynep/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

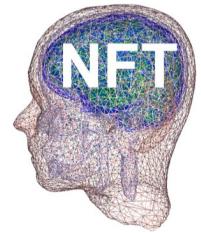
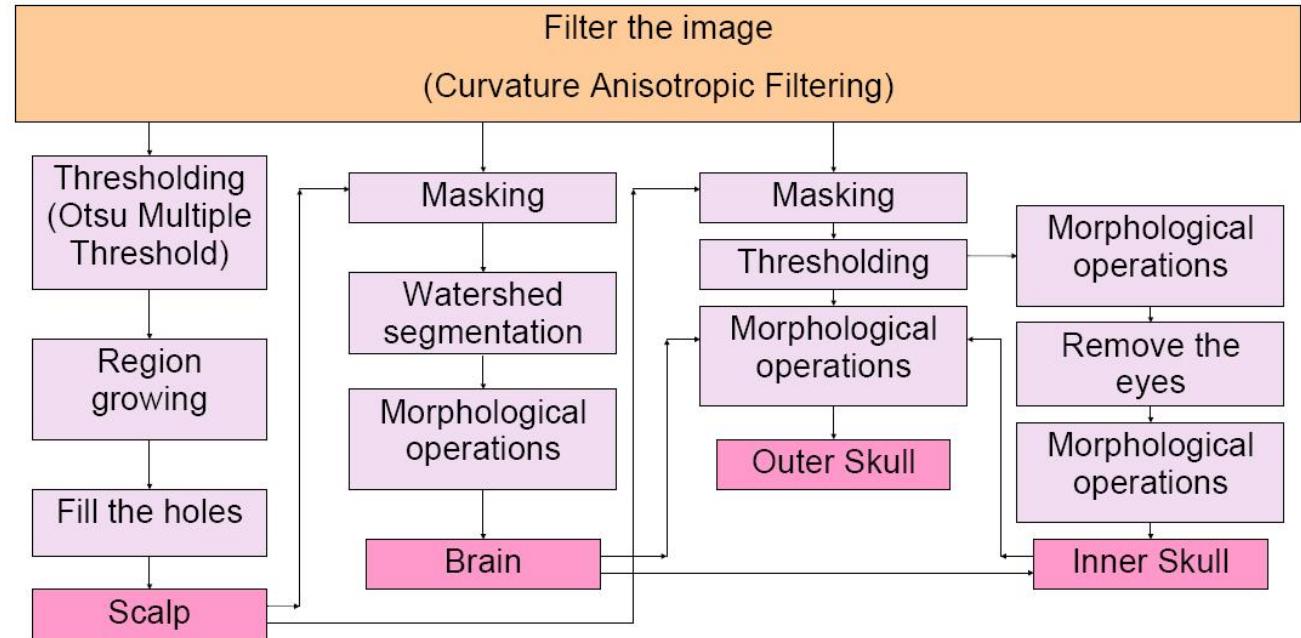
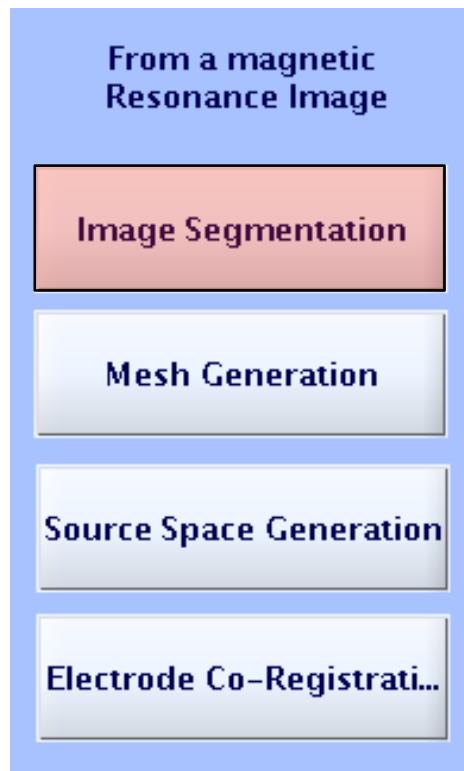


Image Segmentation



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

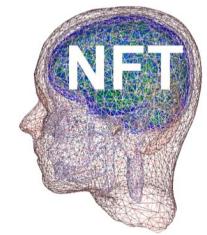
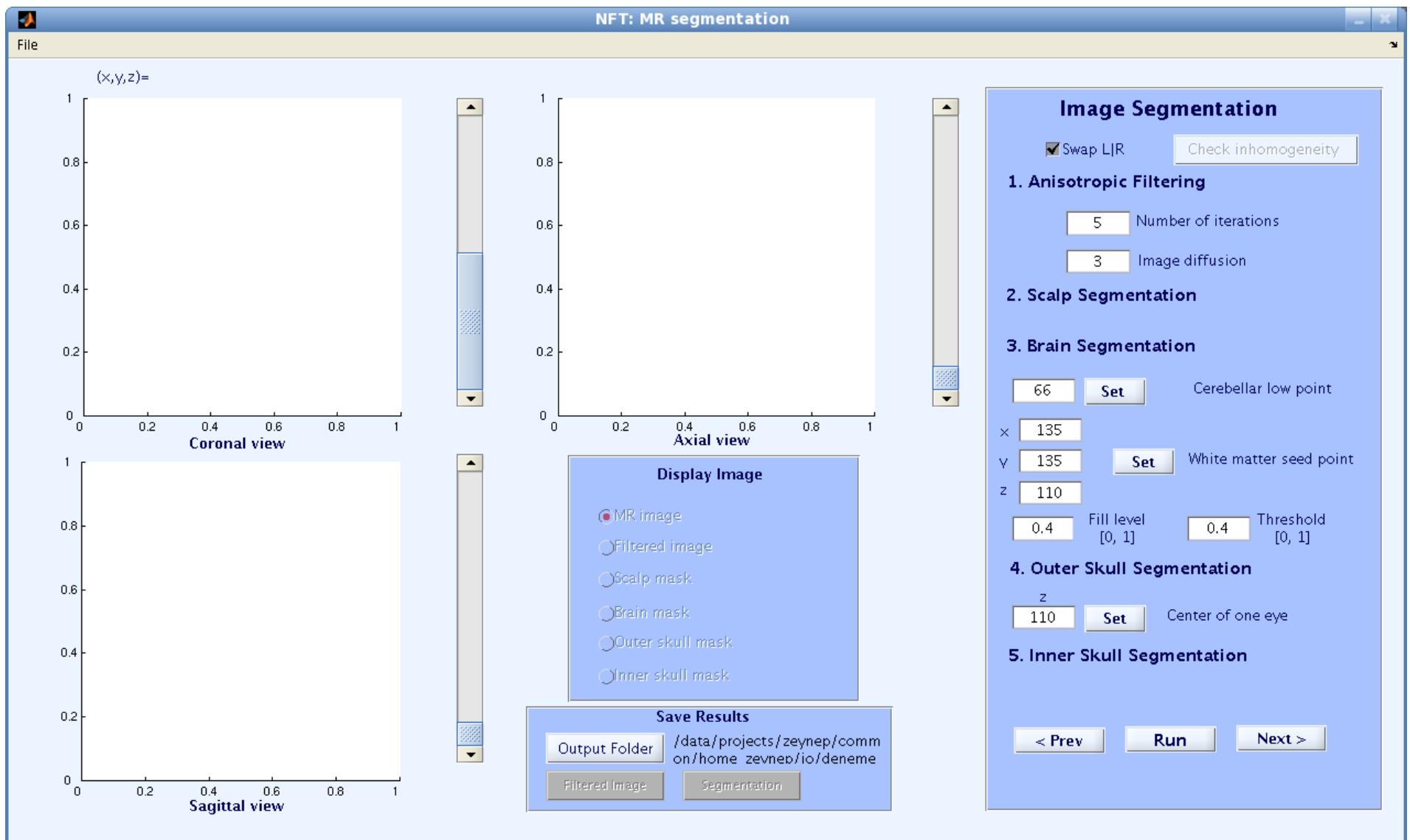


Image Segmentation



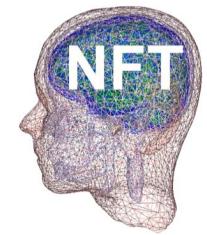


Image Segmentation

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 LIR Check inhomogeneity

1. Anisotropic Filtering

Number of iterations: 5 Image diffusion: 3

2. Scalp Segmentation

3. Brain Segmentation

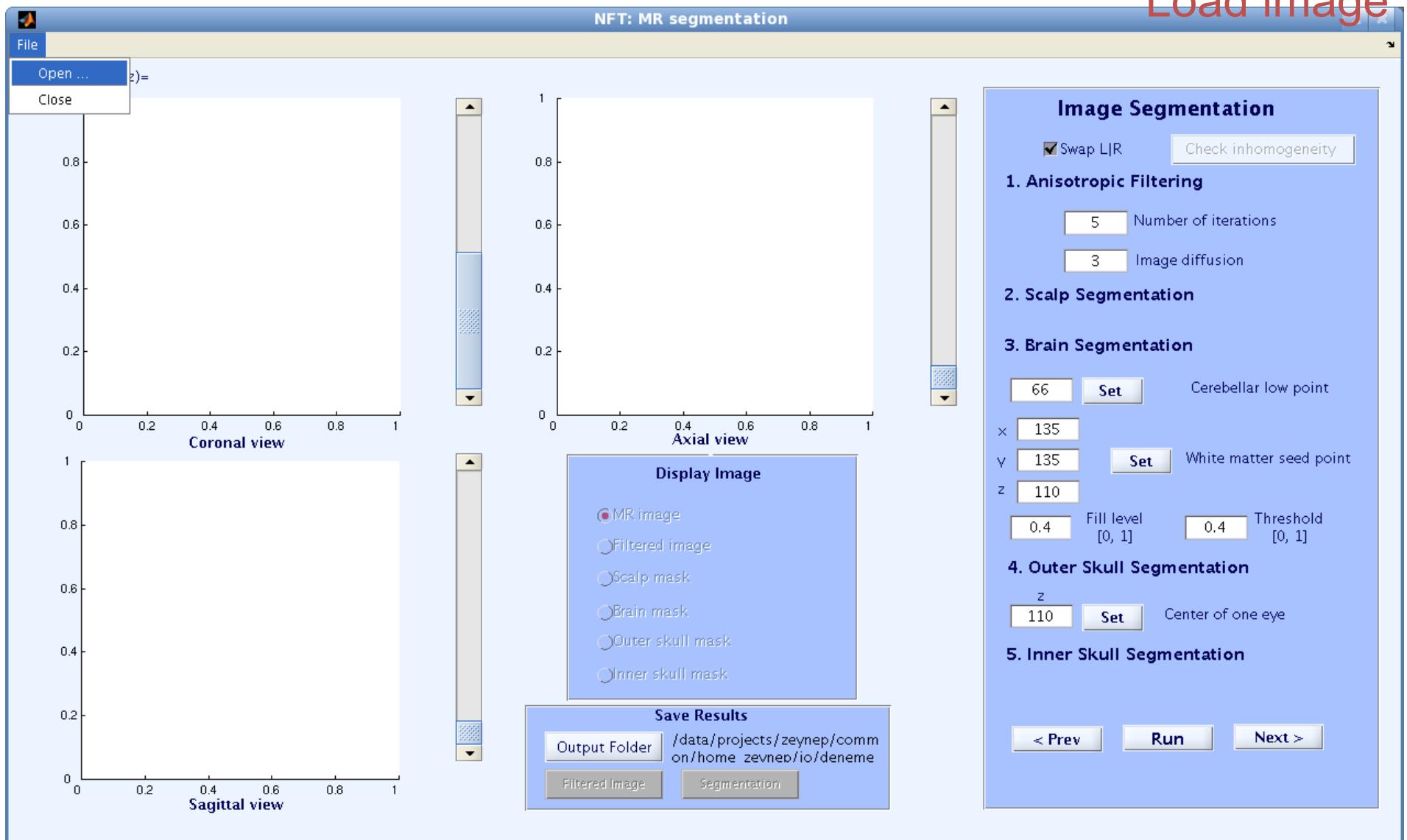
Cerebellar low point: 66 Set
White matter seed point: x: 135, y: 135, z: 110 Set
Fill level: 0.4 [0, 1] Threshold: 0.4 [0, 1]

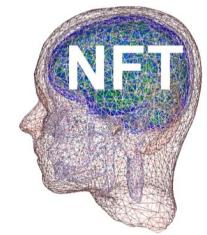
4. Outer Skull Segmentation

Center of one eye: z: 110 Set

5. Inner Skull Segmentation

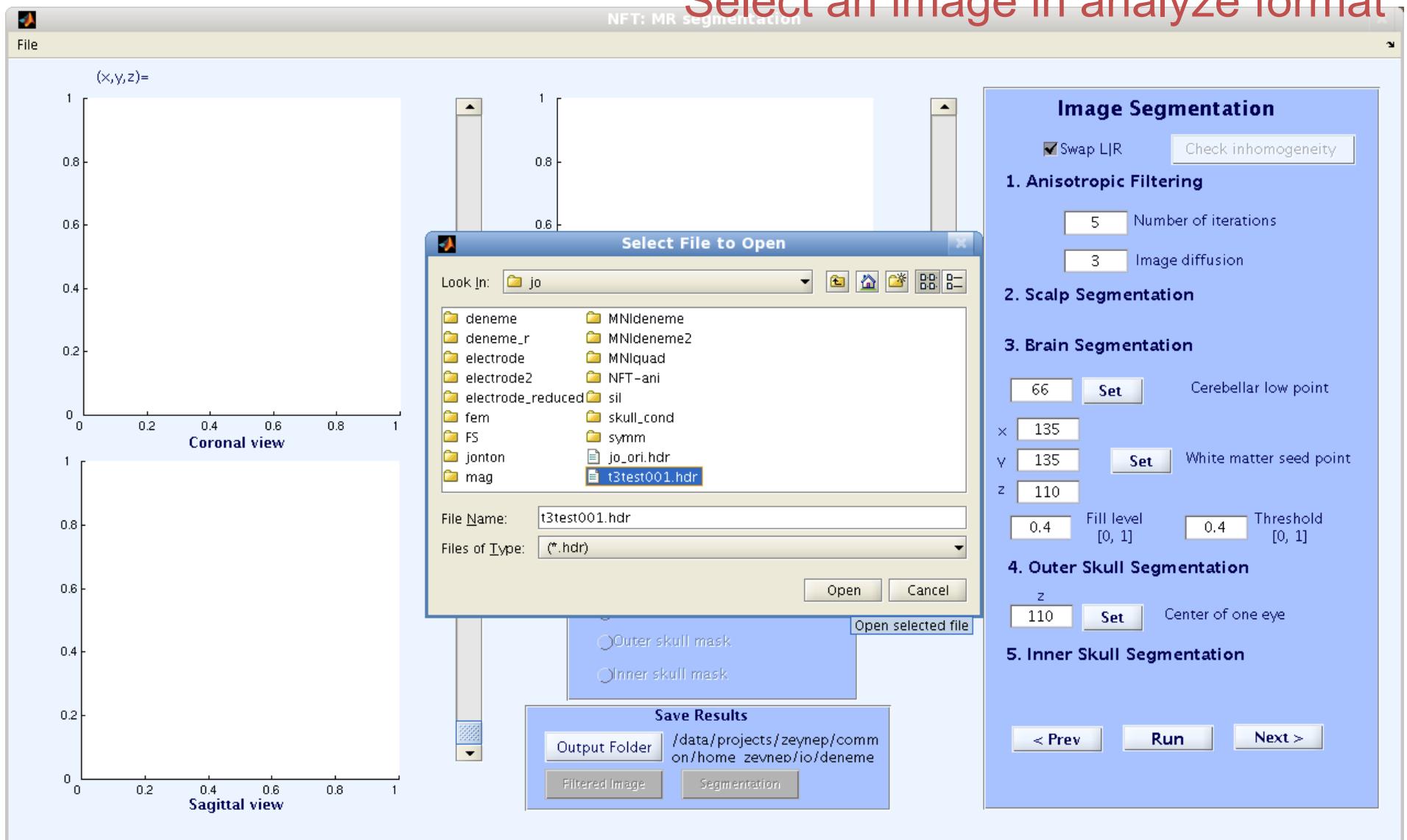
< Prev Run Next >

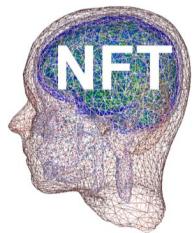




Segmentation

Select an image in analyze format





Segmentation

Run filtering

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 LIR 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]

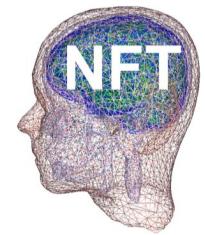
4. Outer Skull Segmentation

z 110 Set Center of one eye

5. Inner Skull Segmentation

< Prev Run Next >

Run anisotropic filtering



Segmentation

NFT: MR segmentation

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

Coronal view

Axial view

Sagittal view

Image Segmentation

Swap LIR Check inhomogeneity

1. Anisotropic Filtering

Number of iterations: 5 Image diffusion: 3

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point: x=66, Set Cerebellar low point: y=135, Set Cerebellar low point: z=110, Set White matter seed point: x=135, Set White matter seed point: y=135, Set White matter seed point: z=110, Set Fill level: 0.4, [0, 1] Threshold: 0.4, [0, 1]

4. Outer Skull Segmentation

Center of one eye: z=110, Set

5. Inner Skull Segmentation

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

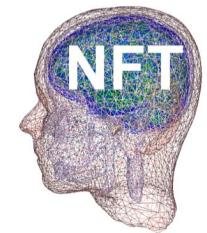
< Prev Run Next >

Image is filtered!

The screenshot shows the NFT: MR segmentation software interface. On the left, three brain slices are displayed: Coronal, Axial, and Sagittal. Each slice has a green crosshair indicating the center. The Coronal and Axial slices show internal brain structures in grayscale, while the Sagittal slice shows the brain within the skull. To the right of the slices is a control panel titled 'Image Segmentation' with several sections: 'Anisotropic Filtering' (with sliders for 'Number of iterations' and 'Image diffusion'), 'Scalp Segmentation', 'Brain Segmentation' (with sliders for 'Cerebellar low point' coordinates x, y, z, 'White matter seed point' coordinates x, y, z, 'Fill level', and 'Threshold'), 'Outer Skull Segmentation' (with a slider for 'Center of one eye' at z=110), and 'Inner Skull Segmentation'. Below these sections are 'Display Image' and 'Save Results' sections. The 'Display Image' section contains radio buttons for 'MR image' (selected), 'Filtered image', 'Scalp mask', 'Brain mask', 'Outer skull mask', and 'Inner skull mask'. The 'Save Results' section includes an 'Output Folder' set to '/data/projects/zeynep/comm on/home_zeynep/io/deneme', and buttons for 'Filtered Image' and 'Segmentation'. At the bottom, there are navigation buttons '< Prev', 'Run' (highlighted in red), and 'Next >', and a message '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_zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

Swap LIR Check inhomogeneity

1. Anisotropic Filtering

Number of iterations: 5 Image diffusion: 3

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point: x: 135, y: 135, z: 110 Set Threshold: 0.4 [0, 1]

White matter seed point: x: 135, y: 135, z: 110 Set Fill level: 0.4 [0, 1] Threshold: 0.4 [0, 1]

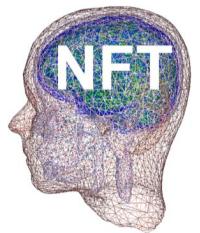
4. Outer Skull Segmentation

Center of one eye: z: 110 Set

5. Inner Skull Segmentation

< Prev Run Next >

Image is filtered!



Segmentation

Click 'Next' for scalp segmentation

NFT: MR segmentation

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

Coronal view Axial view Sagittal view

Image Segmentation

Swap LIR 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

Display Image

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

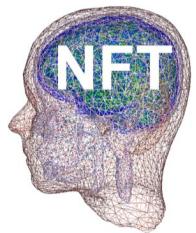
Save Results

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

Filtered Image Segmentation

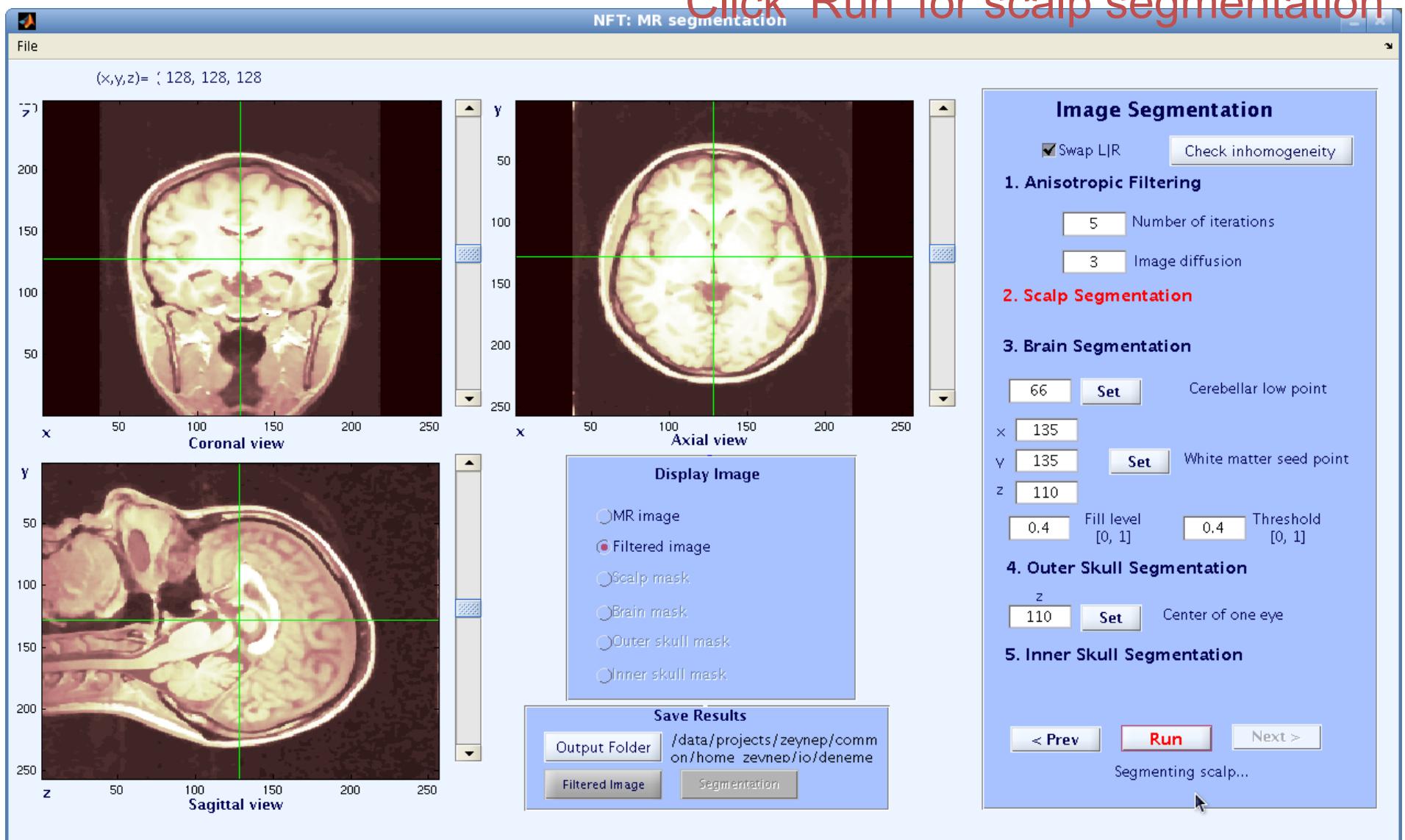
< Prev Run Next >

Image is filtered!



Segmentation

Click 'Run' for scalp segmentation



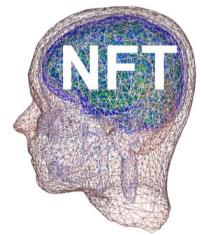


Image Segmentation

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 LIR Check inhomogeneity

1. Anisotropic Filtering

Number of iterations: 5 Image diffusion: 3

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point: x=66, Set Cerebellar low point: y=135, Set Cerebellar low point: z=110, Set

White matter seed point: x=135, Set White matter seed point: y=135, Set White matter seed point: z=110, Set

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

4. Outer Skull Segmentation

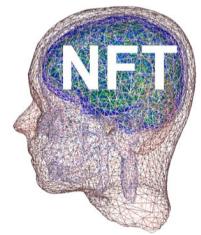
Center of one eye: z=110, Set

5. Inner Skull Segmentation

< Prev Run Next >

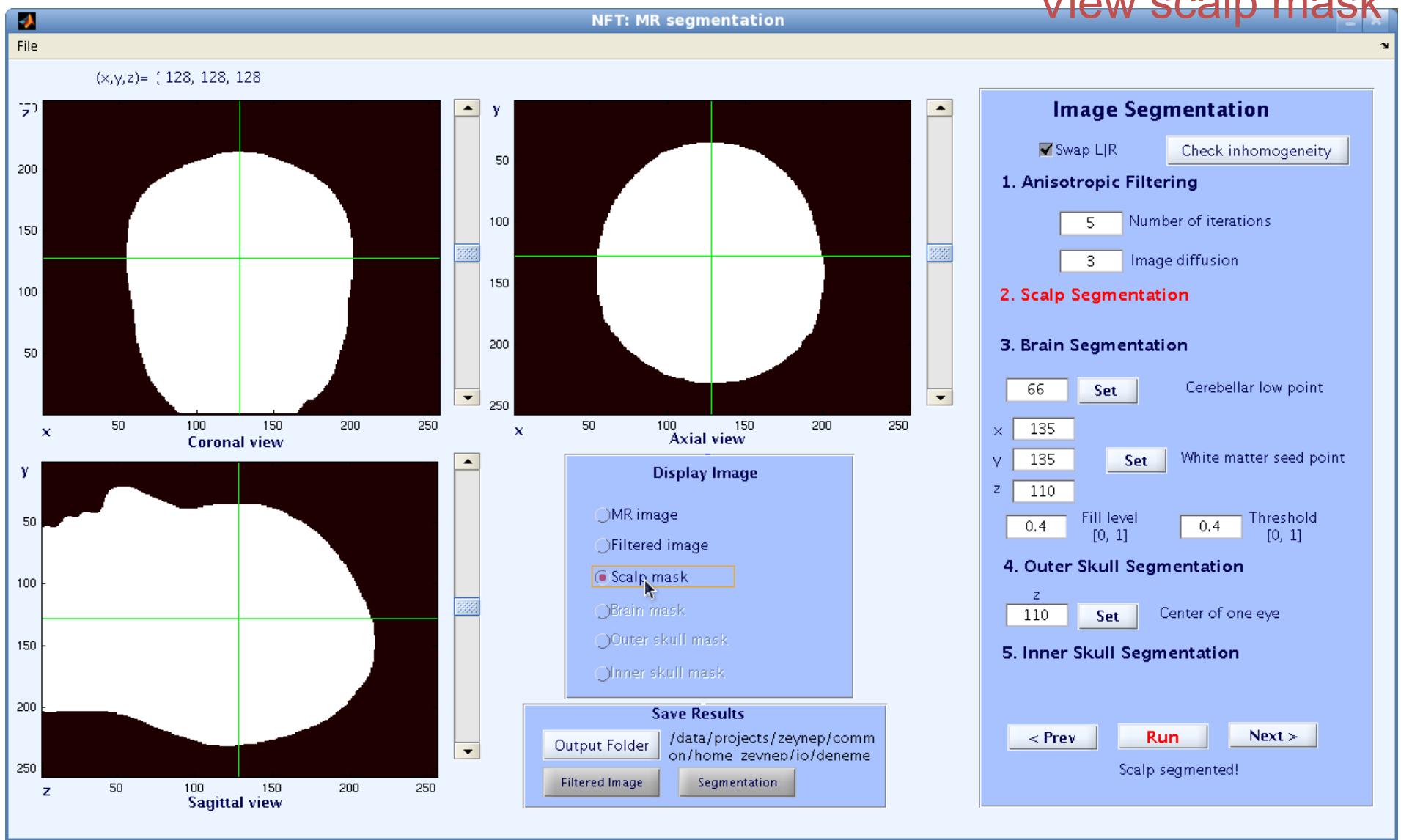
Scalp segmented!

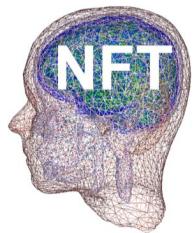
The screenshot shows a Windows-style application window titled "NFT: MR segmentation". On the left, three 3D brain volume renderings are displayed in Coronal, Axial, and Sagittal planes. Each view has a green crosshair indicating the current slice position. To the right of the images is a control panel with several sections: "Image Segmentation" (with a "Swap LIR" checkbox and "Check inhomogeneity" button), "Anisotropic Filtering" (with "Number of iterations" set to 5 and "Image diffusion" set to 3), "Scalp Segmentation" (highlighted in red), "Brain Segmentation" (with coordinates for cerebellar low point and white matter seed point), "Outer Skull Segmentation" (with a coordinate for center of one eye), and "Inner Skull Segmentation". The "Save Results" section at the bottom allows users to choose an output folder and provides buttons for "Filtered Image" and "Segmentation". A message "Scalp segmented!" is displayed at the bottom right.



Segmentation

View scalp mask





Segmentation

Click 'Next' for brain segmentation

NFT: MR segmentation

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

Coronal view Axial view Sagittal view

Image Segmentation

Swap LIR Check inhomogeneity

1. Anisotropic Filtering

5 Number of iterations
3 Image diffusion

2. Scalp 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]

3. Brain Segmentation

4. Outer Skull Segmentation

z 110 Set Center of one eye

5. Inner Skull Segmentation

Display Image

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

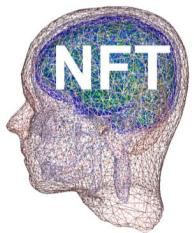
Save Results

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

Filtered Image Segmentation

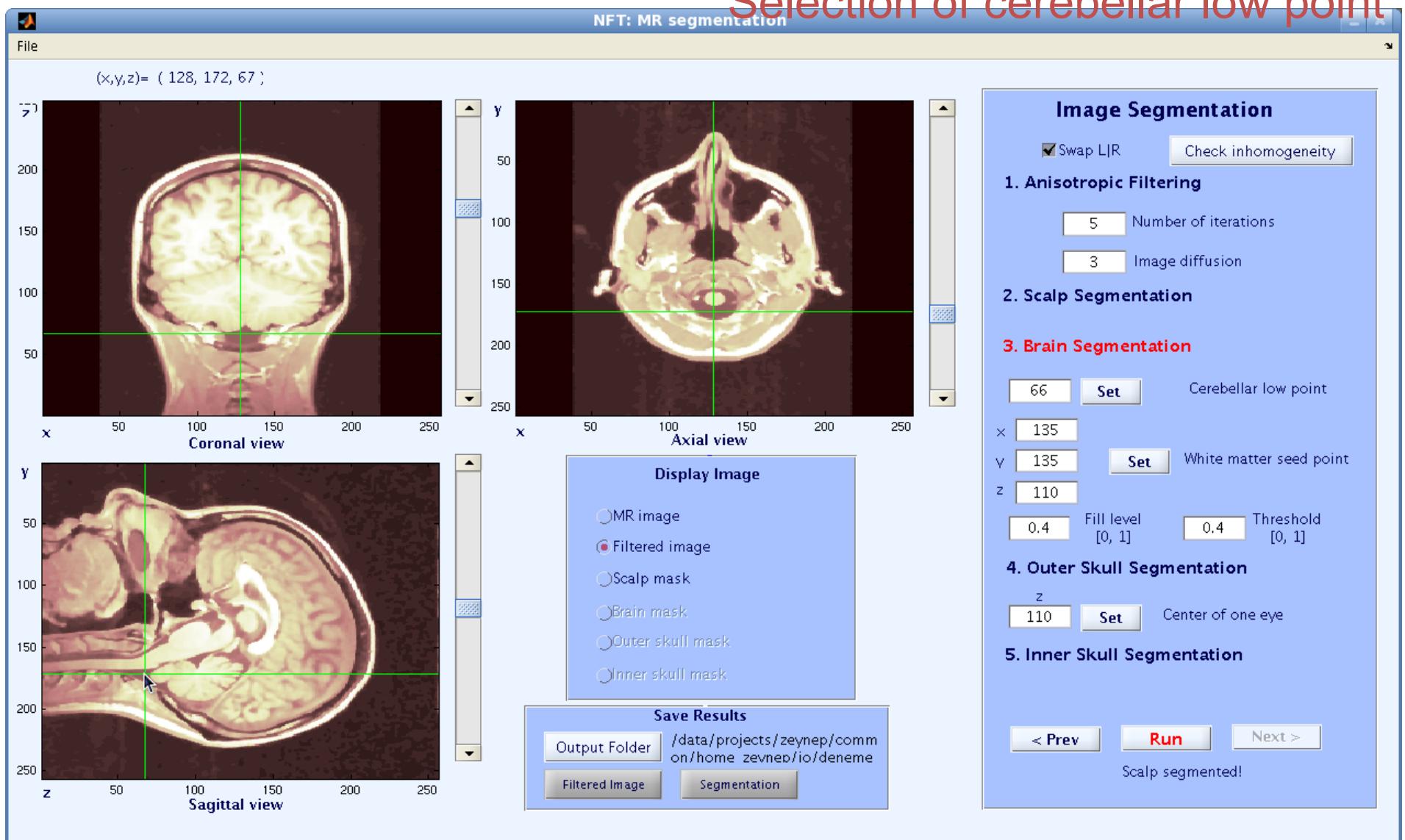
< Prev Run Next >

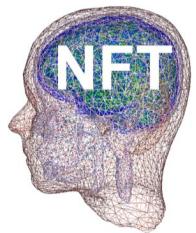
Scalp segmented!



Segmentation

Selection of cerebellar low point





Segmentation

Click 'Set'

NFT: MR segmentation

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

Coronal view

Axial view

Sagittal view

Image Segmentation

1. Anisotropic Filtering

Swap LIR Check inhomogeneity

Number of iterations: 5

Image diffusion: 3

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point: Set (x: 67, y: 135, z: 110)

White matter seed point: Set (x: 135, y: 135, z: 110)

Fill level: 0.4 [0, 1]

Threshold: 0.4 [0, 1]

4. Outer Skull Segmentation

Center of one eye: Set (z: 110)

5. Inner Skull Segmentation

Display Image

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

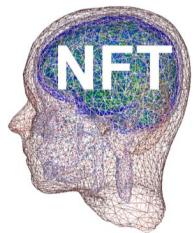
Save Results

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

Filtered Image

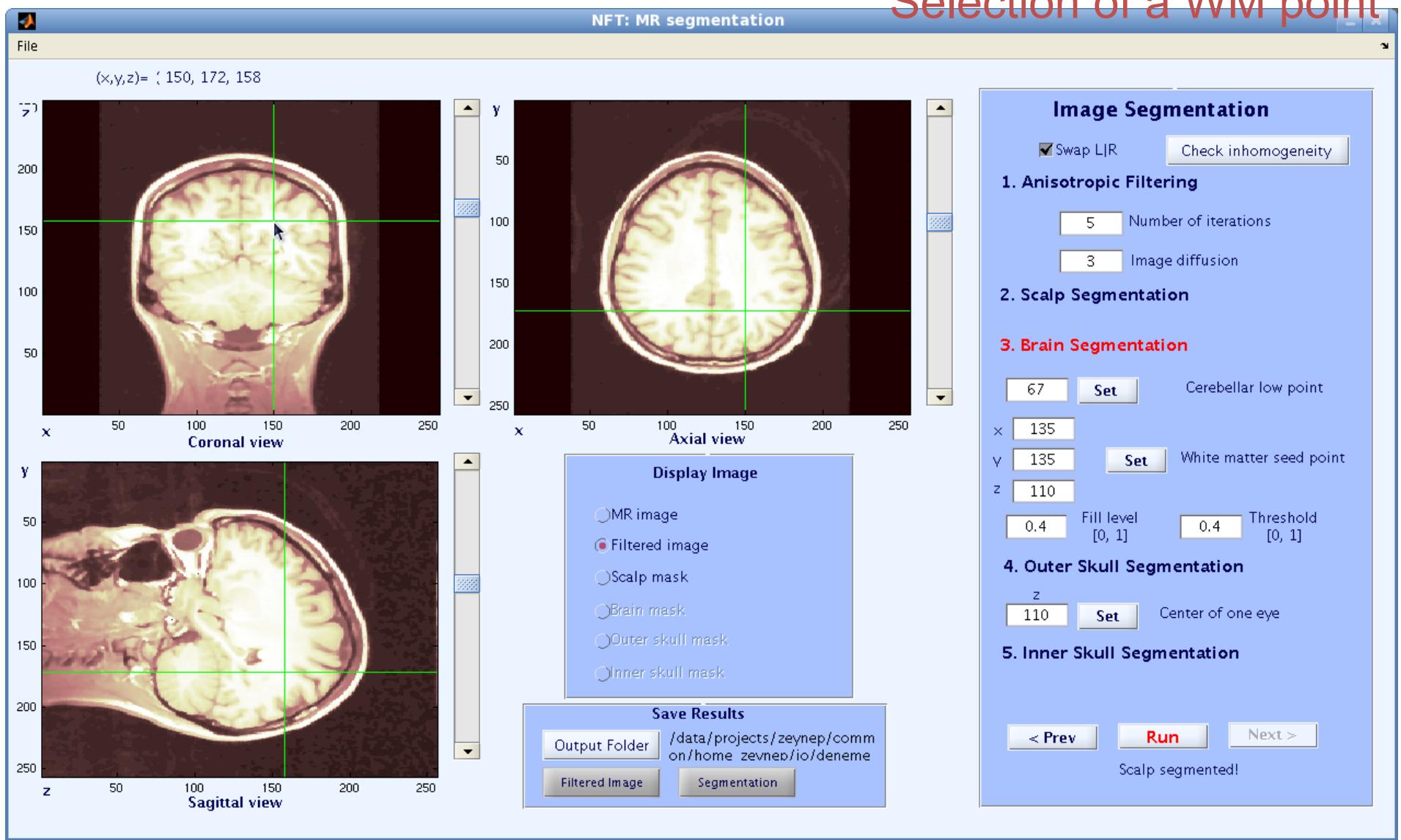
Segmentation

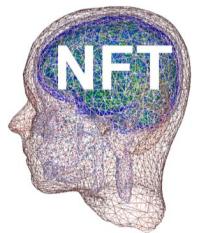
Scalp segmented!



Segmentation

Selection of a WM point





Segmentation

Click 'Set'

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_zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

Swap LIR Check inhomogeneity

1. Anisotropic Filtering

Number of iterations: 5 Image diffusion: 3

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point: 67 Set

White matter seed point: x 172, y 158, z 150 Set

Fill level: 0.4 Threshold: 0.4

4. Outer Skull Segmentation

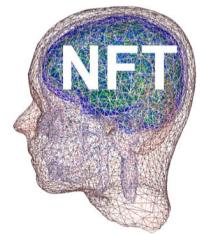
Center of one eye: z 110 Set

5. Inner Skull Segmentation

< Prev Run Next >

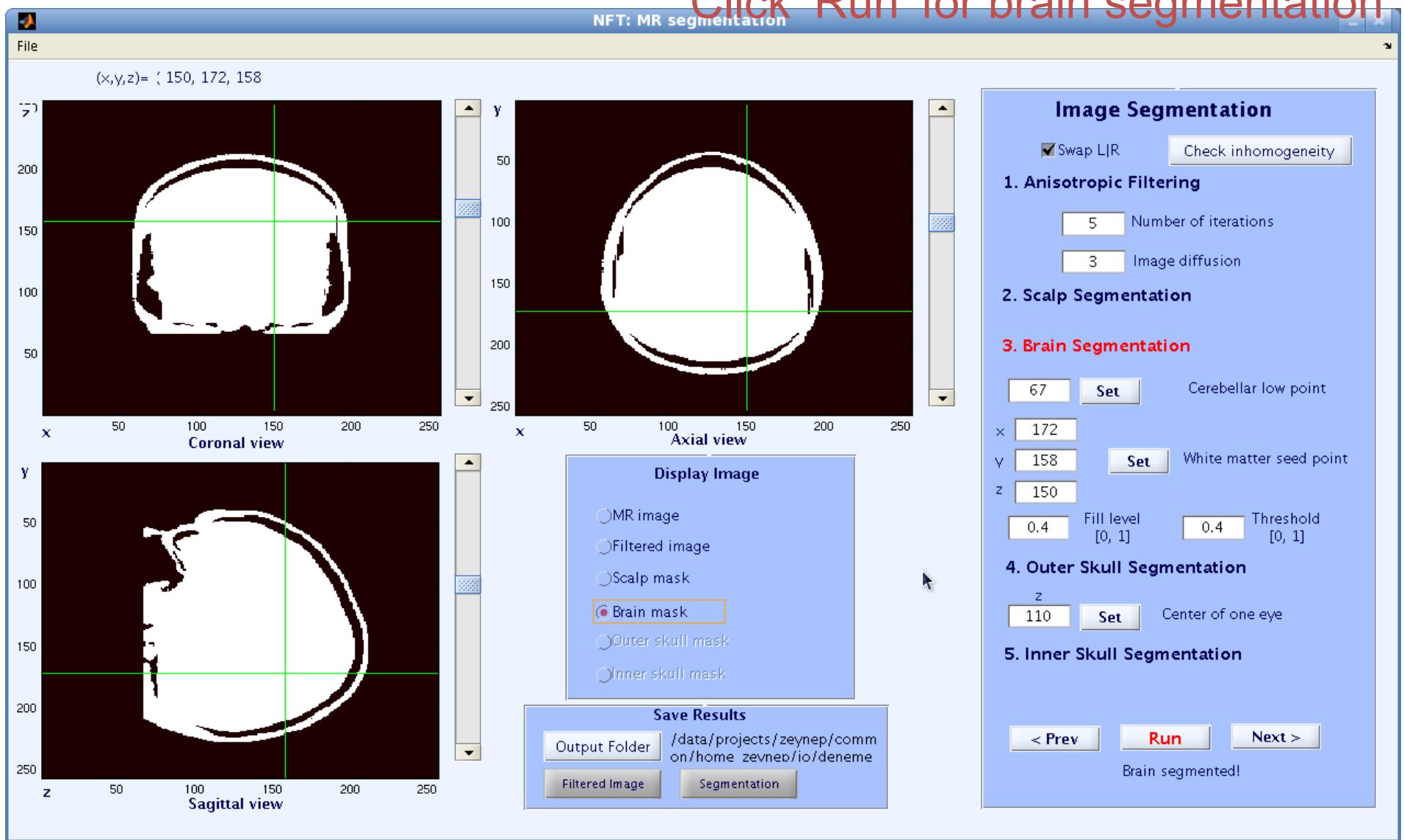
Scalp segmented!

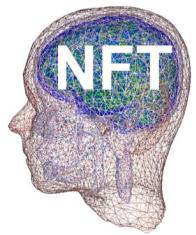
The screenshot shows the NFT: MR segmentation software interface. It features three 3D brain volume slices: Coronal, Axial, and Sagittal. Each slice has a green crosshair indicating the current segmentation point at coordinates (150, 172, 158). On the right side, there's a control panel for 'Image Segmentation' with sections for 'Anisotropic Filtering', 'Scalp Segmentation', 'Brain Segmentation' (with a 'Set' button over the 'White matter seed point' parameters), 'Outer Skull Segmentation', and 'Inner Skull Segmentation'. A 'Save Results' section at the bottom allows saving to an output folder. A red 'Click 'Set'' annotation points to the 'Set' button in the 'Brain Segmentation' section.



Segmentation

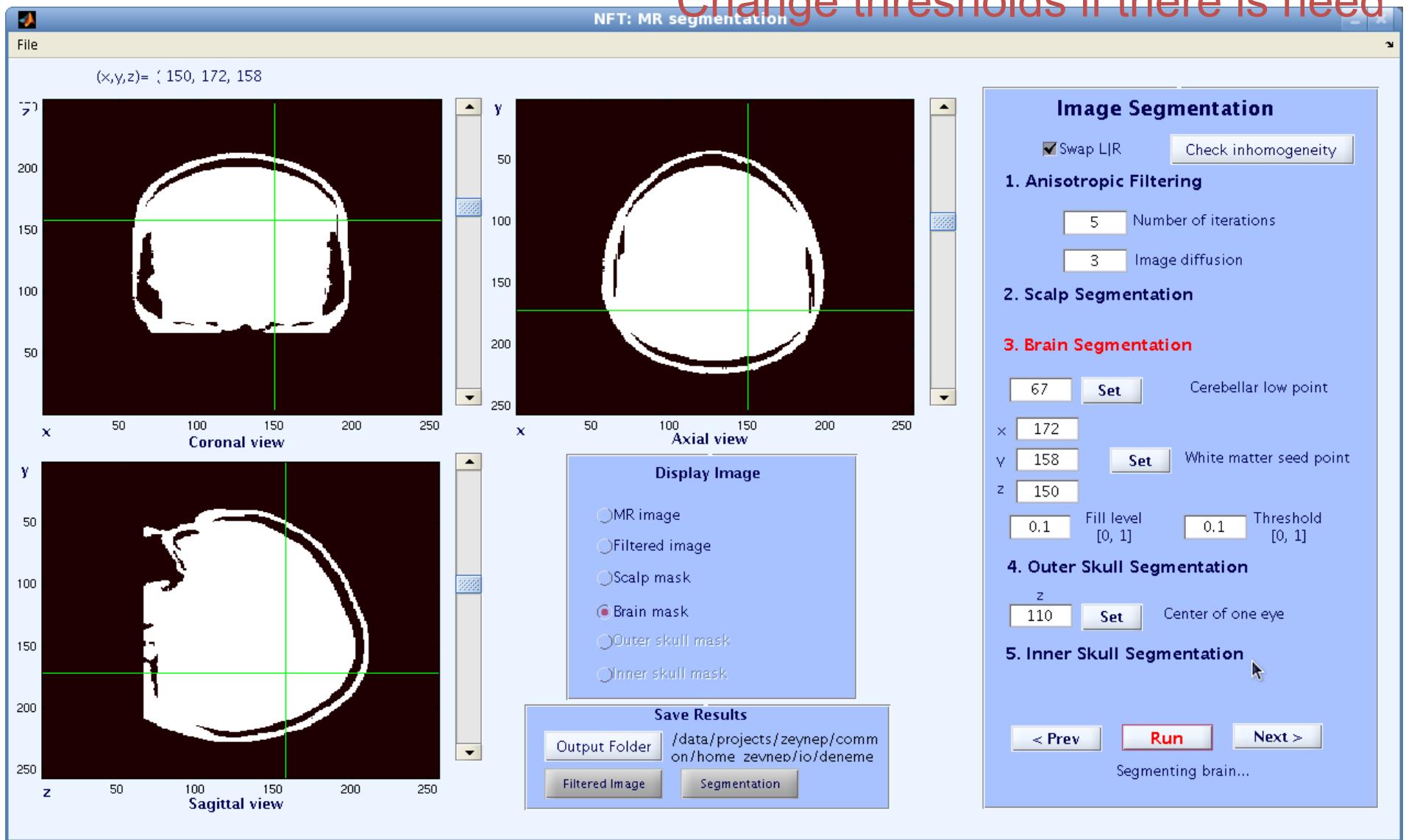
Click 'Run' for brain segmentation

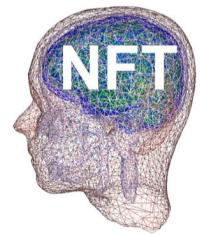




Segmentation

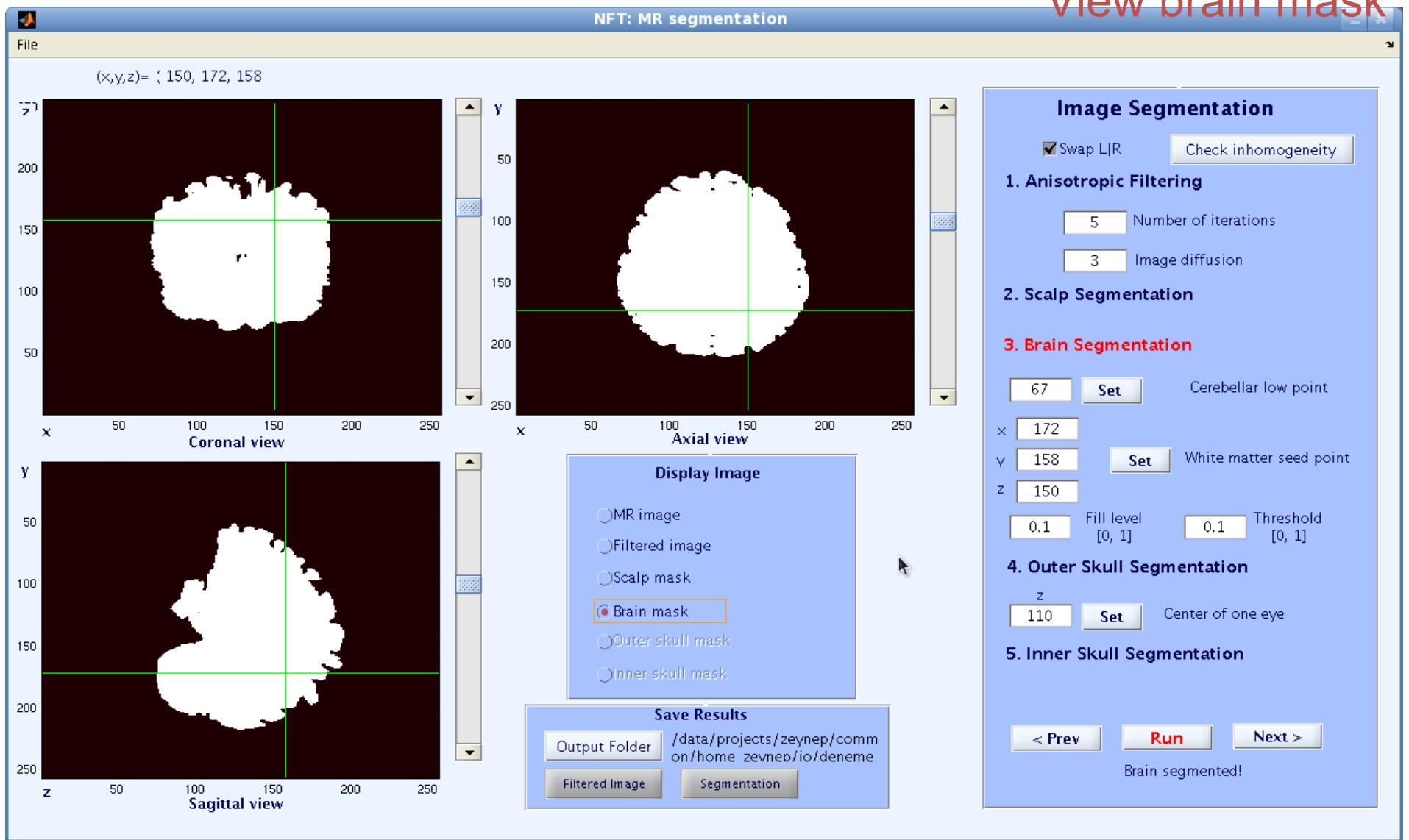
Change thresholds if there is need

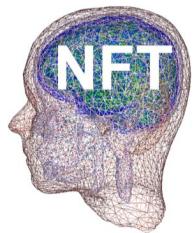




Segmentation

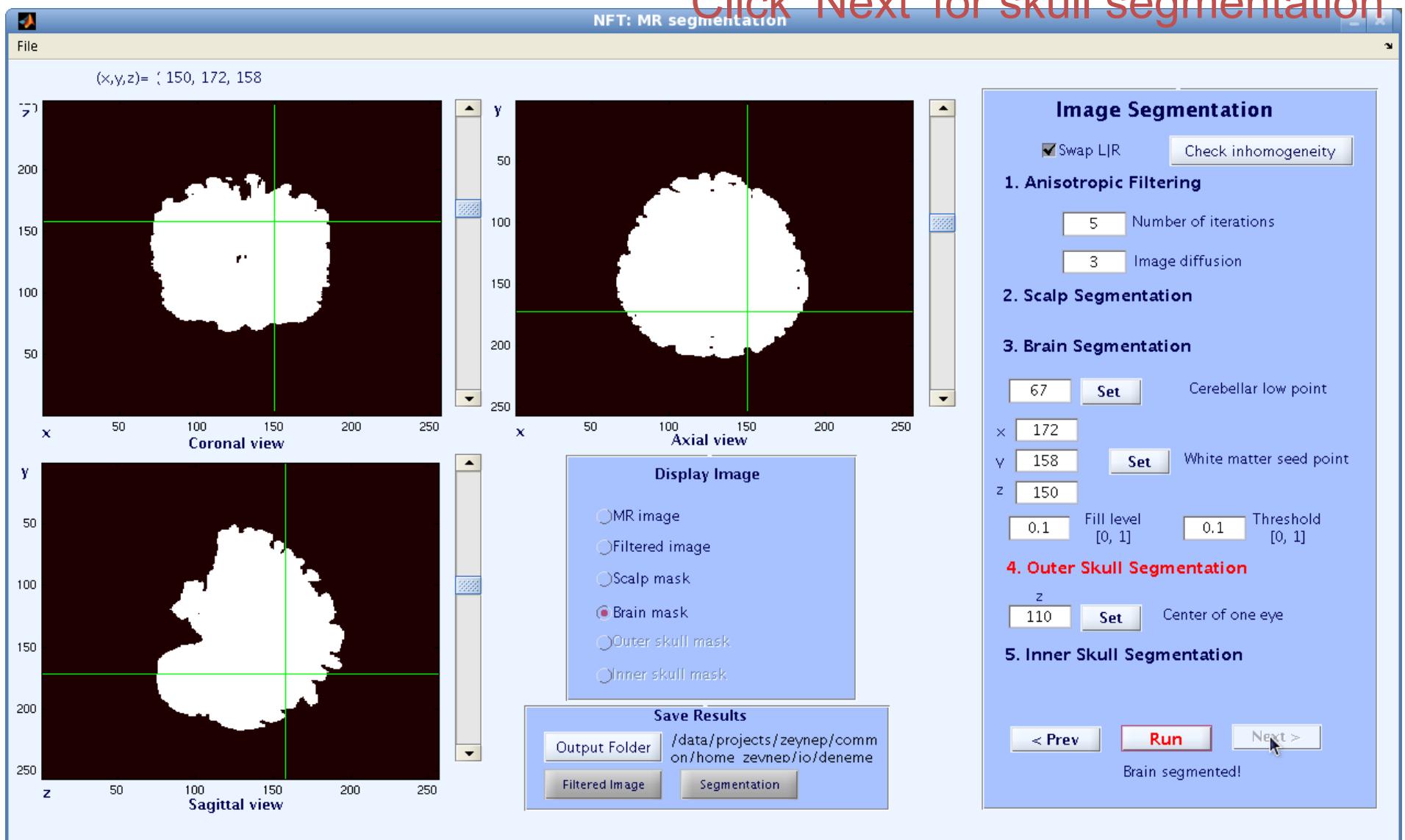
View brain mask

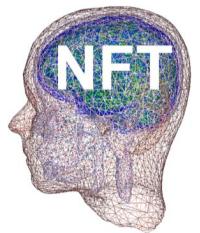




Segmentation

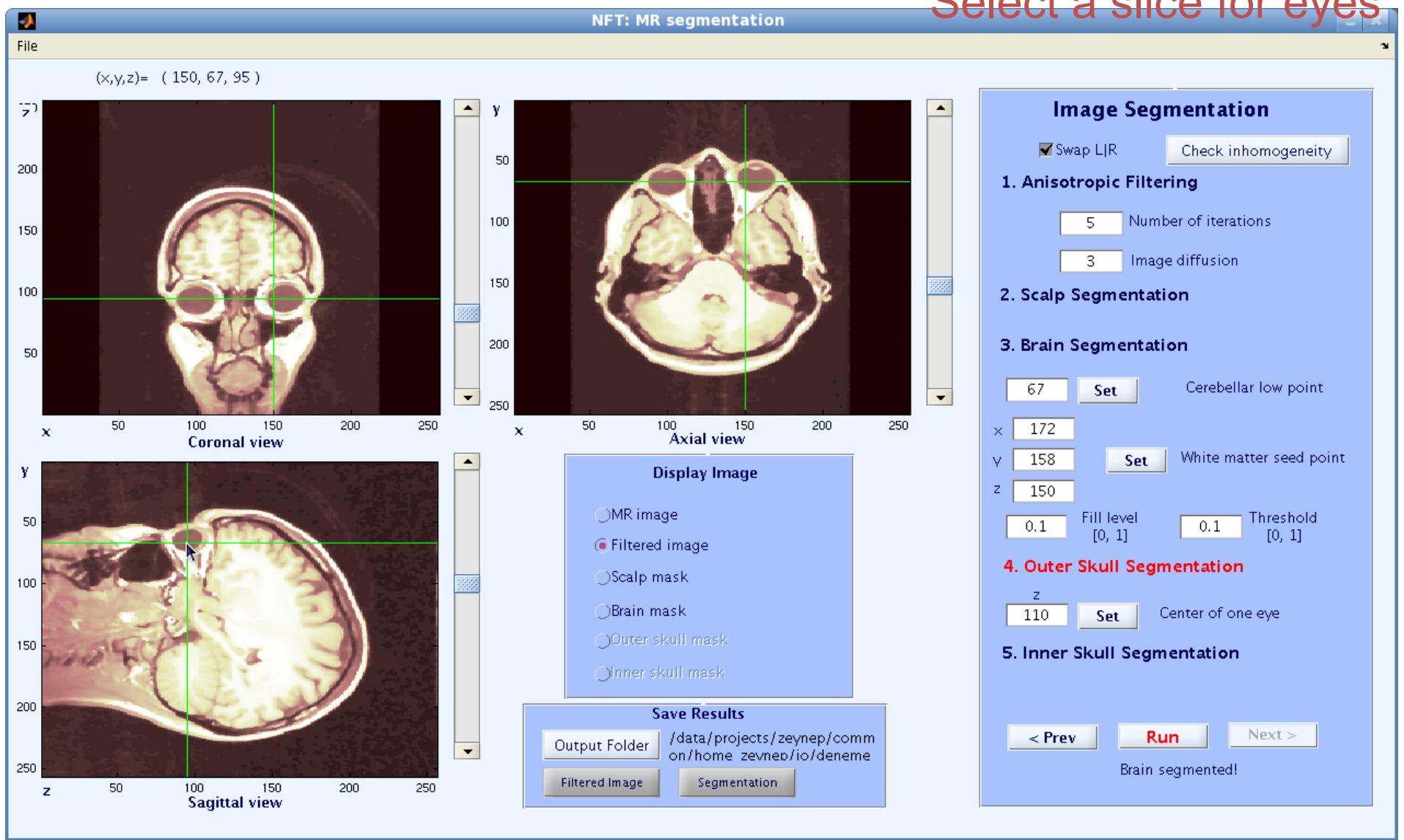
Click 'Next' for skull segmentation

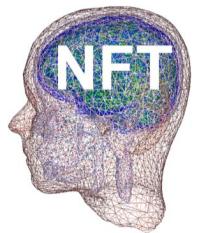




Segmentation

Select a slice for eyes





Segmentation

Click 'Set'

NFT: MR segmentation

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

Coronal view

Axial view

Sagittal view

Image Segmentation

Swap LIR Check inhomogeneity

1. Anisotropic Filtering

Number of iterations: 5

Image diffusion: 3

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point: x: 67, Set, y: 172, z: 158, White matter seed point: x: 158, Set, y: 150, z: 95, Fill level: 0.1, Threshold: 0.1

4. Outer Skull Segmentation

Center of one eye: z: 95, Set

5. Inner Skull Segmentation

Display Image

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

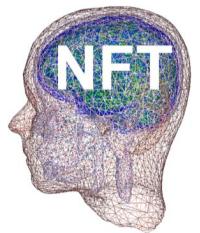
Save Results

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

Filtered Image, Segmentation

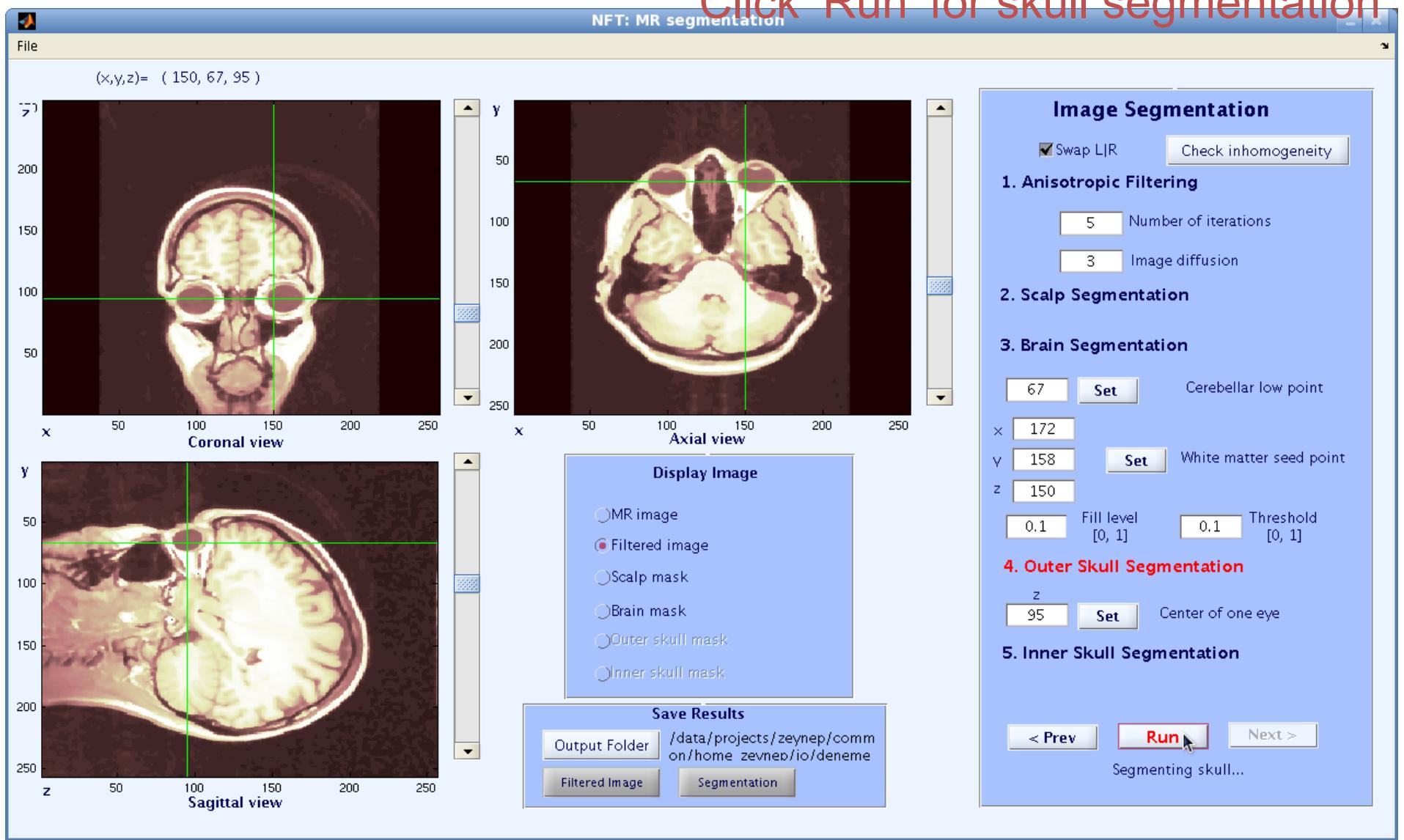
< Prev, Run, Next >

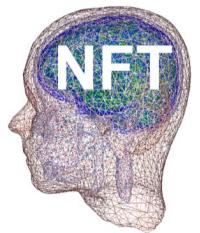
Brain segmented!



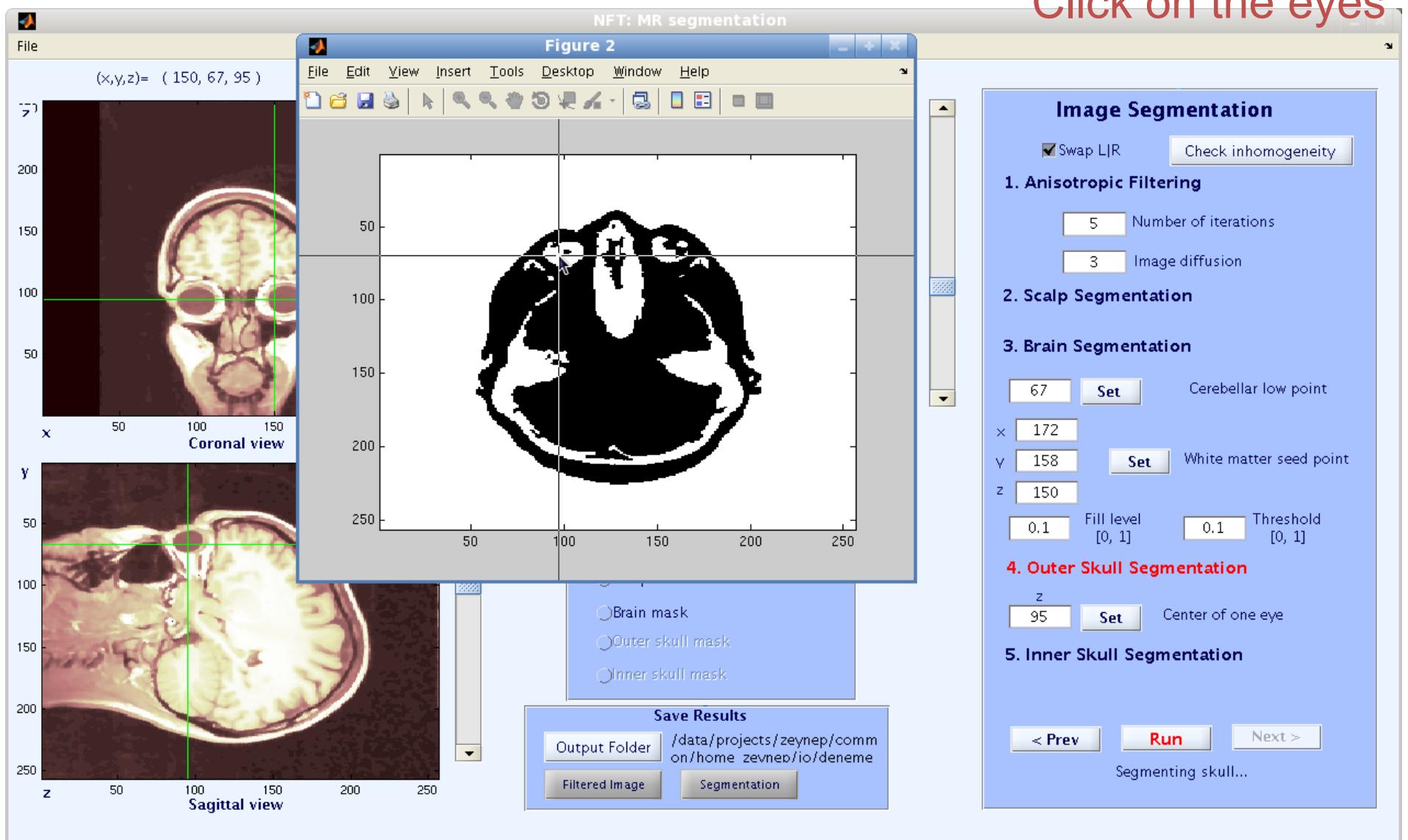
Segmentation

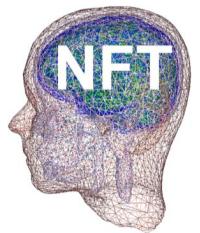
Click 'Run' for skull segmentation



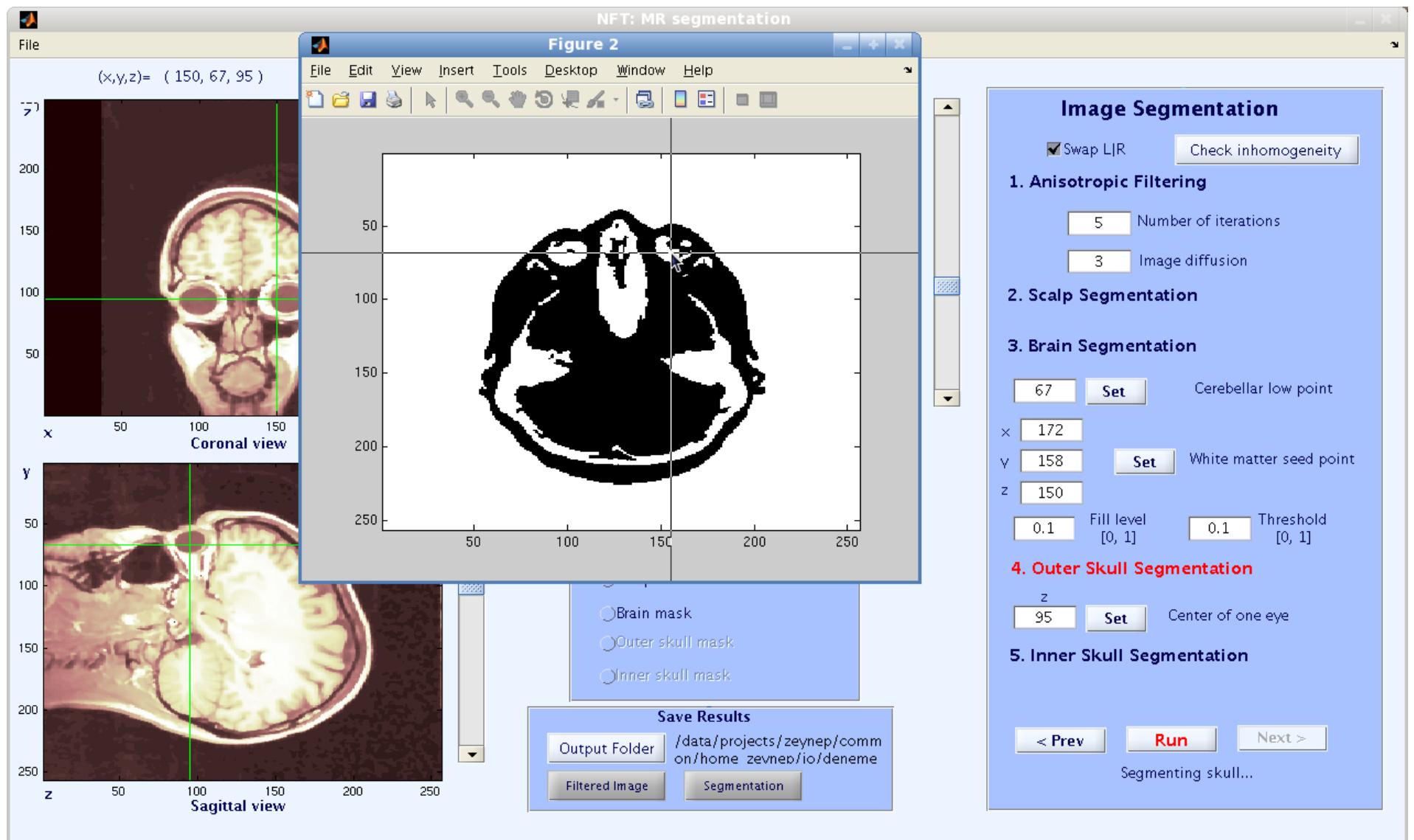


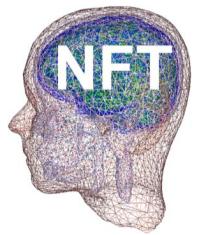
Segmentation



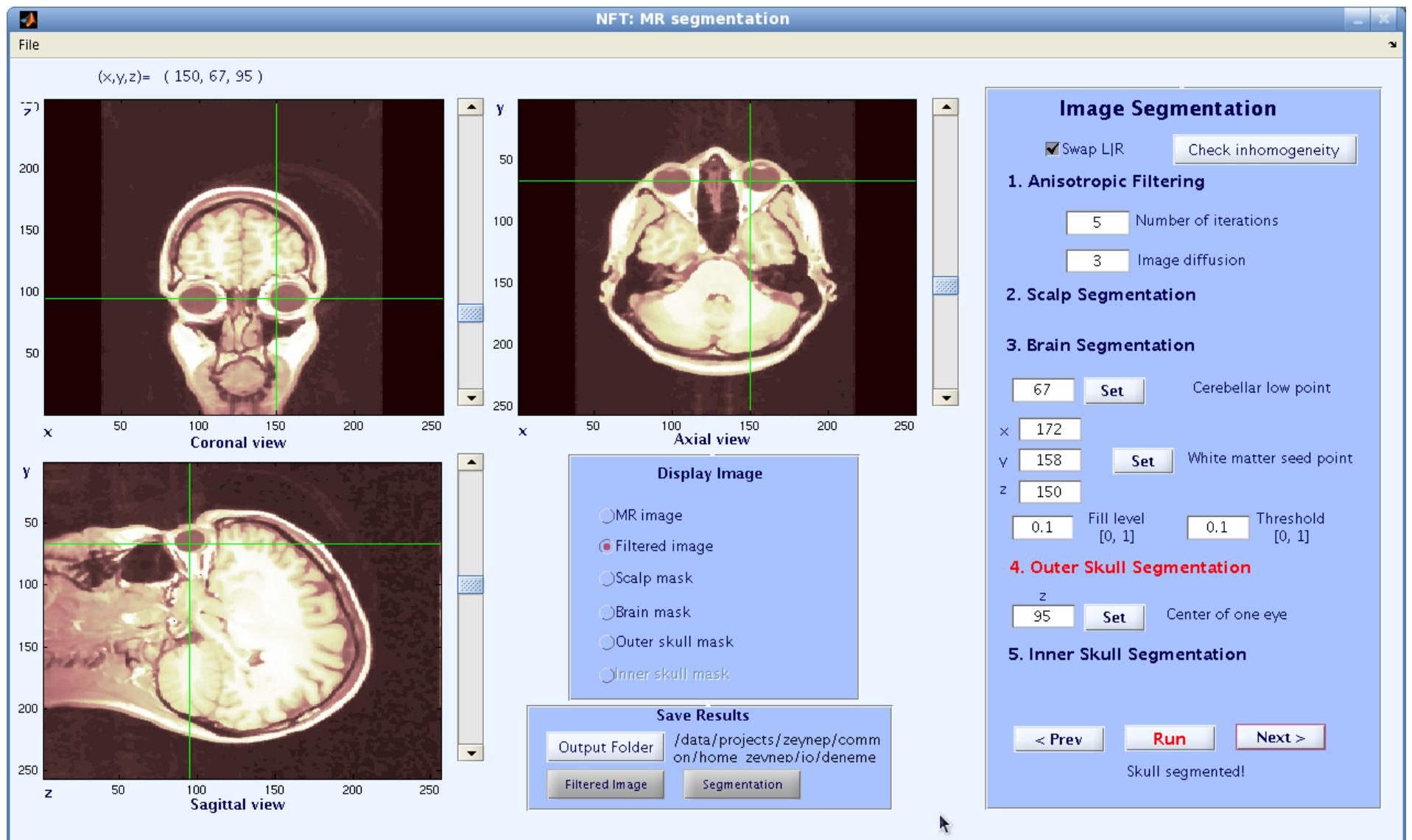


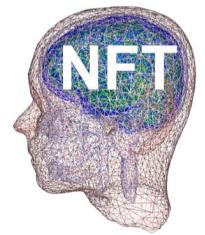
Segmentation





Segmentation





Segmentation

View skull segmentation

NFT: MR segmentation

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

Coronal view

Axial view

Sagittal view

Image Segmentation

1. Anisotropic Filtering

Swap LIR Check inhomogeneity

Number of iterations: 5

Image diffusion: 3

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point: x 67, Set

White matter seed point: y 172, Set; z 158, Set

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

4. Outer Skull Segmentation

Center of one eye: z 95, Set

5. Inner Skull Segmentation

Display Image

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

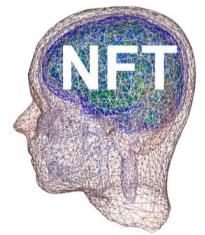
Save Results

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

Filtered Image, Segmentation

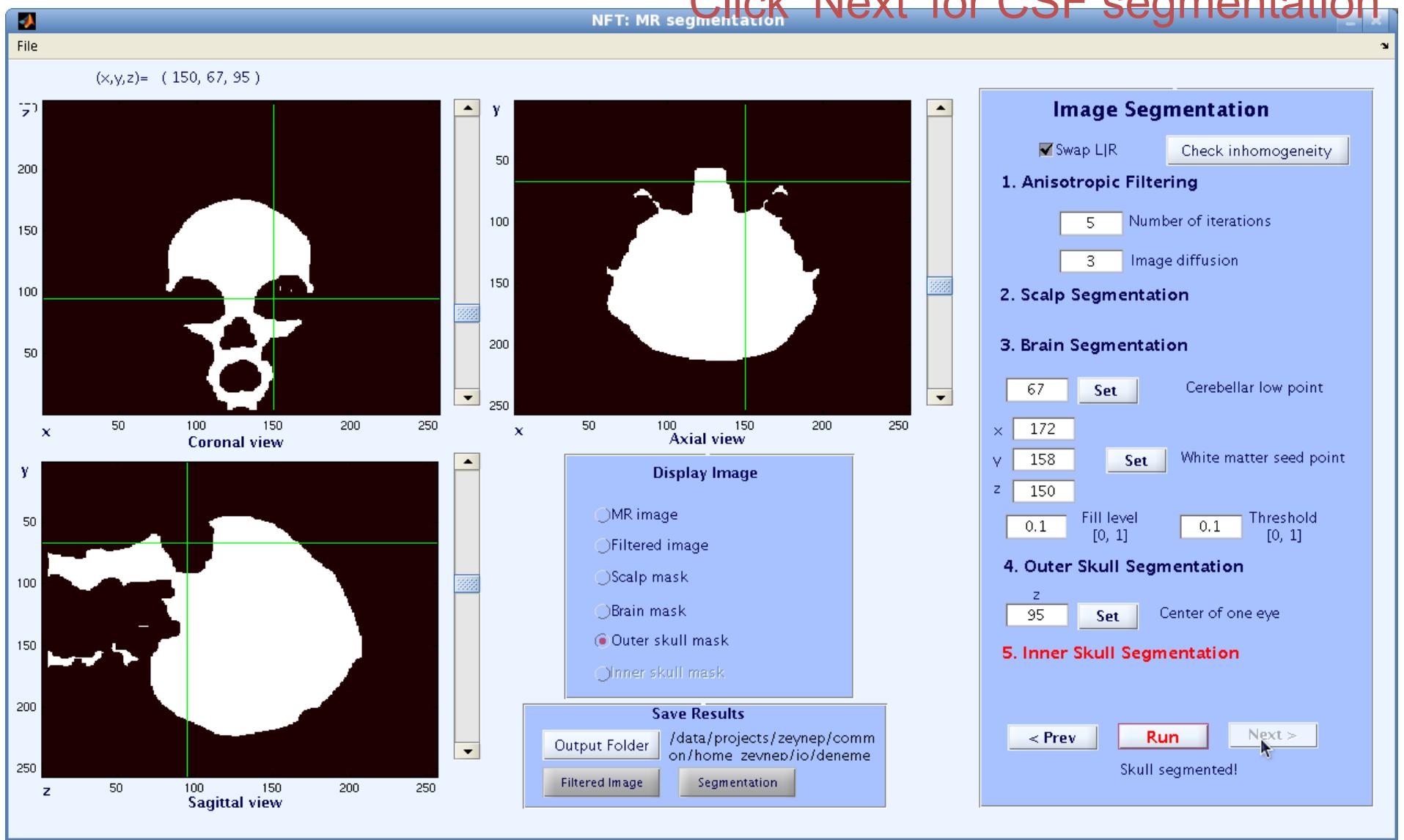
< Prev, Run, Next >

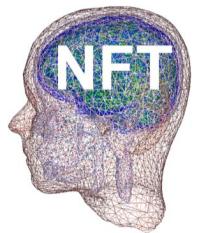
Skull segmented!



Segmentation

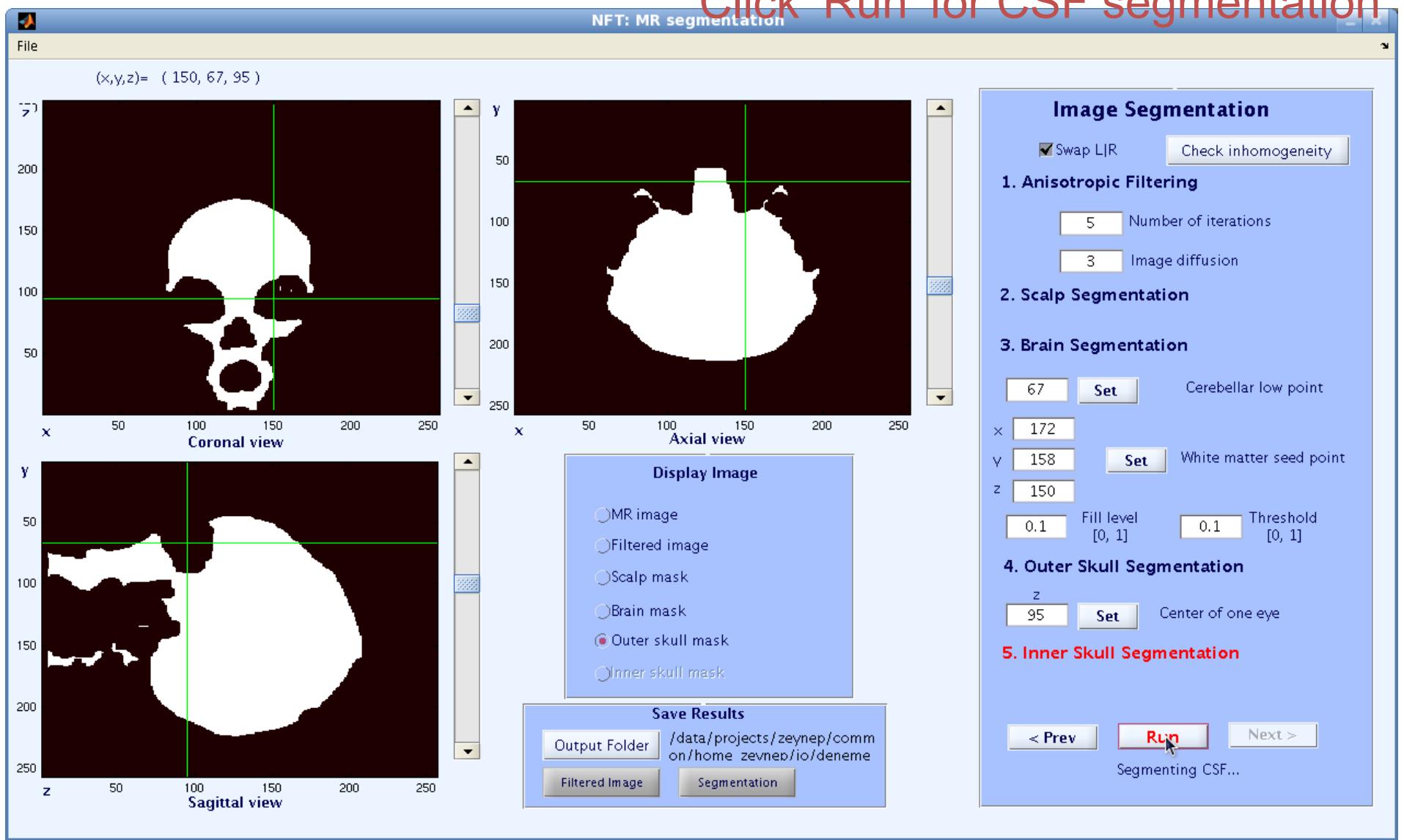
Click 'Next' for CSF segmentation

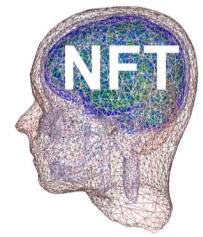




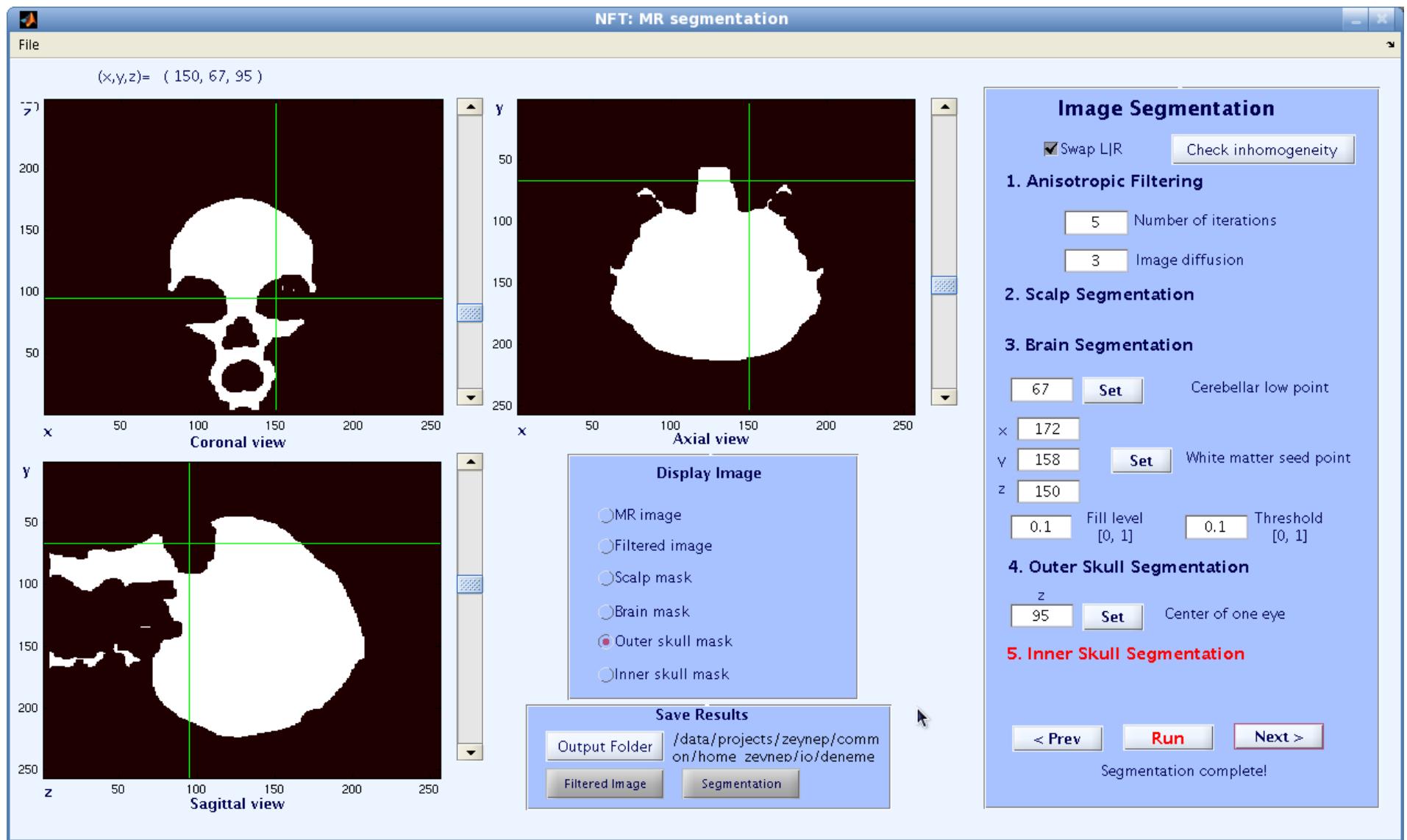
Segmentation

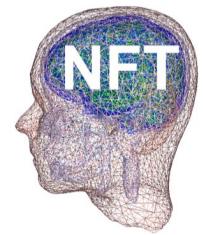
Click 'Run' for CSF segmentation





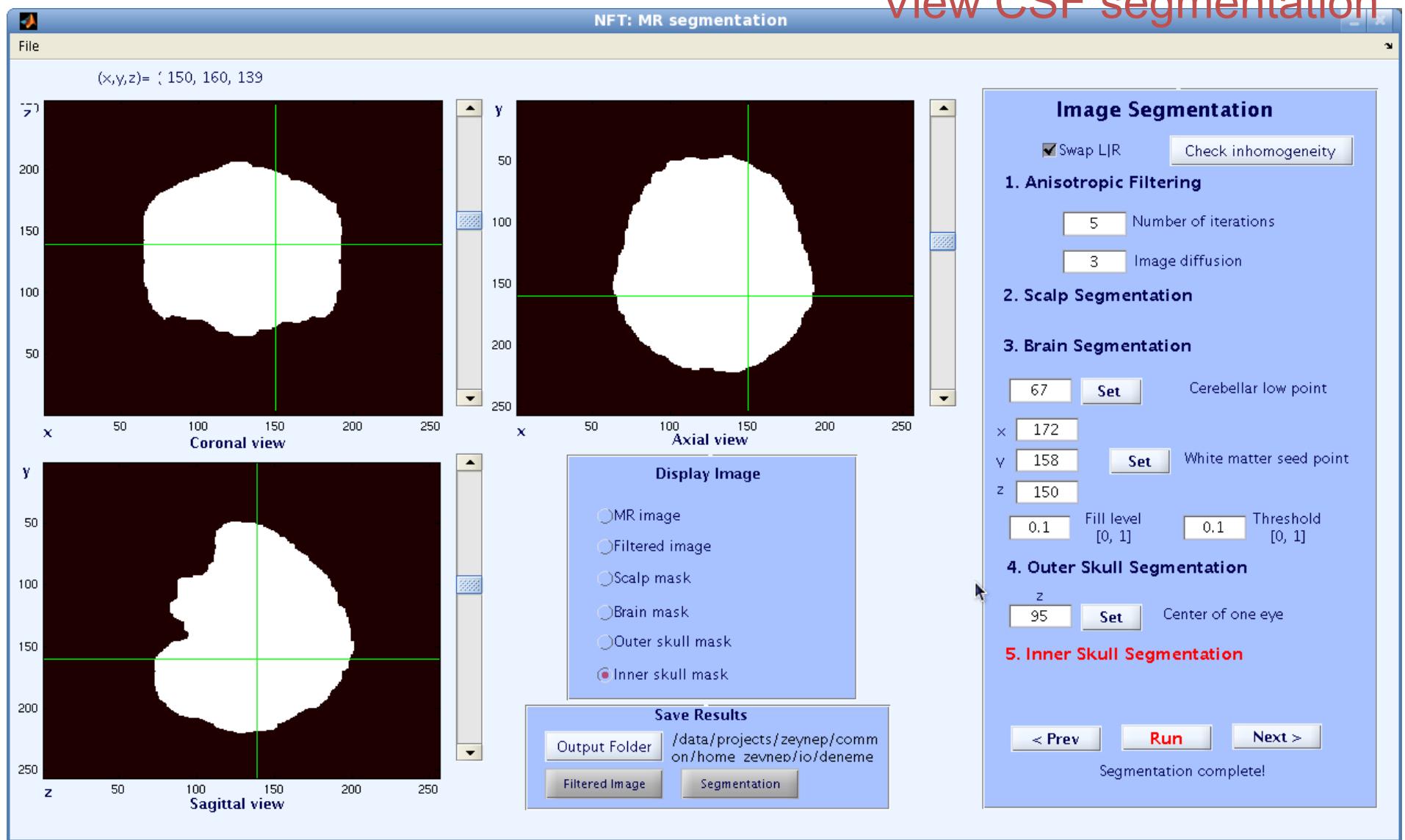
Segmentation

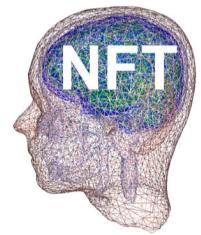




Segmentation

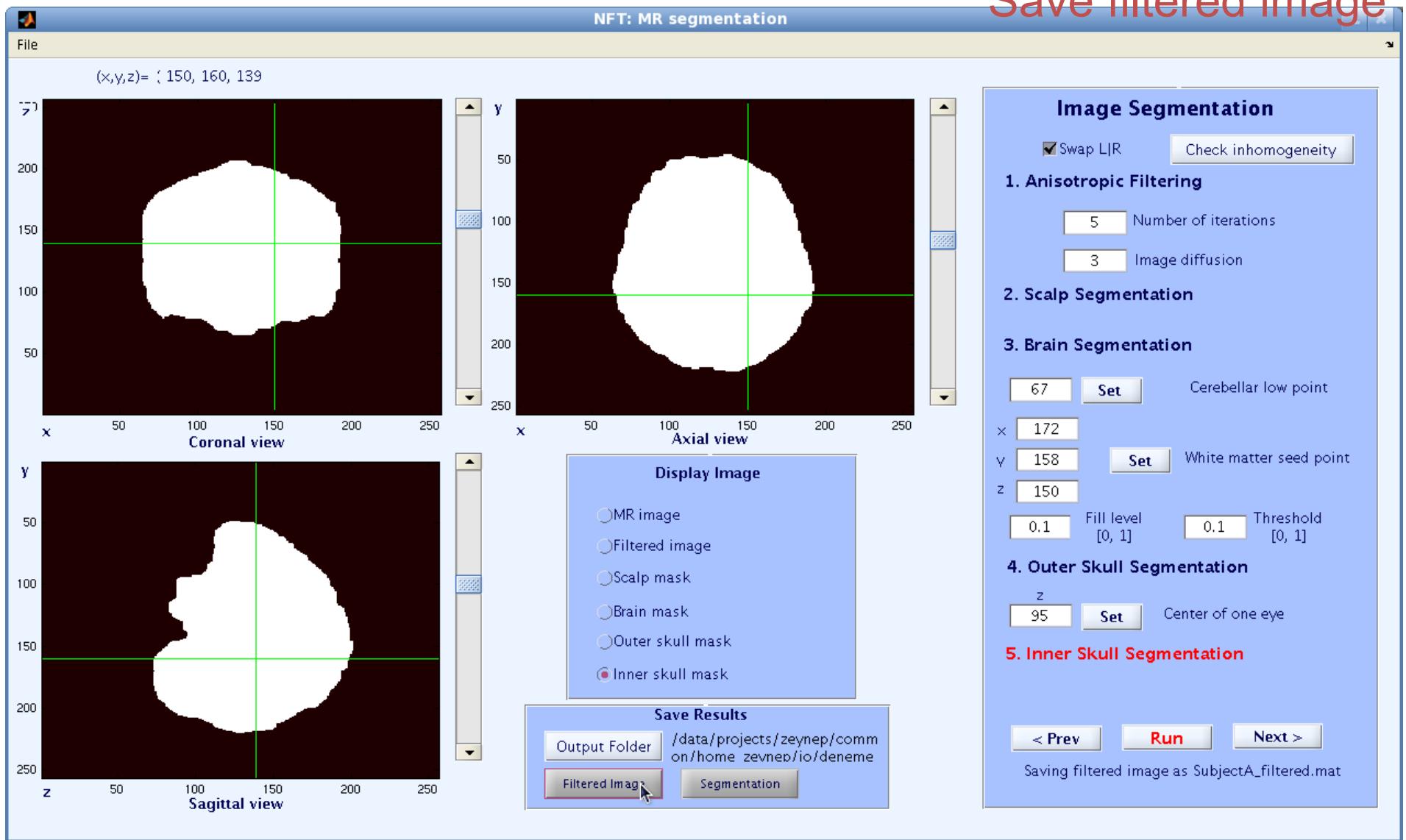
View CSF segmentation

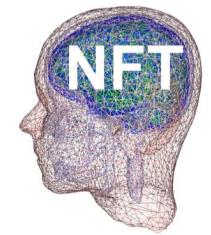




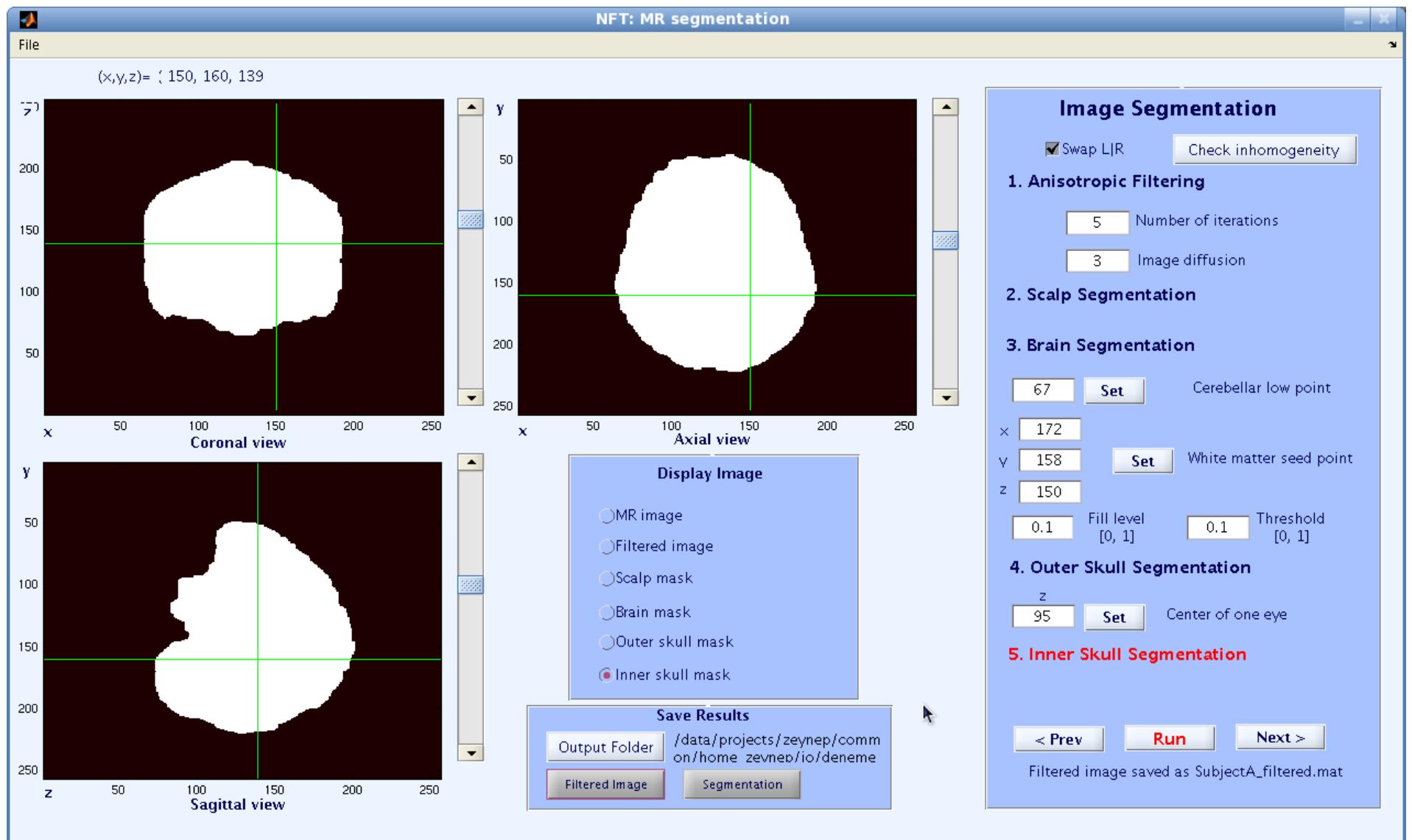
Segmentation

Save filtered image



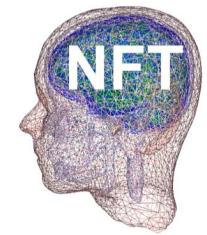


Segmentation





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_zeynep/io/deneme

Filtered Image Segmentation

Image Segmentation

Swap LIR Check inhomogeneity

1. Anisotropic Filtering

Number of iterations: 5 Image diffusion: 3

2. Scalp Segmentation

3. Brain Segmentation

Cerebellar low point: 67 Set

White matter seed point: x 172, y 158, z 150 Set

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

4. Outer Skull Segmentation

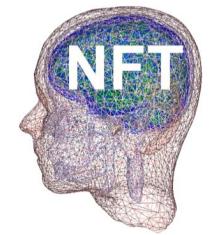
Center of one eye: z 95 Set

5. Inner Skull Segmentation

< Prev Run Next >

Saving segmentation as SubjectA_segments.mat

A screenshot of the NFT: MR segmentation software. The interface shows three 3D brain slices (Coronal, Axial, Sagittal) with white segmentation masks. On the right, a control panel contains various segmentation parameters and a 'Save Results' section. The 'Save Results' section shows the output folder as '/data/projects/zeynep/comm on/home_zeynep/io/deneme'. The 'Run' button is highlighted in red.



Segmentation

NFT: MR segmentation

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

Coronal view Axial view Sagittal view

Image Segmentation

Swap LIR 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 >

Segmentation saved as SubjectA_segments.mat

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

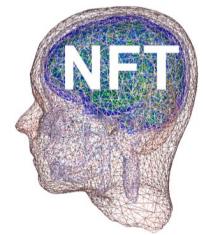


Image Segmentation

Command Window

New to MATLAB? Watch this [Video](#), see [Demos](#), or read [Getting Started](#).

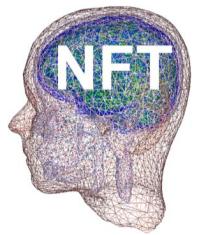
```
>> dir SubjectA*
SubjectA_mri.mat      SubjectA_segments.mat

>> load SubjectA_mri
>> mri

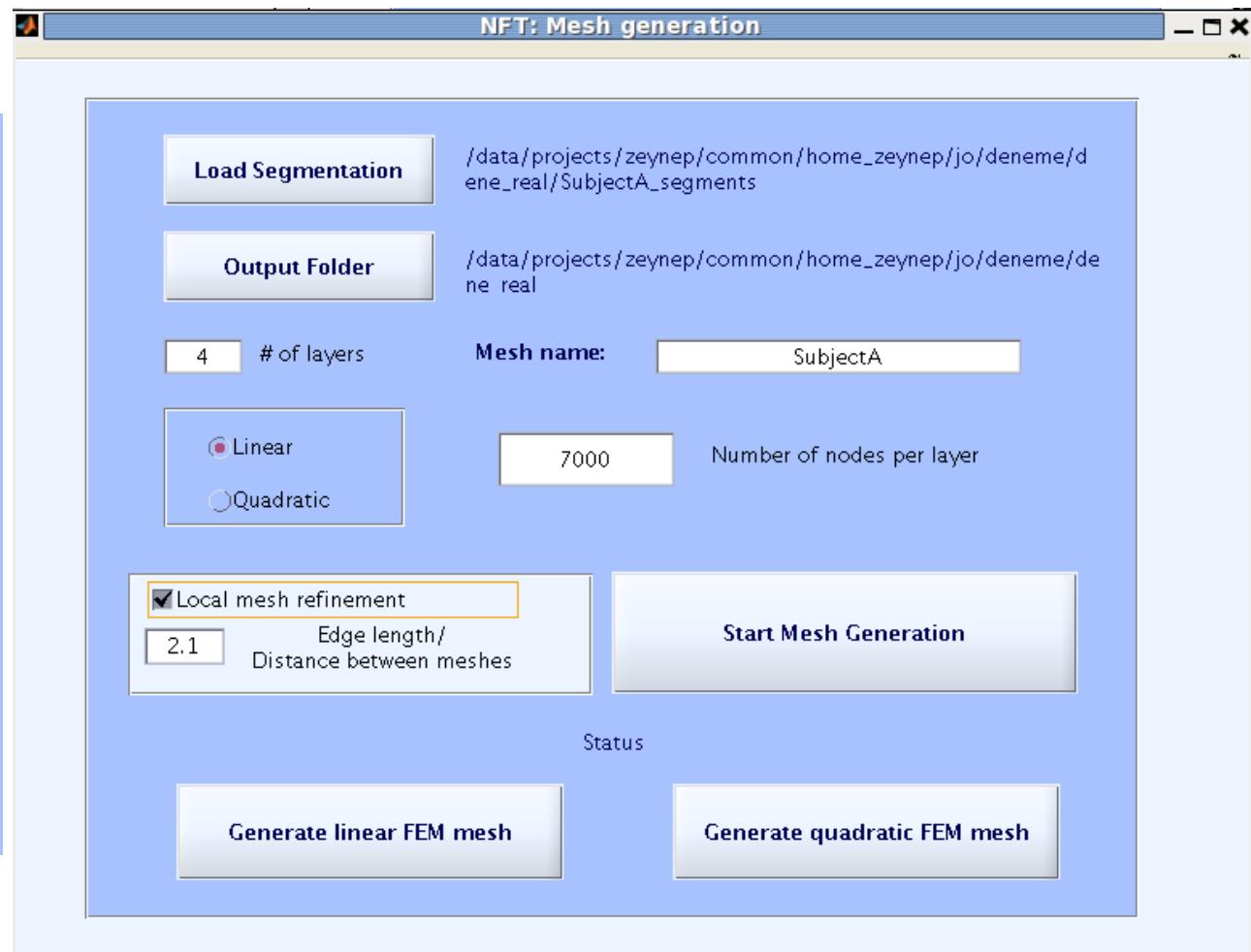
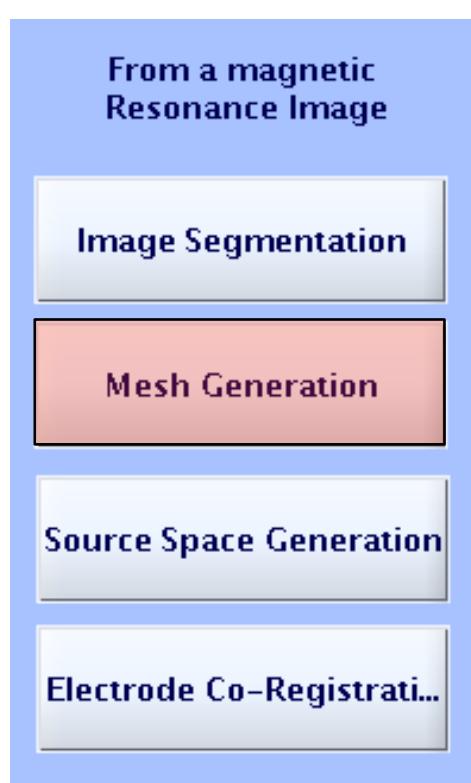
mri =
    dim: [256 256 256]
    xgrid: [1x256 double]
    ygrid: [1x256 double]
    zgrid: [1x256 double]
    anatomy: [256x256x256 double]
    transform: [4x4 double]
    hdr: []

>> load SubjectA_segments
>> Segm

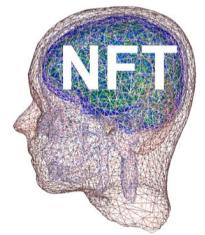
Segm =
    scalpmask: [256x256x256 logical]
    brainmask: [256x256x256 logical]
    outerskullmask: [256x256x256 logical]
    innerskullmask: [256x256x256 logical]
```



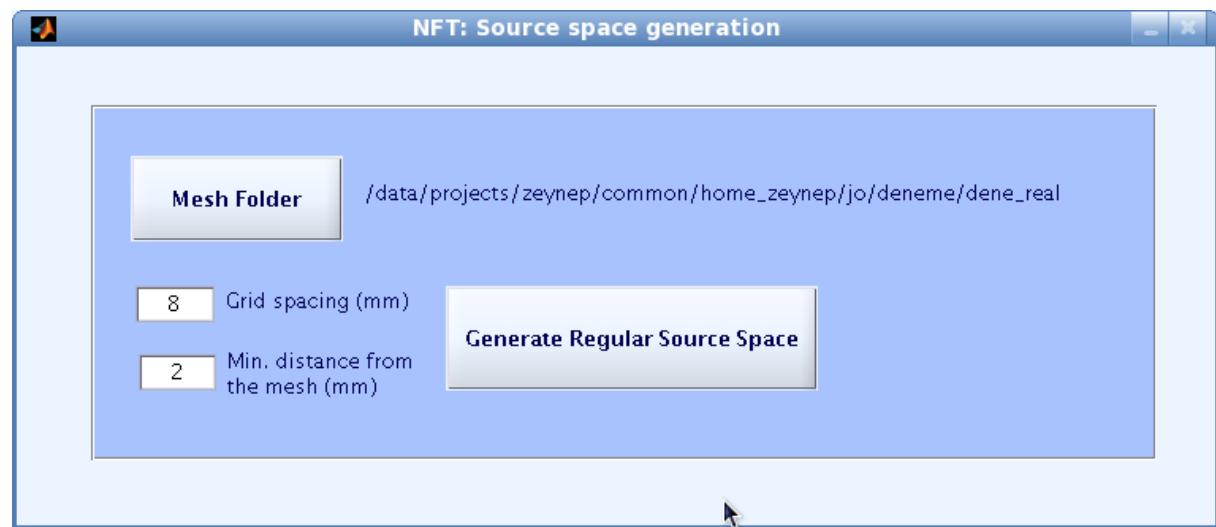
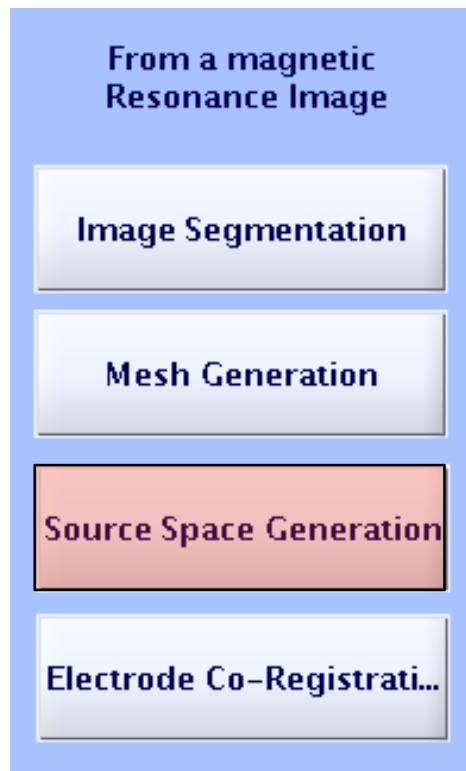
Mesh Generation



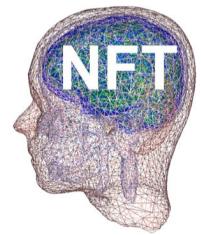
Generate Mesh for a 3 or 4 layer head model



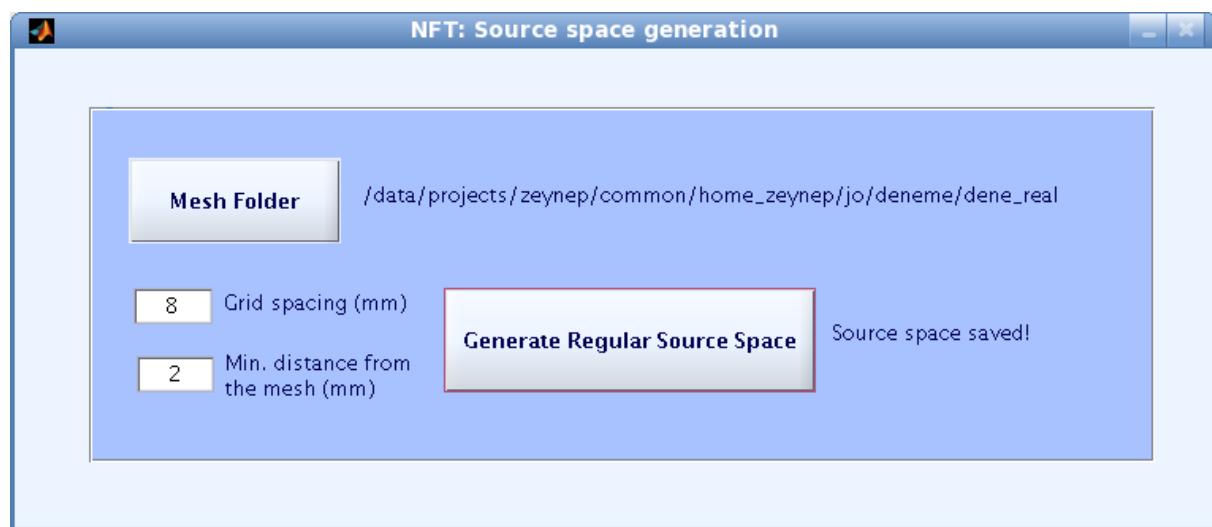
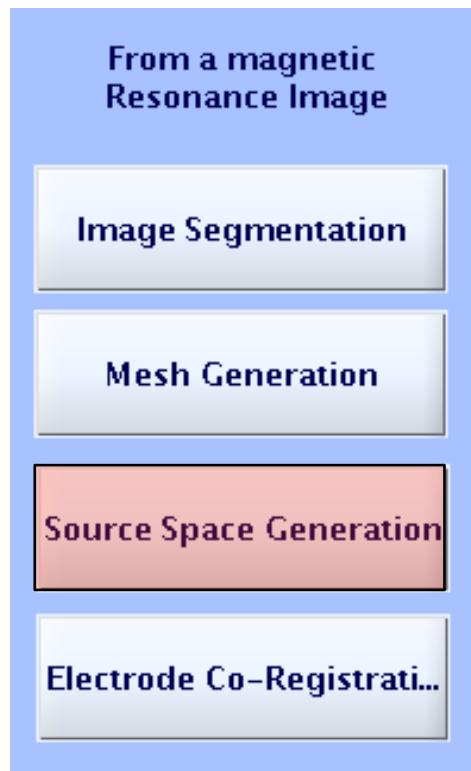
Source Space Generation



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

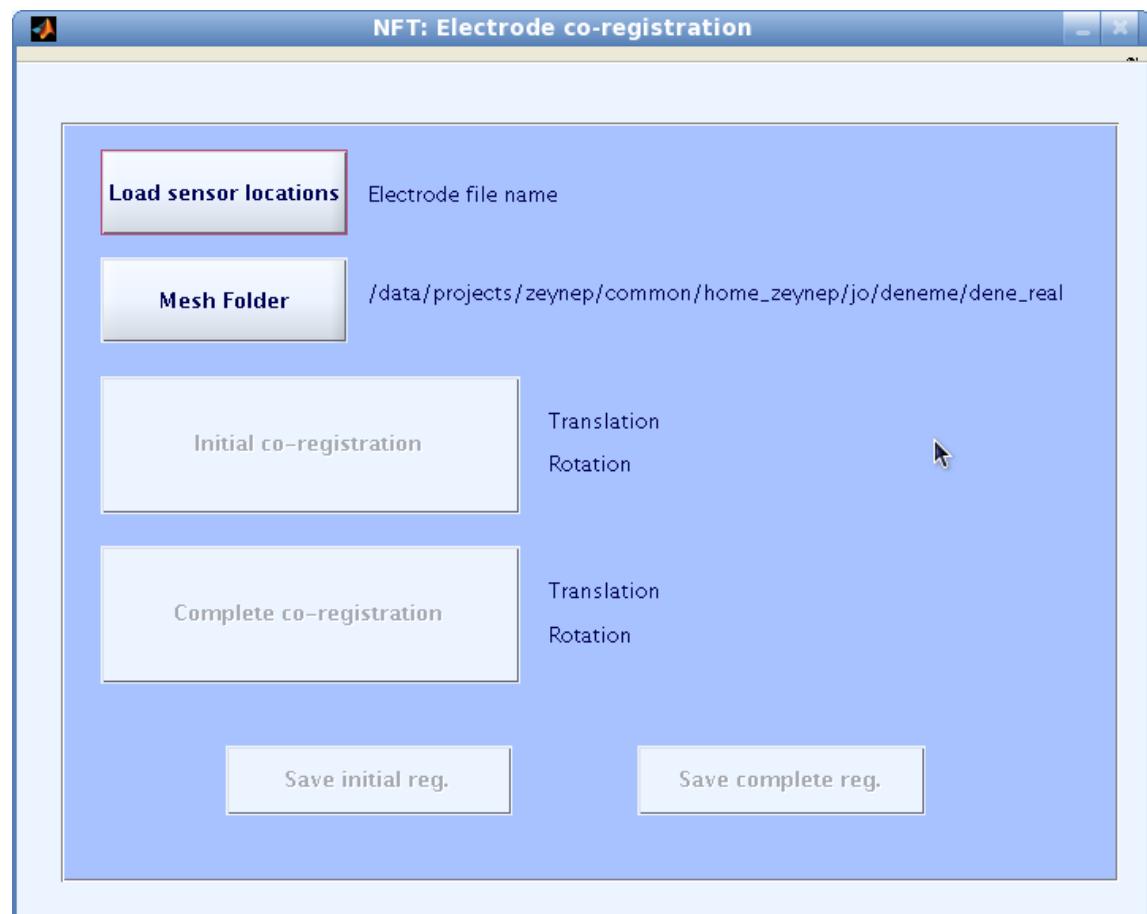
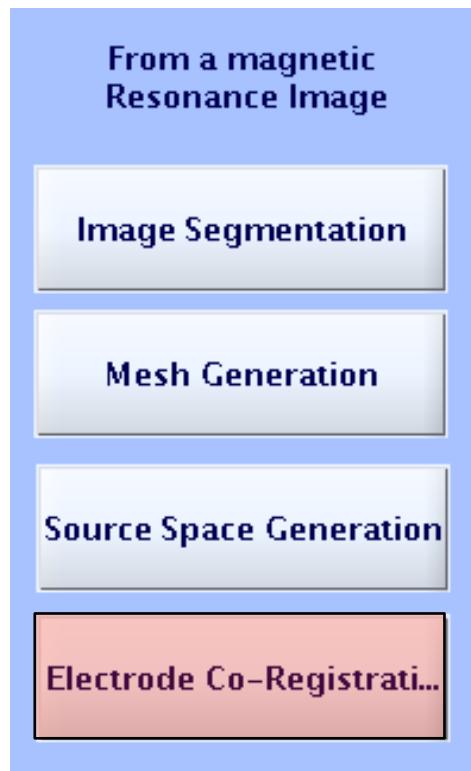
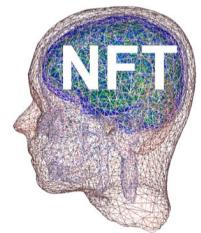


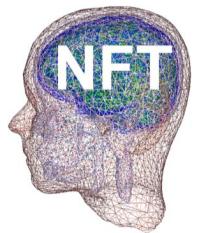
Source Space Generation





Electrode Co-registration





Electrode Co-registration

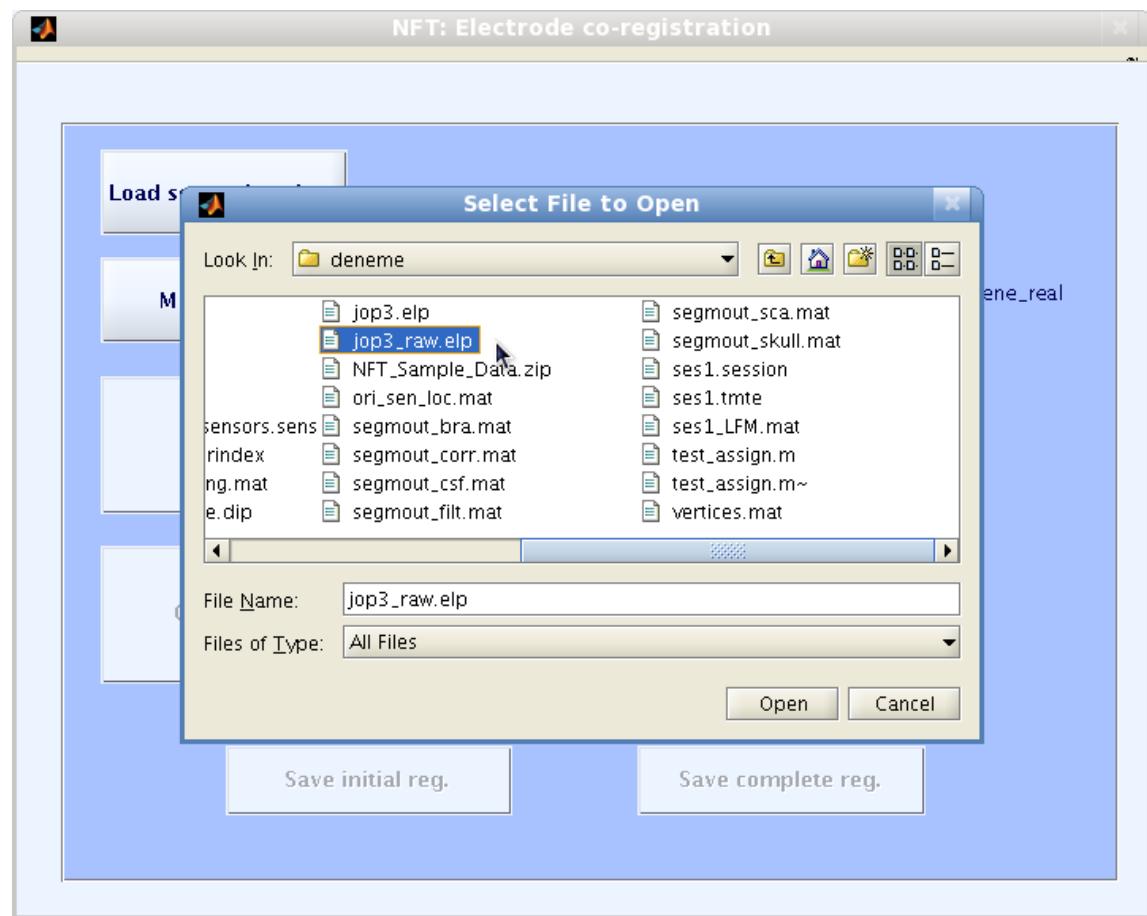
From a magnetic Resonance Image

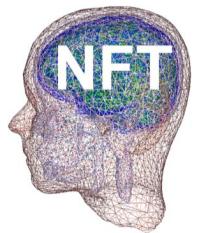
Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registration...





Electrode Co-registration

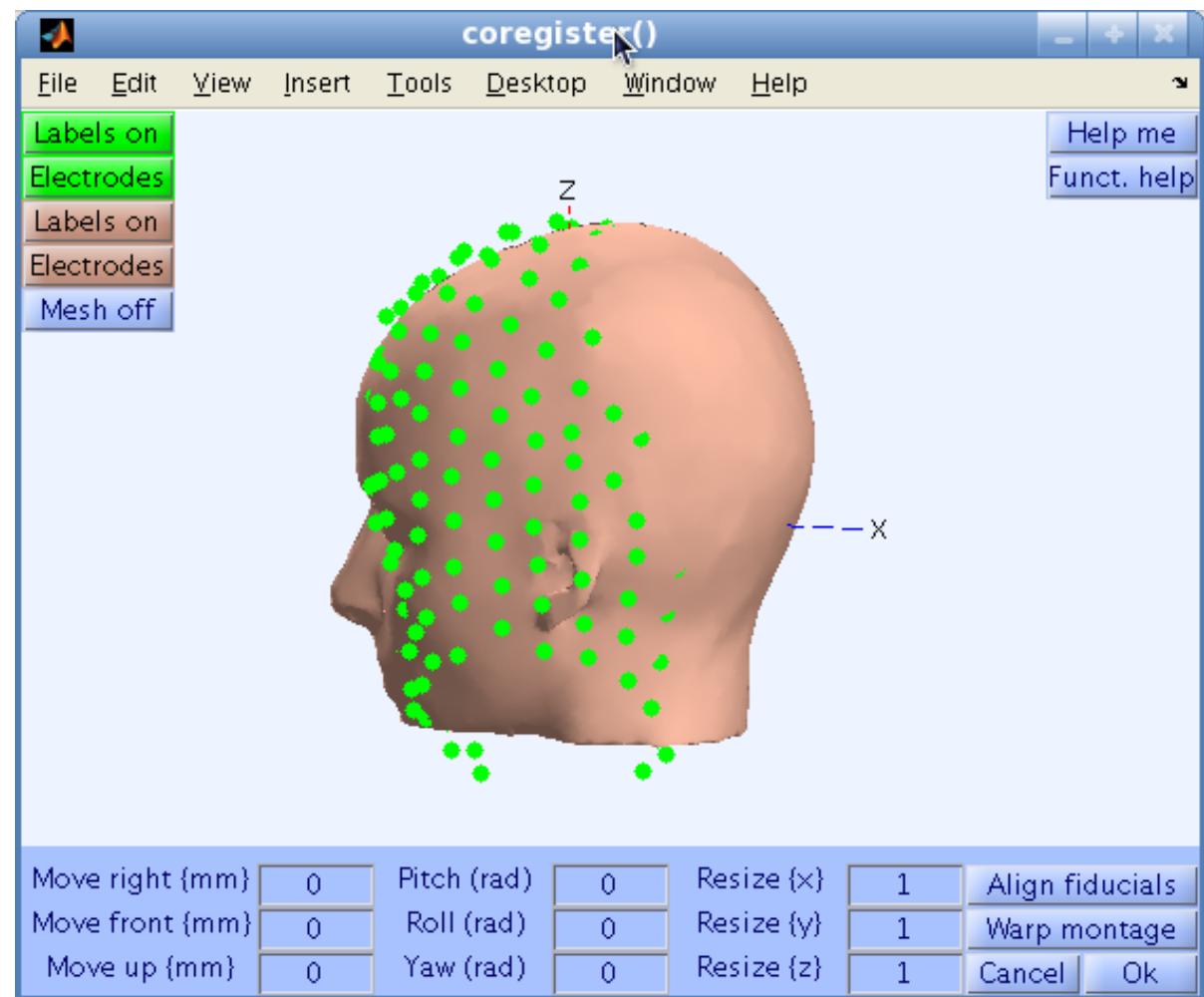
From a magnetic Resonance Image

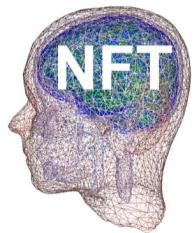
Image Segmentation

Mesh Generation

Source Space Generation

Electrode Co-Registration...





Electrode Co-registration

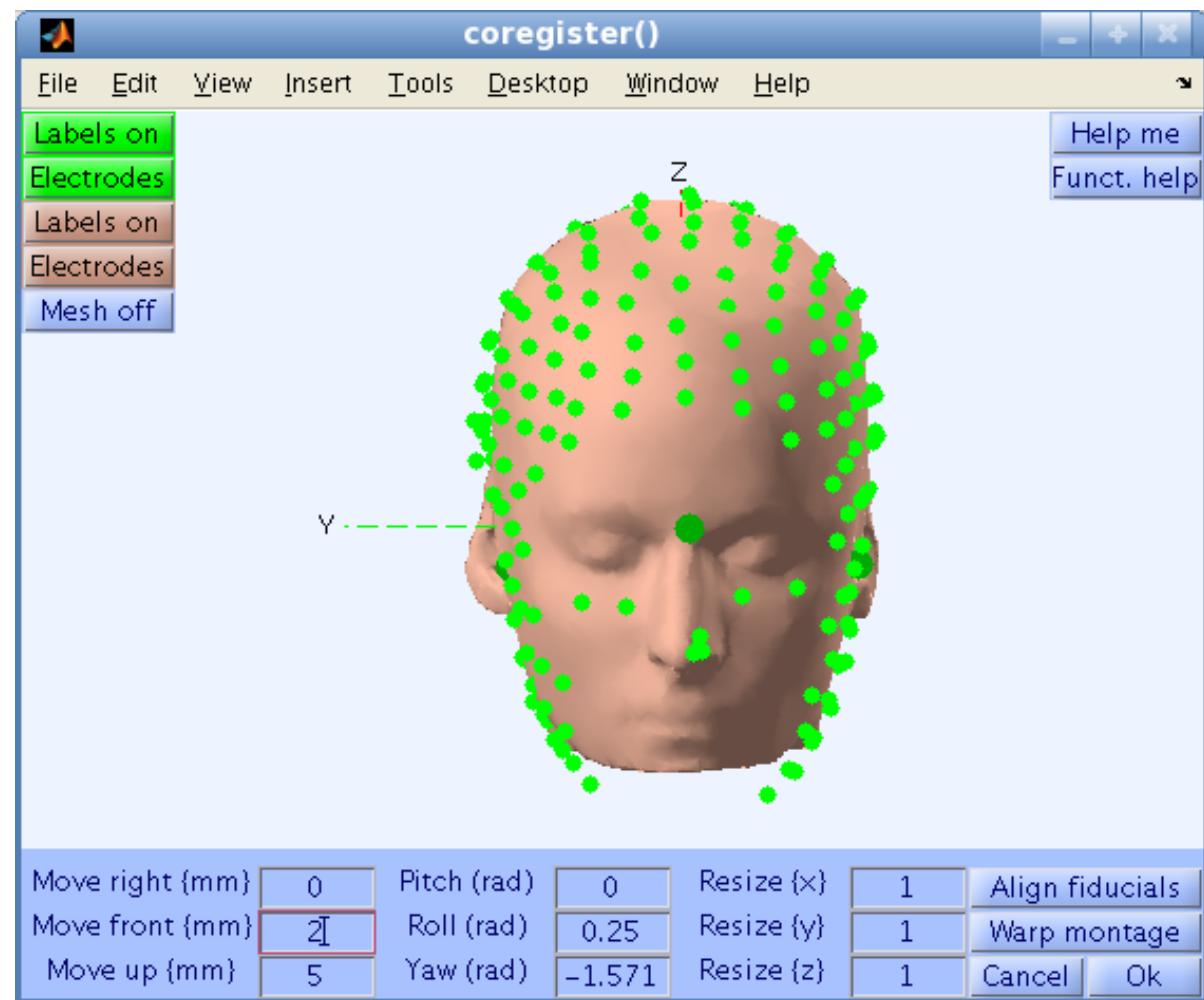
From a magnetic Resonance Image

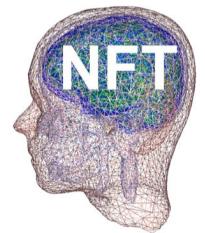
Image Segmentation

Mesh Generation

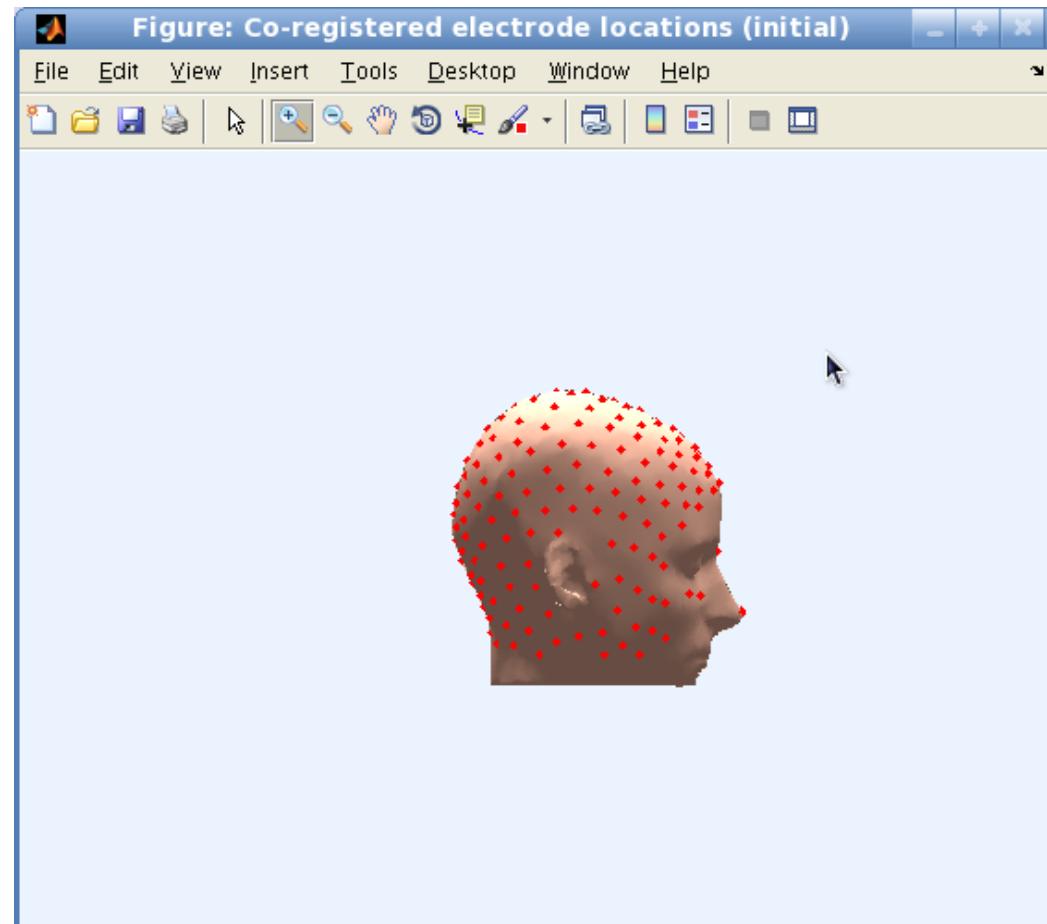
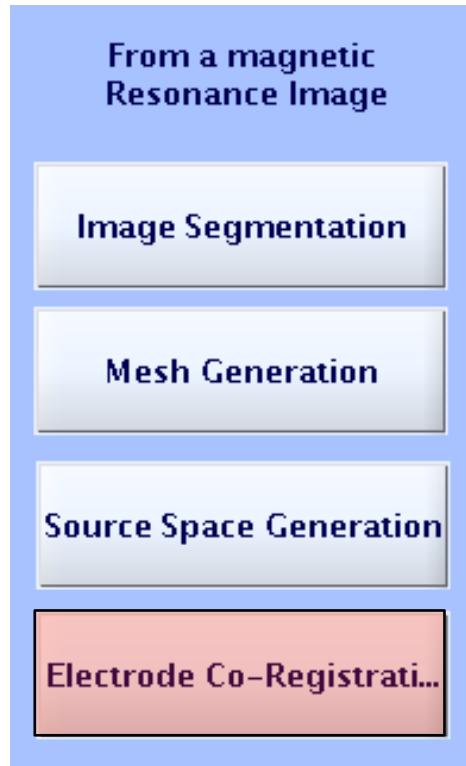
Source Space Generation

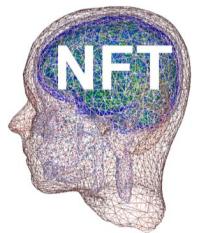
Electrode Co-Registration...



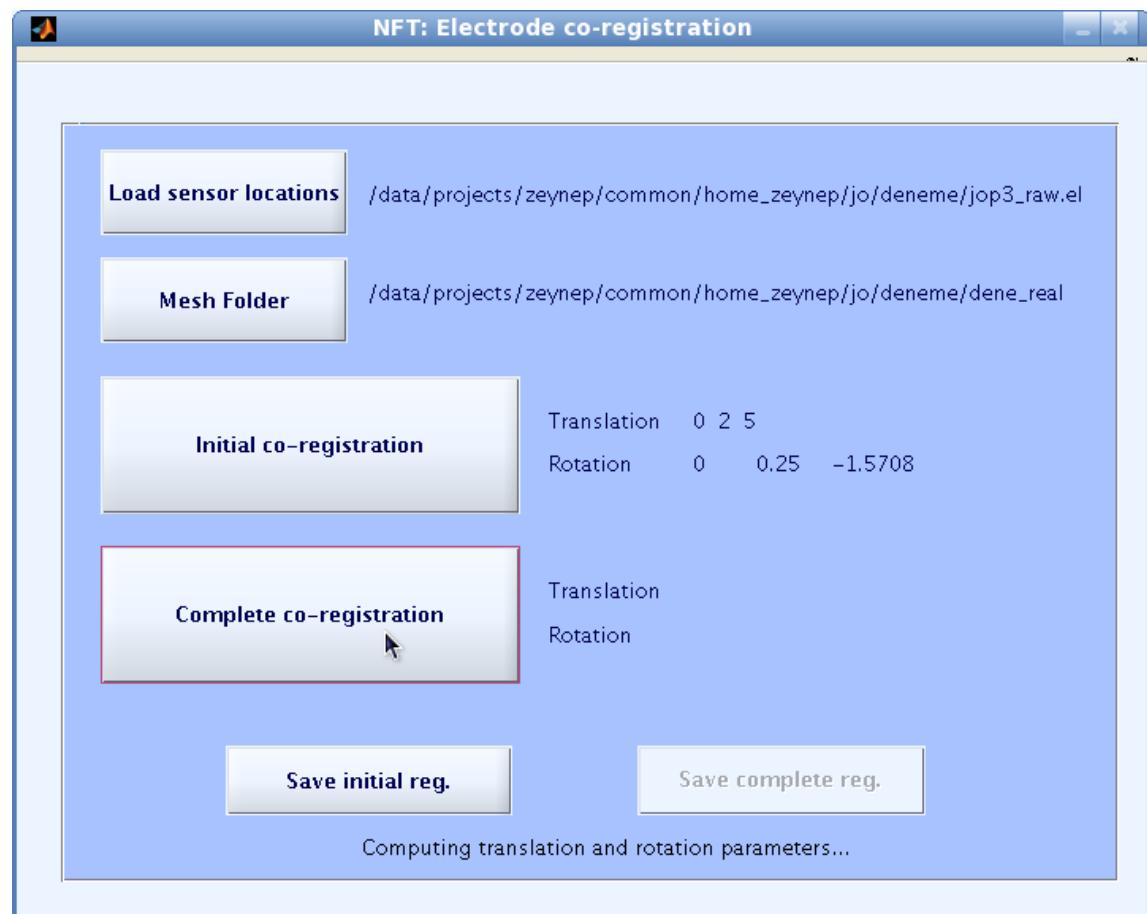
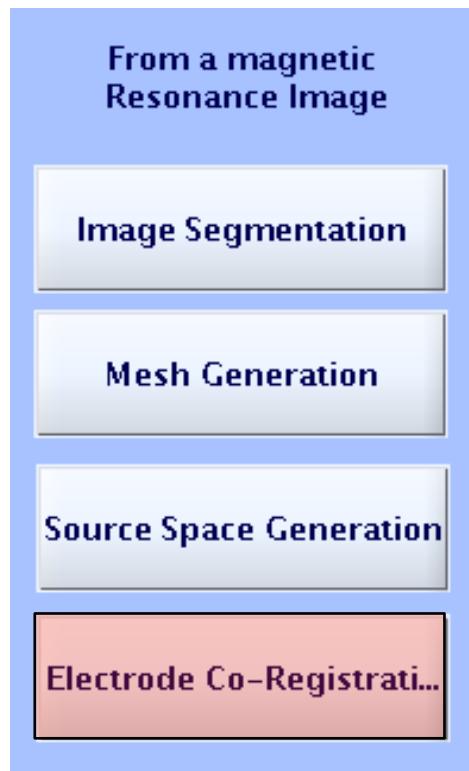


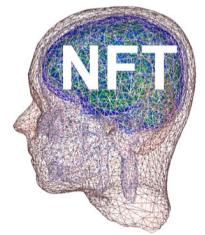
Electrode Co-registration



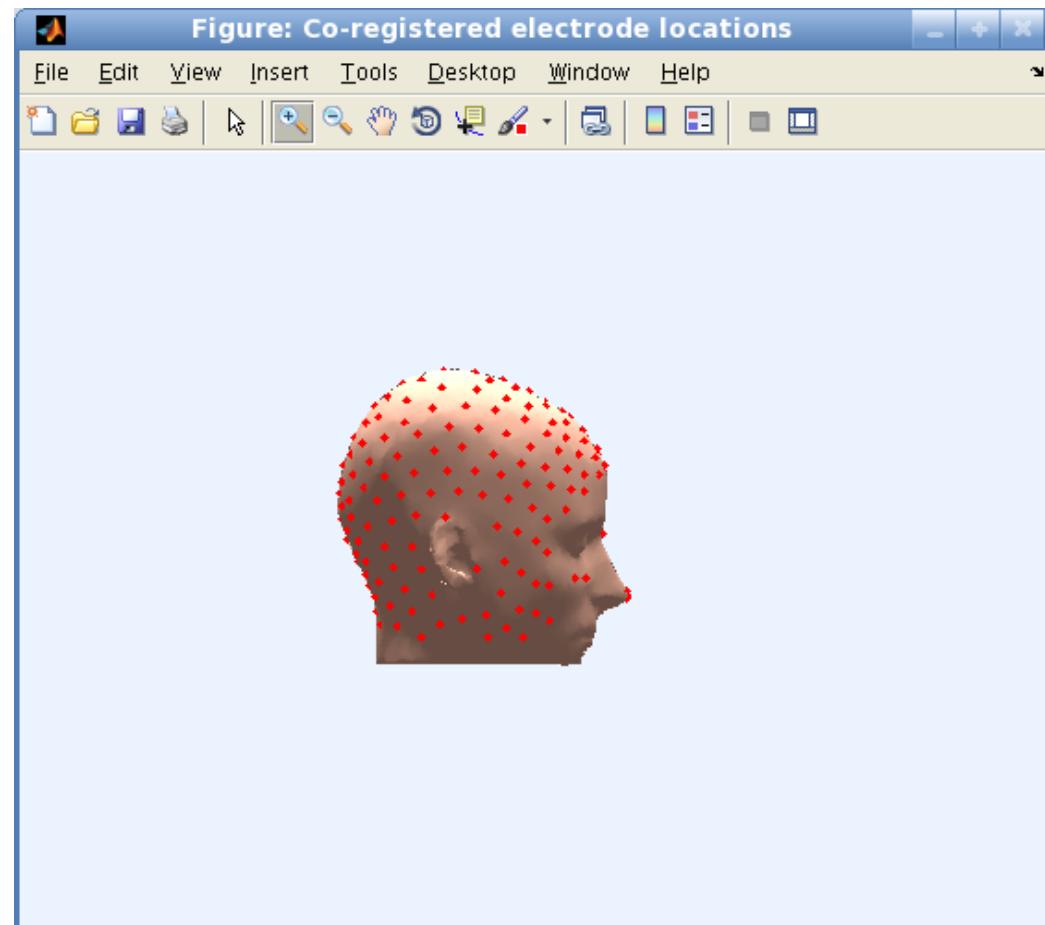
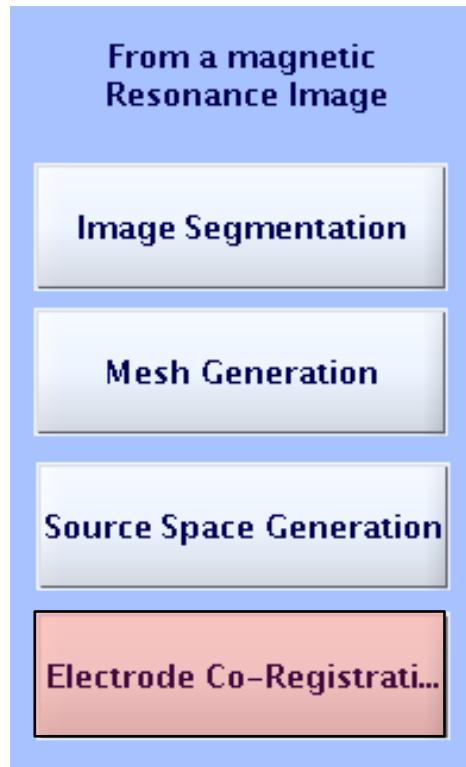


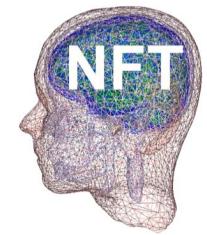
Electrode Co-registration



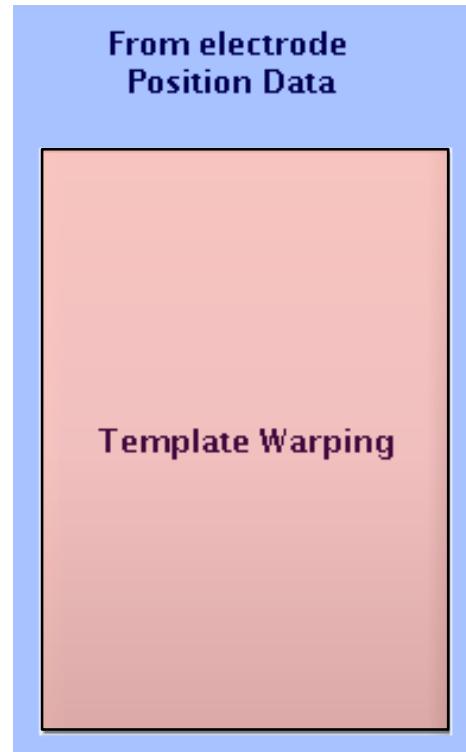


Electrode Co-registration

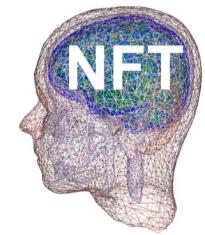




Head Modeling from Electrode Position Data



- ◆ 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

Load sensor data

4 # of layers (3 or 4)

Output Folder

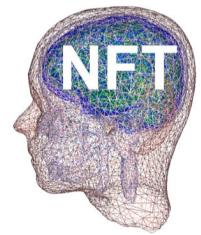
/data/projects/zeynep/common/home_zeynep/jo/dene
me/dene_mni

MNI head model

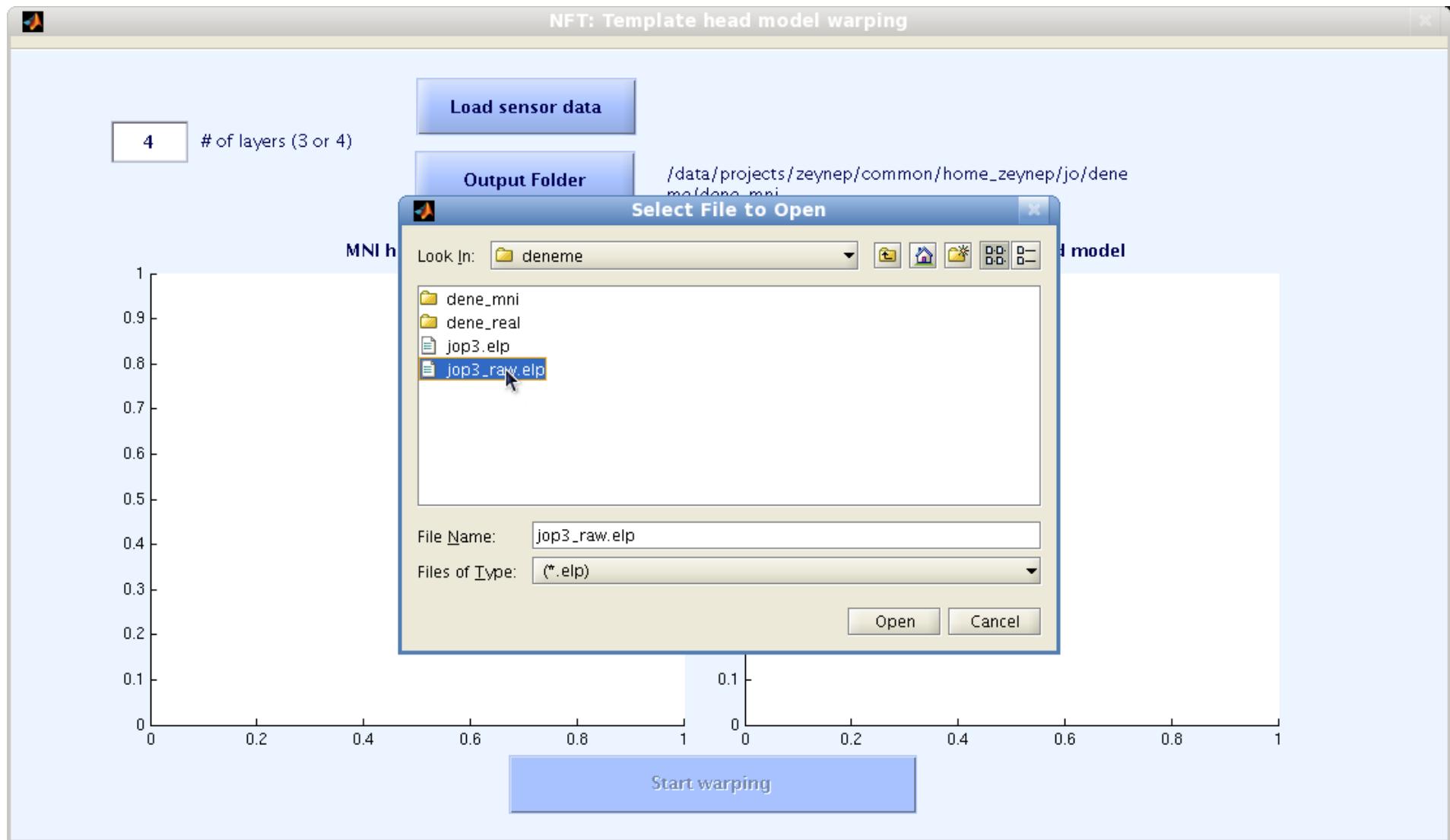
Warped MNI head model

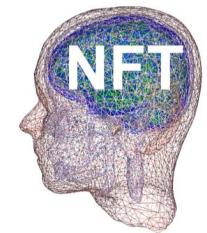
Start warping

A screenshot of a Windows application window titled "NFT: Template head model warping". The window contains several controls and two plots. On the left, a dropdown menu shows the value "4" and the label "# of layers (3 or 4)". To its right is a "Load sensor data" button. Below these are two buttons: "Output Folder" and a text field containing the path "/data/projects/zeynep/common/home_zeynep/jo/dene me/dene_mni". At the bottom center is a large "Start warping" button. Above the "Start warping" button are two plots. The left plot is labeled "MNI head model" and the right plot is labeled "Warped MNI head model". Both plots have axes ranging from 0 to 1 on both the x and y axes. The plots are currently empty, showing only the axes and grid lines.

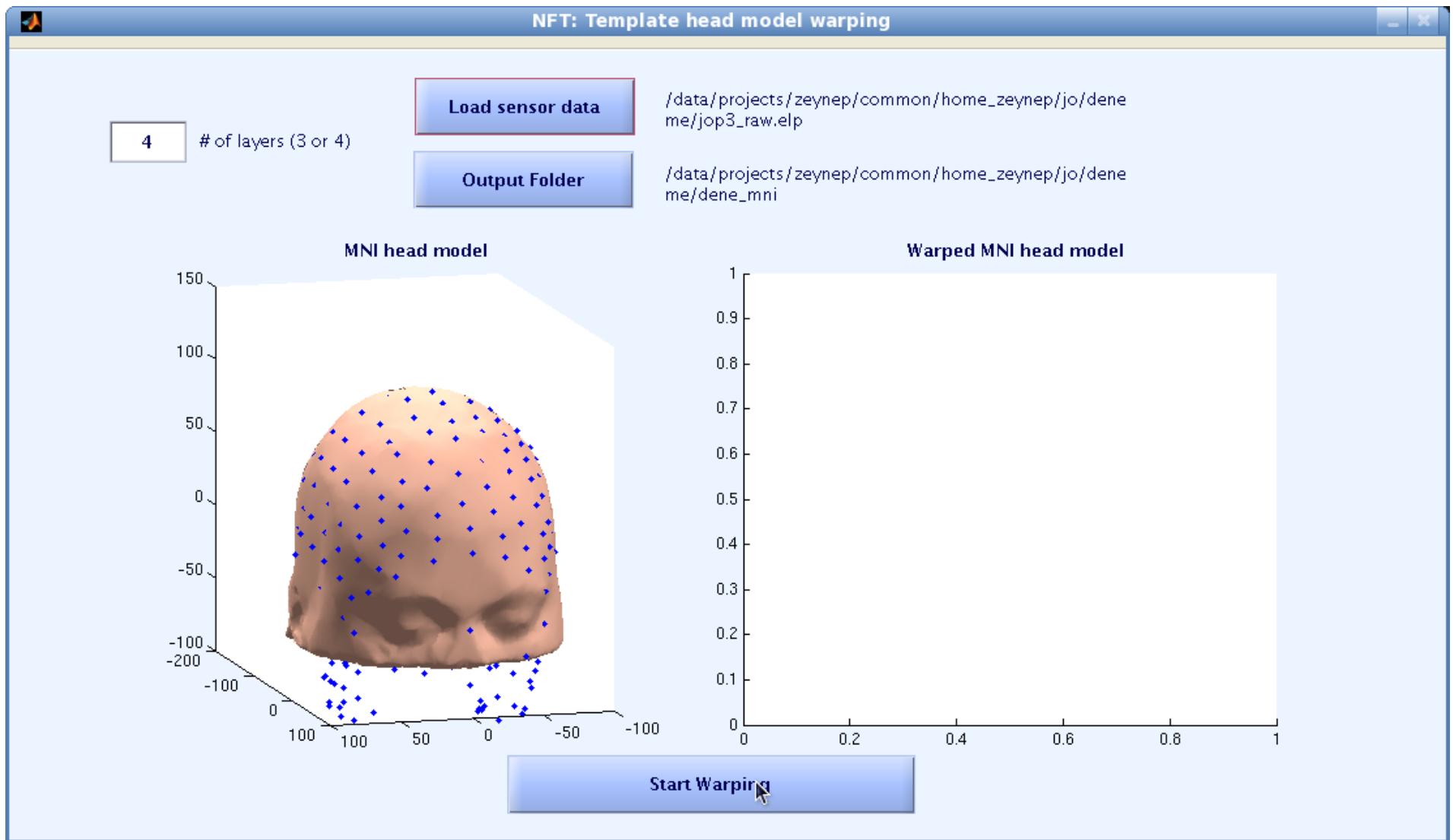


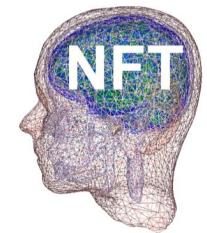
Template Warping





Template Warping





Template Warping

NFT: Template head model warping

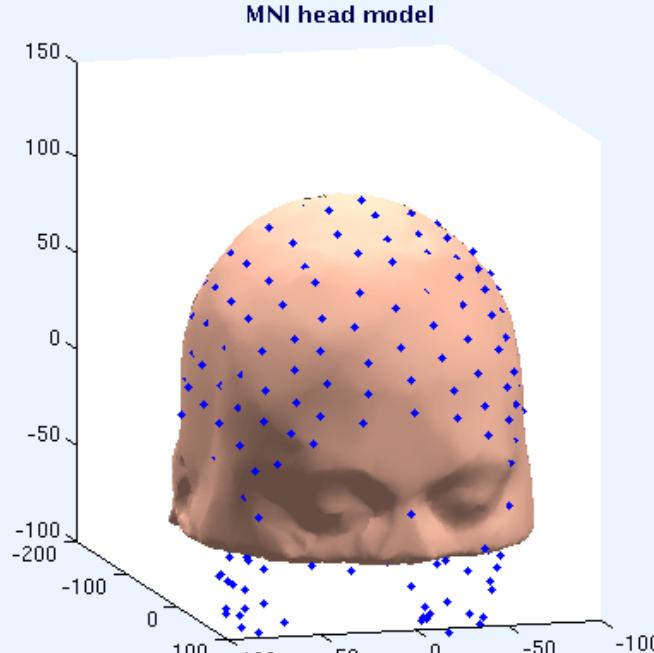
Load sensor data
Output Folder

4 # of layers (3 or 4)

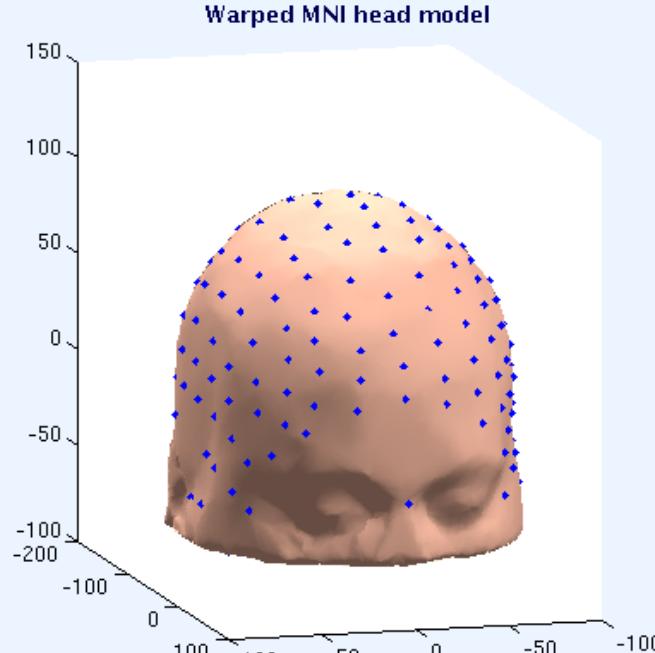
/data/projects/zeynep/common/home_zeynep/jo/dene
me/jop3_raw.elp

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

MNI head model

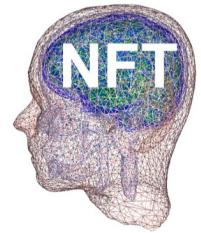


Warped MNI head model



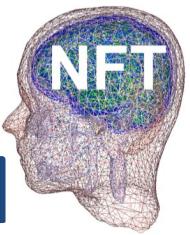
Mesh Warped!!

A screenshot of a software application window titled "NFT: Template head model warping". The window contains several input fields and buttons. On the left, there is a dropdown menu set to "4" with the label "# of layers (3 or 4)". To the right of this are two buttons: "Load sensor data" and "Output Folder". Below these are two text input fields showing file paths: "/data/projects/zeynep/common/home_zeynep/jo/dene me/jop3_raw.elp" and "/data/projects/zeynep/common/home_zeynep/jo/dene me/dene_mni". The main area of the window displays two 3D head models. The left one is labeled "MNI head model" and shows a brown mesh with numerous blue dots representing sensor data points. The right one is labeled "Warped MNI head model" and shows the same mesh but with the points warped to a different position. Both models have axes (x, y, z) ranging from -100 to 150. At the bottom center is a large blue button labeled "Mesh Warped!!" with a cursor arrow pointing to it.



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

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

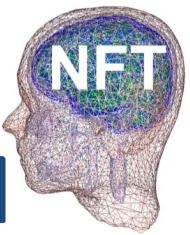
| | | | |
|--|------------|--------|-------|
| SubjectA | Model Name | | |
| Enter conductivity values: | | | |
| 0.33 | Scalp | 0.0042 | Skull |
| 0.33 | Brain | 1.79 | CSF |
| <input checked="" type="checkbox"/> Modified (Isolated Problem Approach) | | | |
| Create Model | | | |
| Value Changed! | | | |

Session

| | |
|---|---------------------|
| sesNov20_10 | Session Name |
| Load Sensors | |
| <input checked="" type="radio"/> Mesh Coordinates | Load |
| <input type="radio"/> 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

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

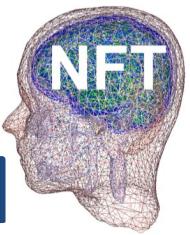
| | | | |
|--|------------|--------|-------|
| SubjectA | Model Name | | |
| Enter conductivity values: | | | |
| 0.33 | Scalp | 0.0042 | Skull |
| 0.33 | Brain | 1.79 | CSF |
| <input checked="" type="checkbox"/> Modified (Isolated Problem Approach) | | | |
| Create Model | | | |
| Generating matrices... | | | |

Session

| | |
|---|---------------------|
| sesNov20_10 | Session Name |
| Load Sensors | |
| <input checked="" type="radio"/> Mesh Coordinates | Load |
| <input type="radio"/> 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

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

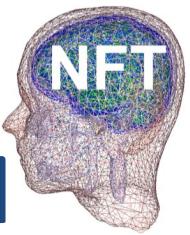
| | | | |
|--|------------|--------|-------|
| SubjectA | Model Name | | |
| Enter conductivity values: | | | |
| 0.33 | Scalp | 0.0042 | Skull |
| 0.33 | Brain | 1.79 | CSF |
| <input checked="" type="checkbox"/> Modified (Isolated Problem Approach) | | | |
| Create Model | | | |
| BEM Model Created | | | |

Session

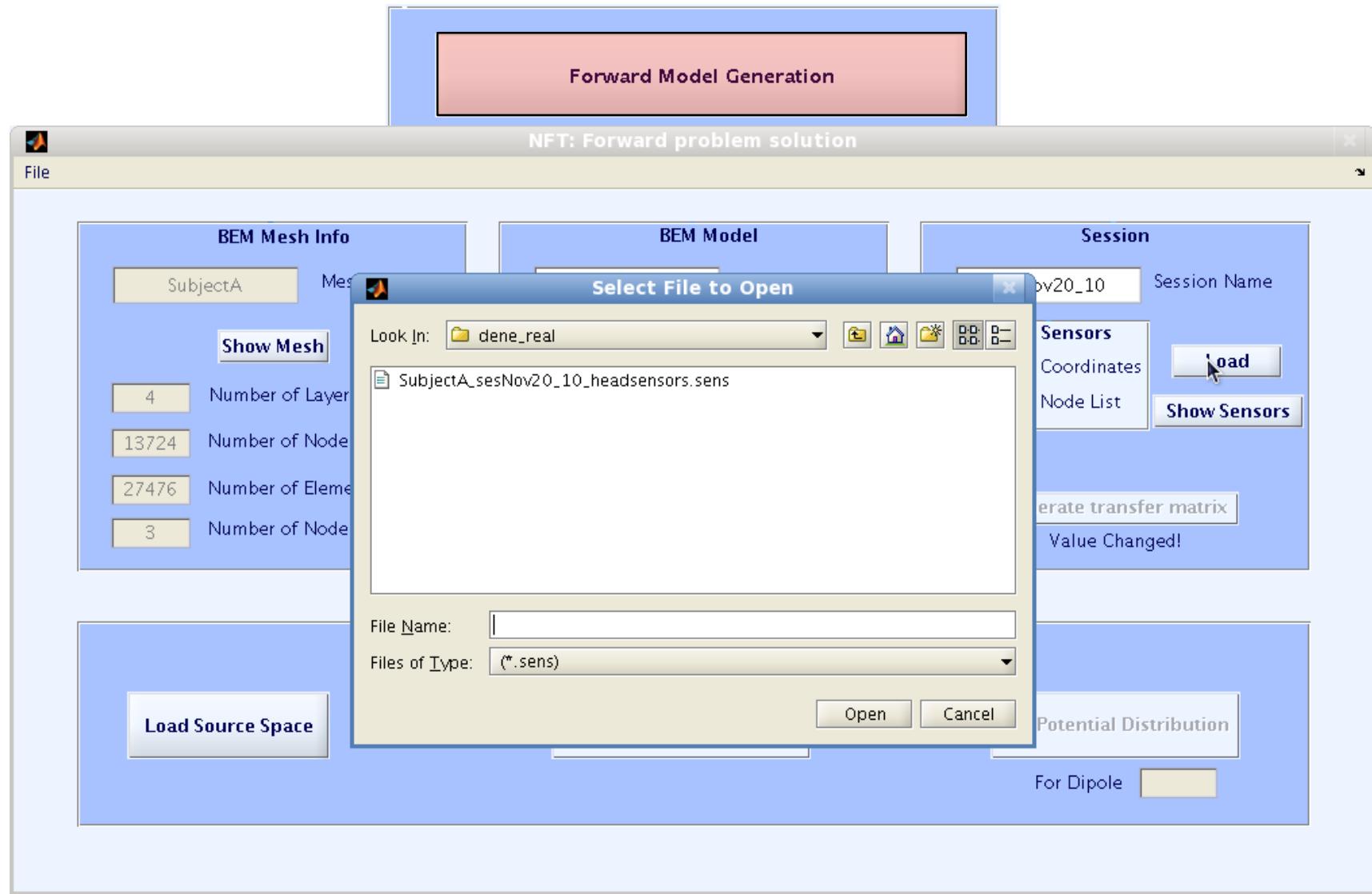
| | |
|---|---------------------|
| sesNov20_10 | Session Name |
| Load Sensors | |
| <input checked="" type="radio"/> Mesh Coordinates | Load |
| <input type="radio"/> Mesh Node List | Show Sensors |
| Generate transfer matrix | |
| Value Changed! | |

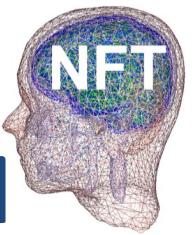
Forward Problem Solution

| |
|------------------------------------|
| Load Source Space |
| Compute Lead Field Matrix |
| Plot Potential Distribution |
| For Dipole |

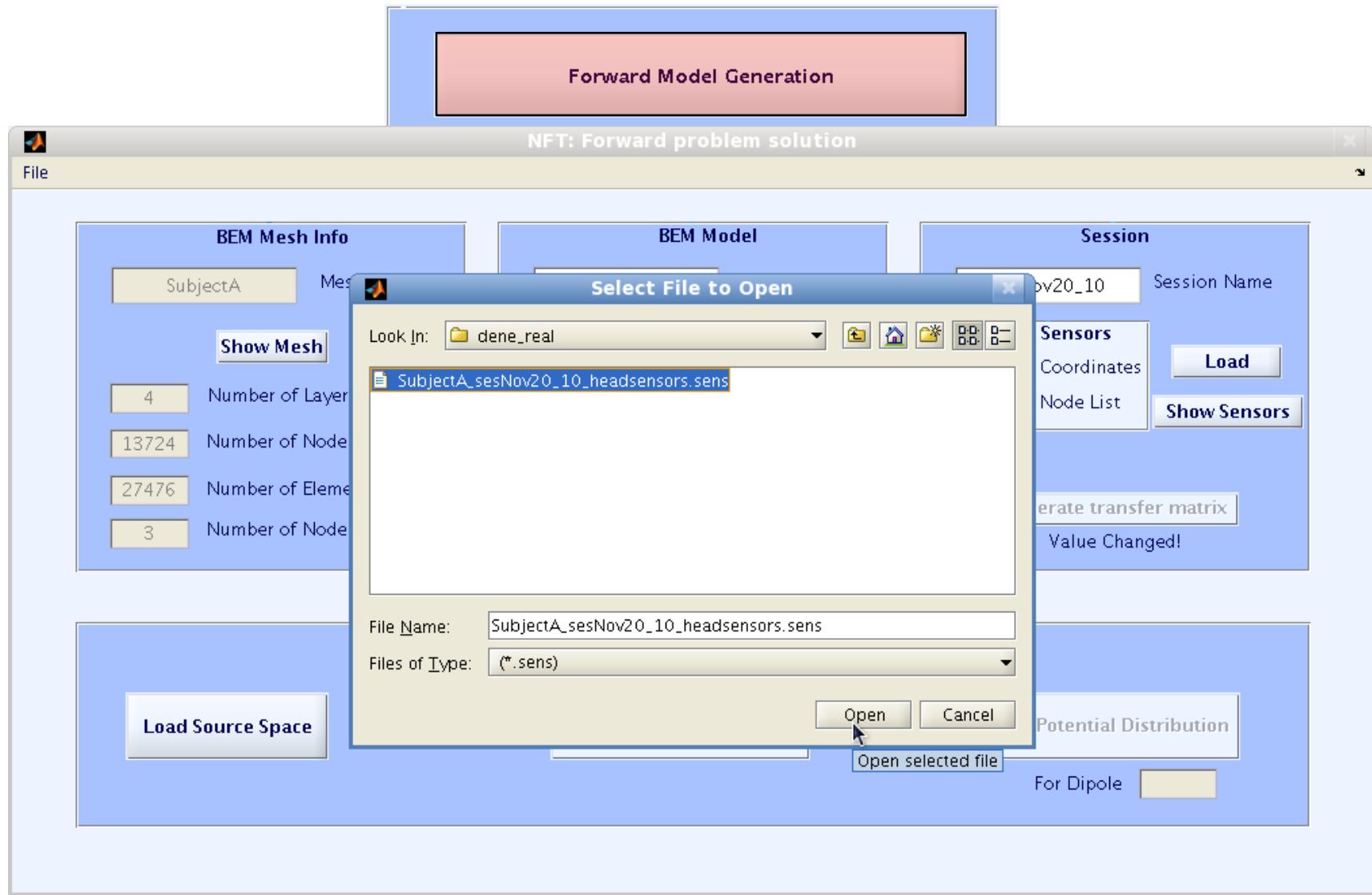


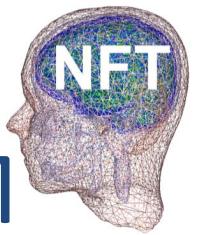
Forward Problem Solution with BEM





Forward Problem Solution with BEM





Forward Problem Solution with BEM

Forward Model Generation

NFT: Forward problem solution

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

Defined (Isolated Problem Approach)
Create Model
BEM Model Created

Session

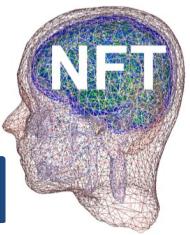
sesNov20_10 Session Name
Load Sensors
 Mesh Coordinates Mesh Node List
Load
Show Sensors
243 Sensors Loaded
Generate transfer matrix
Value Changed!

Forward Problem Solution

Load Source Space **Compute Lead Field Matrix** **Plot Potential Distribution**

For Dipole

A screenshot of a MATLAB graphical user interface titled "NFT: Forward problem solution". The interface is divided into several panels: "BEM Mesh Info" showing subject information and mesh statistics; "BEM Model" for entering conductivity values for Scalp, Brain, and CSF layers; "Session" for managing sensor data (loading coordinates or node lists, generating transfer matrices); and "Forward Problem Solution" for loading source space, computing lead field matrices, and plotting potential distributions. A progress bar in the "BEM Model" panel indicates "calculating sensor matrix...".



Forward Problem Solution with BEM

Forward Model Generation

NFT: Forward problem solution

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

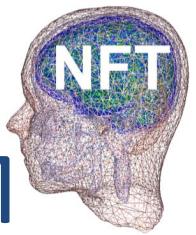
| | | | |
|--|------------|--------|-------|
| SubjectA | Model Name | | |
| Enter conductivity values: | | | |
| 0.33 | Scalp | 0.0042 | Skull |
| 0.33 | Brain | 1.79 | CSF |
| <input checked="" type="checkbox"/> Modified (Isolated Problem Approach) | | | |
| Create Model | | | |
| BEM Model Loaded | | | |

Session

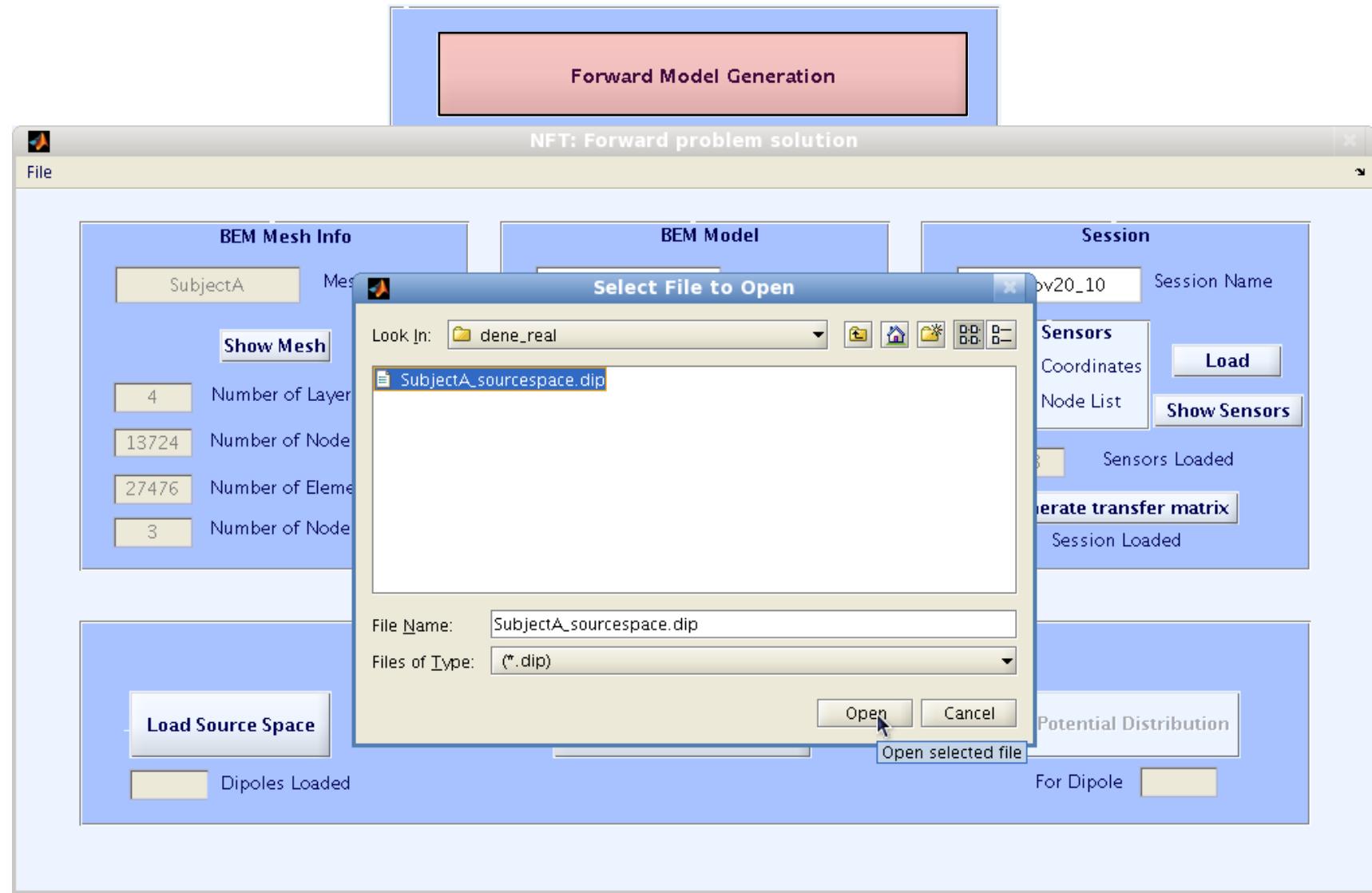
| | |
|---|---------------------|
| sesNov20_10 | Session Name |
| Load Sensors | |
| <input checked="" type="radio"/> Mesh Coordinates | Load |
| <input type="radio"/> Mesh Node List | Show Sensors |
| 243 | Sensors Loaded |
| Generate transfer matrix | |
| Session Loaded | |

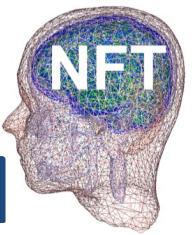
Forward Problem Solution

| |
|------------------------------------|
| Load Source Space |
| Compute Lead Field Matrix |
| Plot Potential Distribution |
| For Dipole |



Forward Problem Solution with BEM





Forward Problem Solution with BEM

Forward Model Generation

NFT: Forward problem solution

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

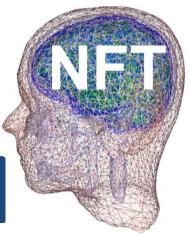
| | | | |
|--|------------|--------|-------|
| SubjectA | Model Name | | |
| Enter conductivity values: | | | |
| 0.33 | Scalp | 0.0042 | Skull |
| 0.33 | Brain | 1.79 | CSF |
| <input checked="" type="checkbox"/> Modified (Isolated Problem Approach) | | | |
| Create Model | | | |
| BEM Model Loaded | | | |

Session

| | |
|---|--------------------------------------|
| sesNov20_10 | Session Name |
| Load Sensors | |
| <input checked="" type="radio"/> Mesh Coordinates | <input type="radio"/> Mesh Node List |
| 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 <input type="button"/> |



Forward Problem Solution with BEM

Forward Model Generation

NFT: Forward problem solution

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

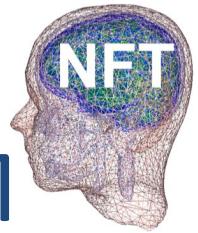
| | | | |
|--|------------|--------|-------|
| SubjectA | Model Name | | |
| Enter conductivity values: | | | |
| 0.33 | Scalp | 0.0042 | Skull |
| 0.33 | Brain | 1.79 | CSF |
| <input checked="" type="checkbox"/> Modified (Isolated Problem Approach) | | | |
| Create Model | | | |
| BEM Model Loaded | | | |

Session

| | |
|---|--------------------------------------|
| sesNov20_10 | Session Name |
| Load Sensors | |
| <input checked="" type="radio"/> Mesh Coordinates | <input type="radio"/> Mesh Node List |
| Show Sensors | |
| 243 | Sensors Loaded |
| Generate transfer matrix | |
| Session Loaded | |

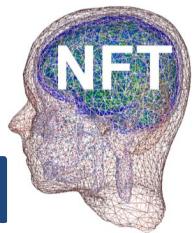
Forward Problem Solution

| |
|------------------------------------|
| Load Source Space |
| 6447 Dipoles Loaded |
| Compute Lead Field Matrix |
| LFM Computed |
| Plot Potential Distribution |
| For Dipole <input type="text"/> |



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

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

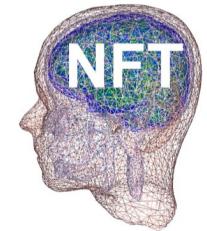
Forward Problem Solution

Load Source Space

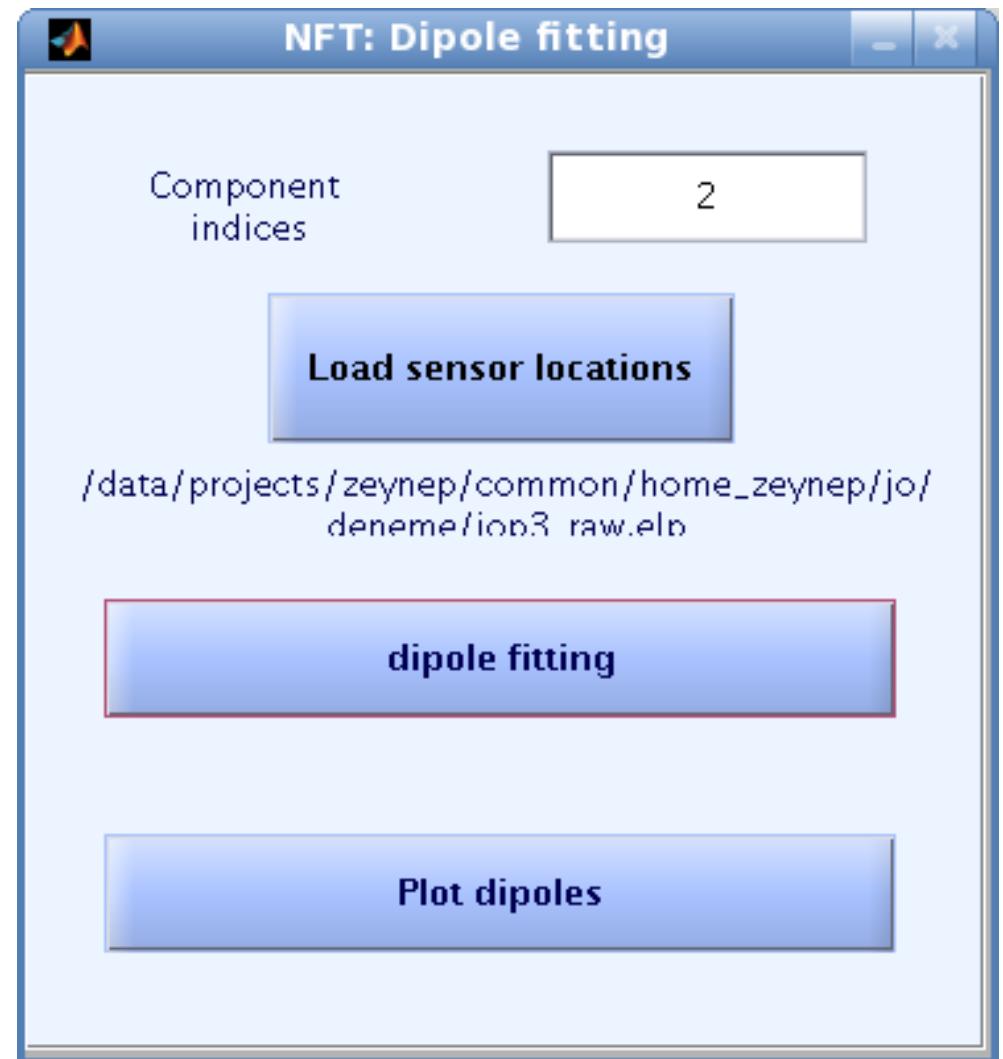
Compute Lead Field Matrix

6447 Dipoles Loaded

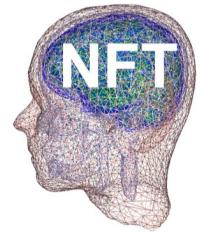
This screenshot shows the NFT: Forward problem solution software interface. The window is titled 'NFT: Forward problem solution'. It has three main sections: 'FEM Mesh Info', 'FEM Session', and 'Forward Problem Solution'. In the 'FEM Mesh Info' section, it displays the mesh name 'SubjectA.1.msh', number of layers (4), number of nodes (185656), and number of nodes per element (4). In the 'FEM Session' section, it shows the session name 'sesNov20_10', conductivity values for Scalp (0.33), Brain (0.33), and CSF (1.79), and the number of sensors loaded (243). It also has a 'Create Session' button and a message 'No Session'. The 'Forward Problem Solution' section contains buttons for 'Load Source Space' and 'Compute Lead Field Matrix', and a message '6447 Dipoles Loaded'.



Dipole Fitting



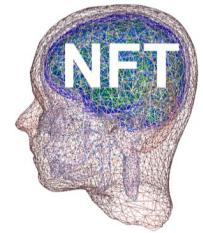
- ◆ Requires EEGLAB integration to access Component indices.
- ◆ Uses FieldTrip in EEGLAB for dipole fitting.



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.