Swartz Center for Computational Neuroscience

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

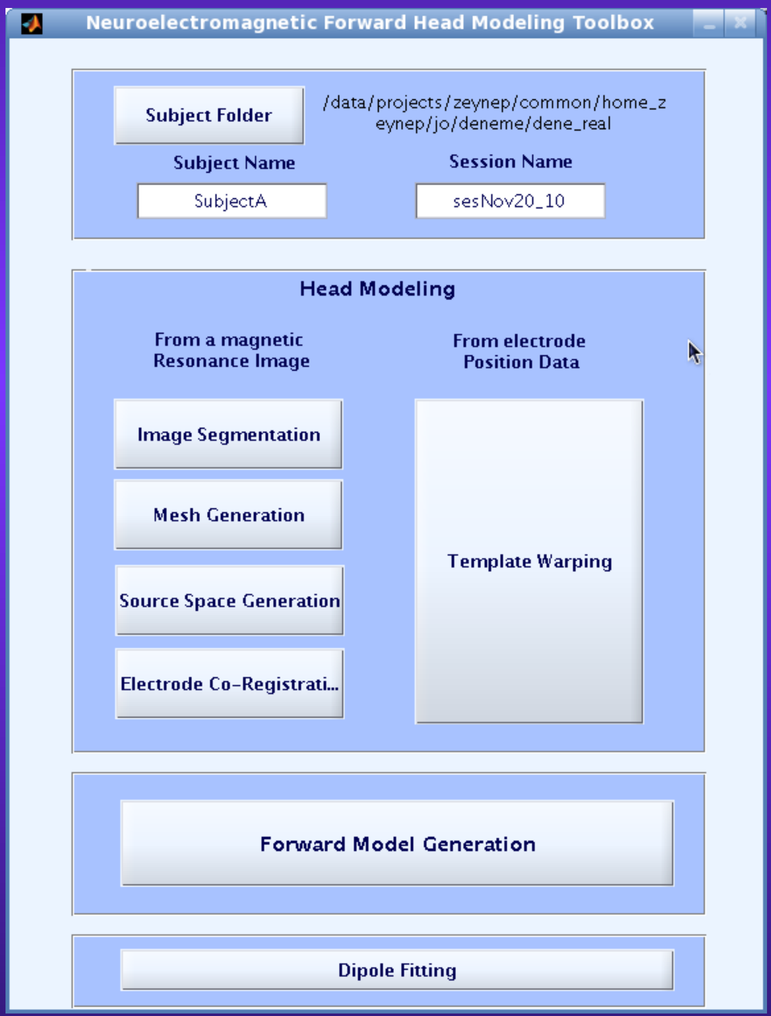
T1 MR Images

- 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

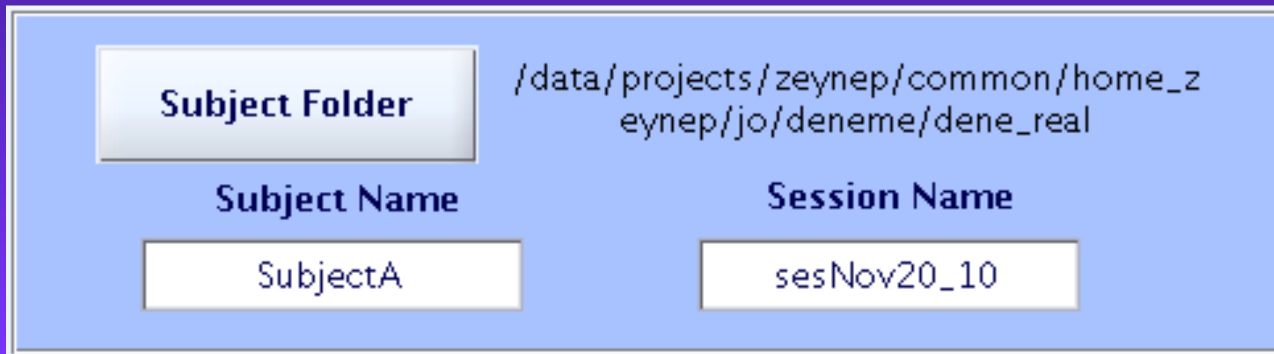
Forward Modeling

Source Localization

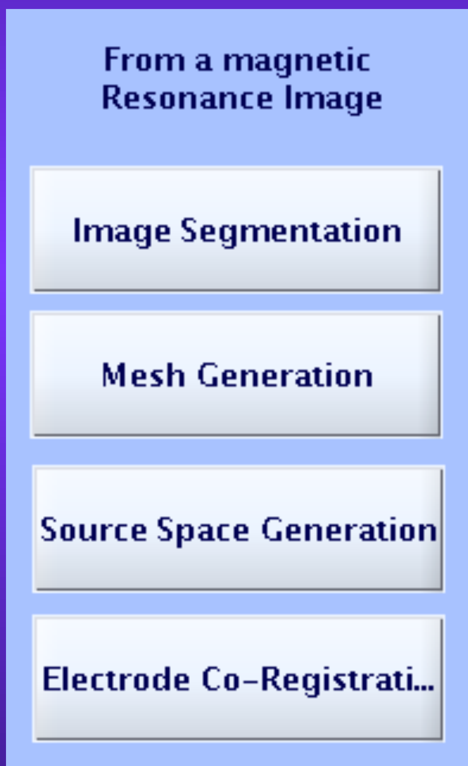
Subject Selection

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

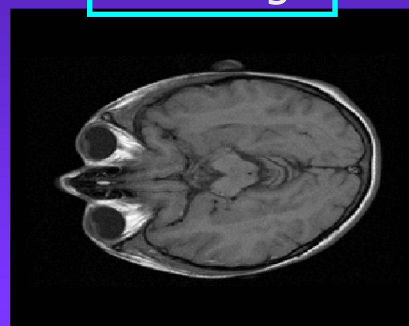
Subject Selection



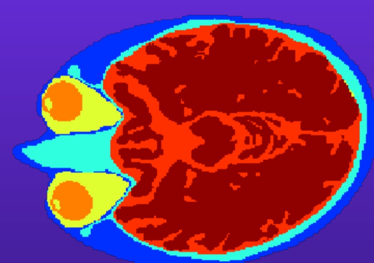
Head Modeling from MR Images



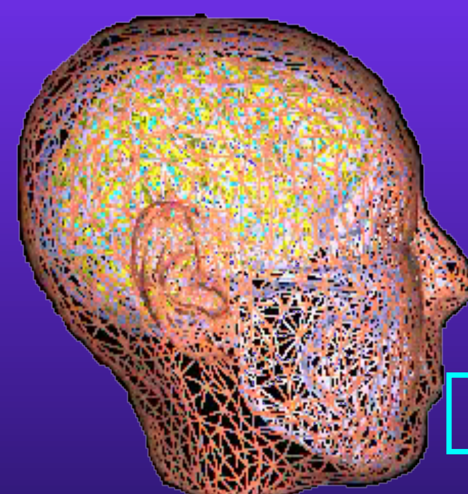
MR image



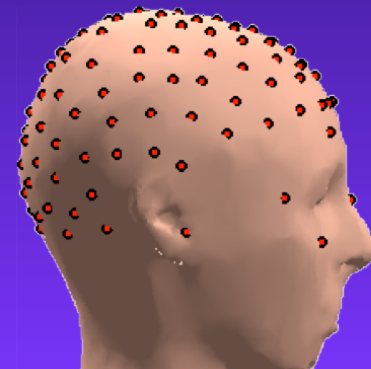
T1-weighted



Segmentation



BEM mesh

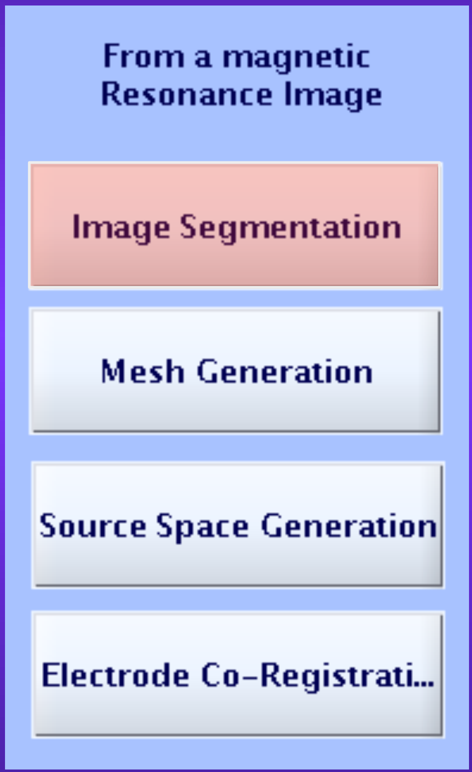


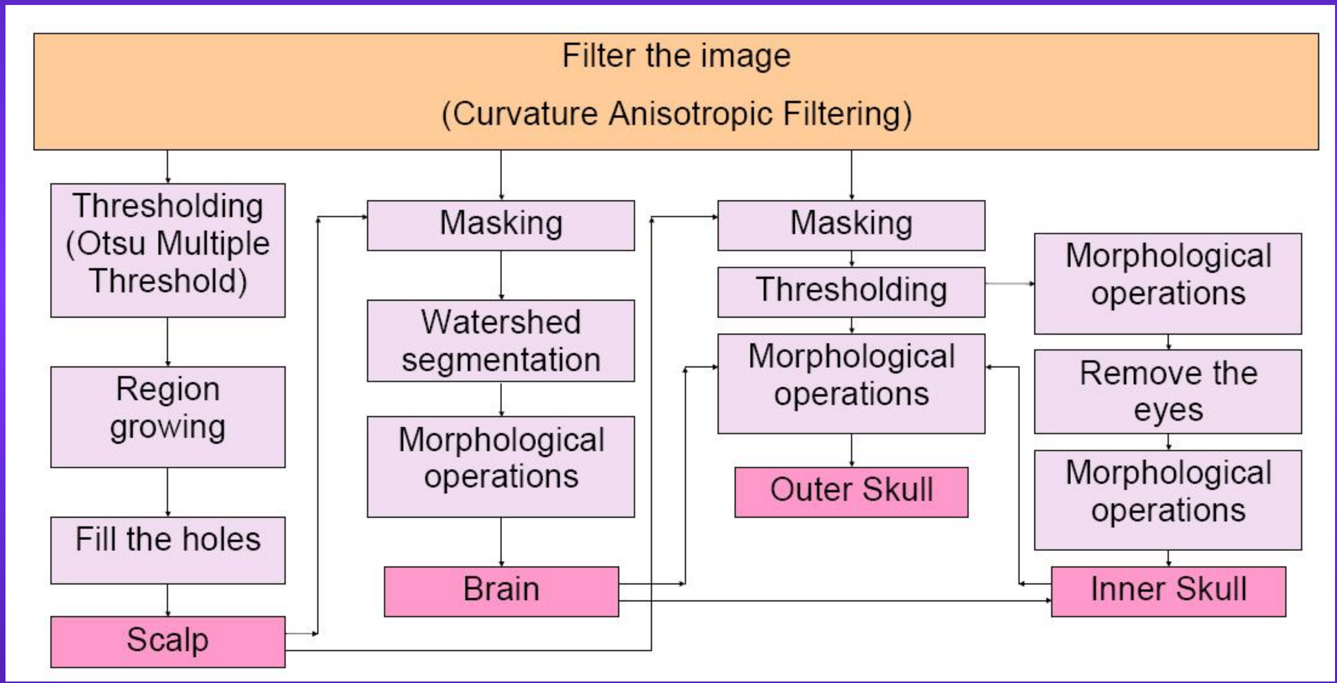
Electrode Registration

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

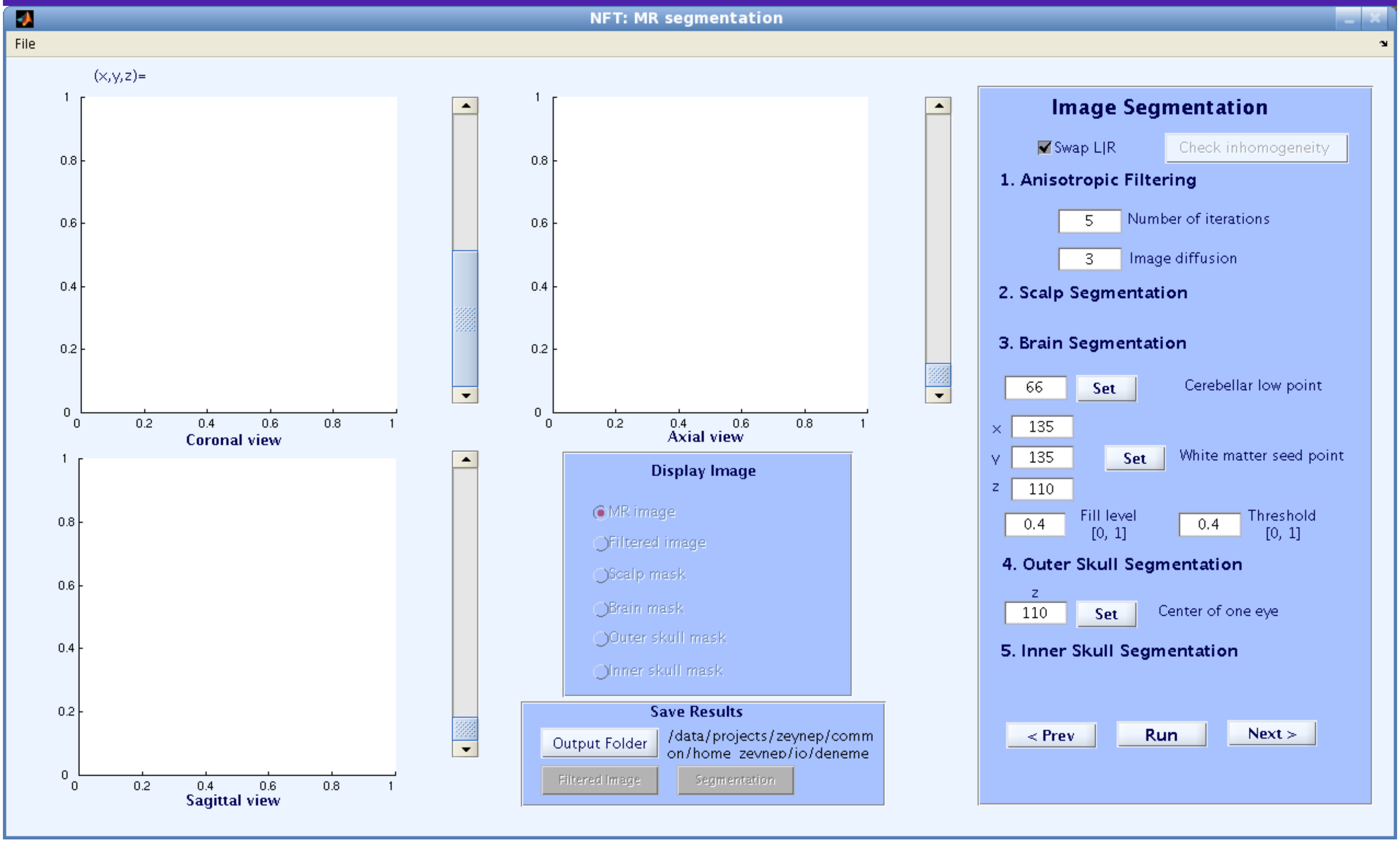
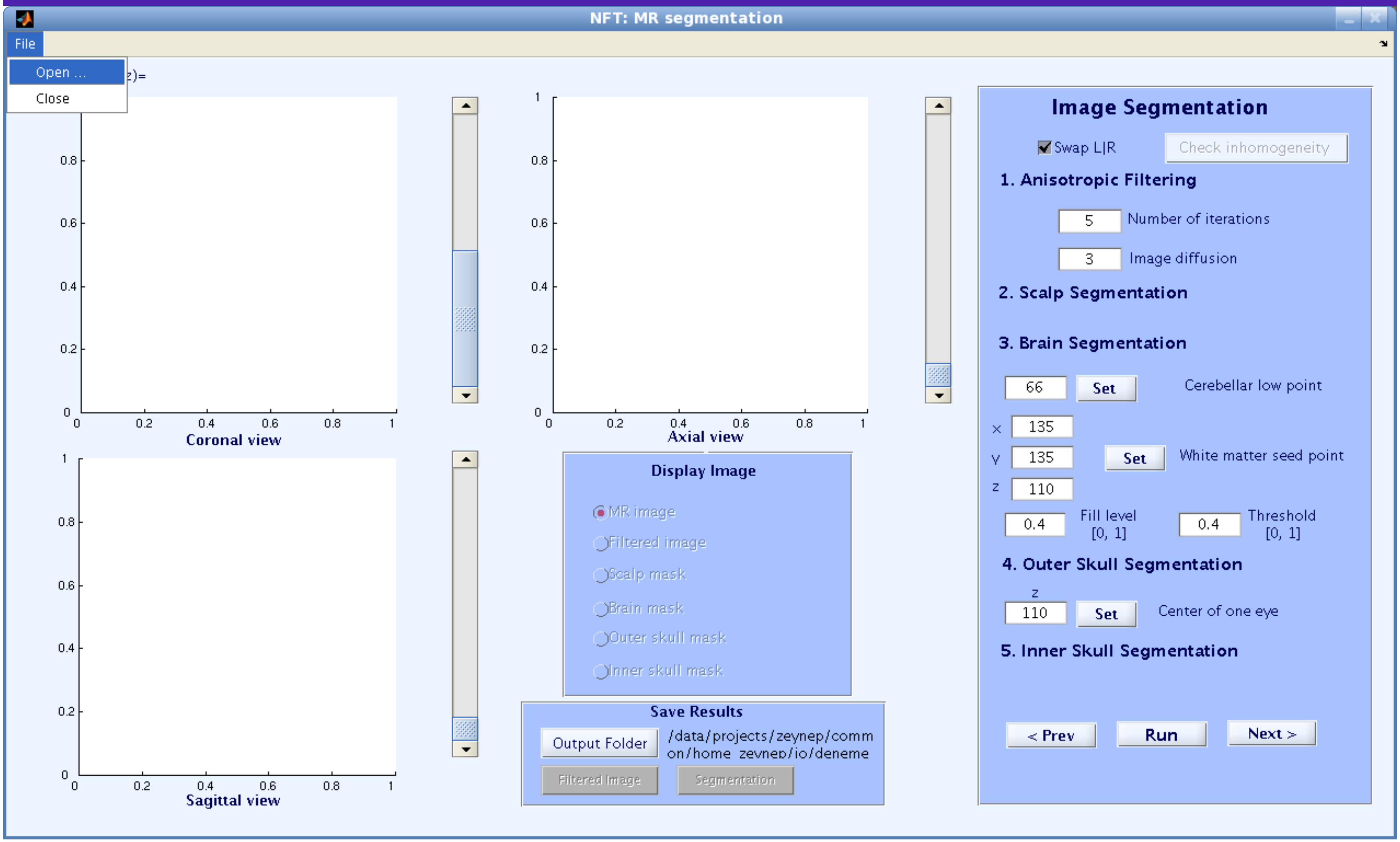
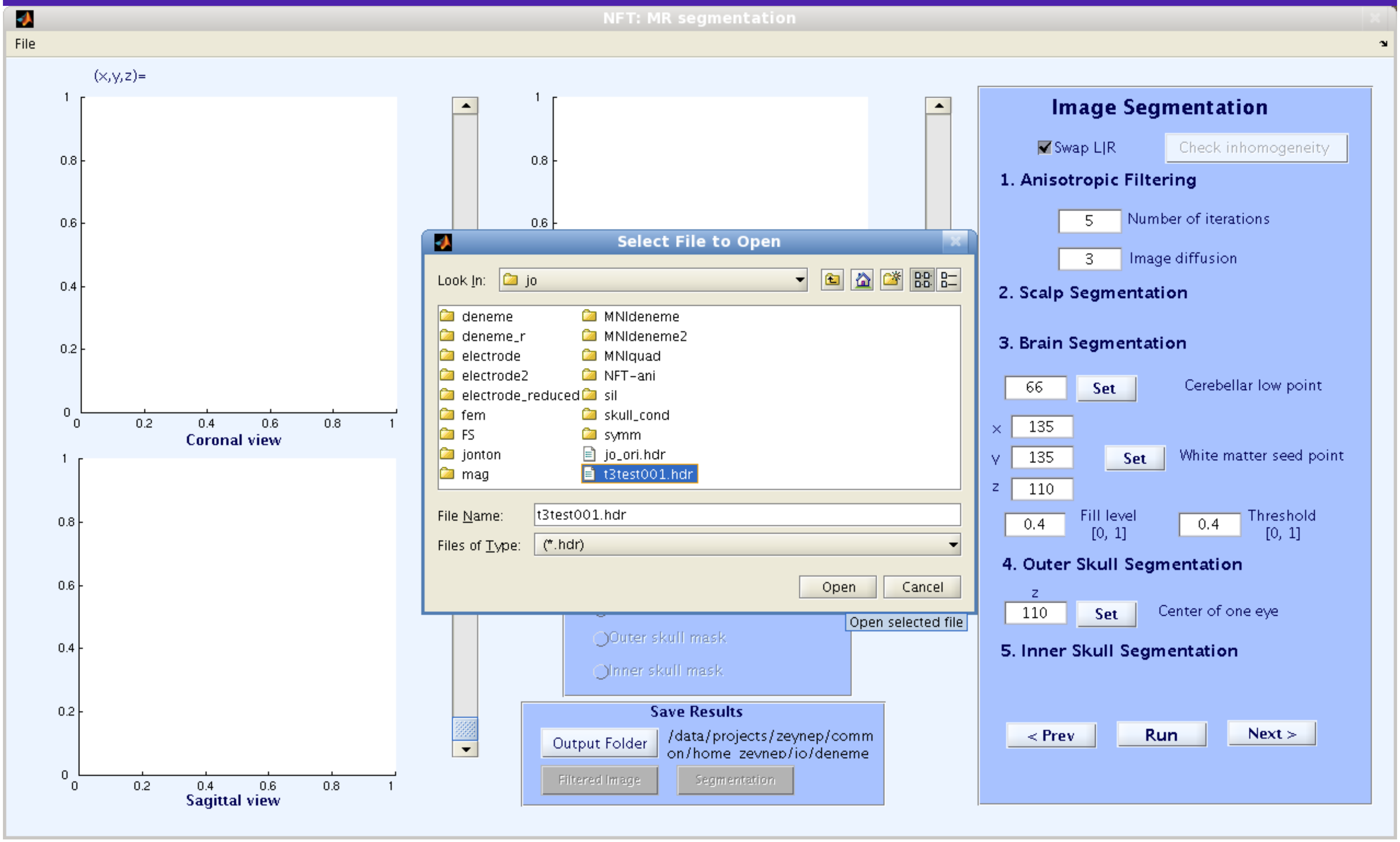


Image Segmentation - load image

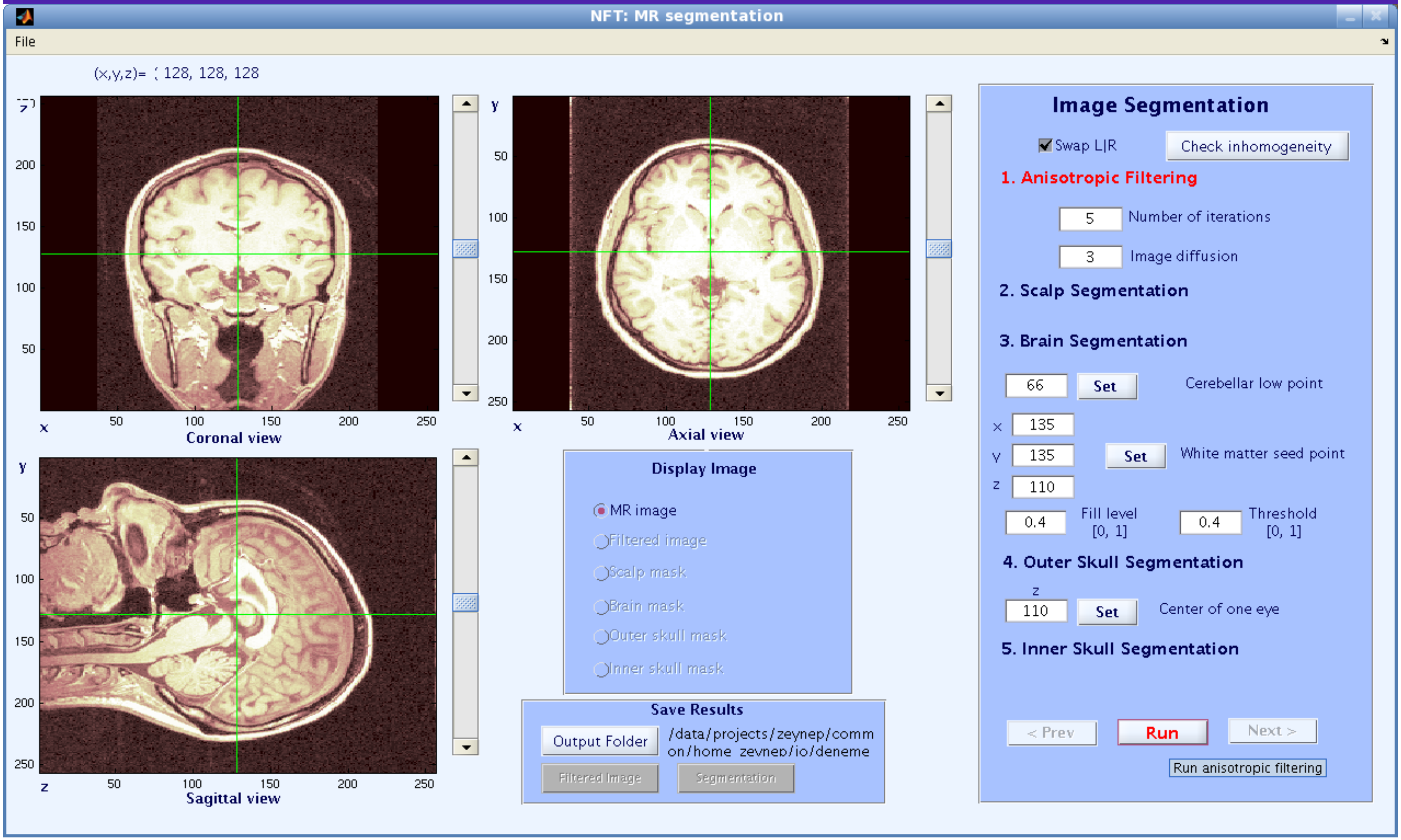


Segmentation Select an image in analyze format

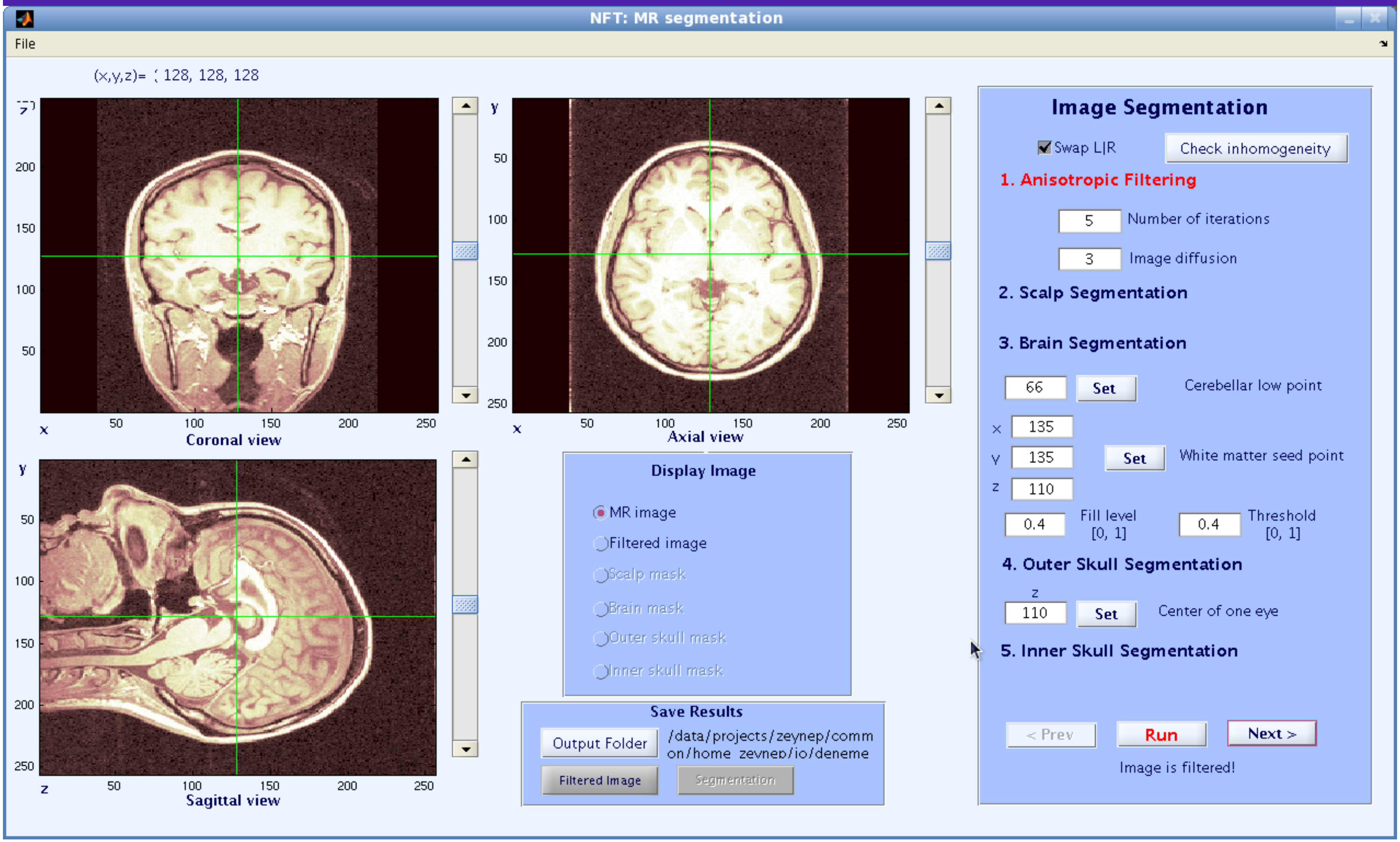


Segmentation

Run filtering

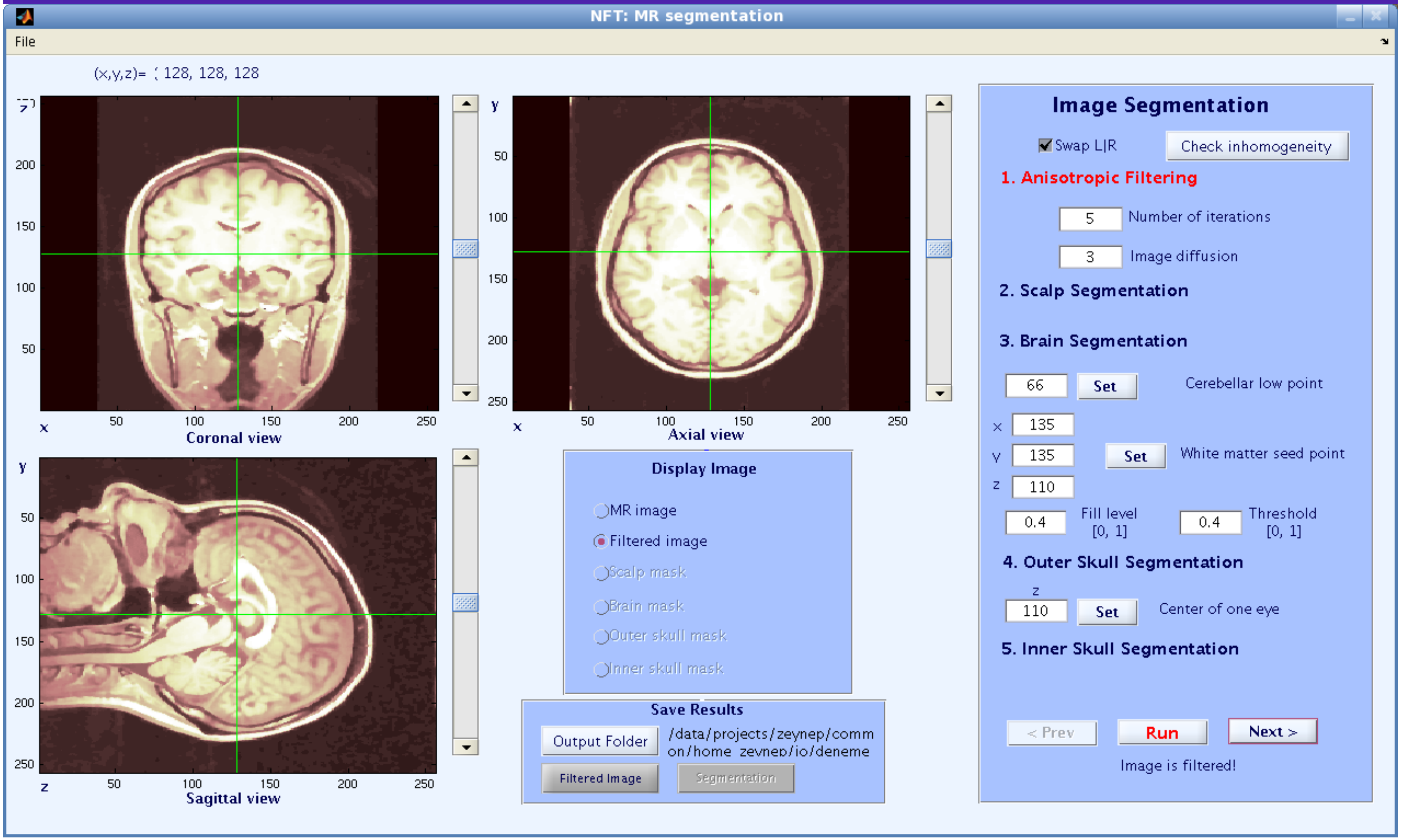


Segmentation



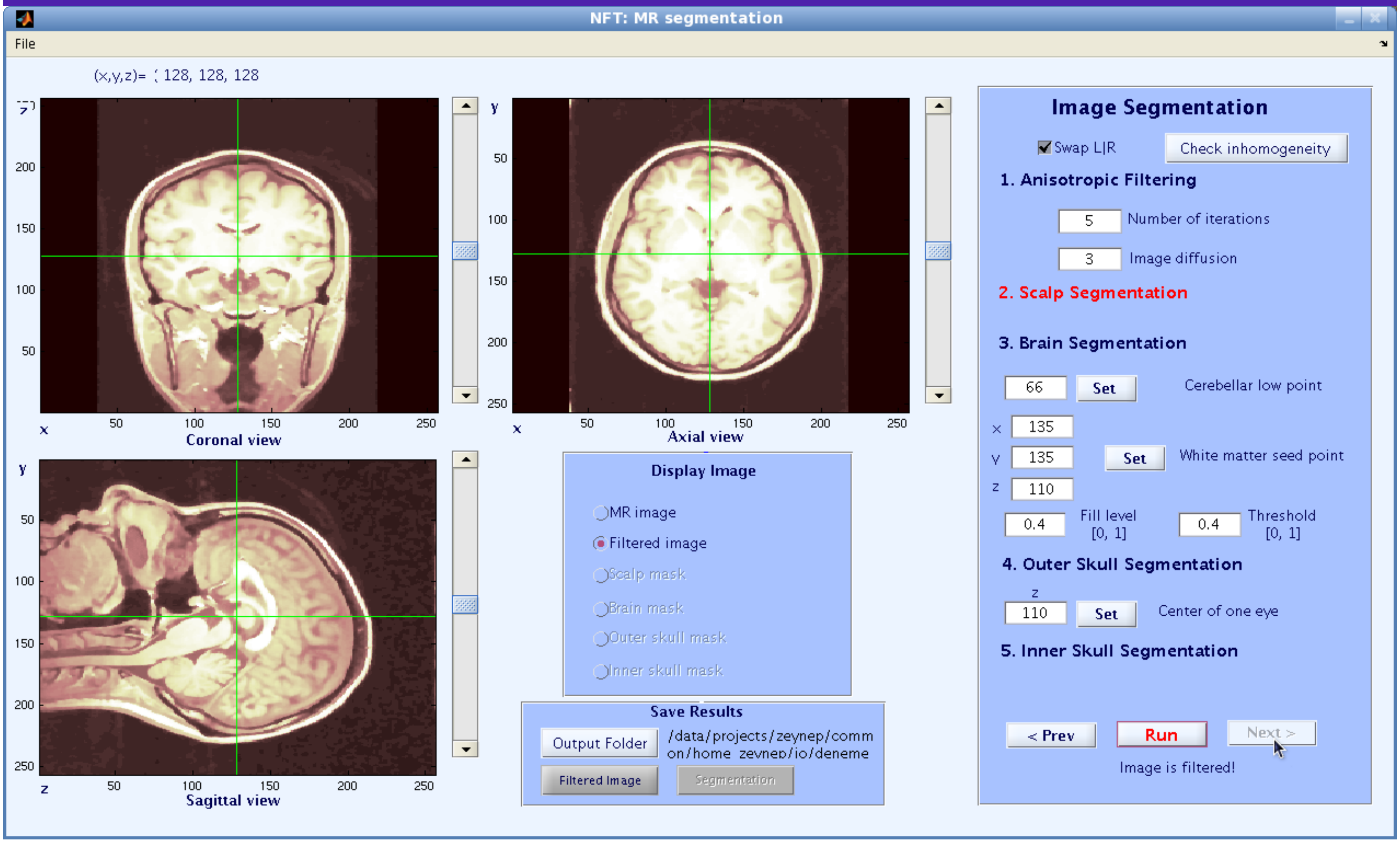
Segmentation

View filtered image



Segmentation

Click 'Next' for scalp segmentation



Segmentation Click 'Run' for scalp segmentation

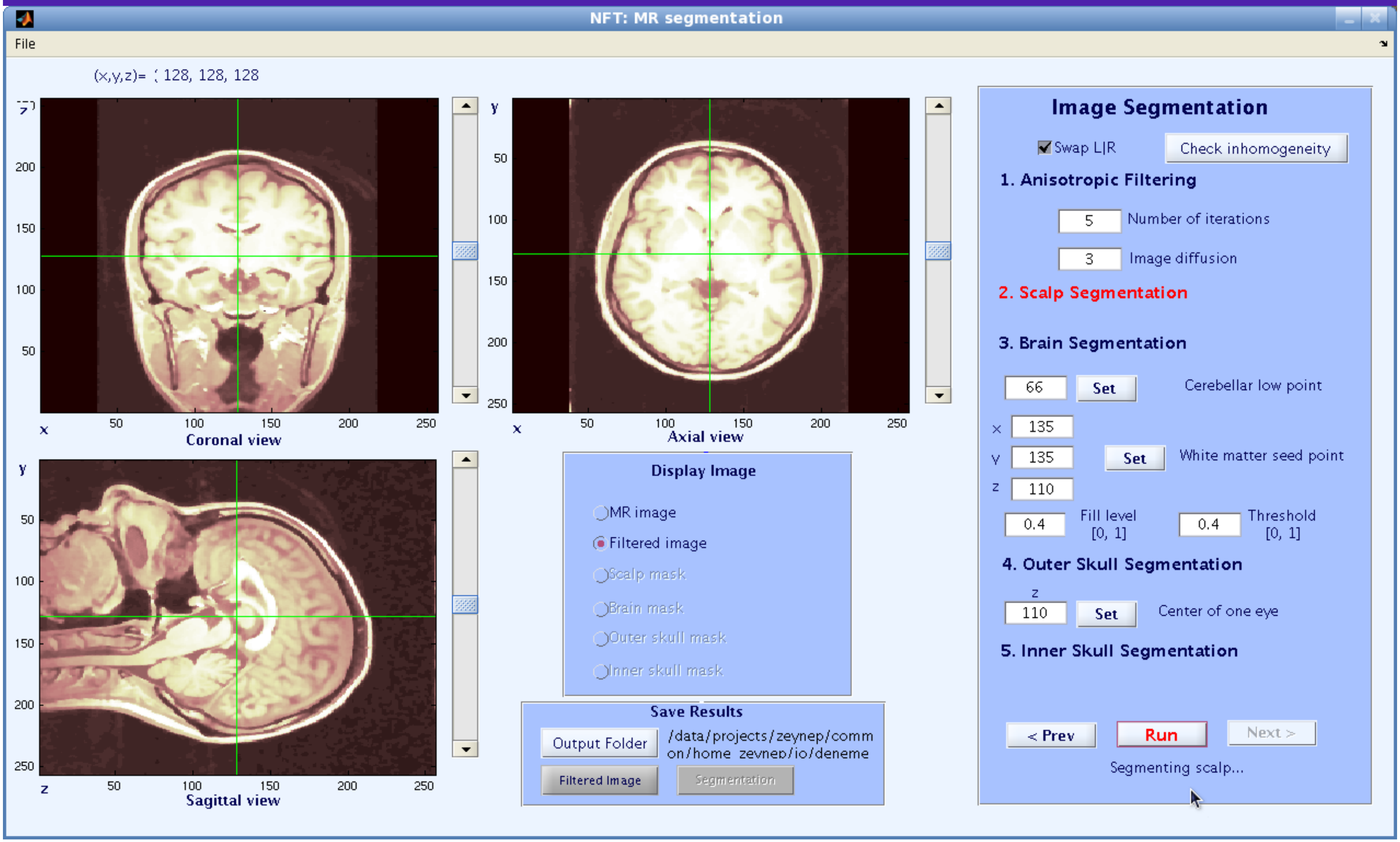
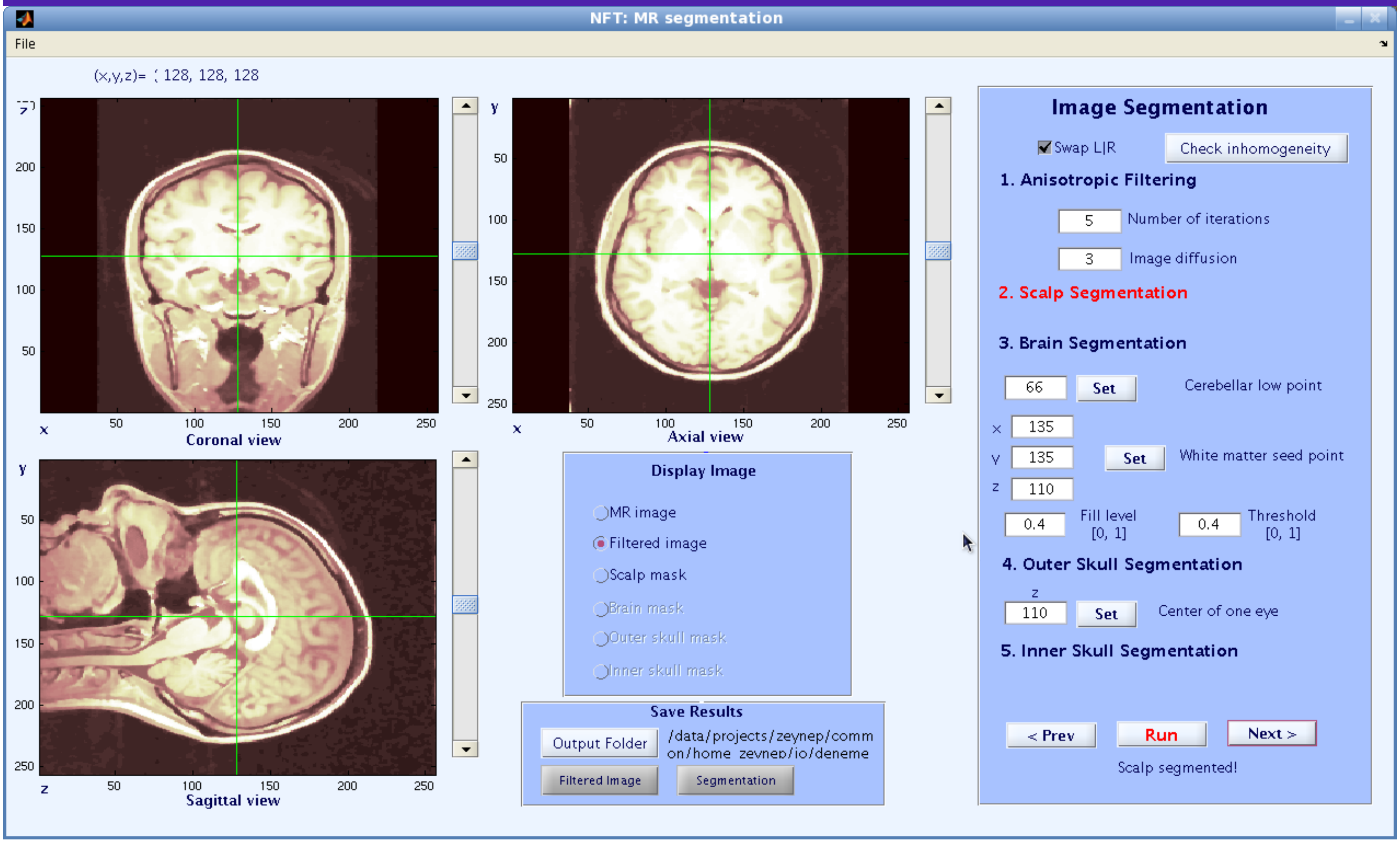
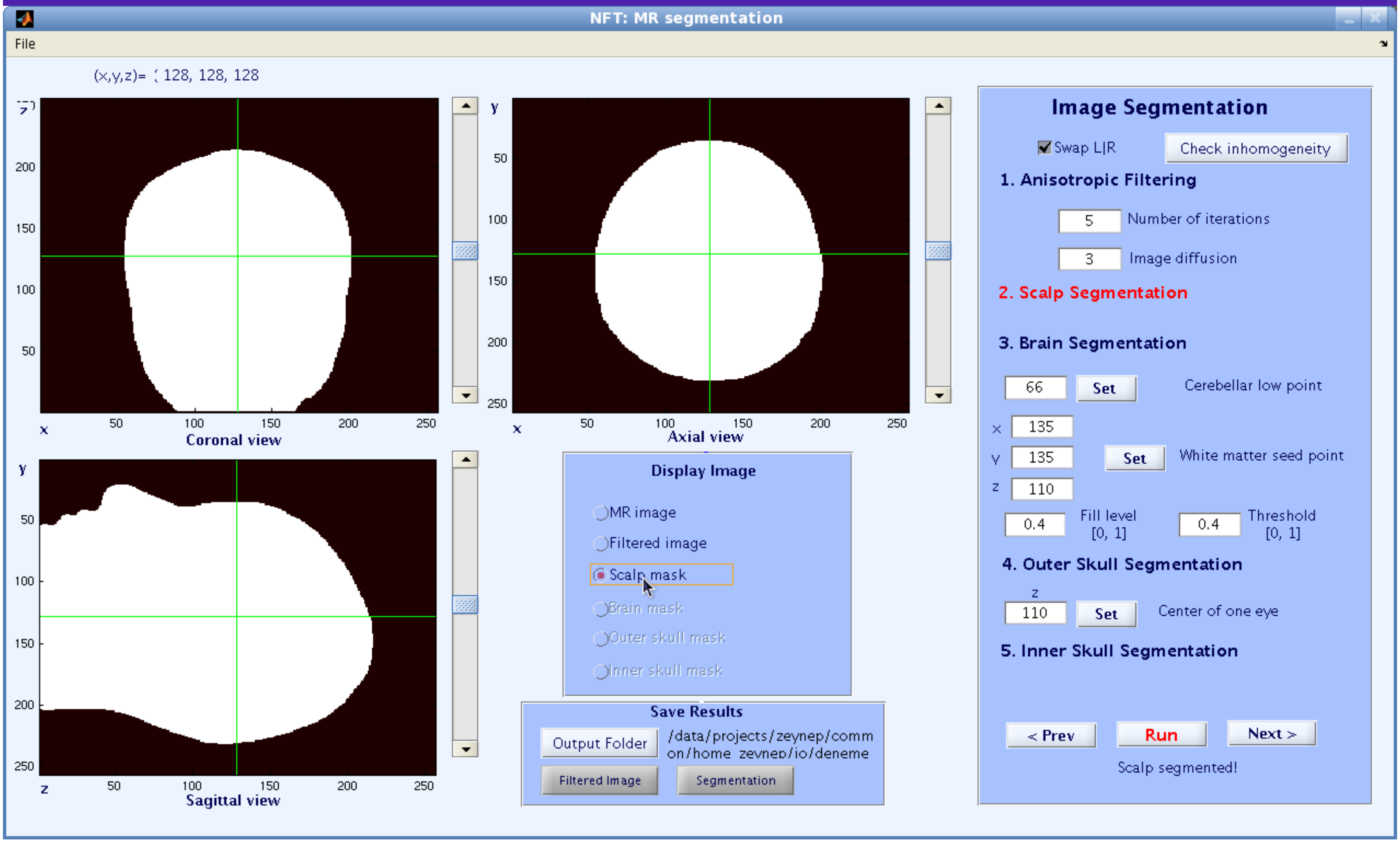


Image Segmentation

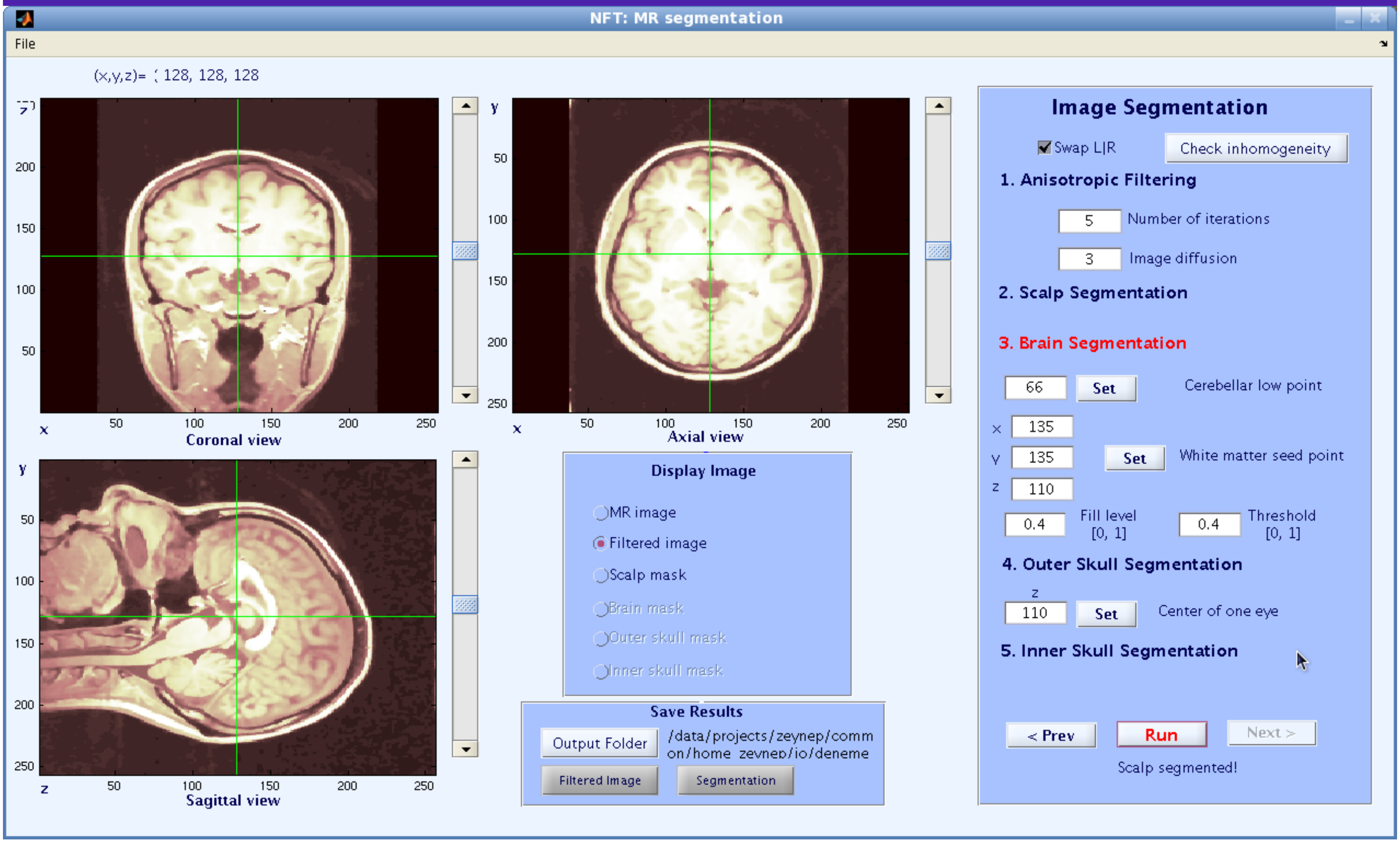


Segmentation

View scalp mask

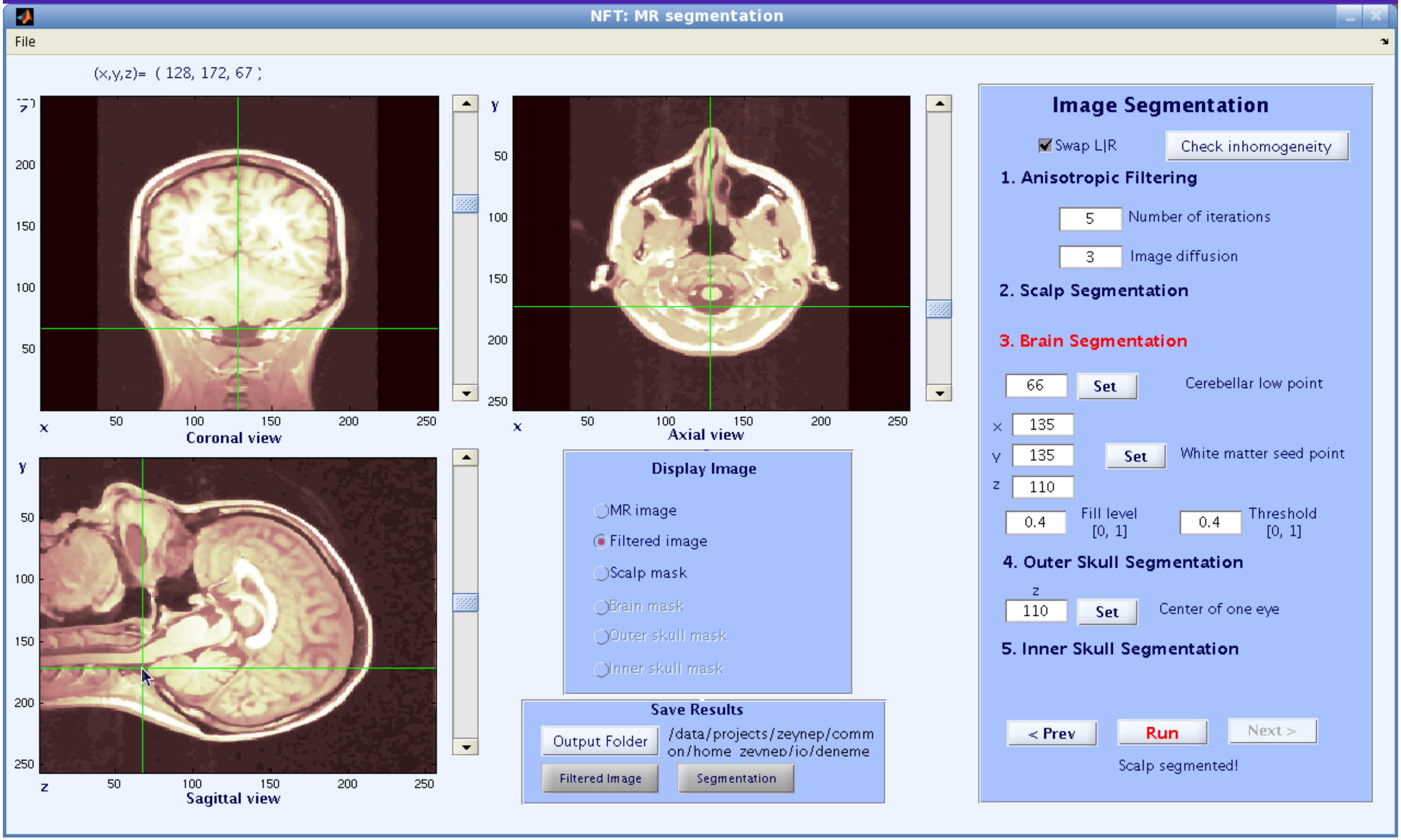


Segmentation Click 'Next' for brain segmentation



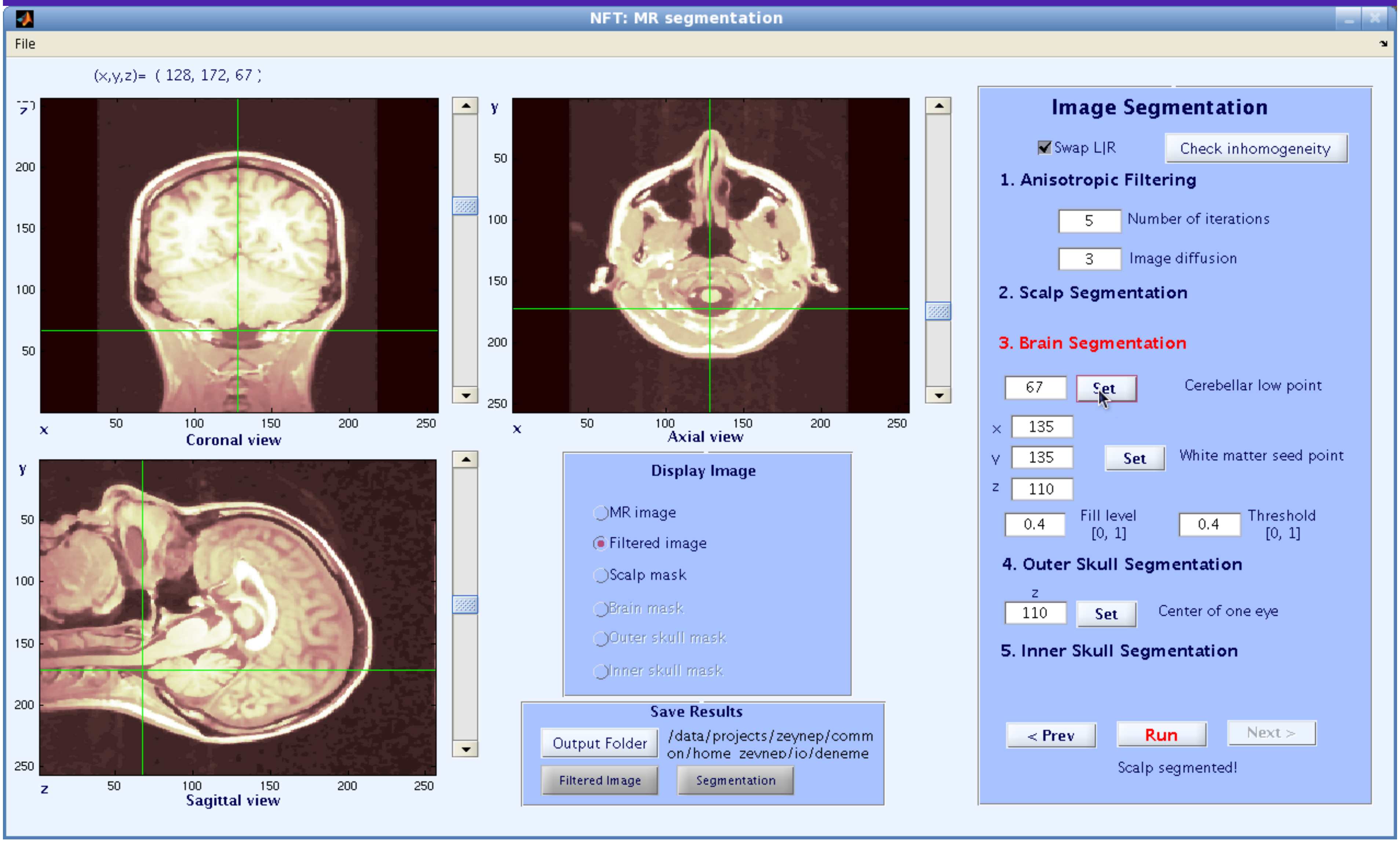
Segmentation

Selection of cerebellar low point



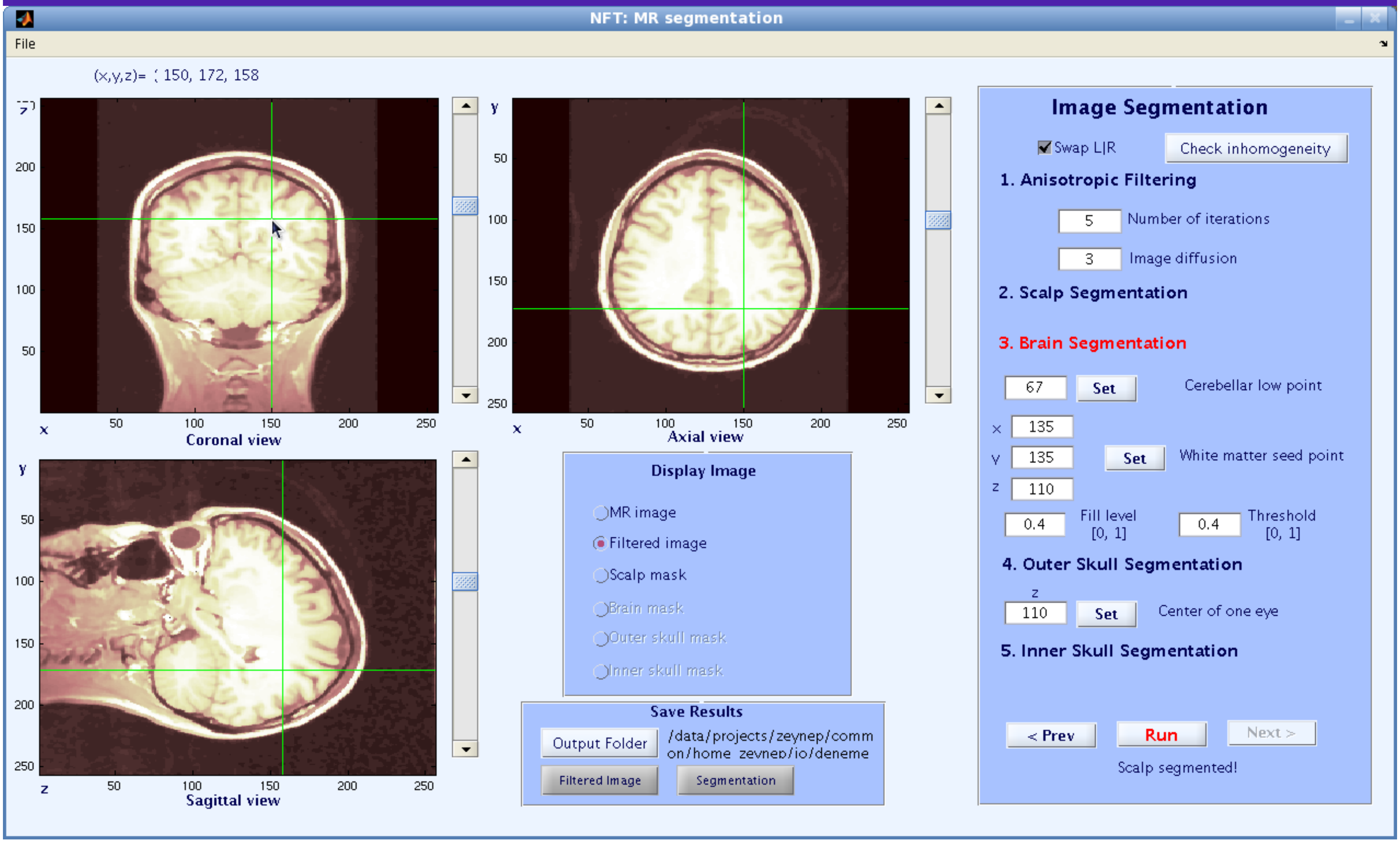
Segmentation

Click 'Set'



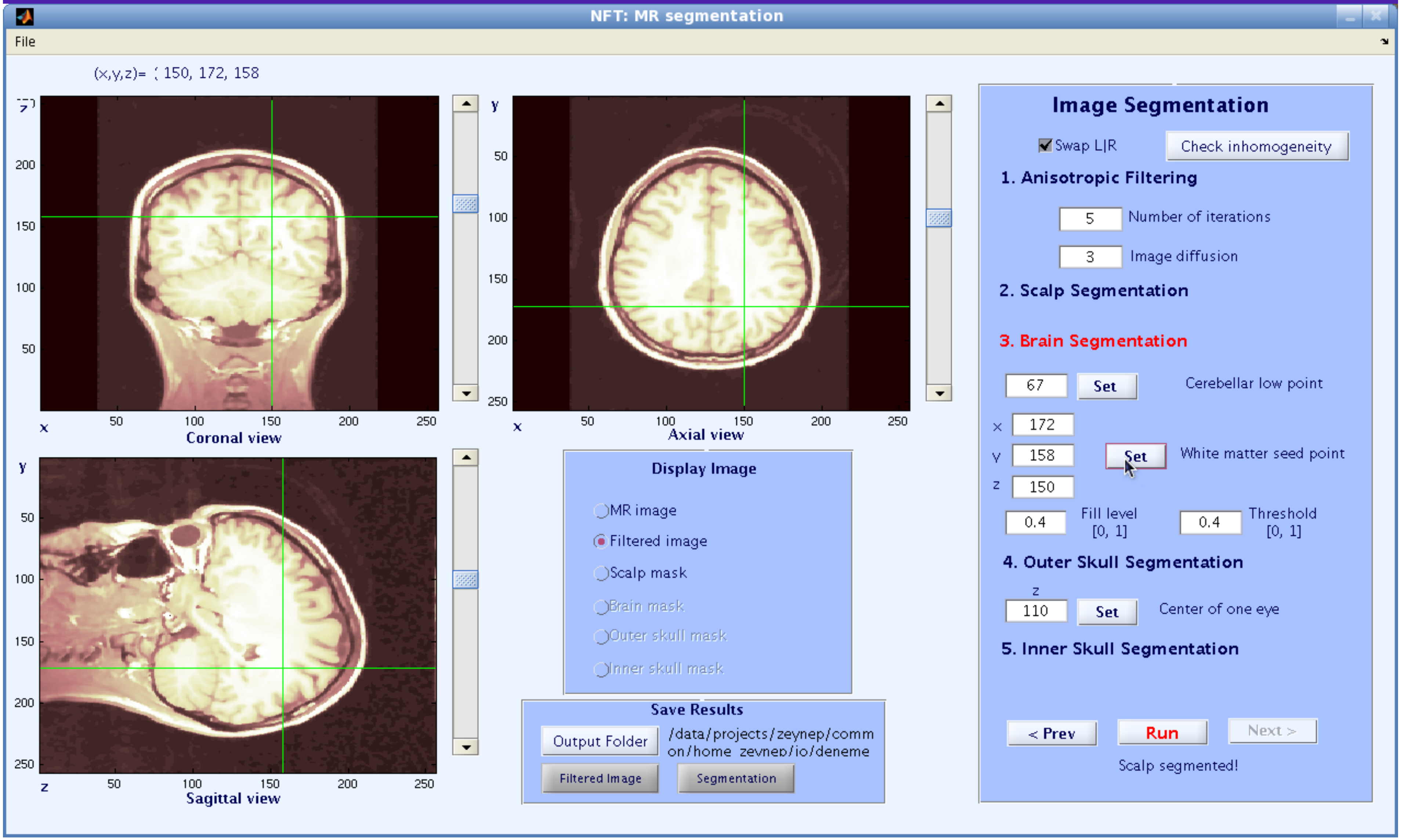
Segmentation

Selection of a WM point

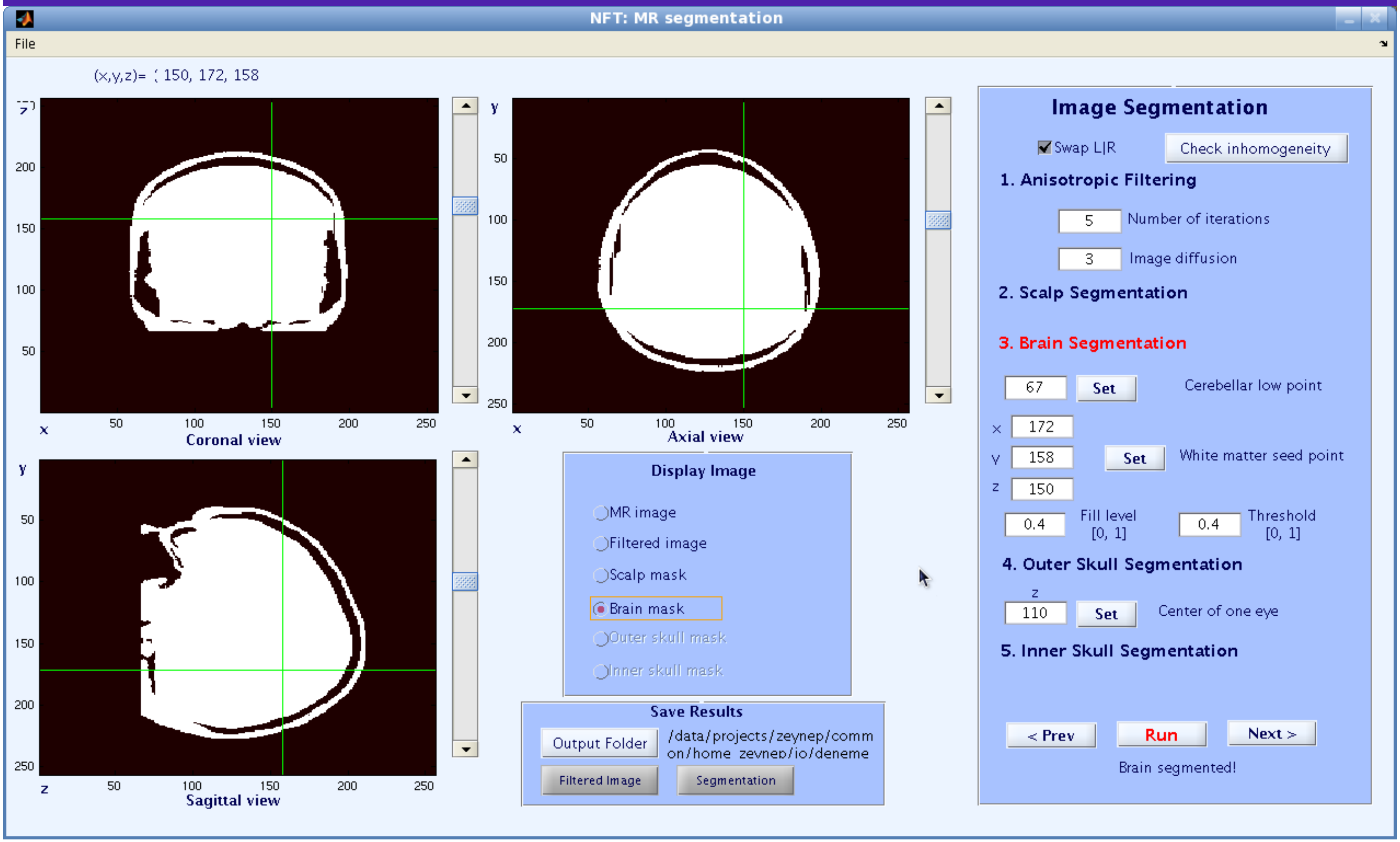


Segmentation

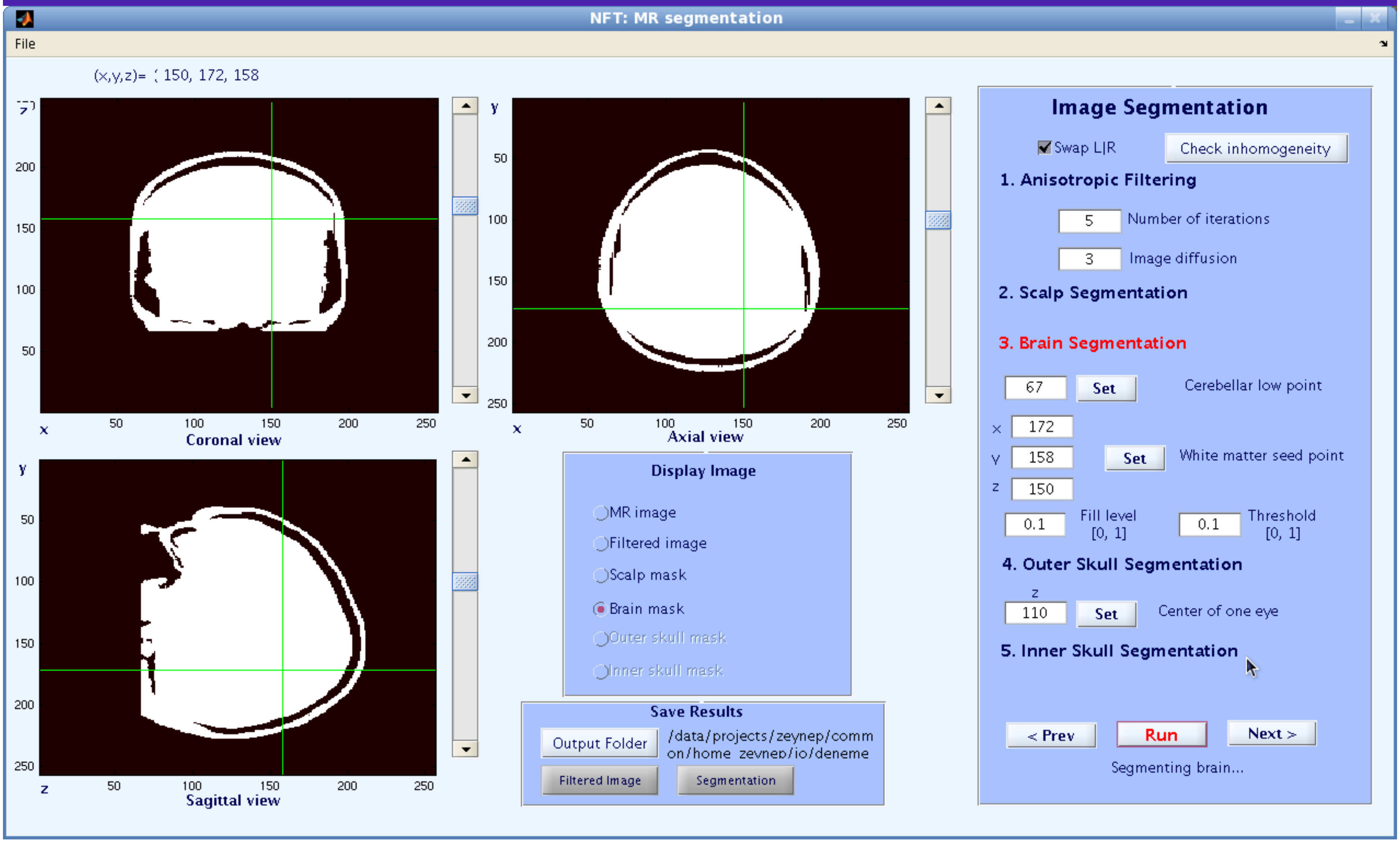
Click ‘Set’



Segmentation
Click 'Run' for brain segmentation

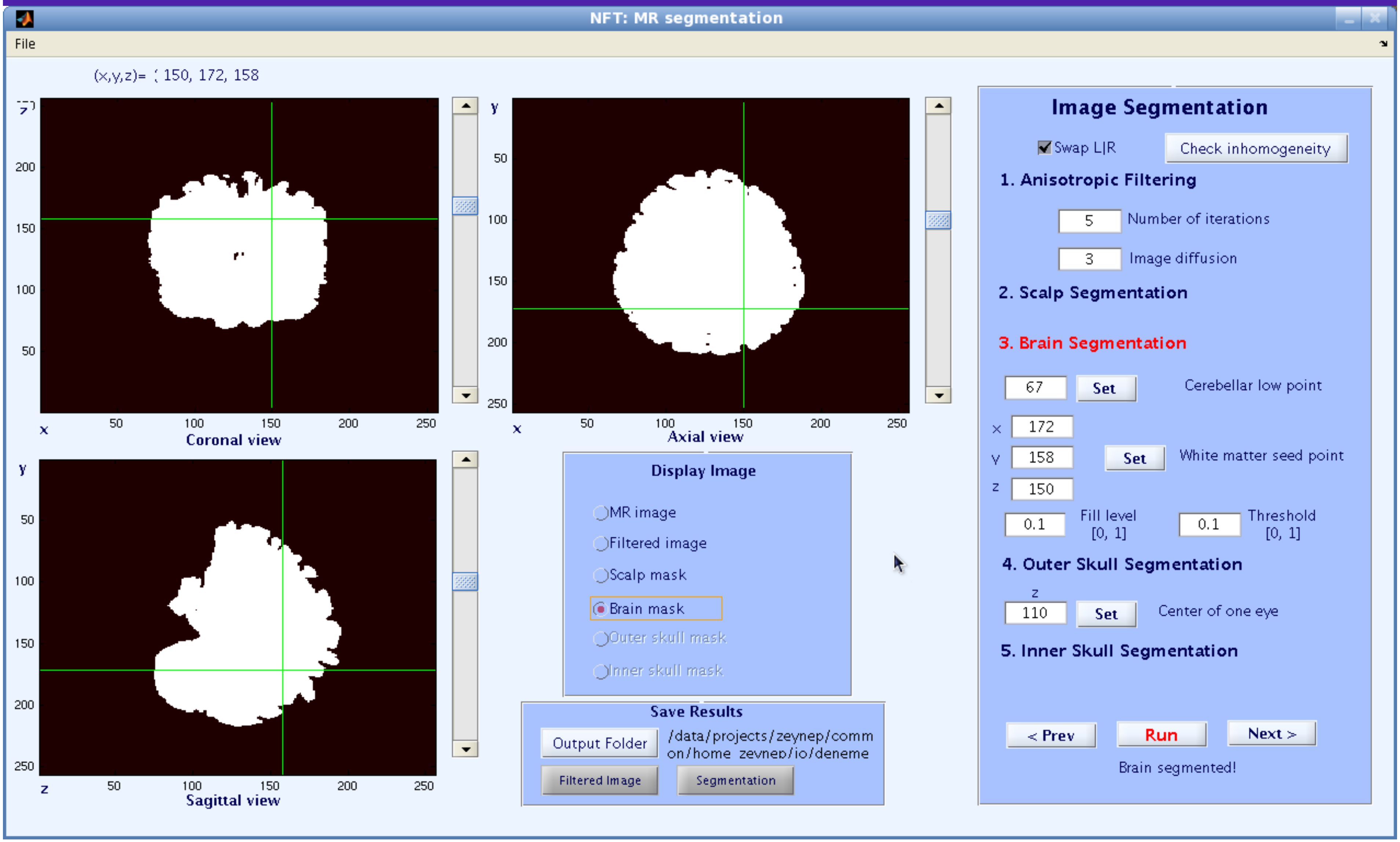


Segmentation Change thresholds if there is need

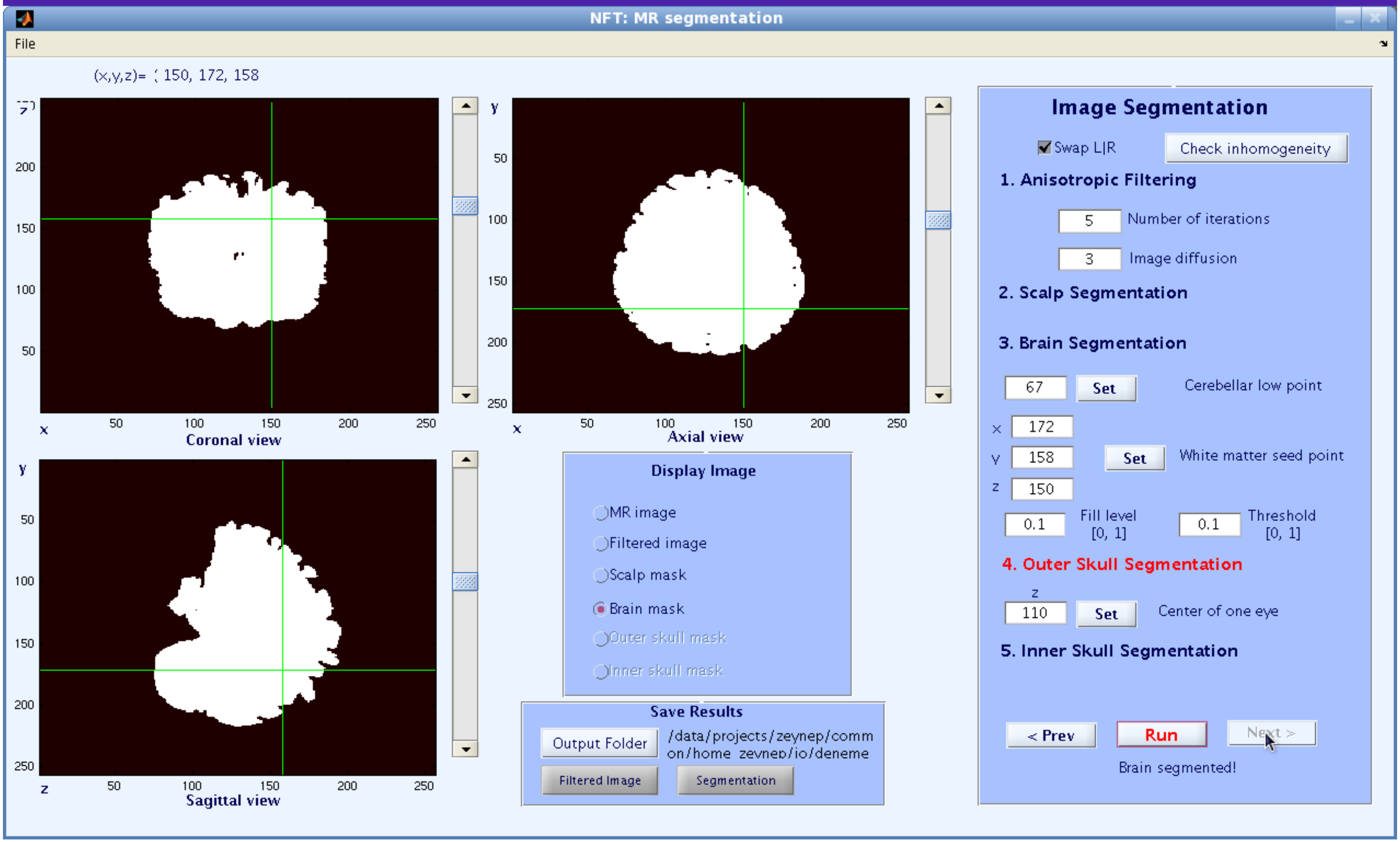


Segmentation

View brain mask

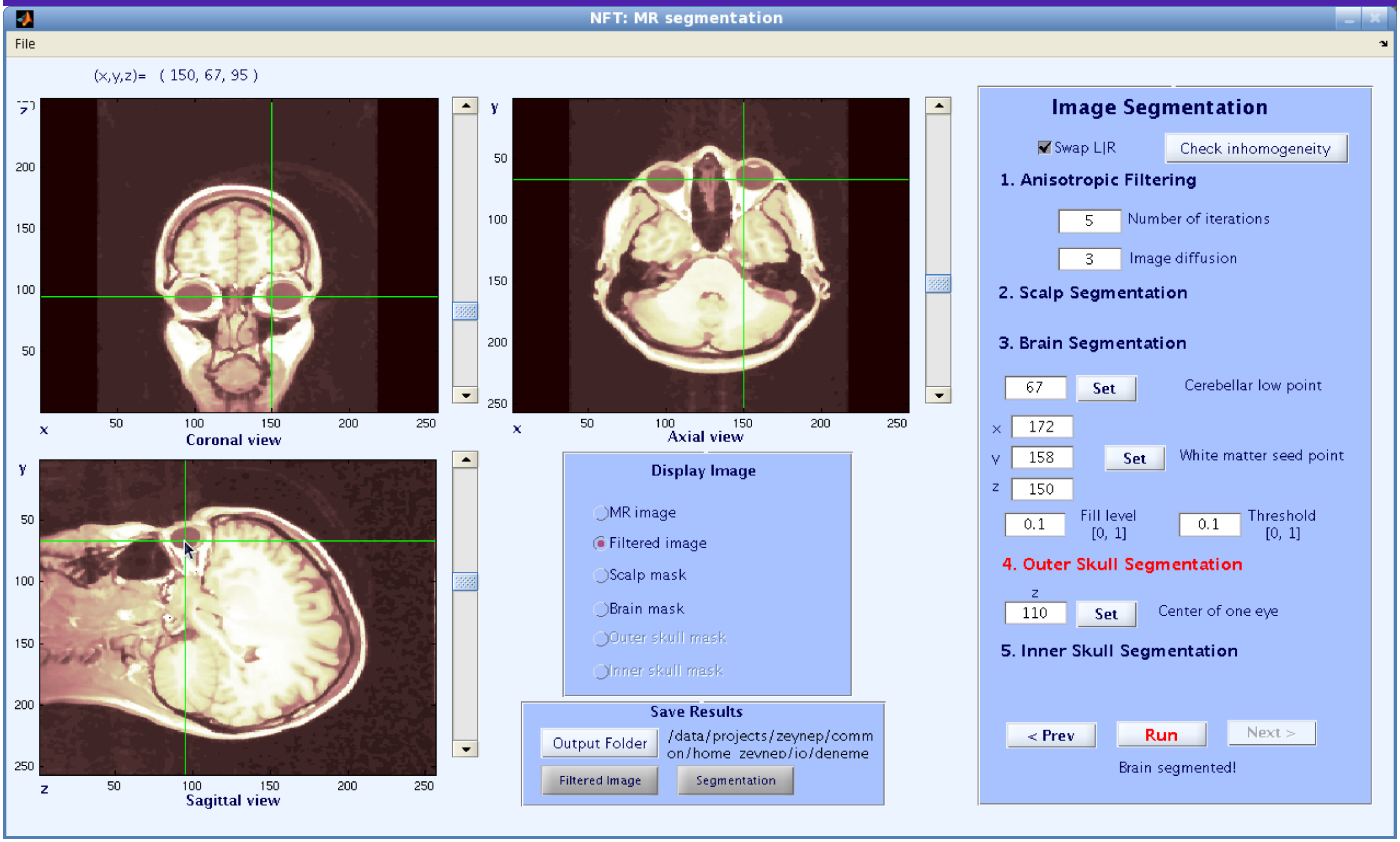


Segmentation Click 'Next' for skull segmentation



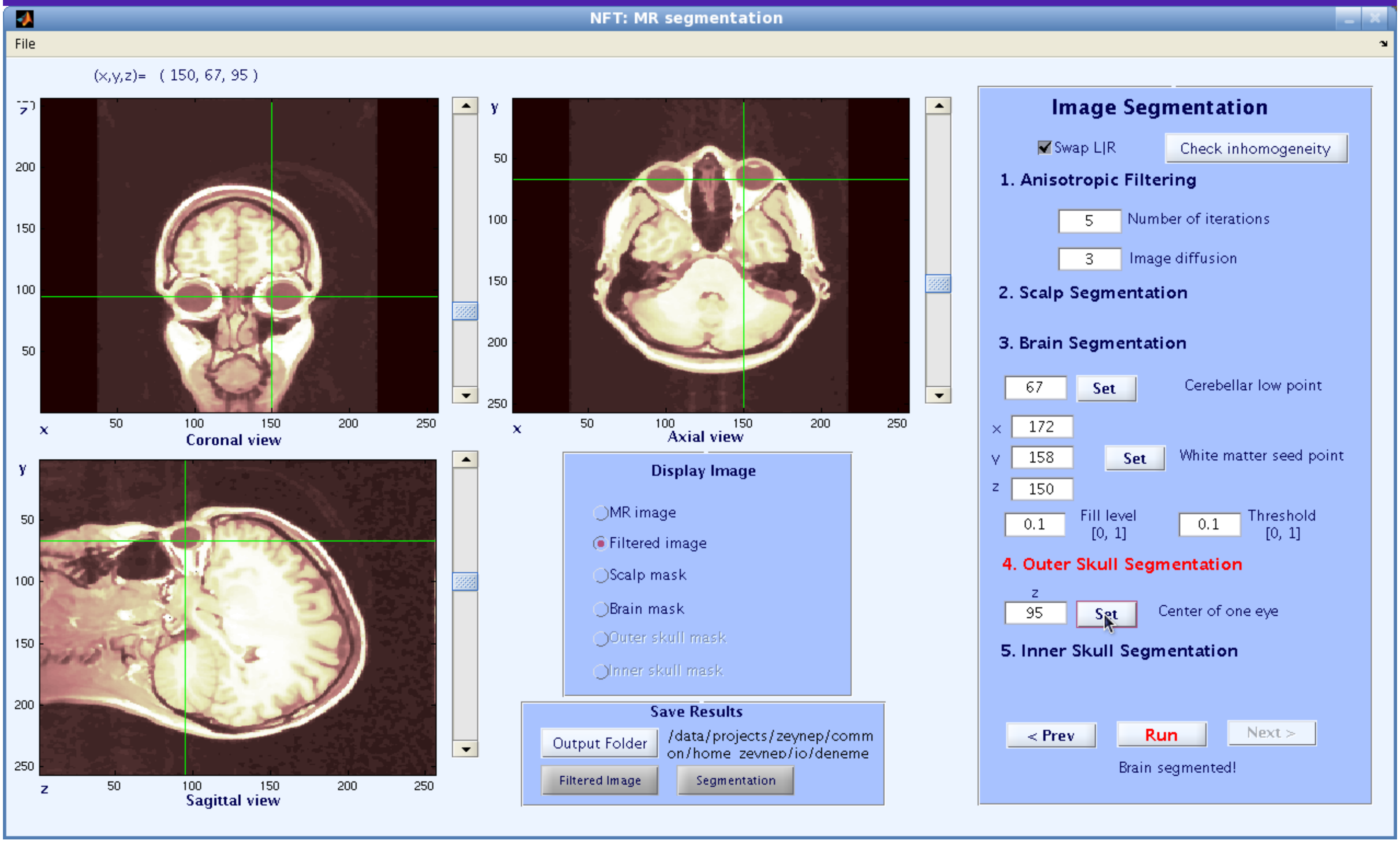
Segmentation

Select a slice for eyes

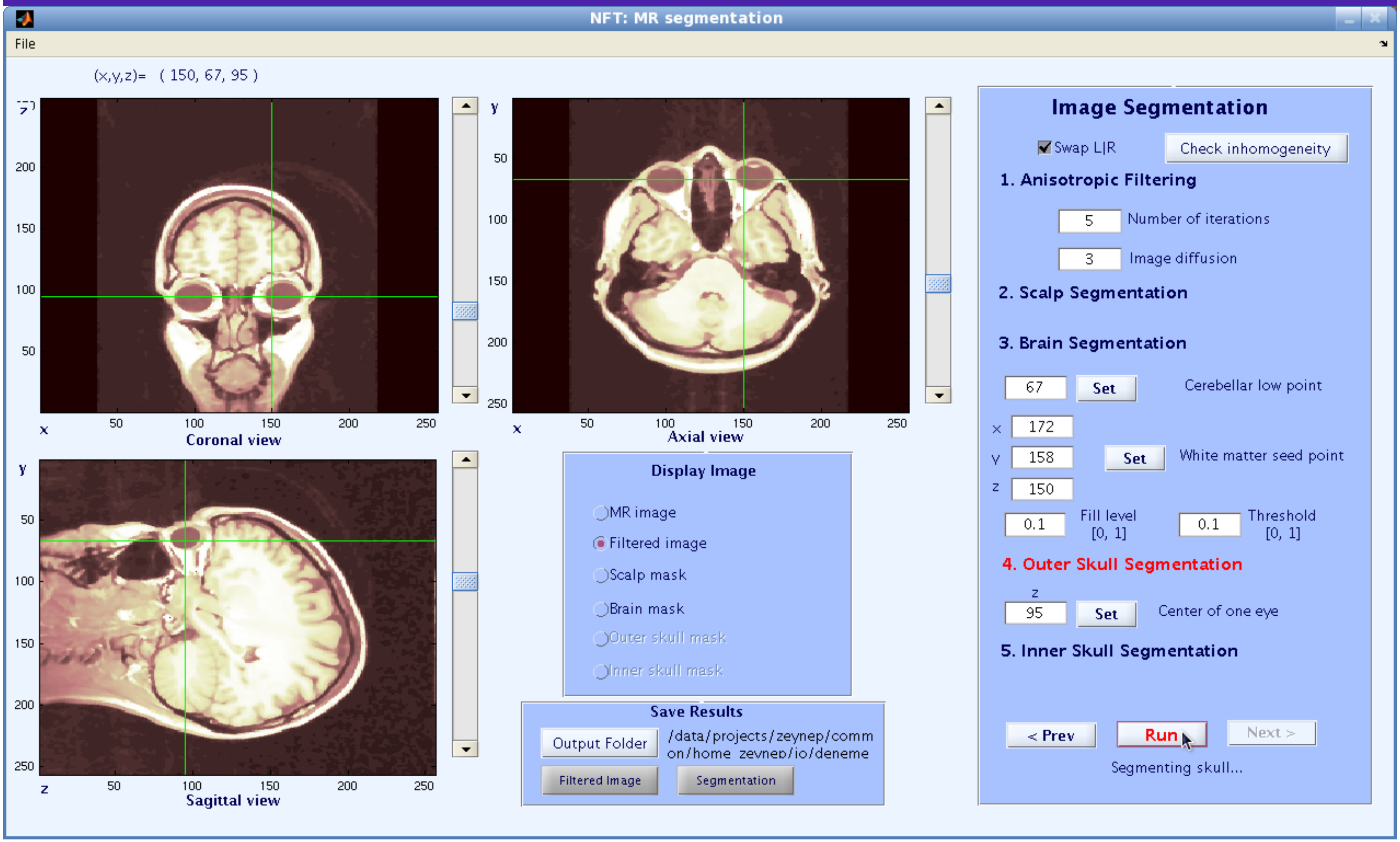


Segmentation

Click ‘Set’

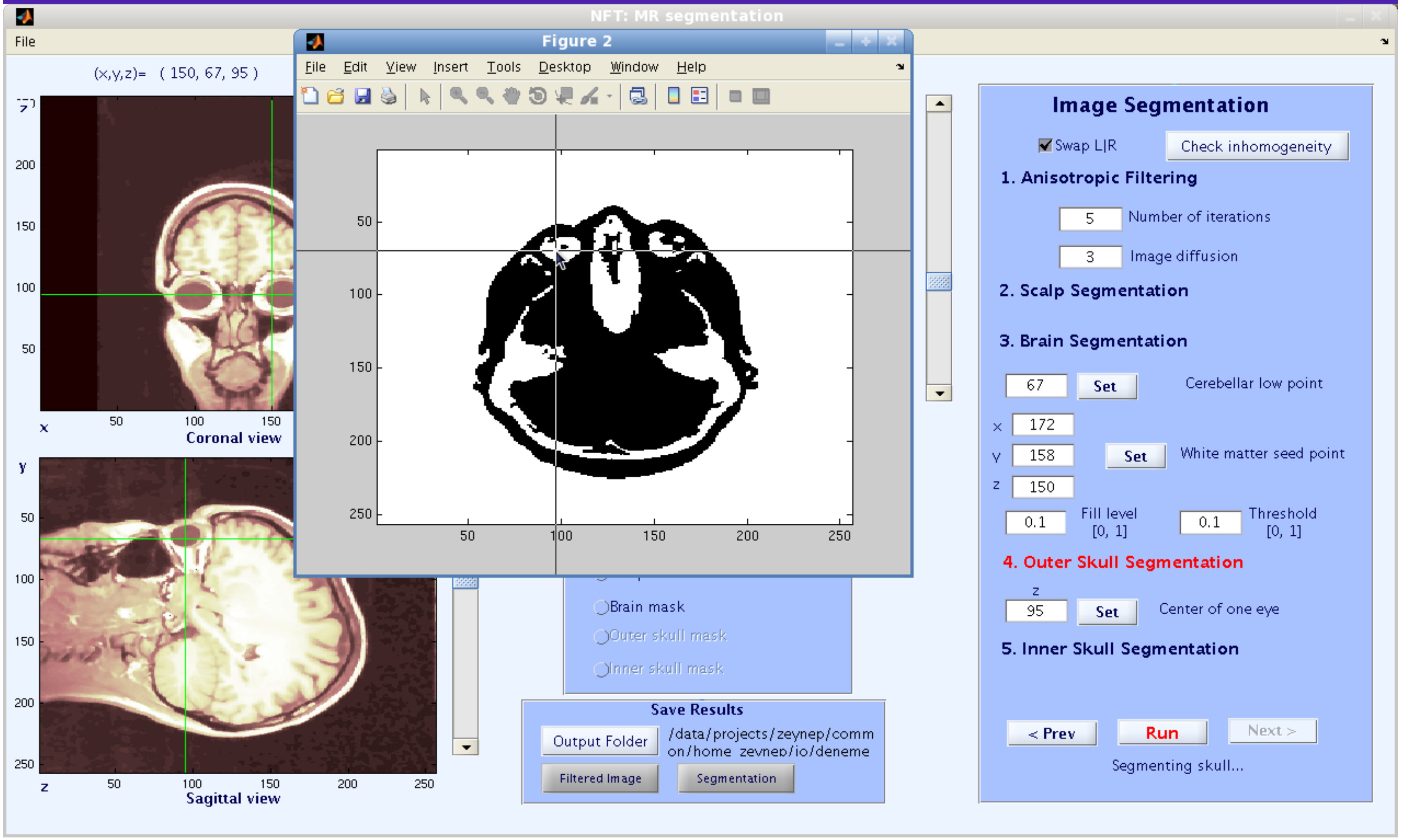


Segmentation Click 'Run' for skull segmentation

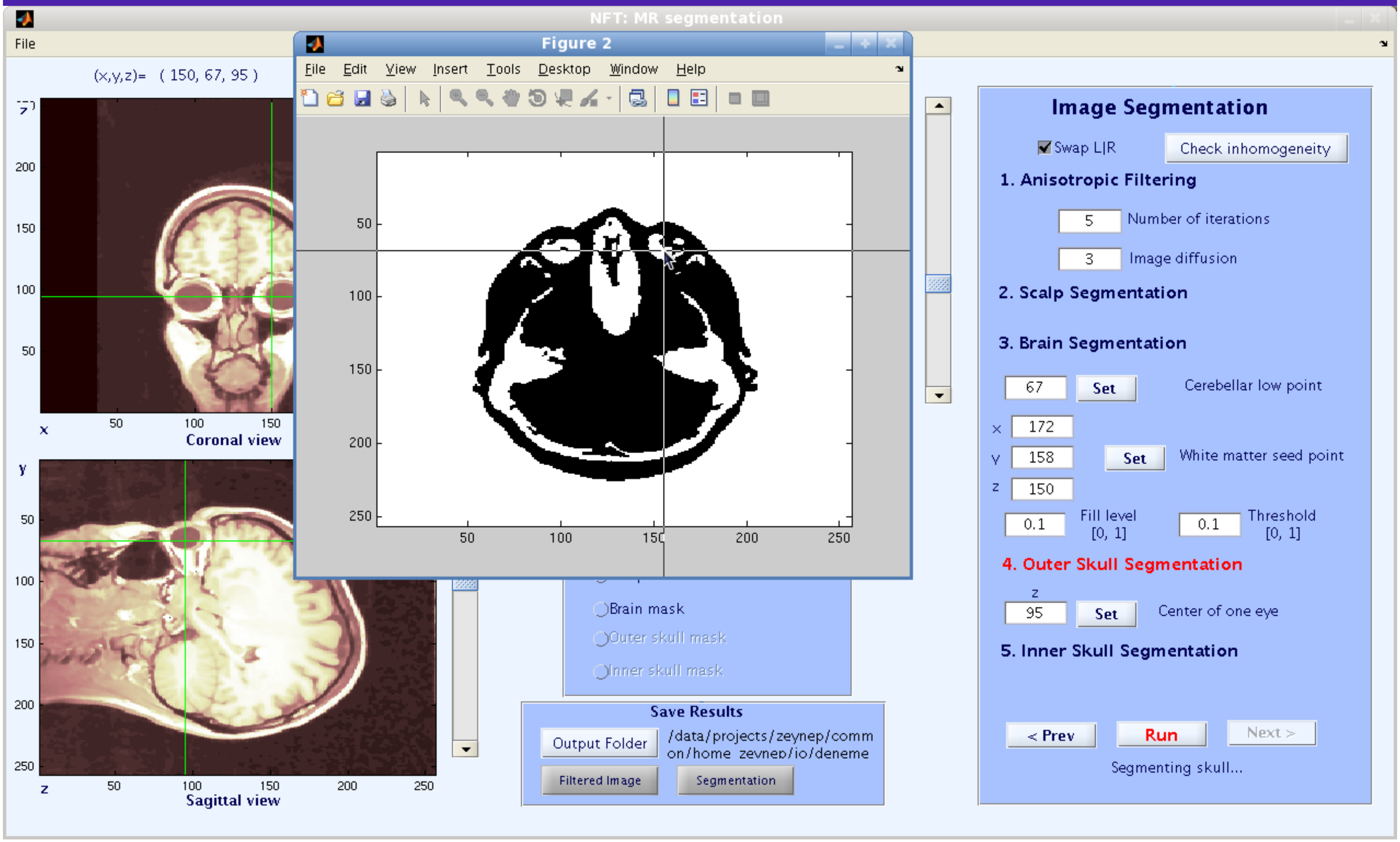


Segmentation

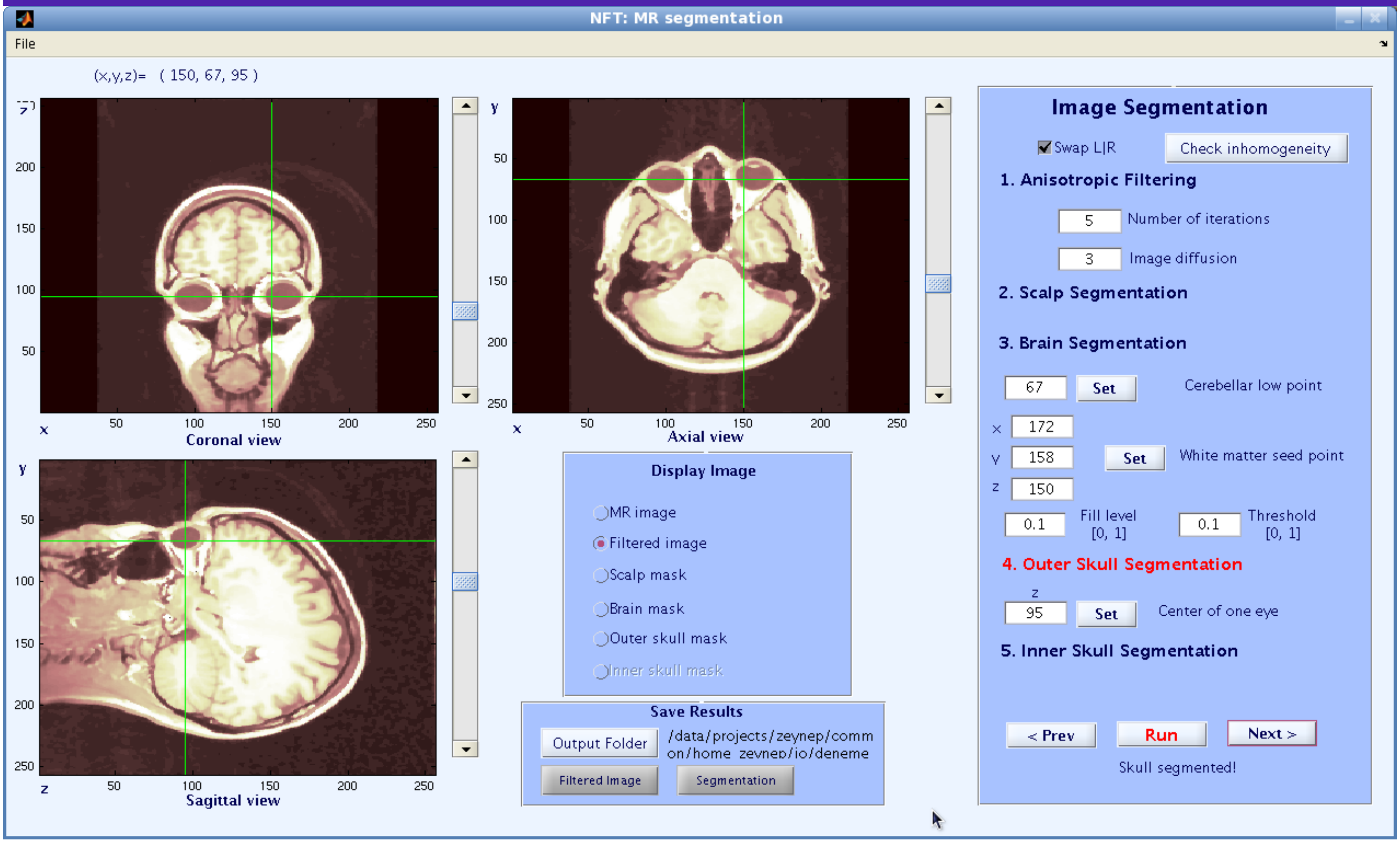
Click on the eyes



Segmentation

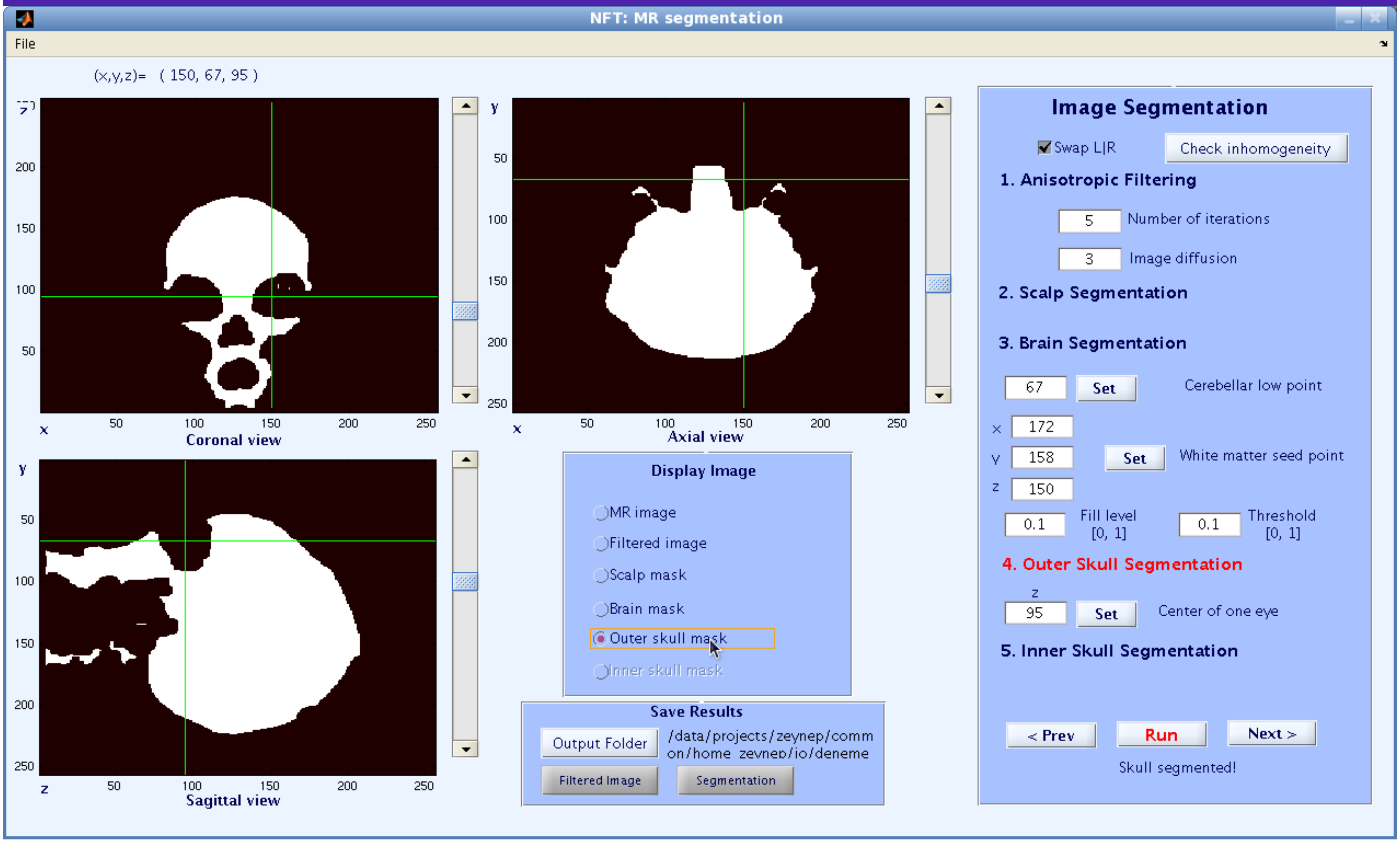


Segmentation

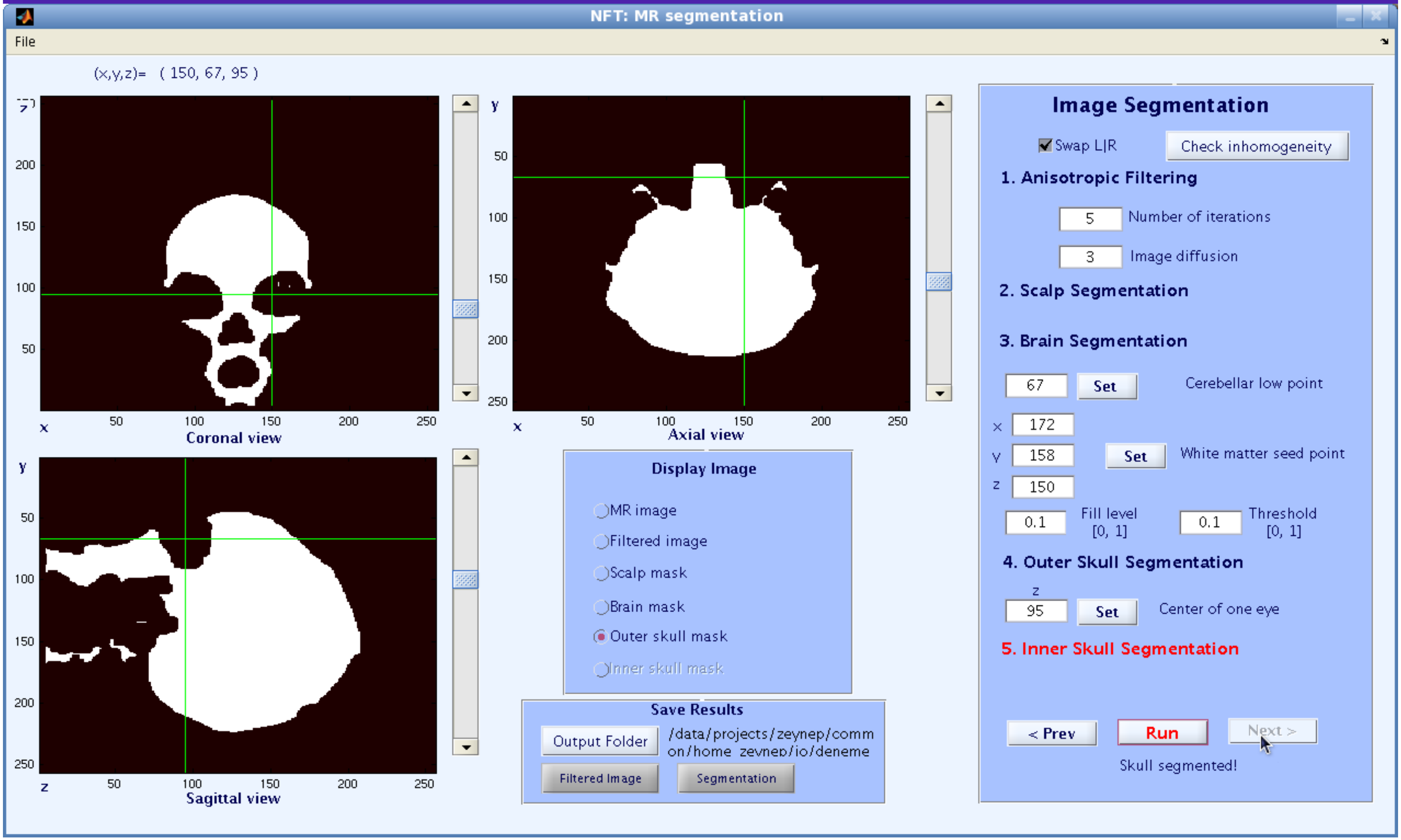


Segmentation

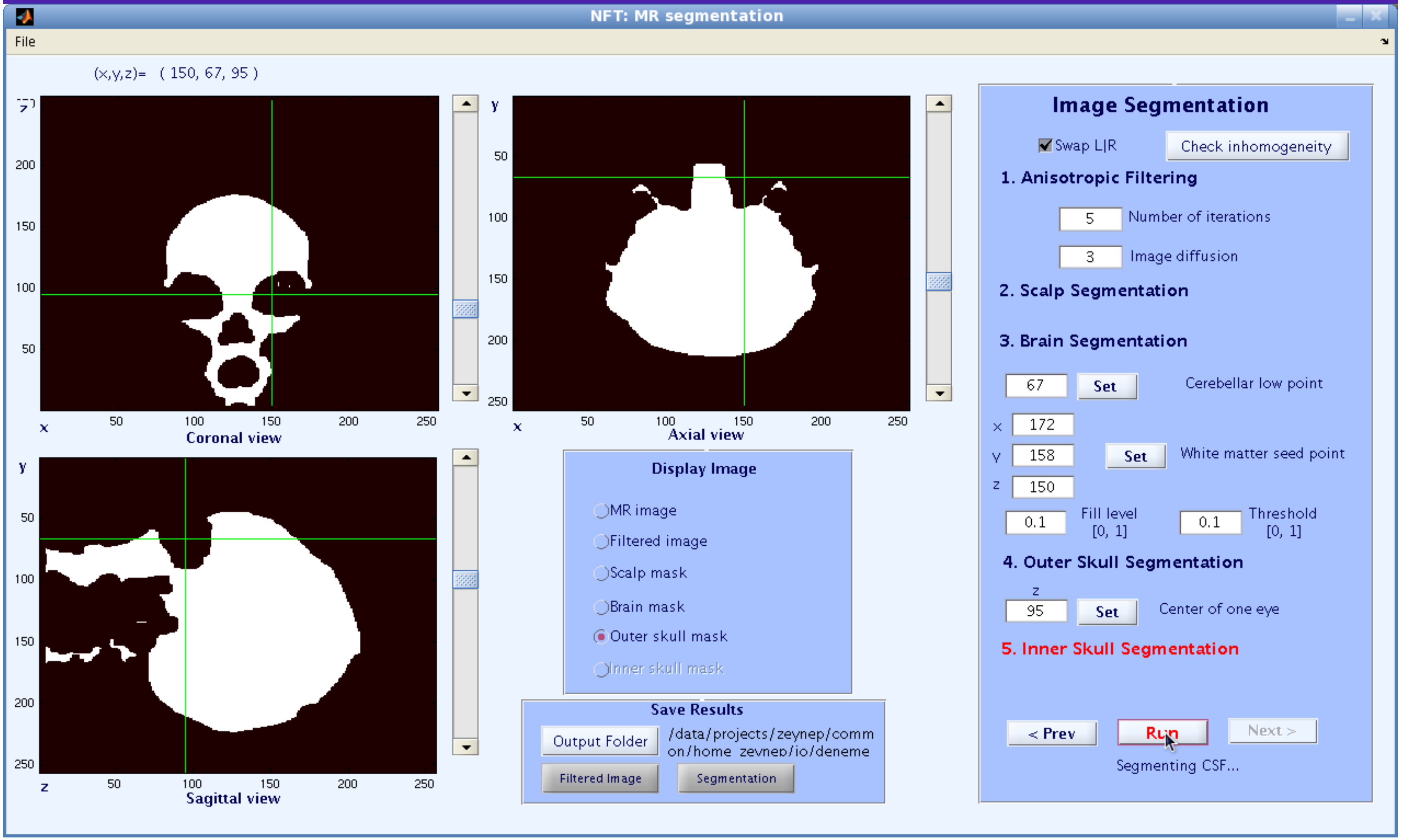
View skull segmentation



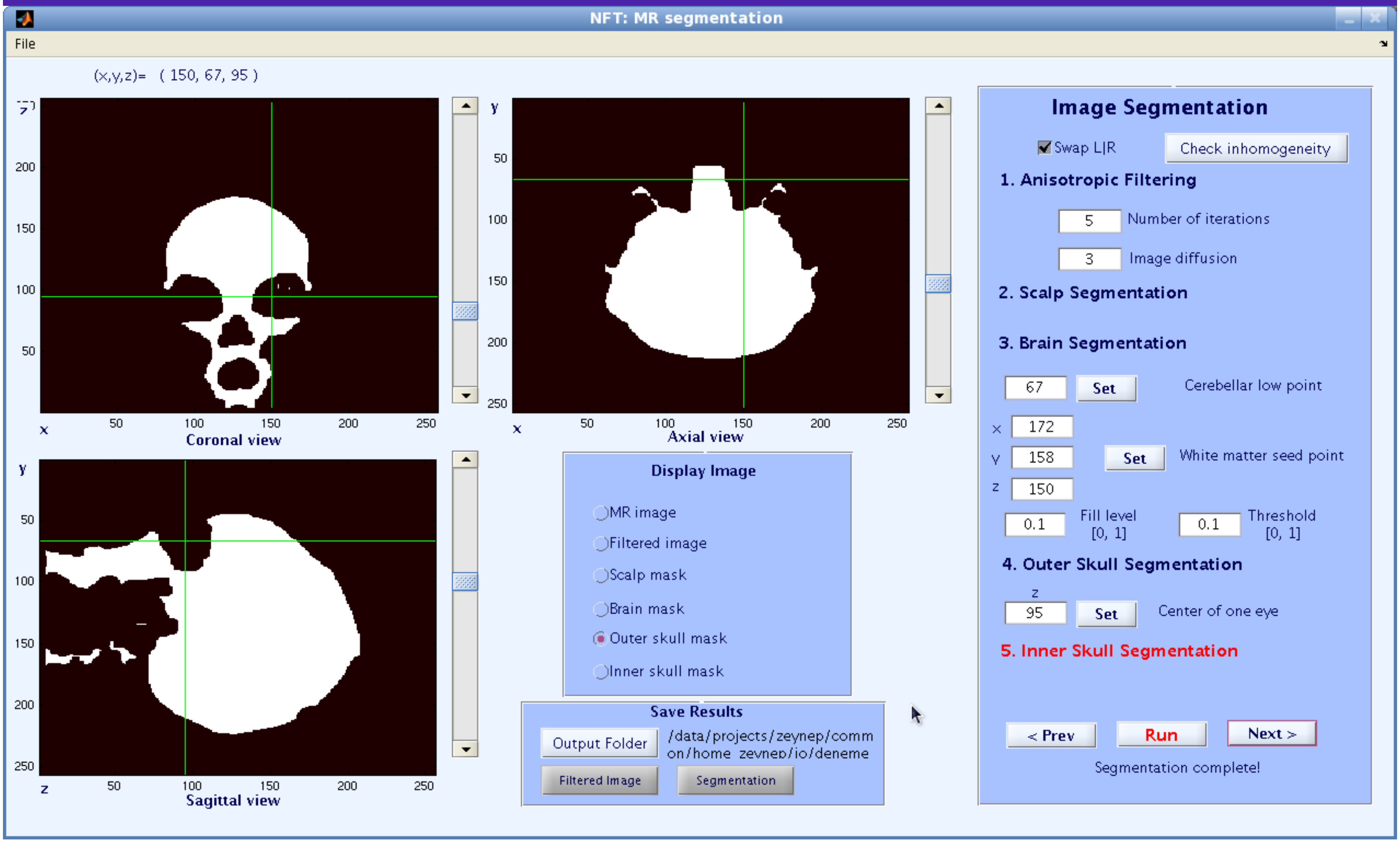
Segmentation Click 'Next' for CSF segmentation



Segmentation Click 'Run' for CSF segmentation

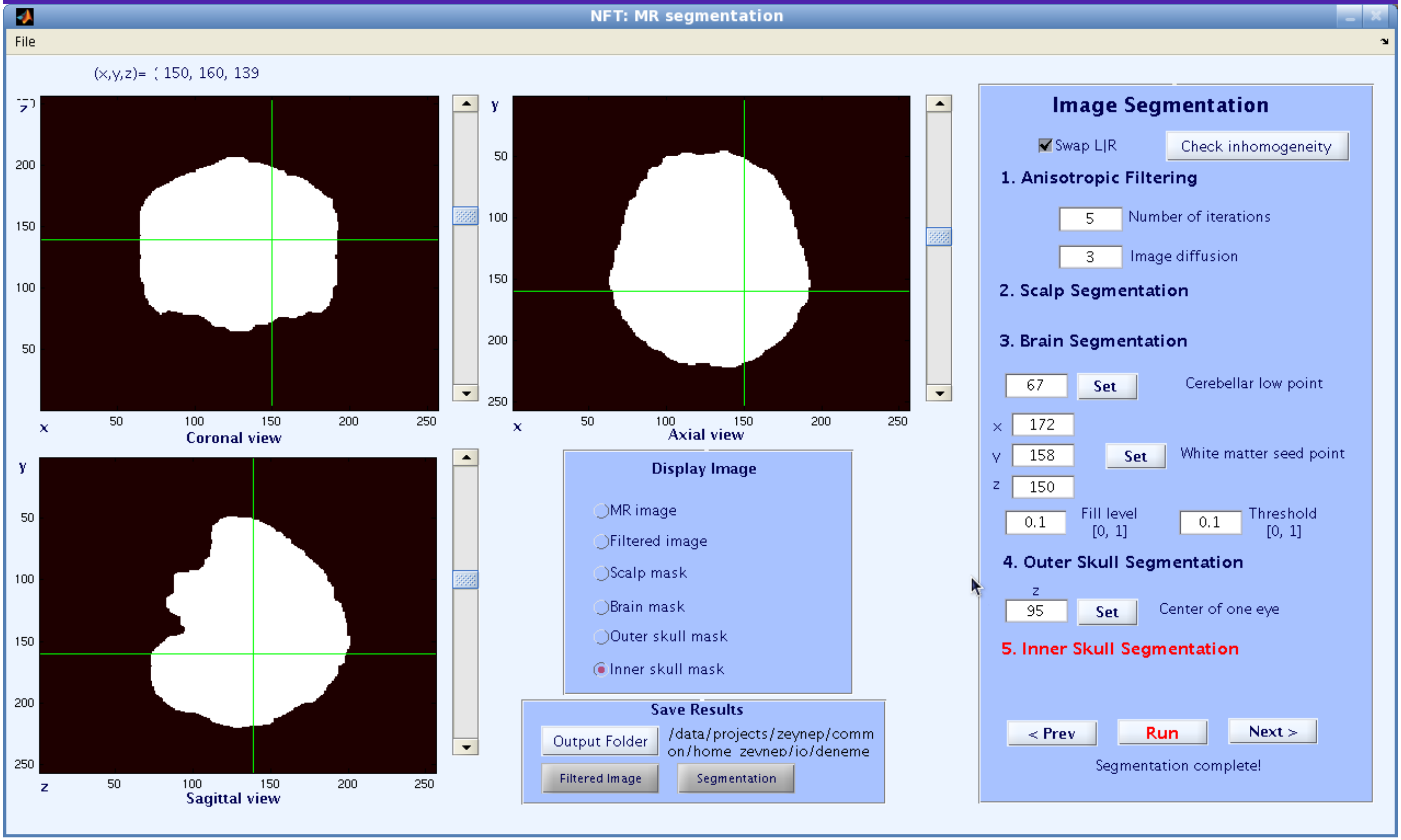


Segmentation



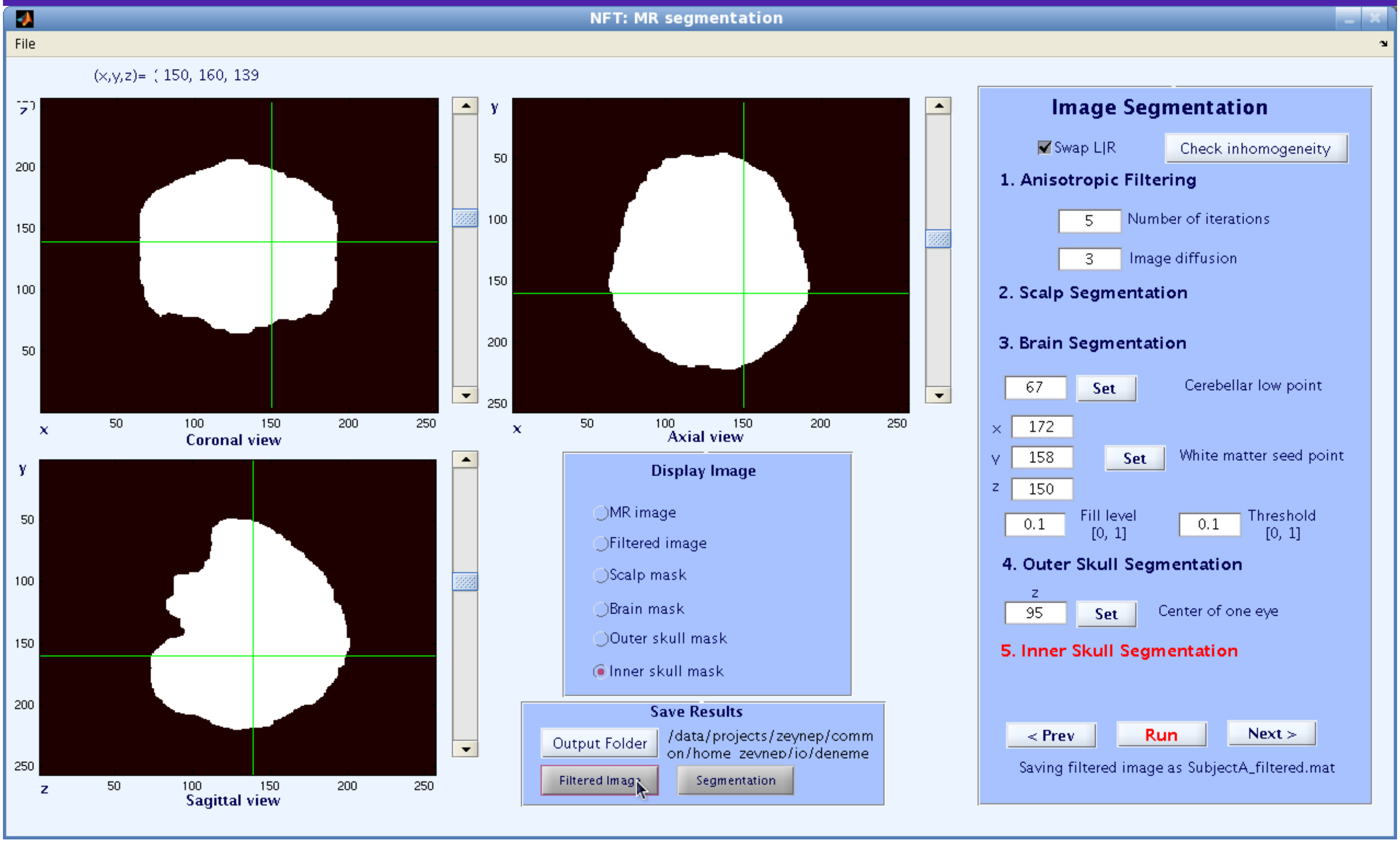
Segmentation

View CSF segmentation

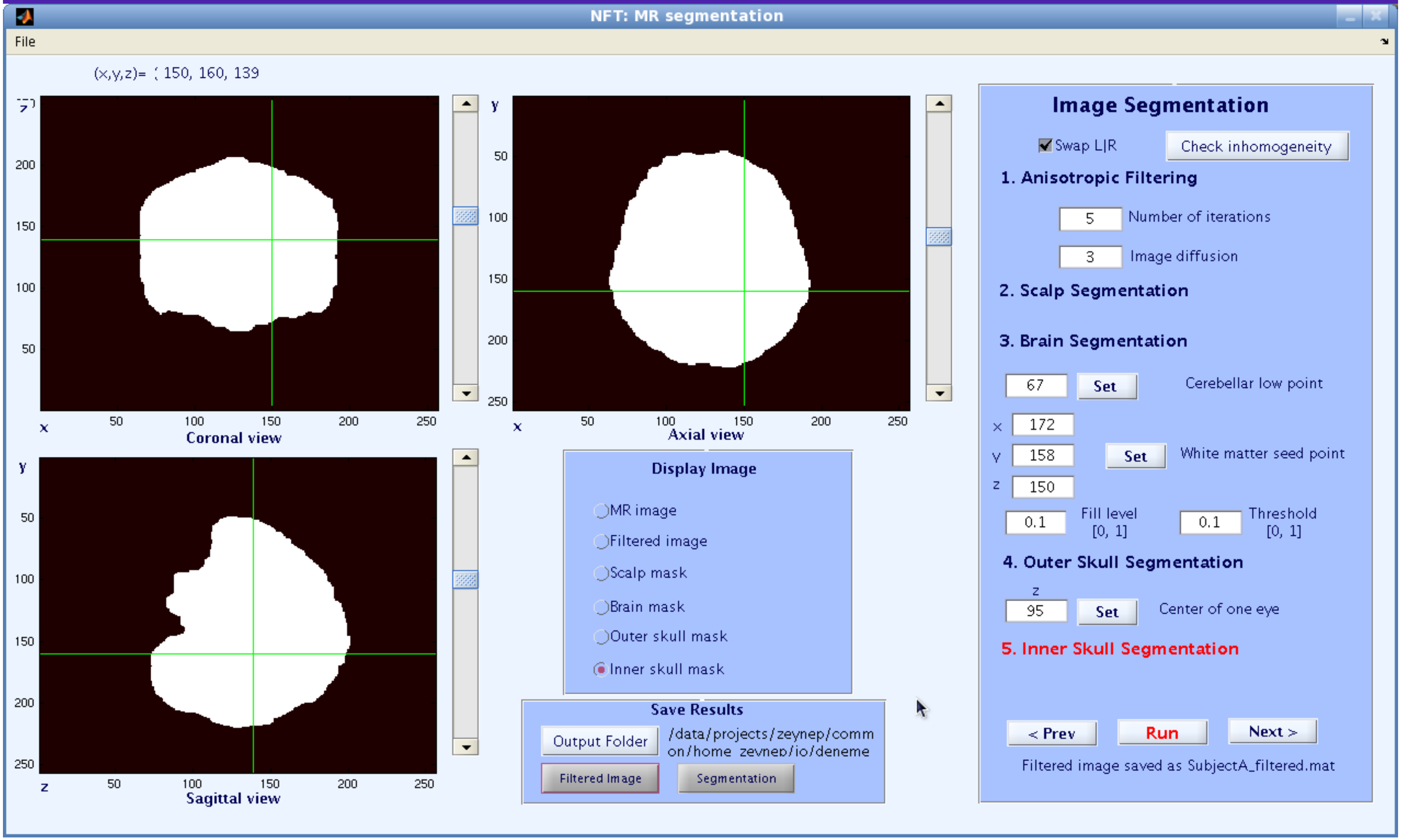


Segmentation

Save filtered image

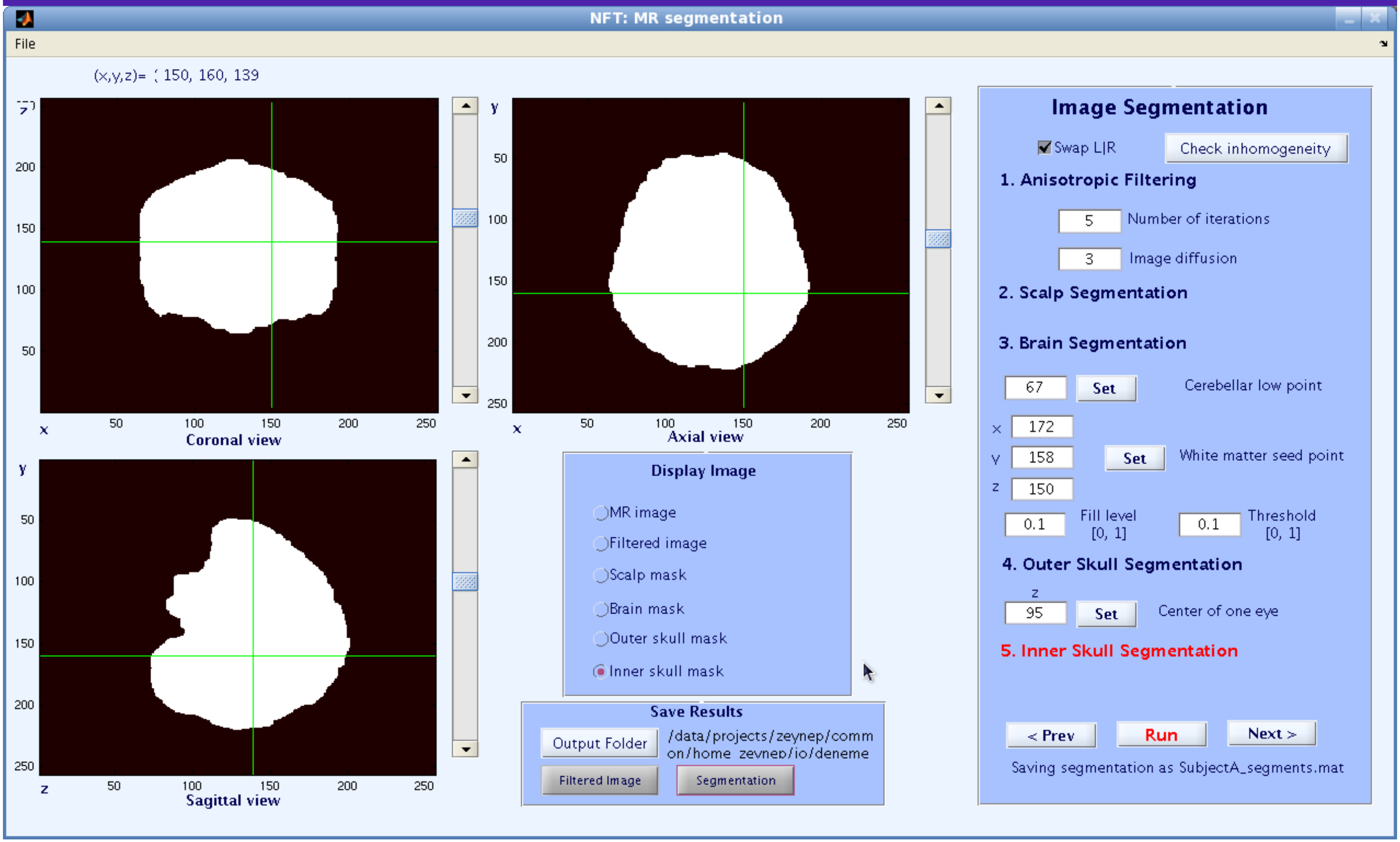


Segmentation



Segmentation

Save segmentation



Segmentation

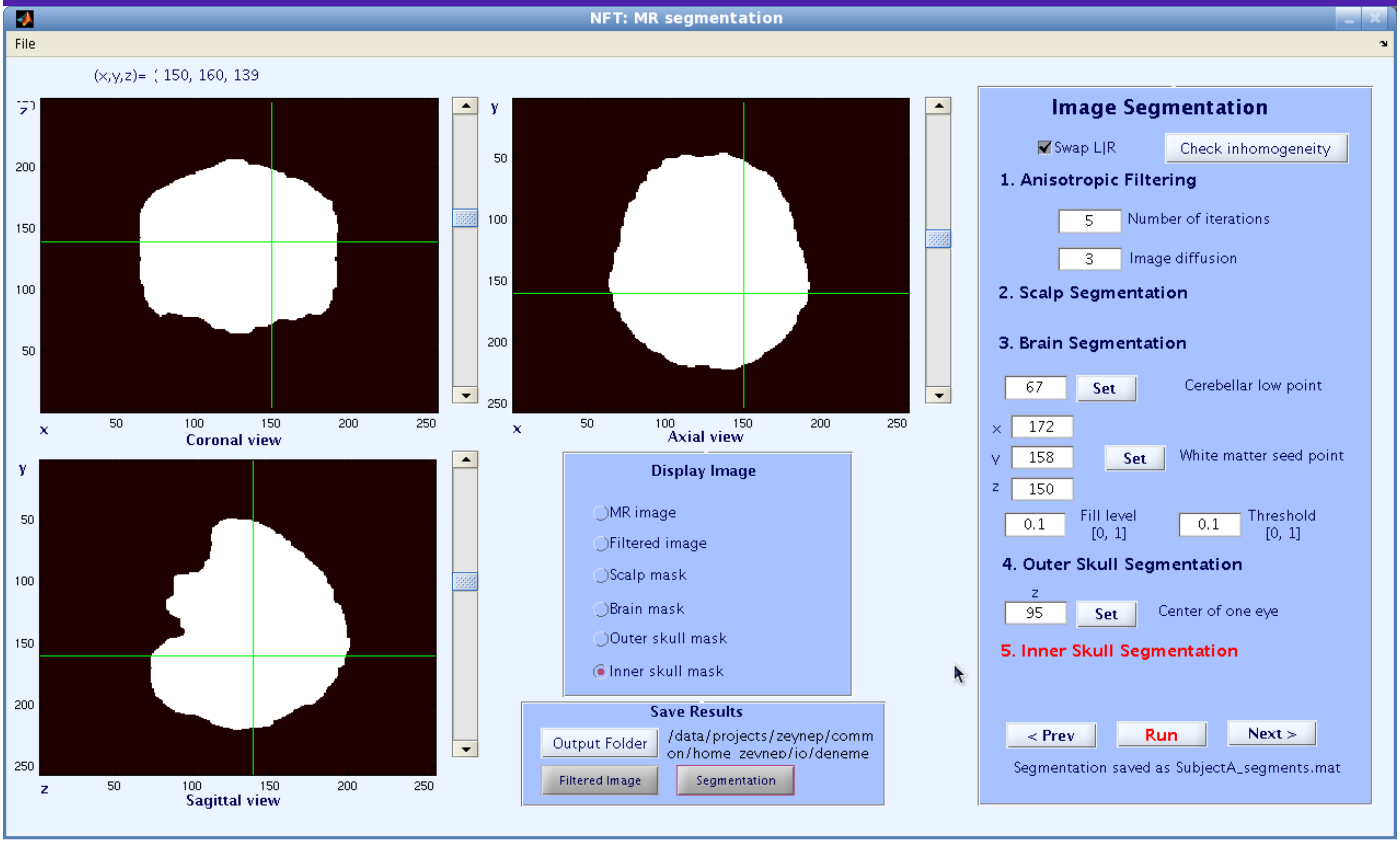


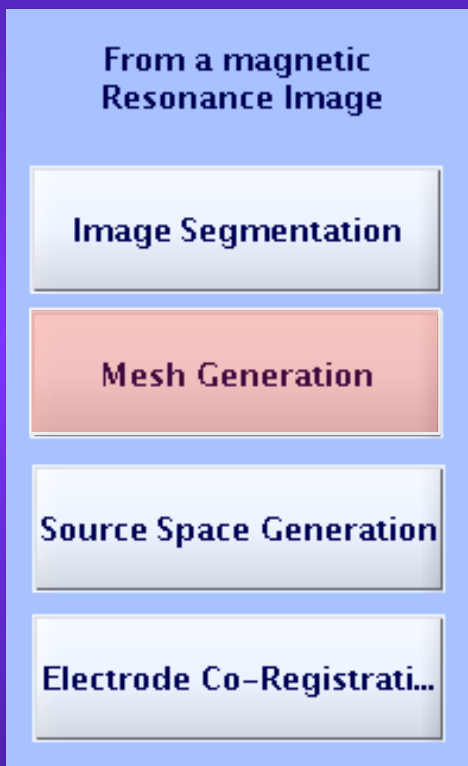
Image Segmentation

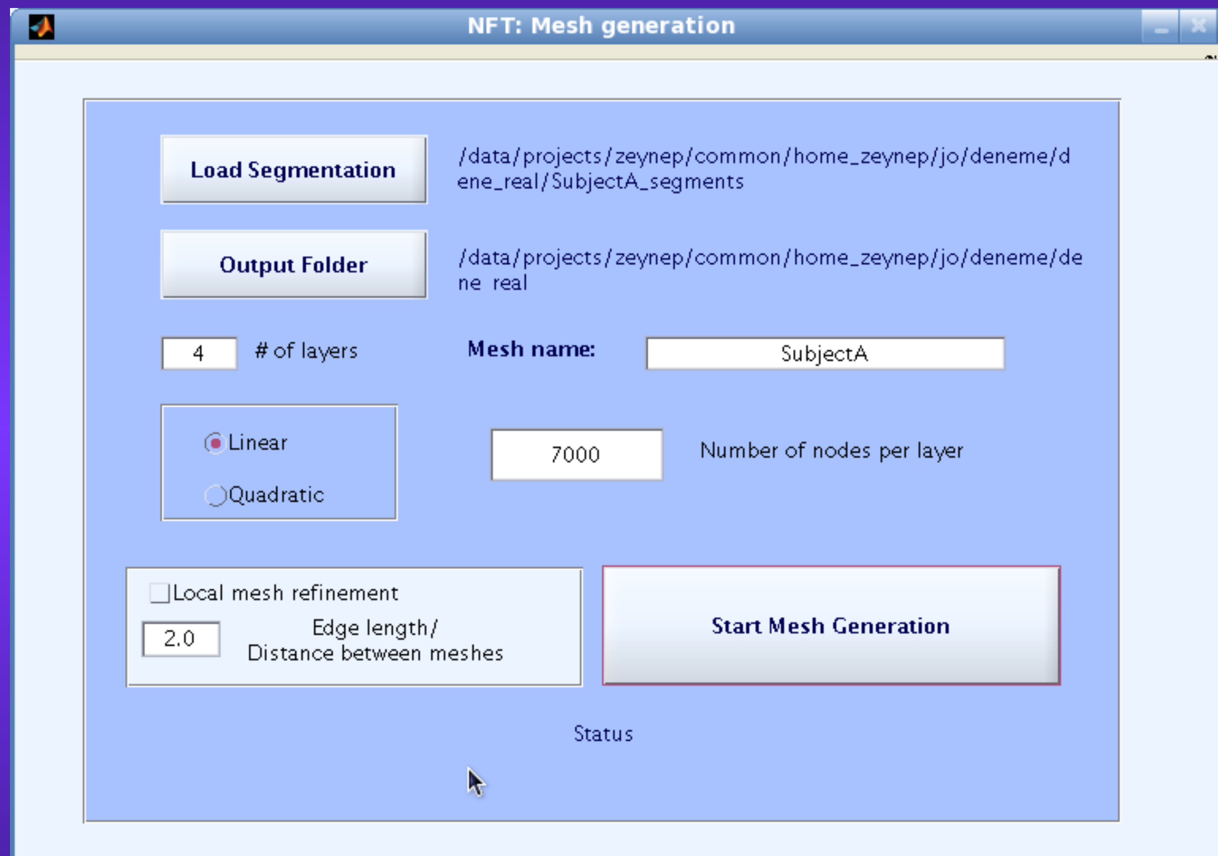
Command Window

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

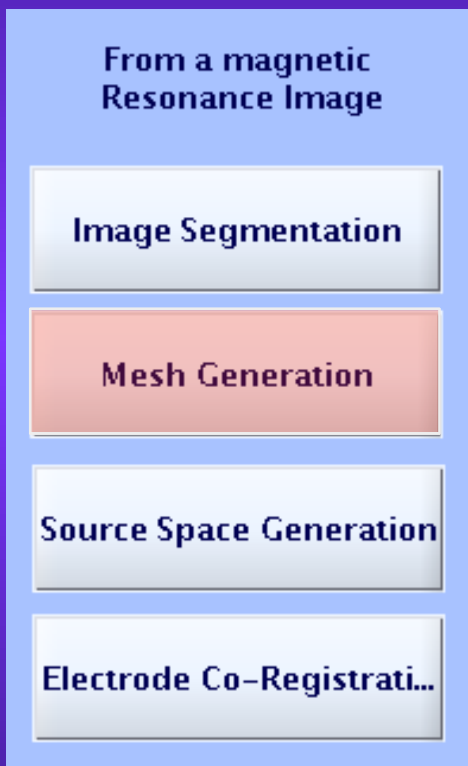


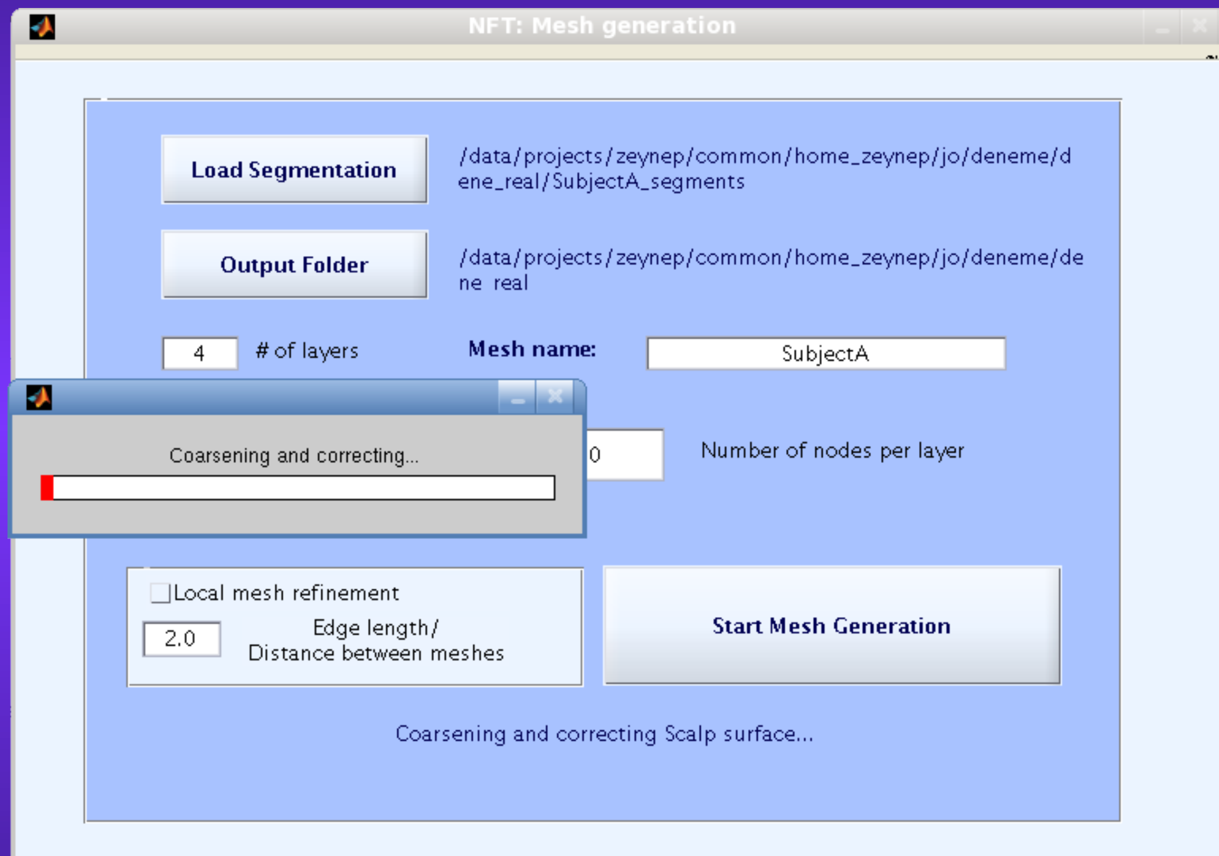


Generate Mesh for a 3 or 4 layer head model

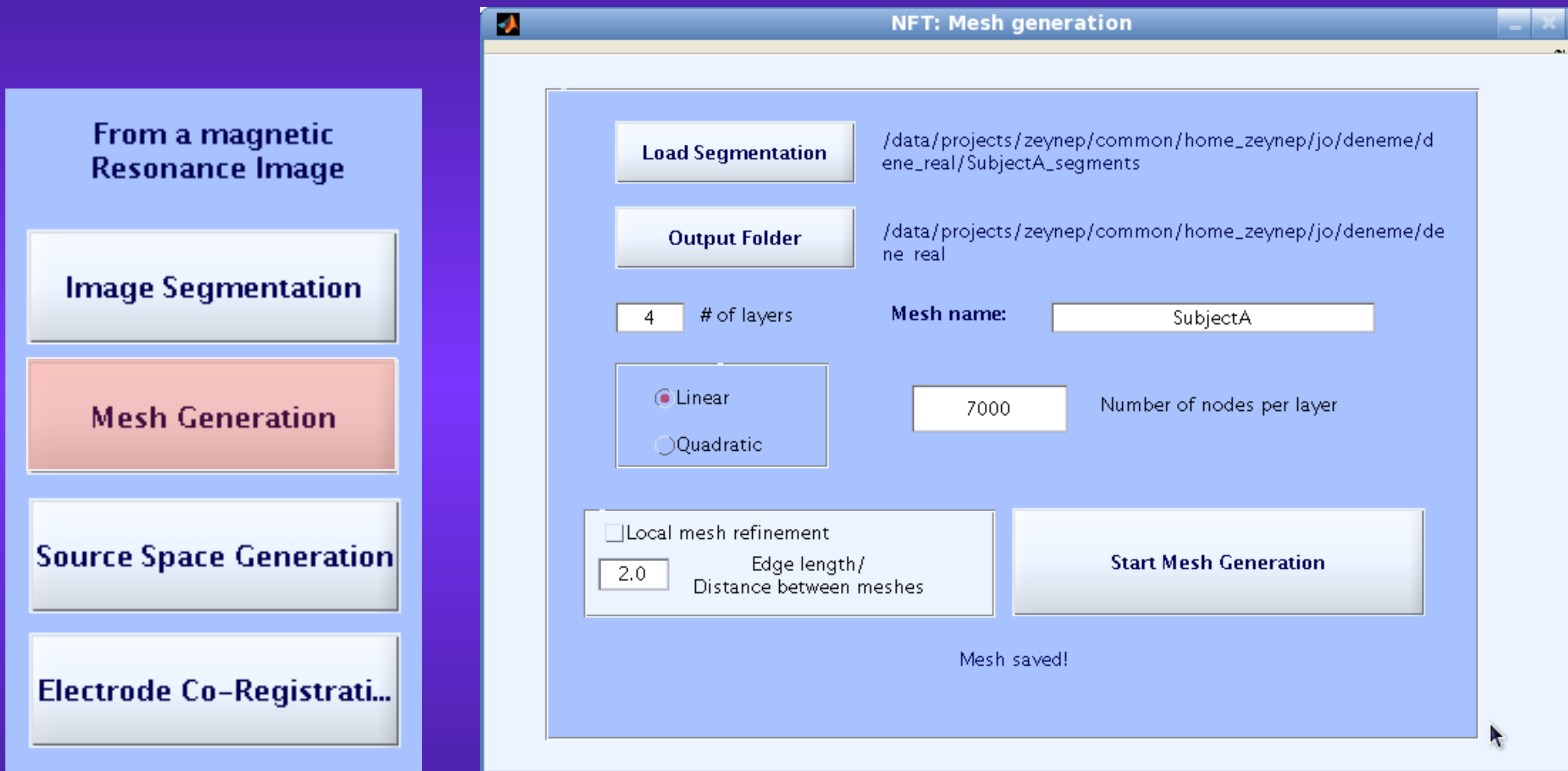
Triangulation, correction, coarsening, refinement

Mesh Generation

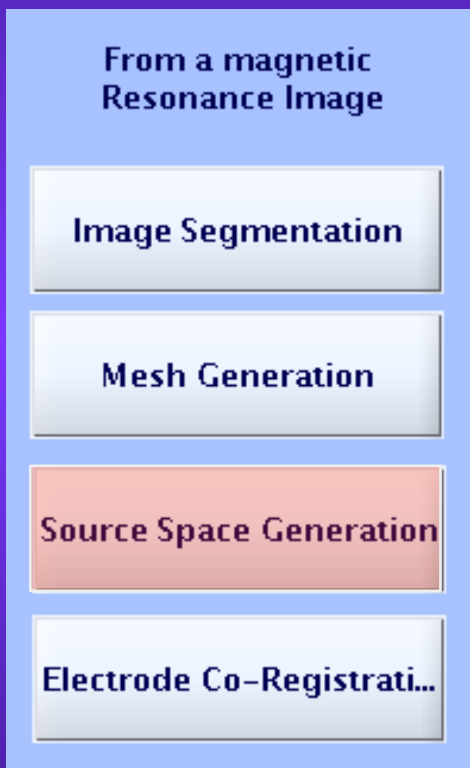




Mesh Generation

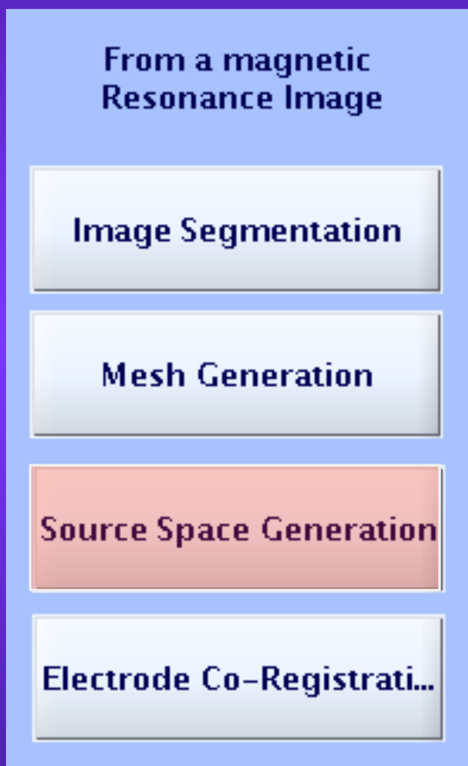


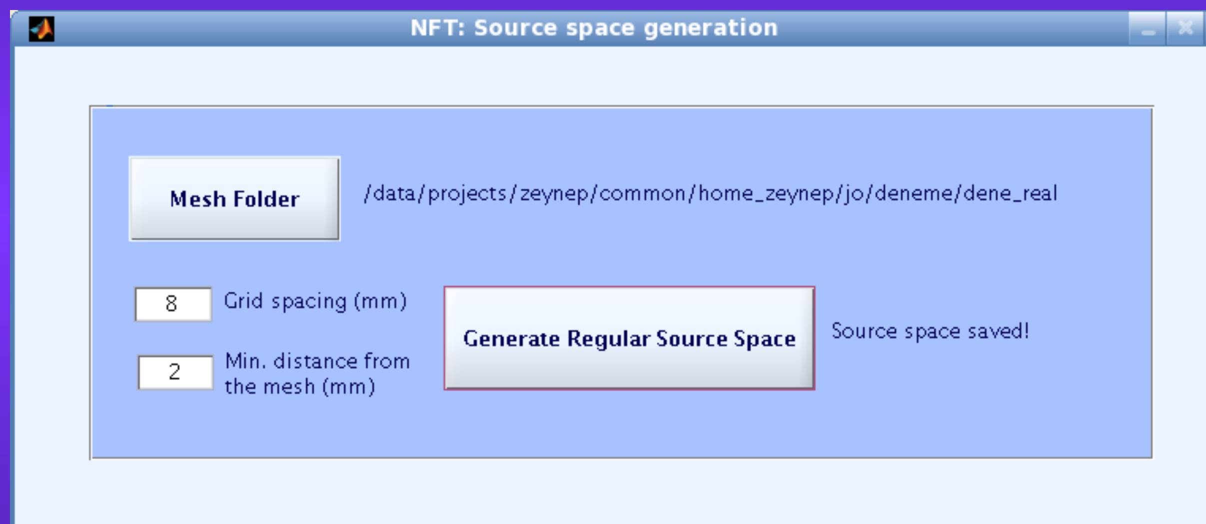
Source Space Generation



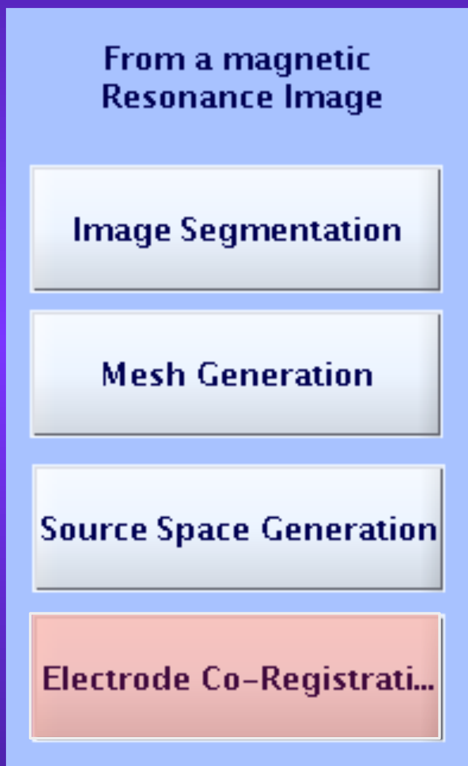
Generates a simple source space:
Regular Grid inside the brain
With a given spacing and distance to the mesh

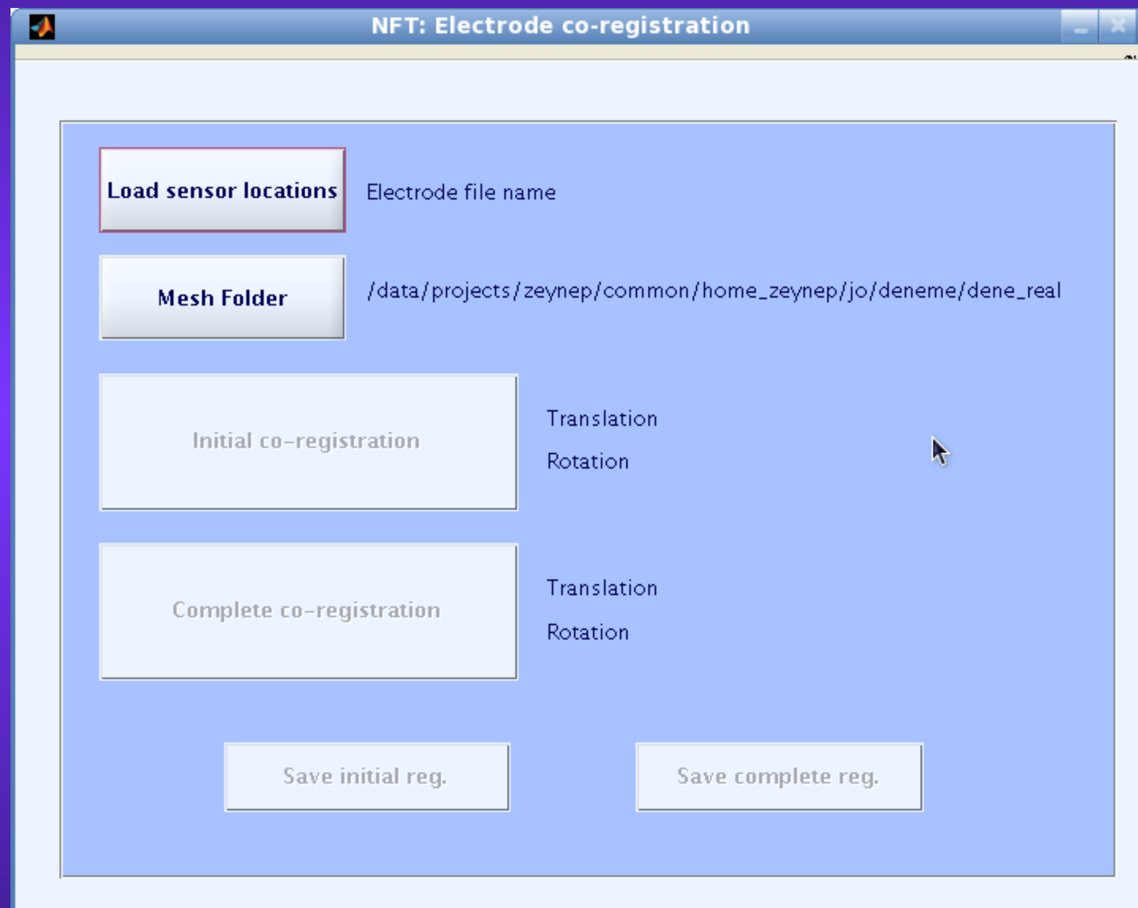
Source Space Generation



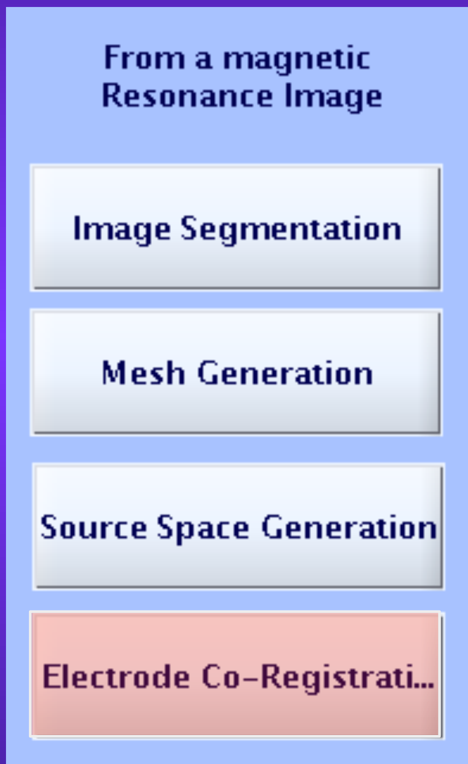


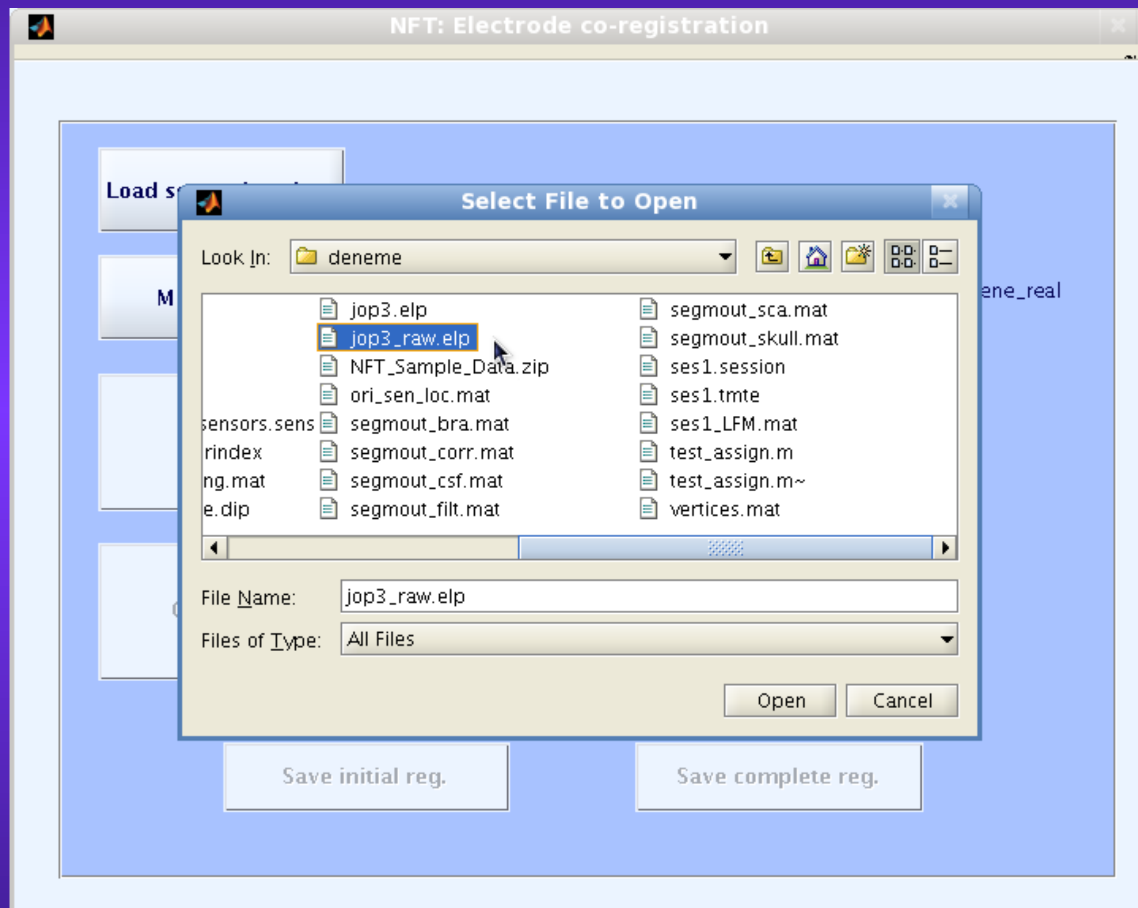
Electrode Co-registration



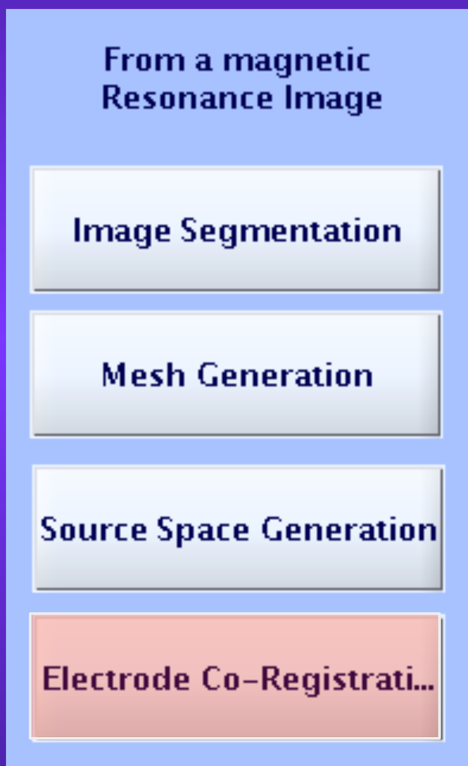


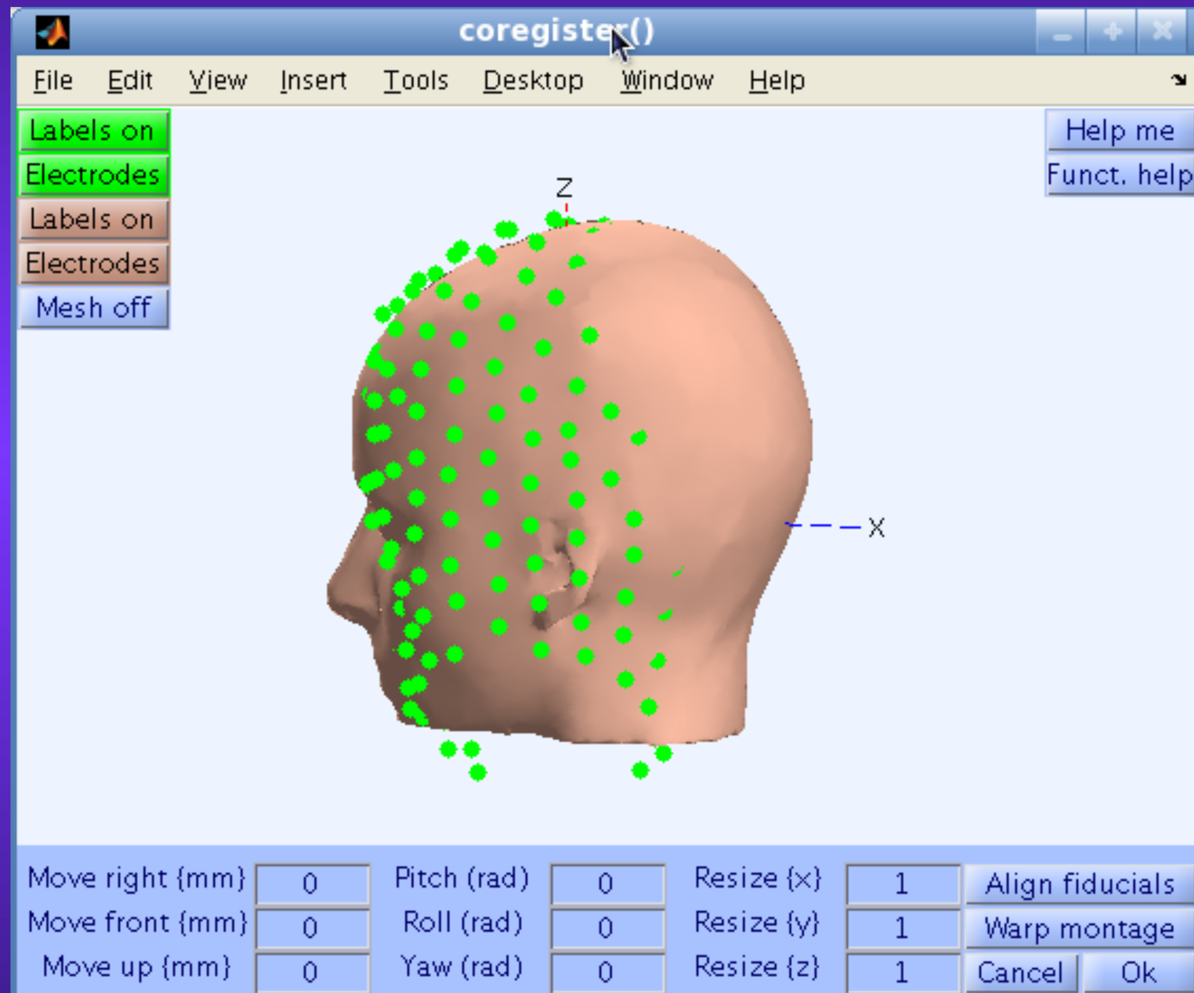
Electrode Co-registration



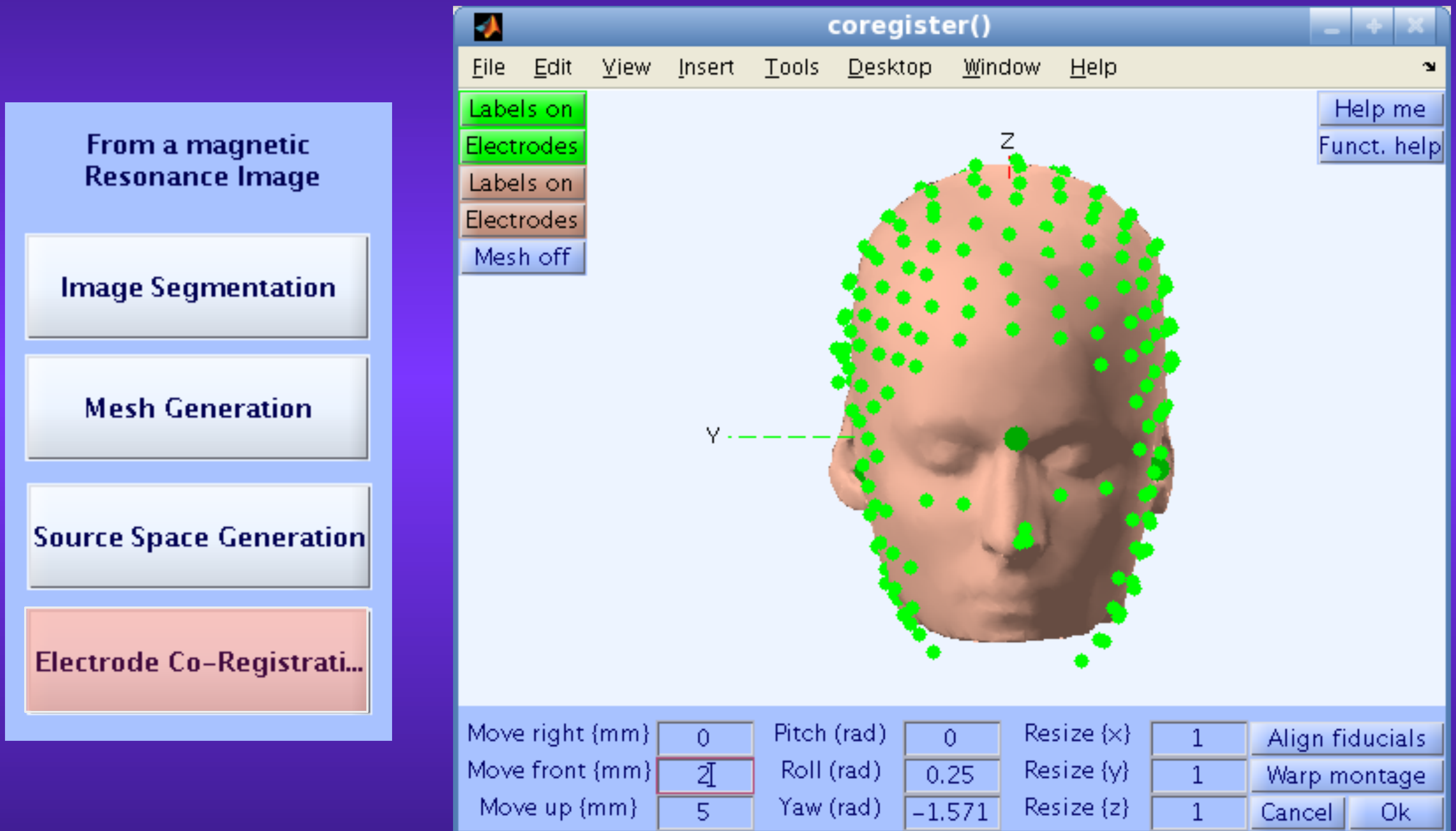


Electrode Co-registration

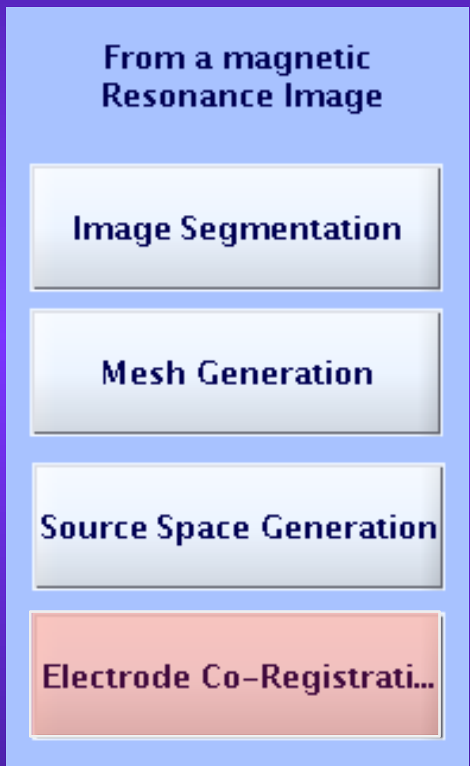


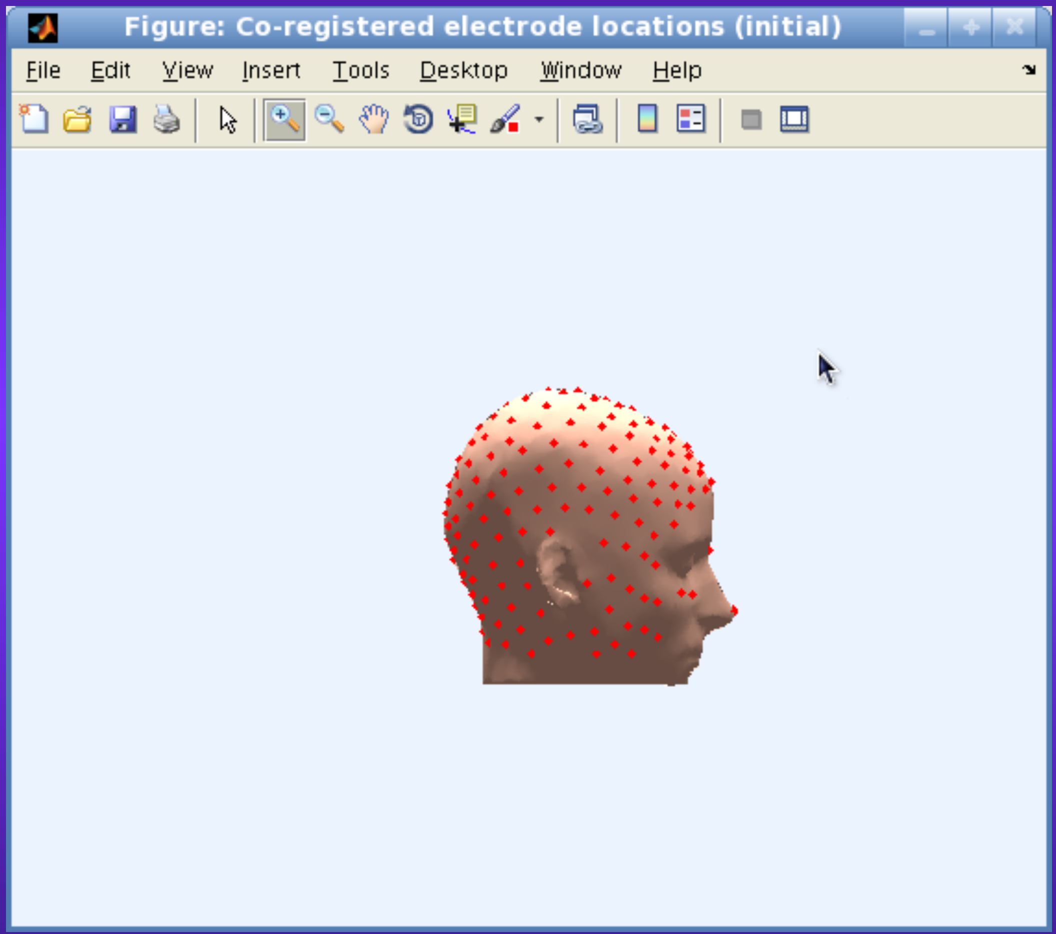


Electrode Co-registration

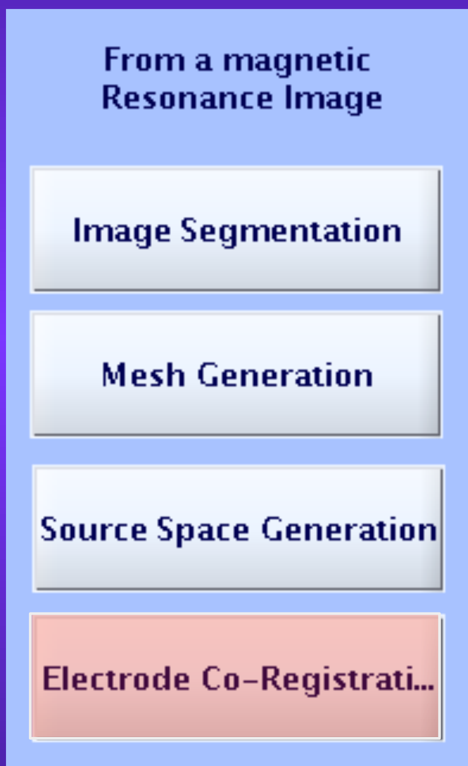


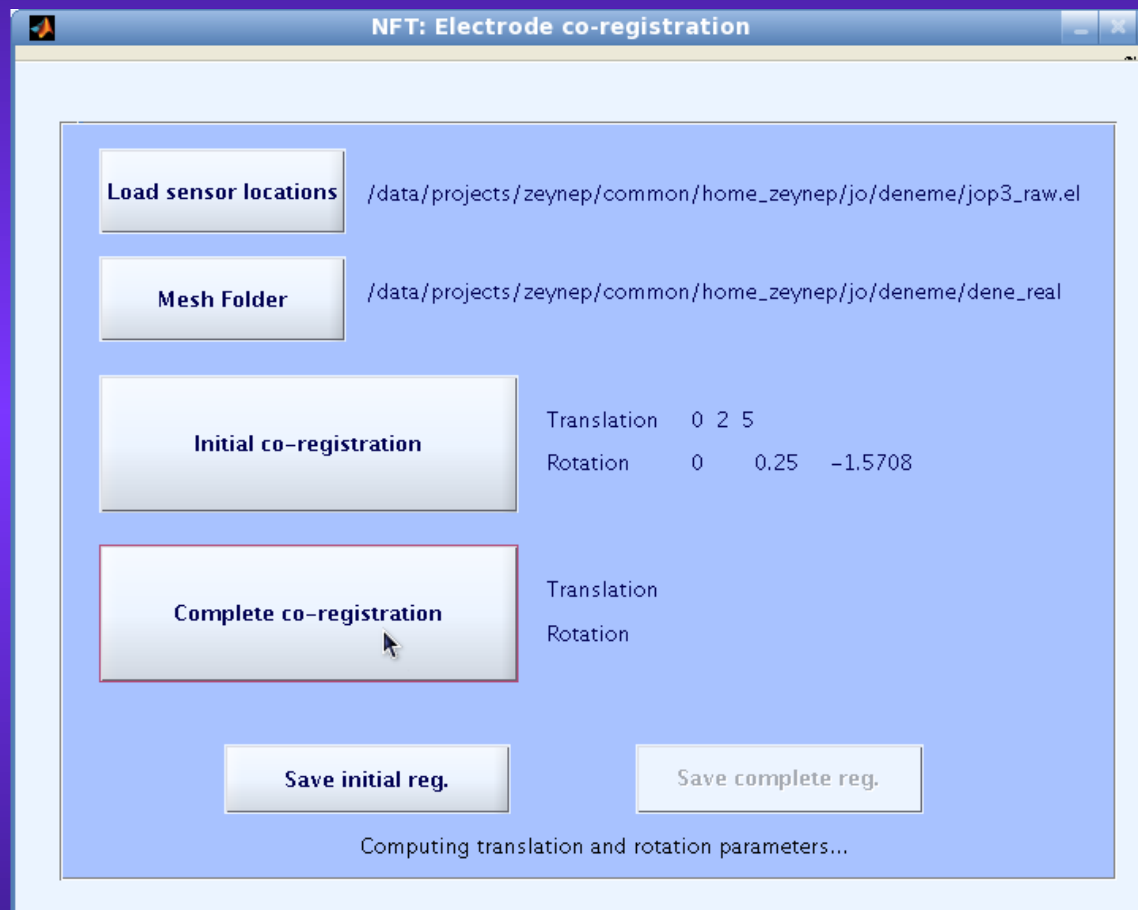
Electrode Co-registration





Electrode Co-registration





Electrode Co-registration

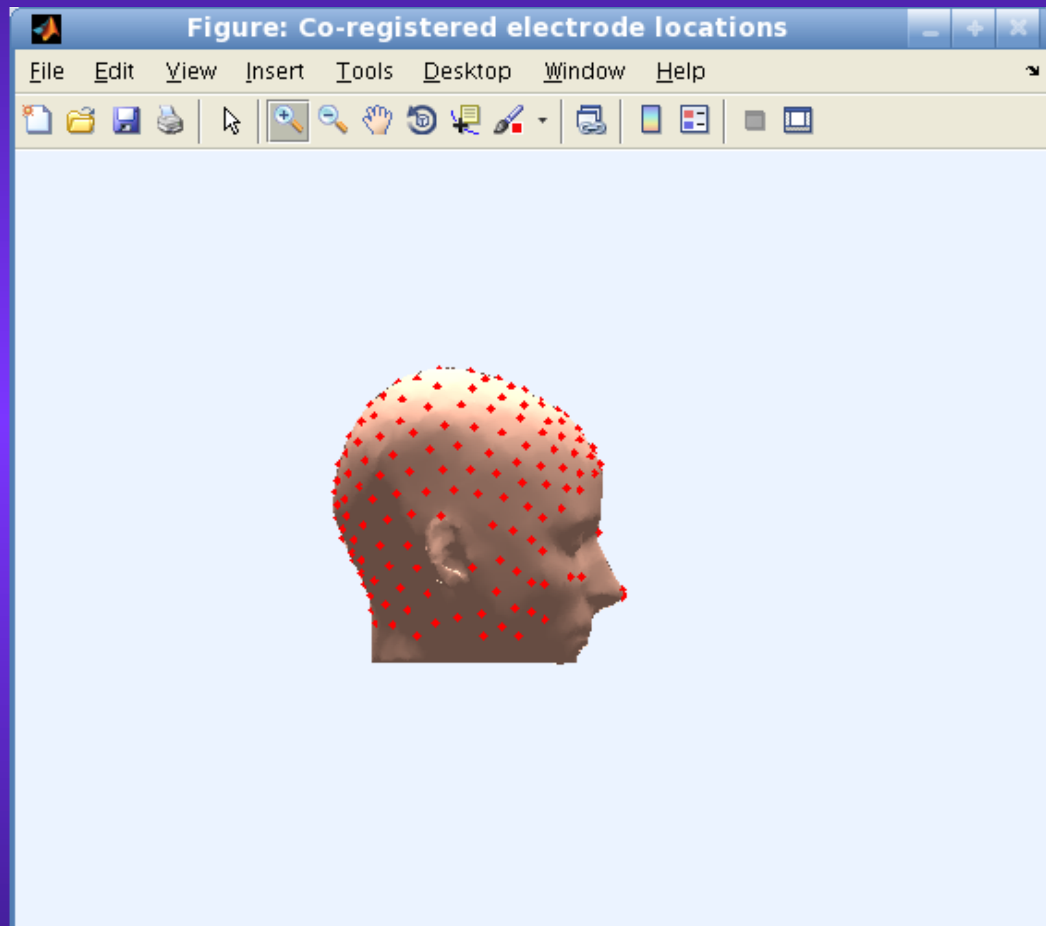
From a magnetic Resonance Image

Image Segmentation

Mesh Generation

Source Space Generation

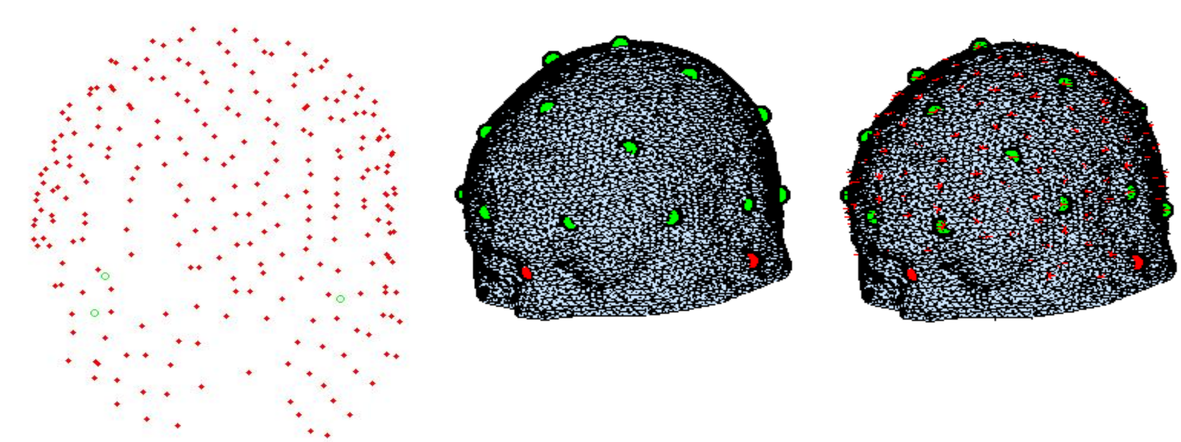
Electrode Co-Registrati...



Head Modeling from Electrode Position Data

From electrode Position Data

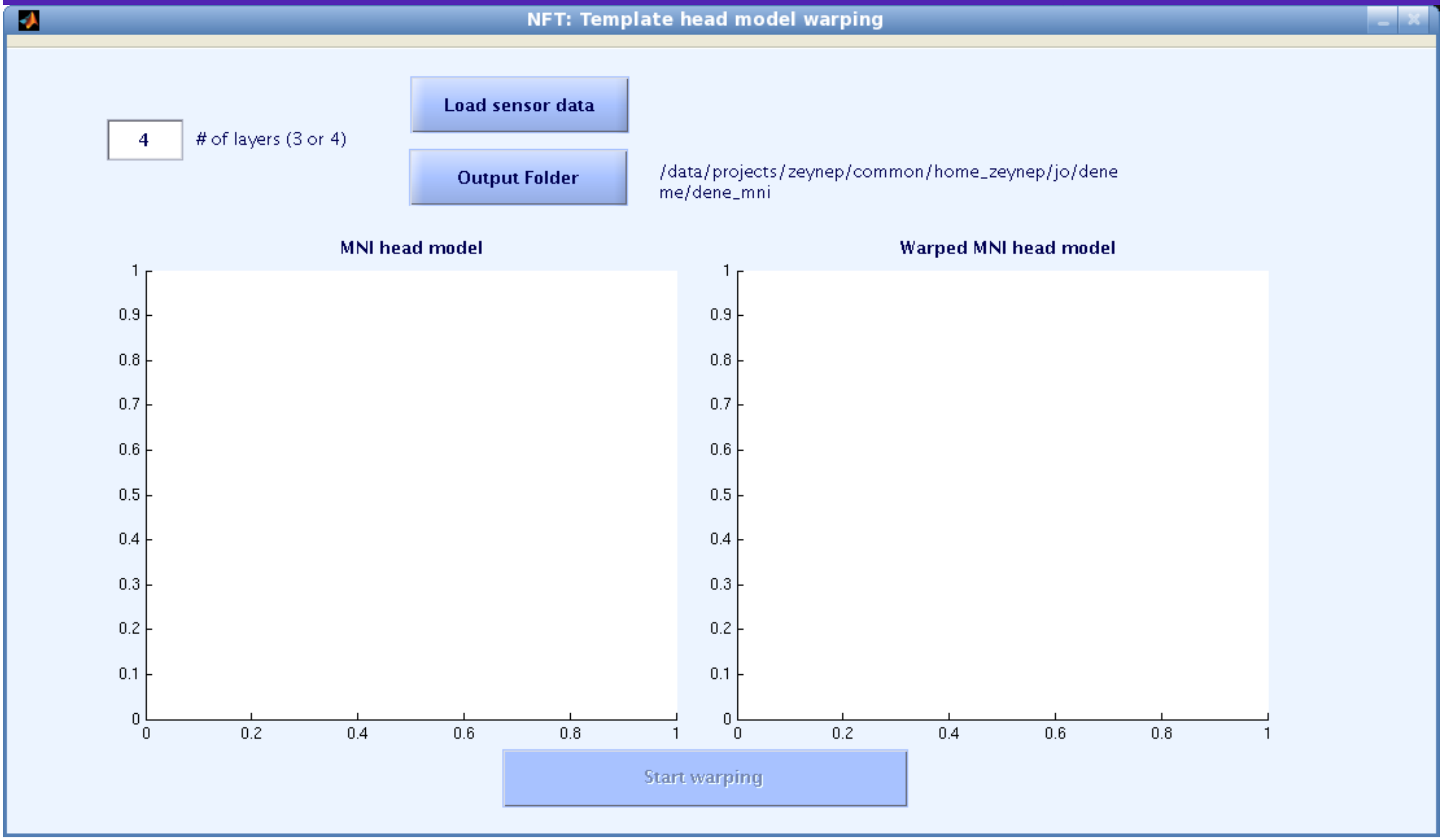
Template Warping



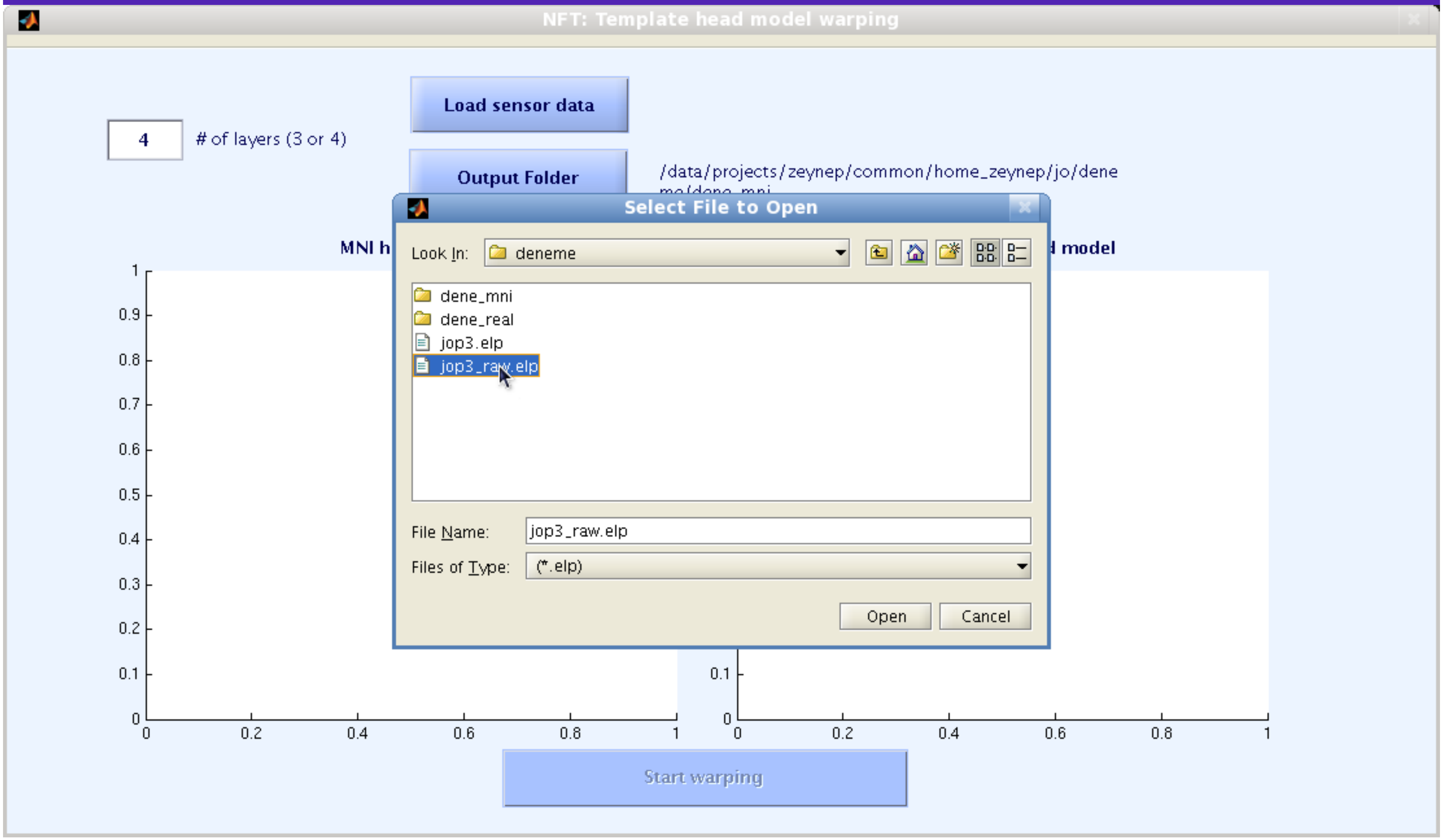
Digitizer locations   Template model   Warped model

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

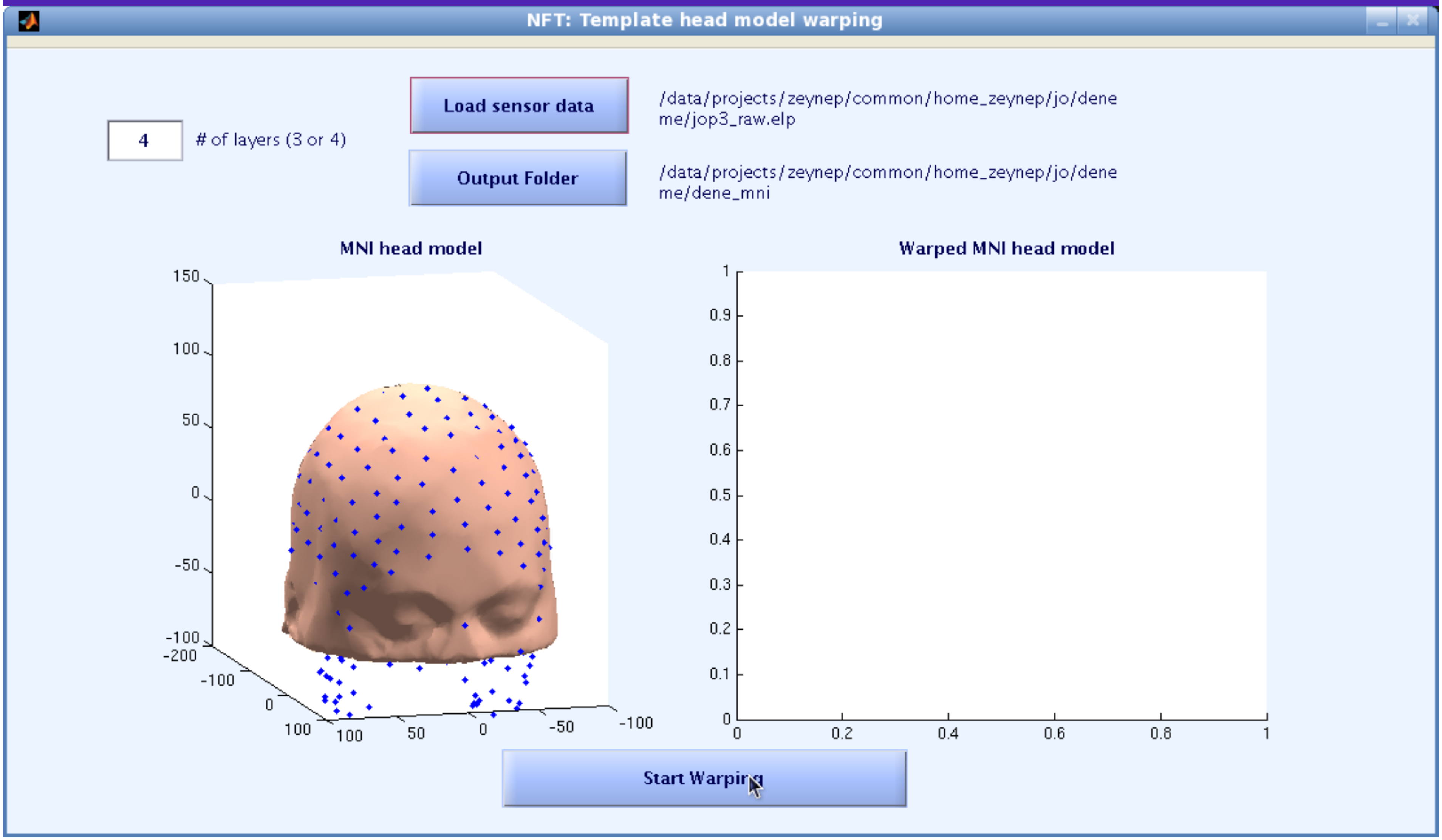
Template Warping



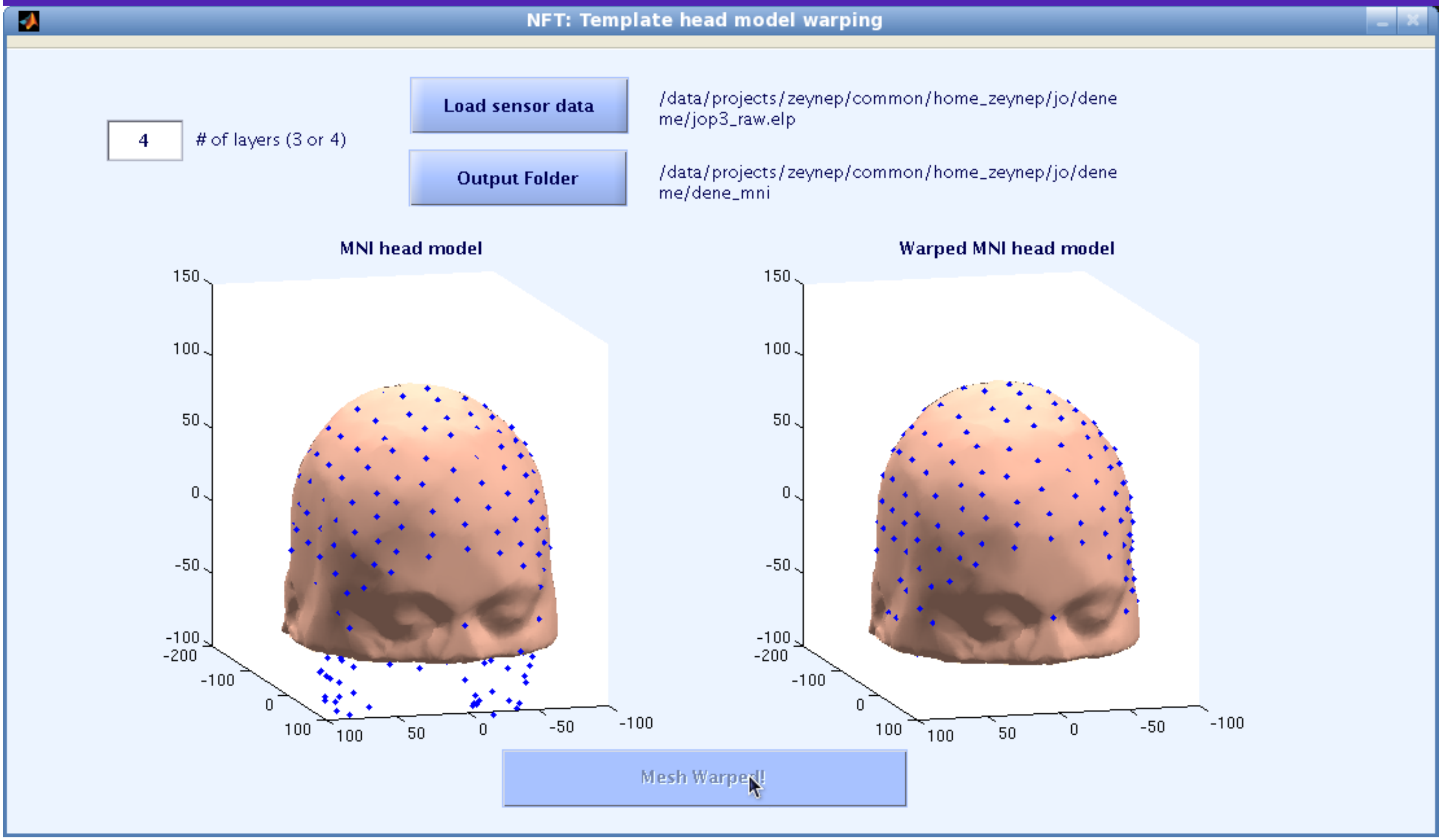
Template Warping



Template Warping



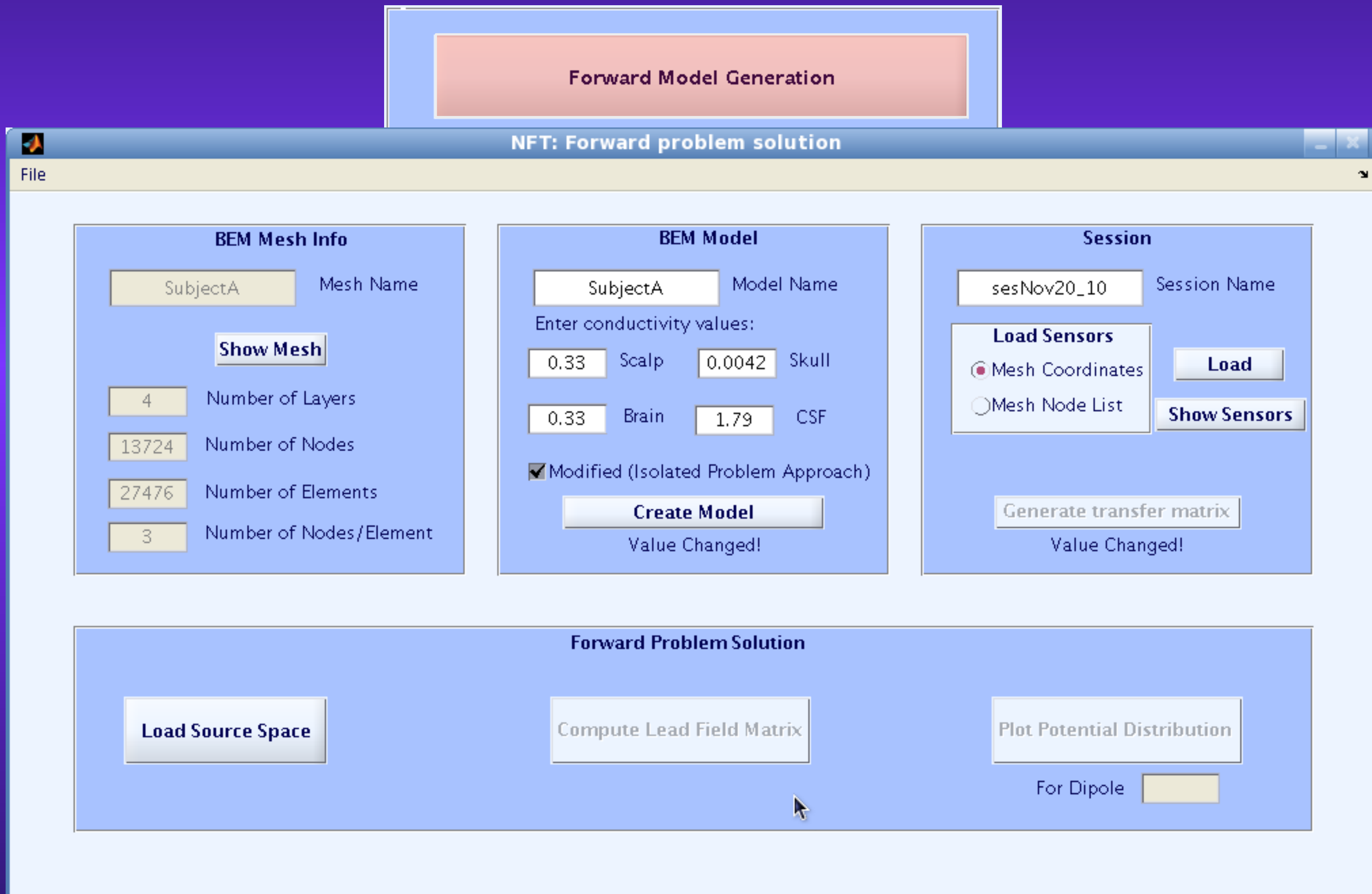
Template Warping



Forward Model Generation

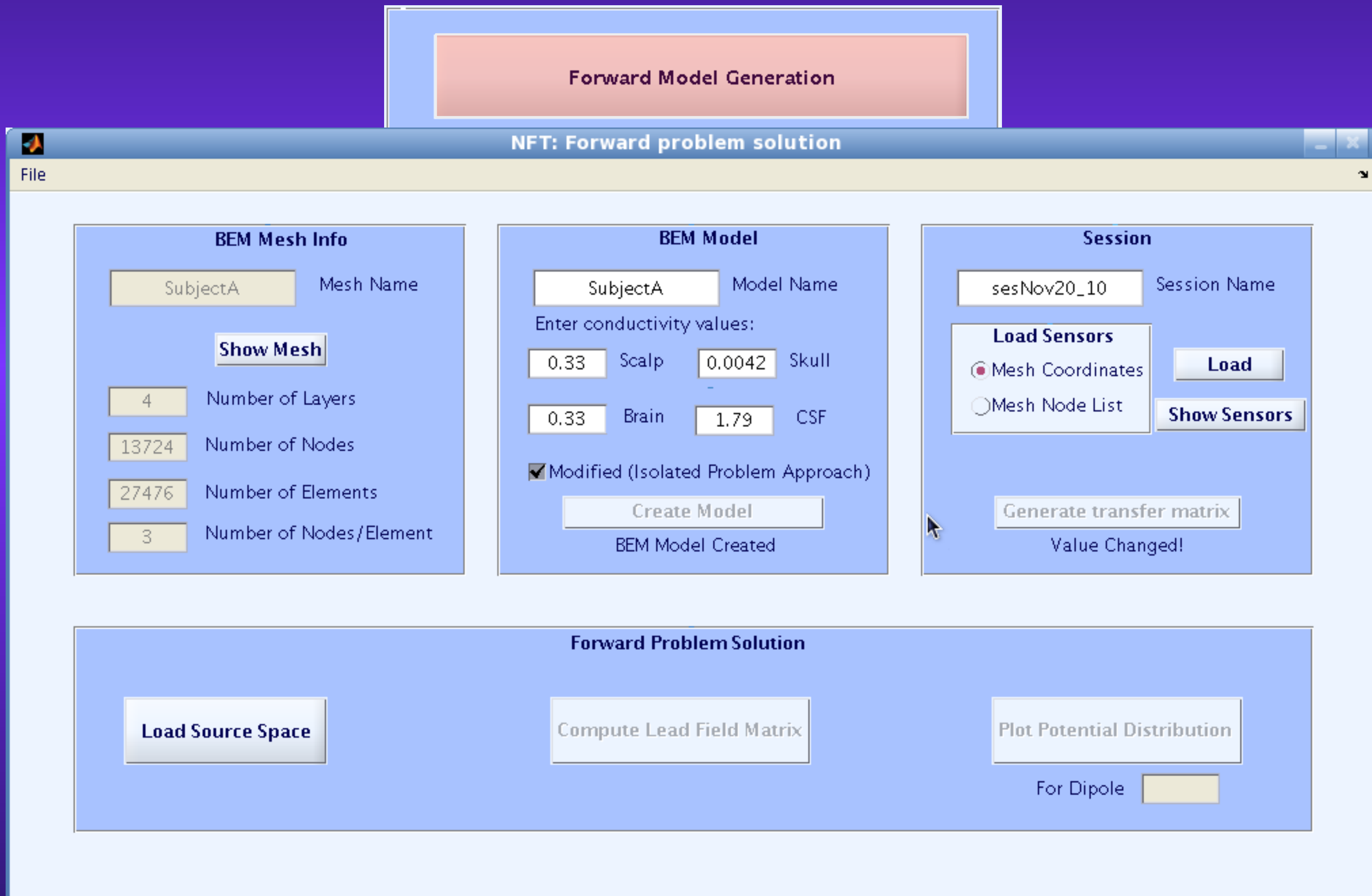
- Generates the Forward Model from Meshes
  - Uses the Boundary Element Method
- Three Structures
  - Mesh
  - Model (Mesh + Electrical Properties)
  - Session (Model + Sensors)

Forward Problem Solution

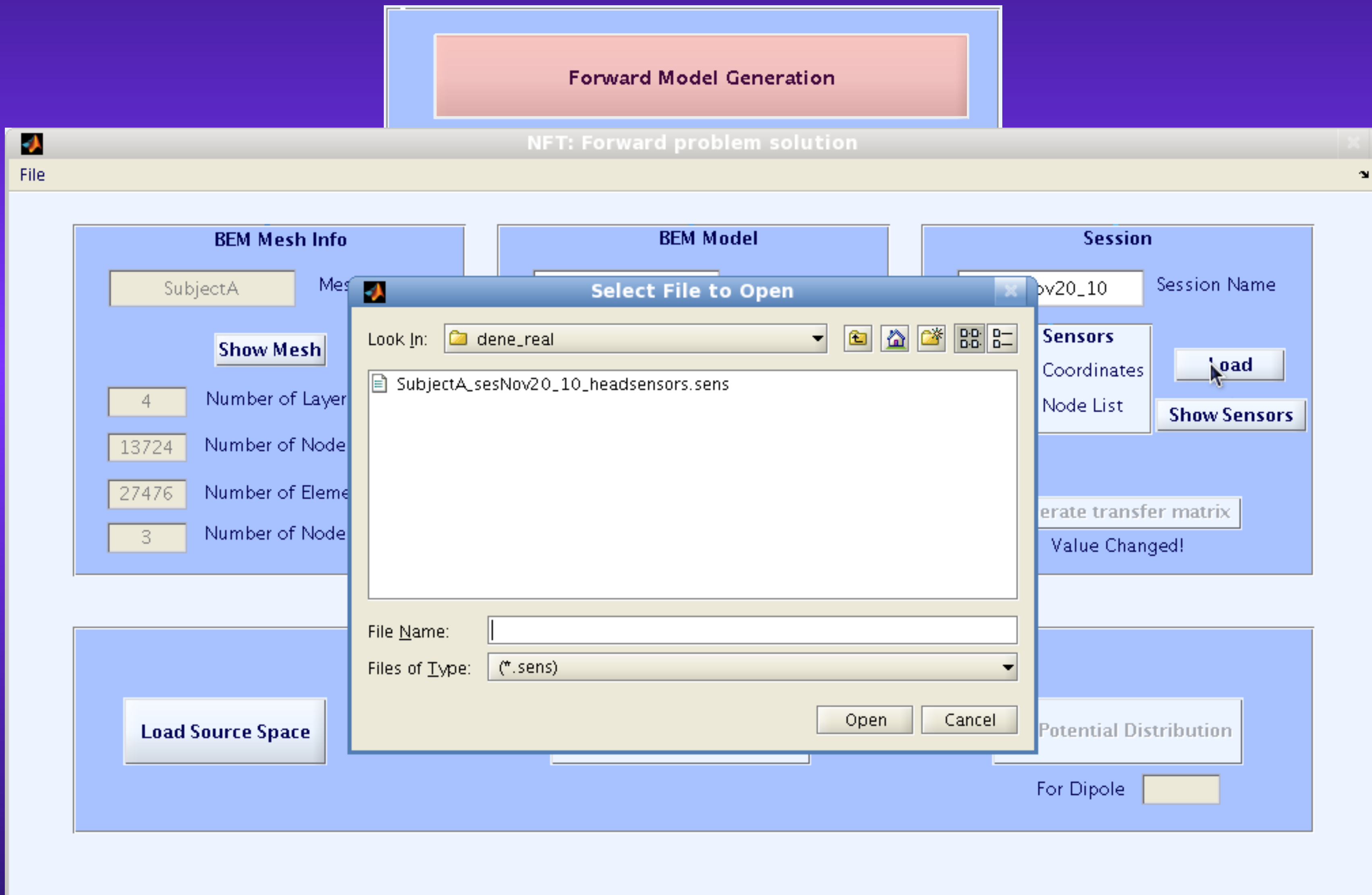


Forward Problem Solution

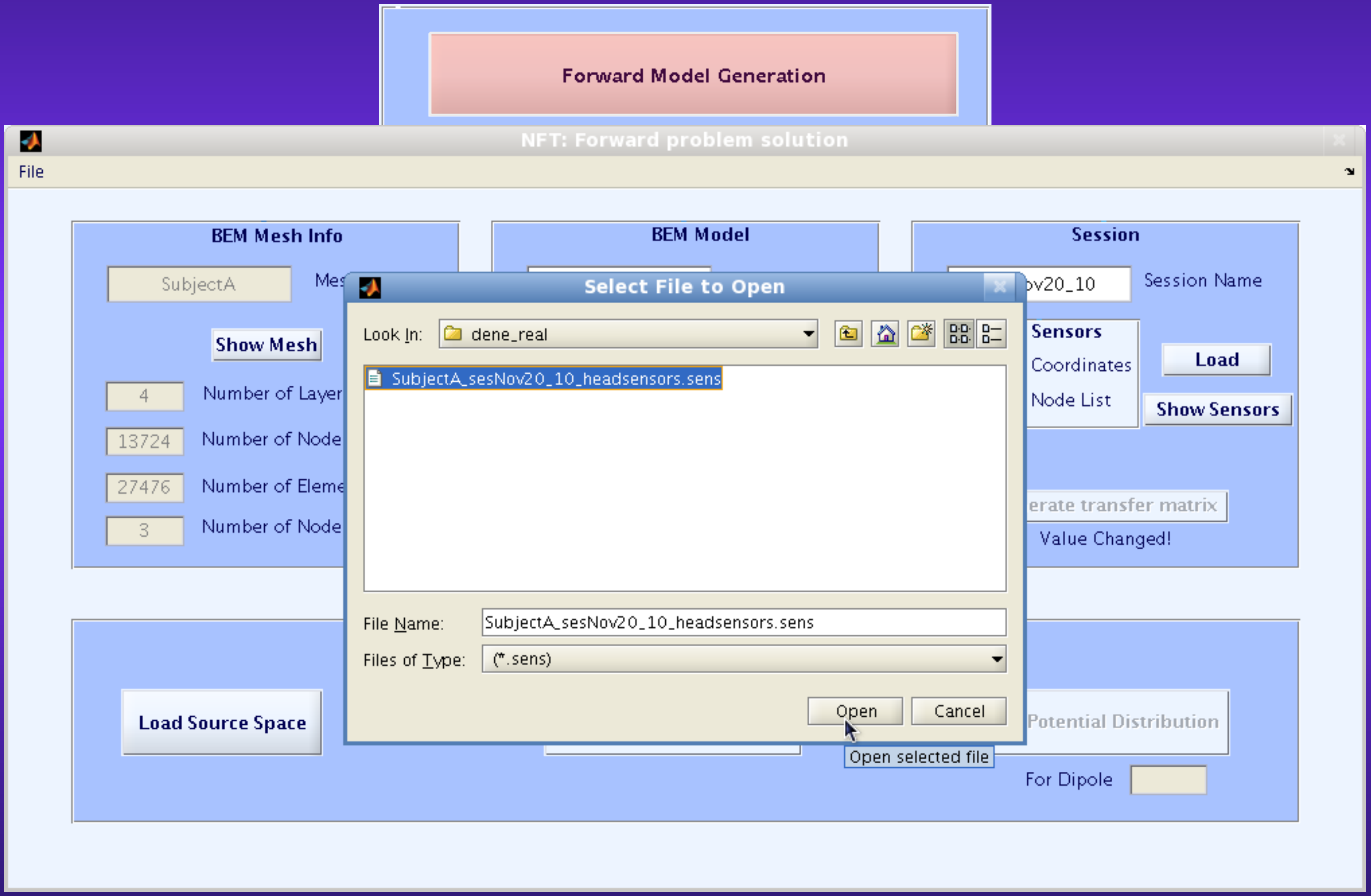
Forward Problem Solution



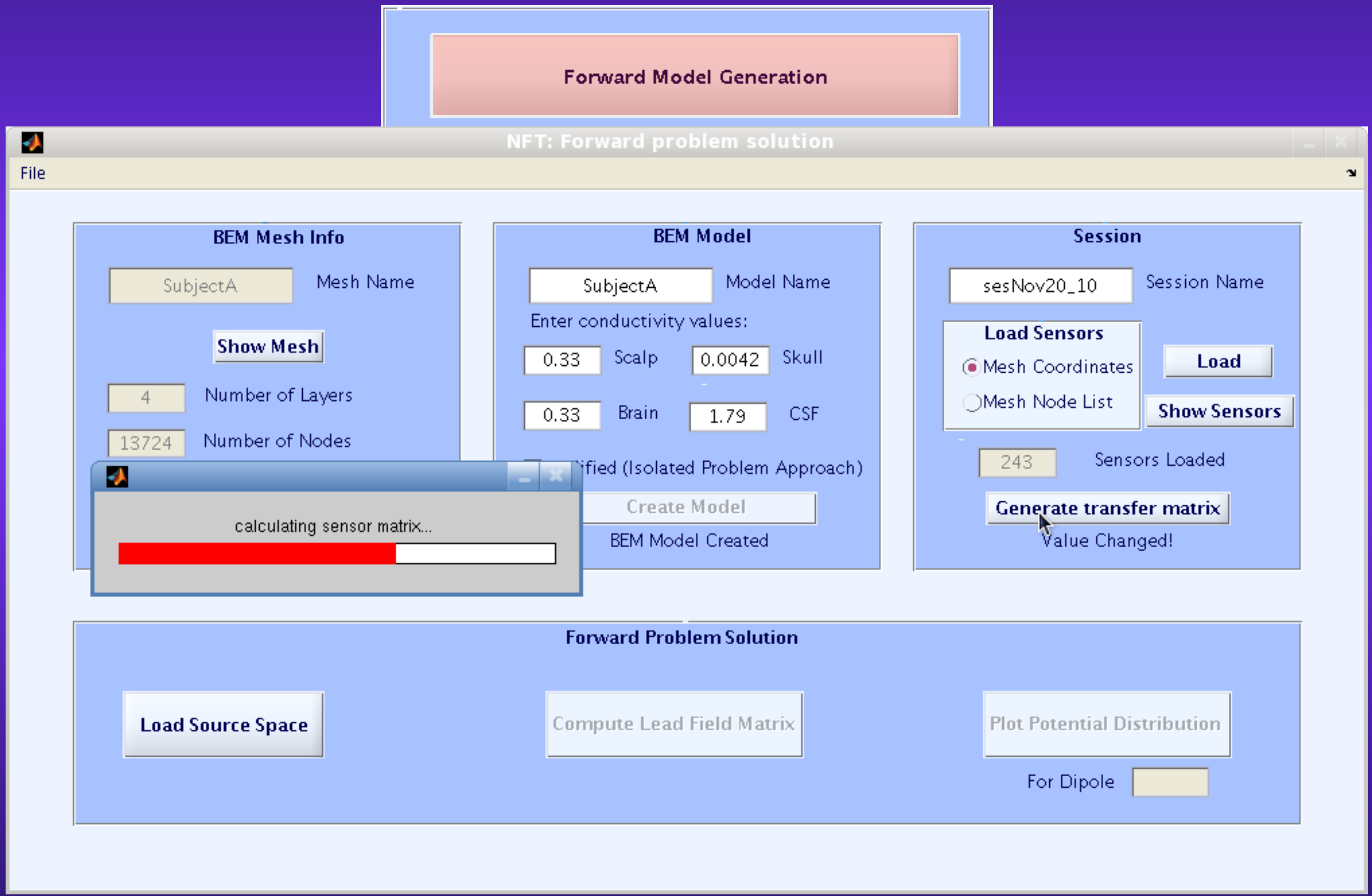
Forward Problem Solution



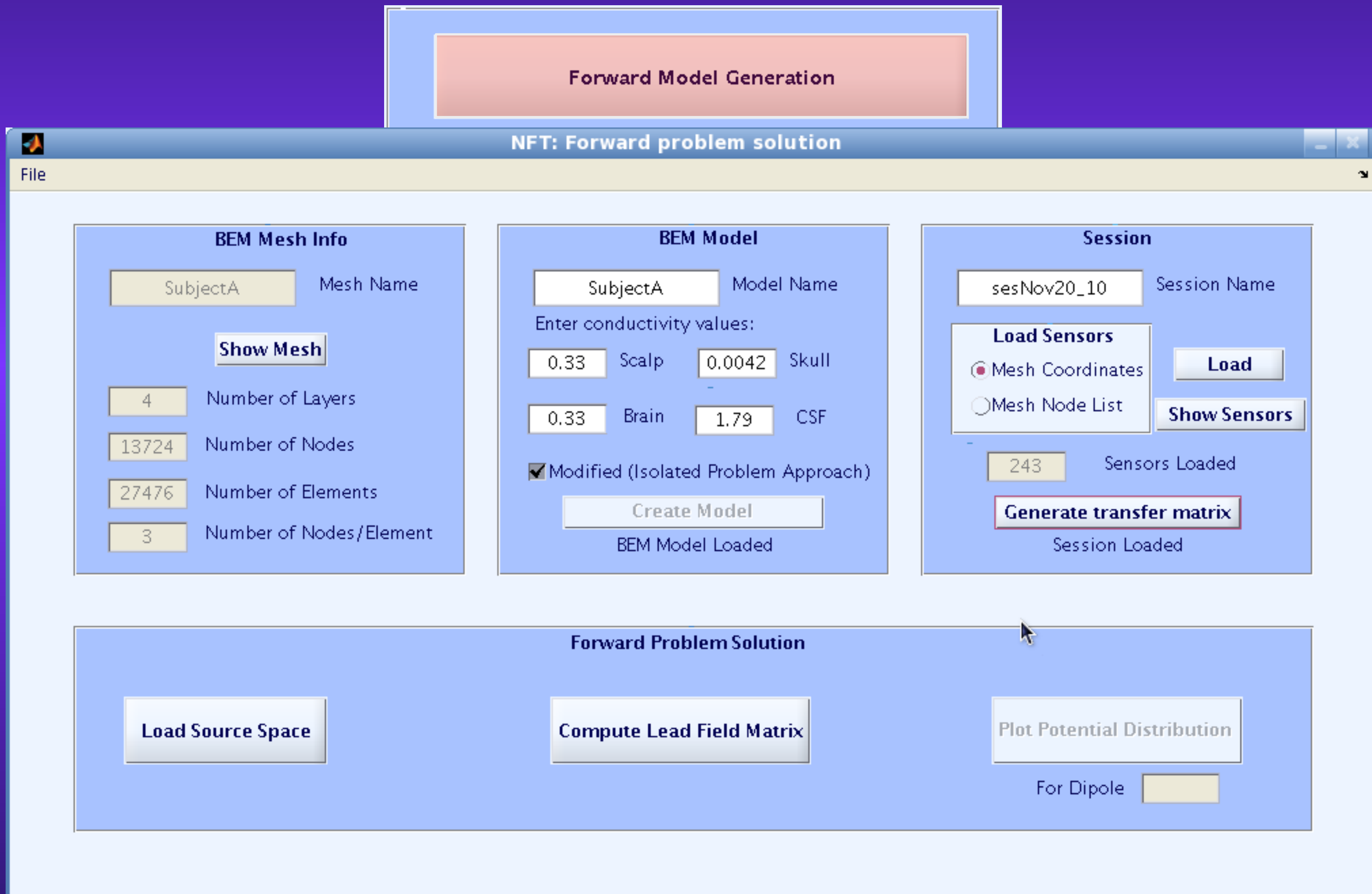
Forward Problem Solution



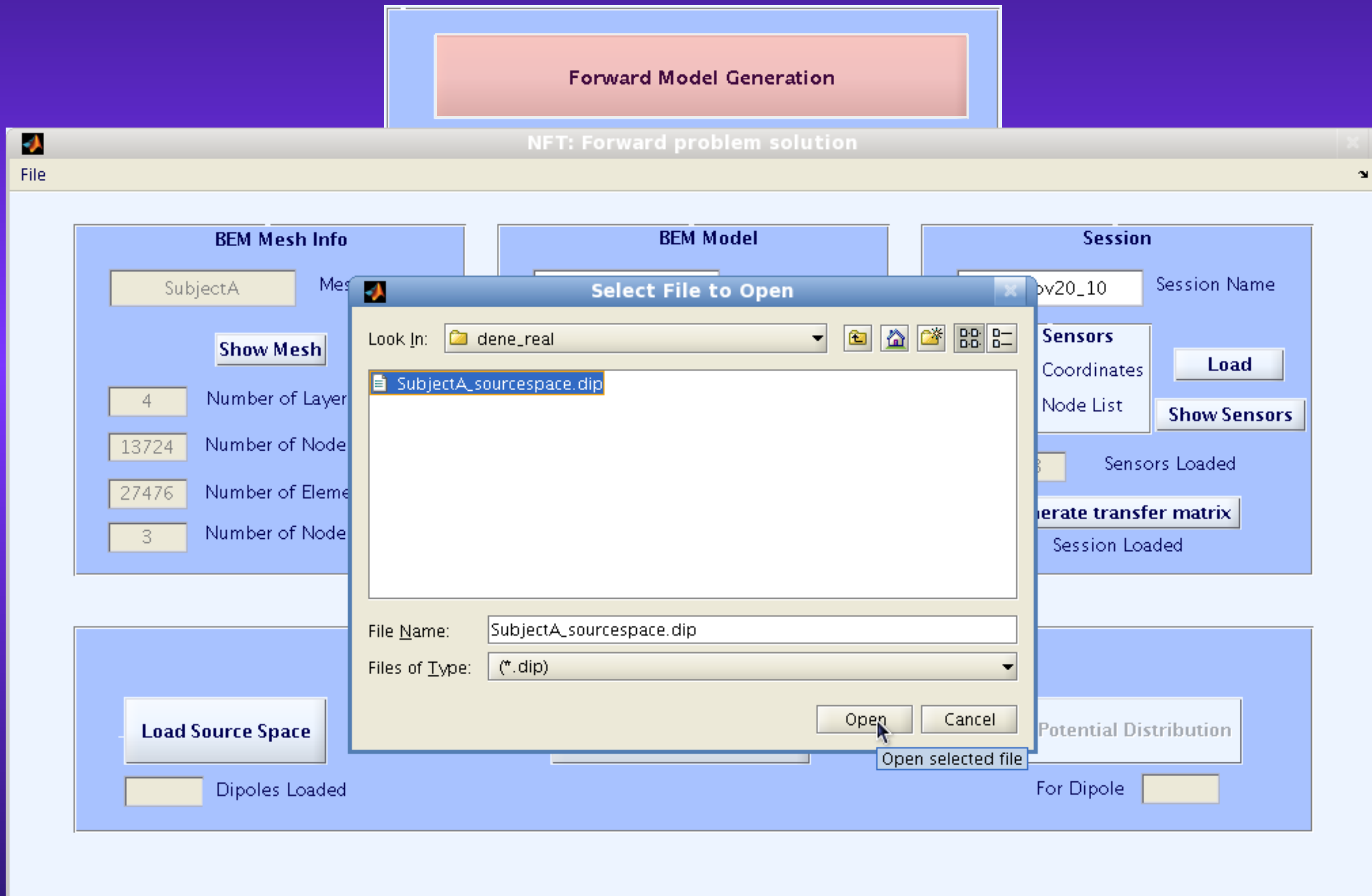
Forward Problem Solution



Forward Problem Solution

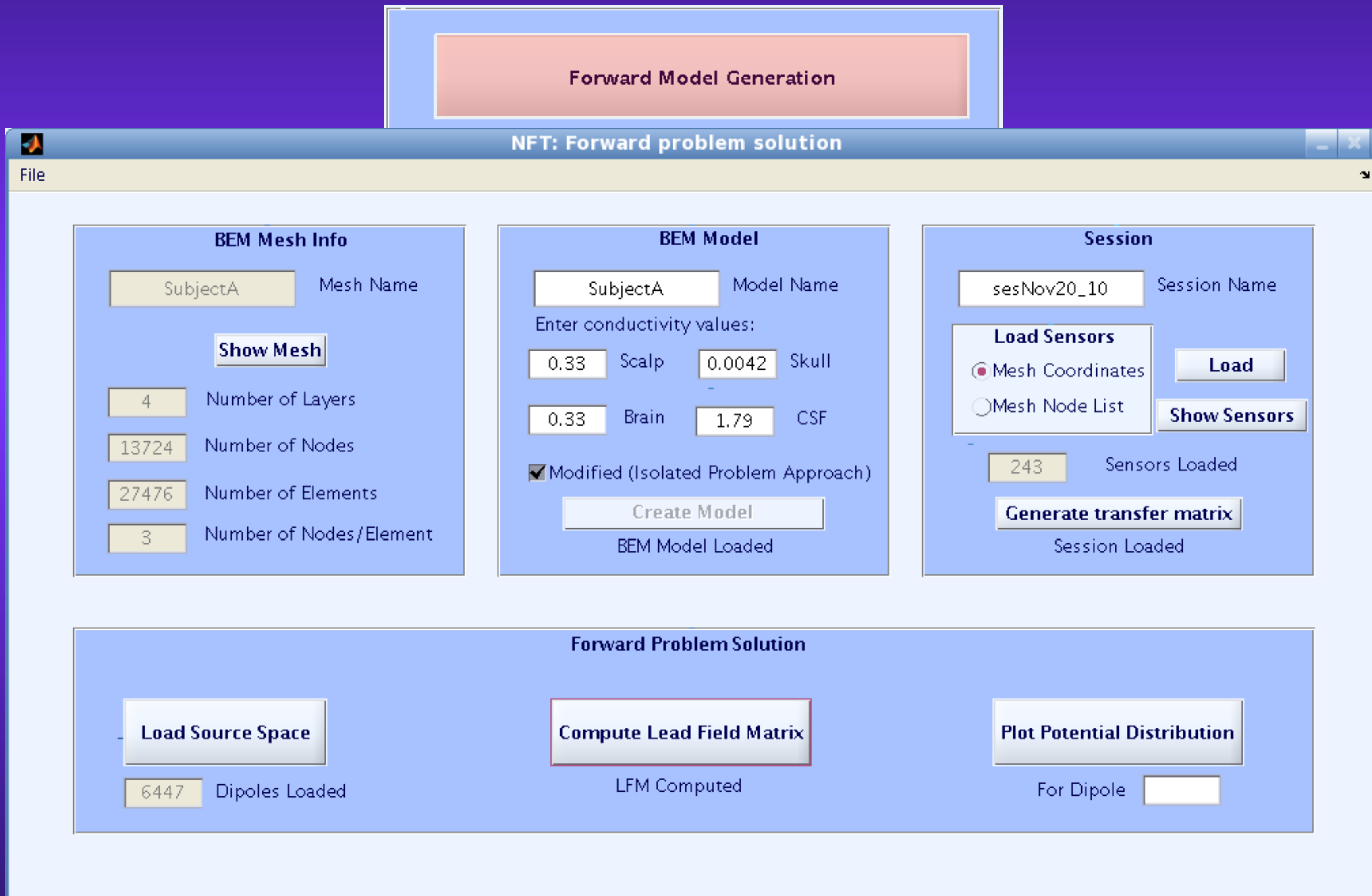


Forward Problem Solution



Forward Problem Solution

Forward Problem Solution



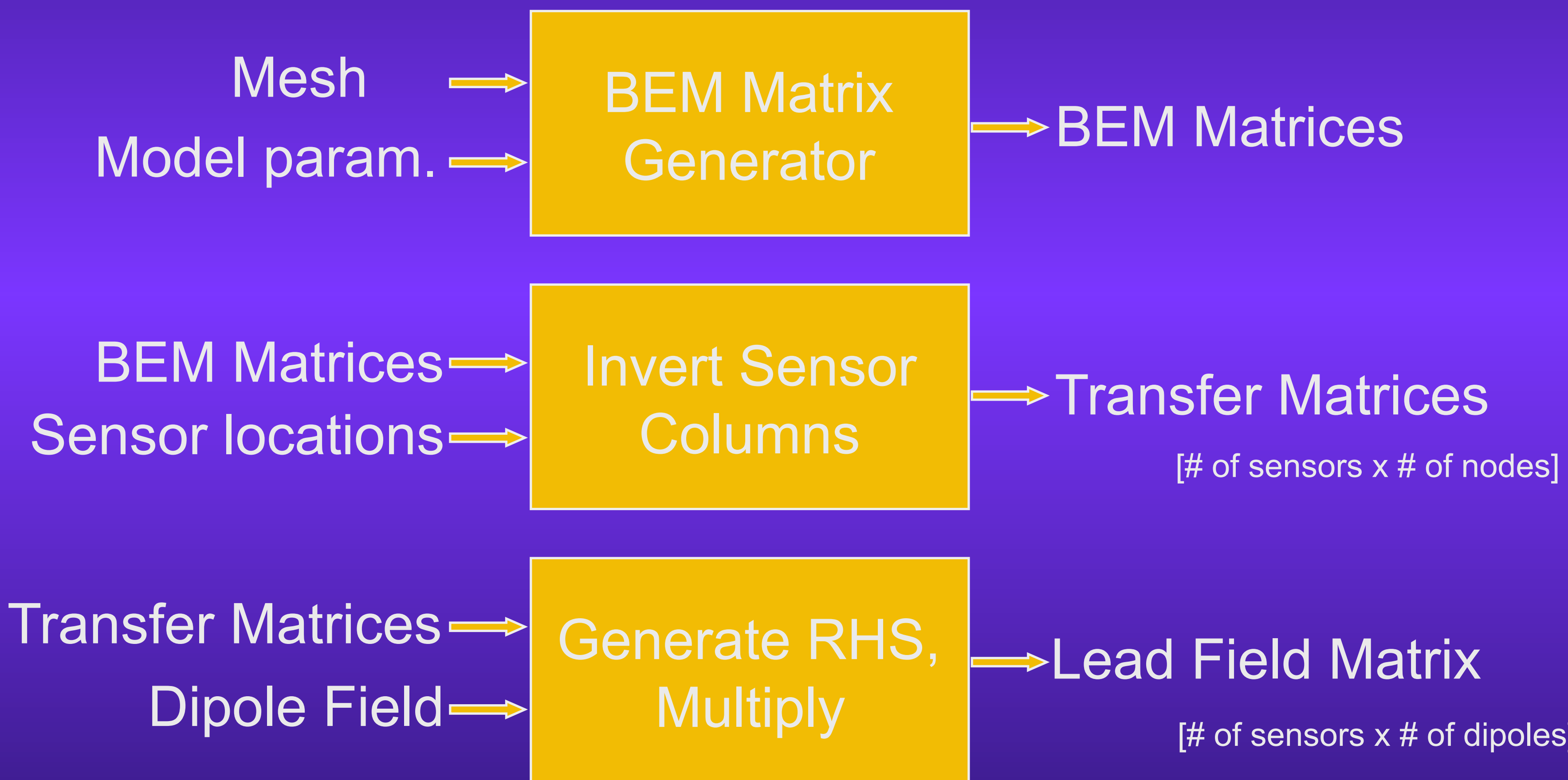
Forward Problem Solution

Command Window

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

```
>> dir *.sens

SubjectA_sesNov20_10_headsensors.sens

>> load SubjectA_sesNov20_10_headsensors.sens
>> whos SubjectA_sesNov20_10_headsensors
  Name                                    Size              Bytes  Class     Attributes

  SubjectA_sesNov20_10_headsensors      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

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

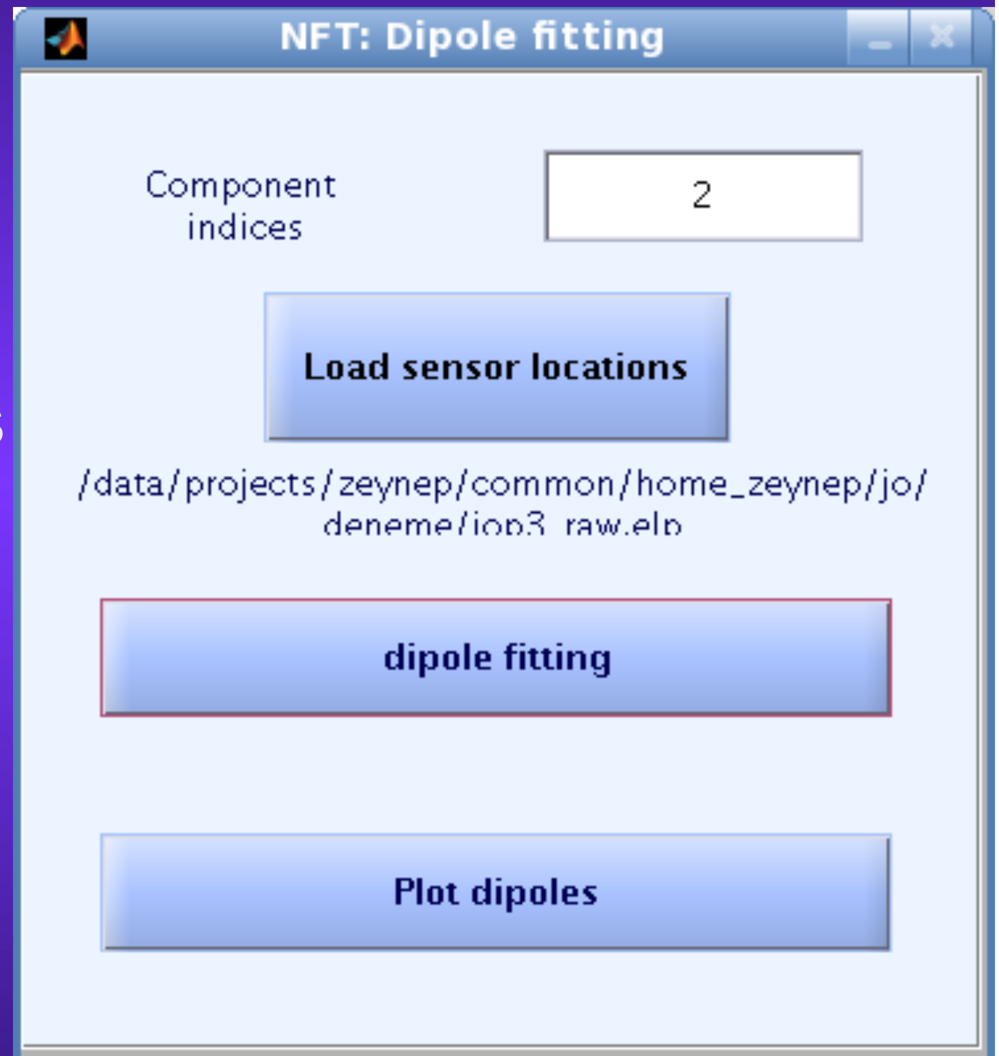
Forward Problem Solution



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



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

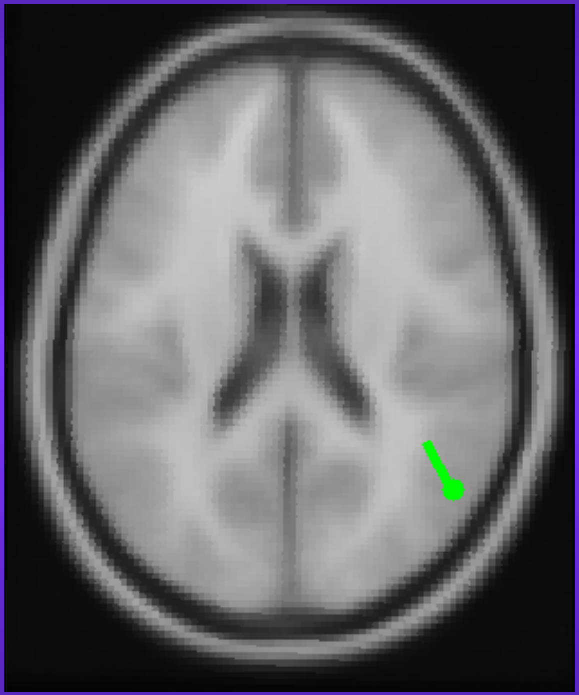
Localization error (mm)

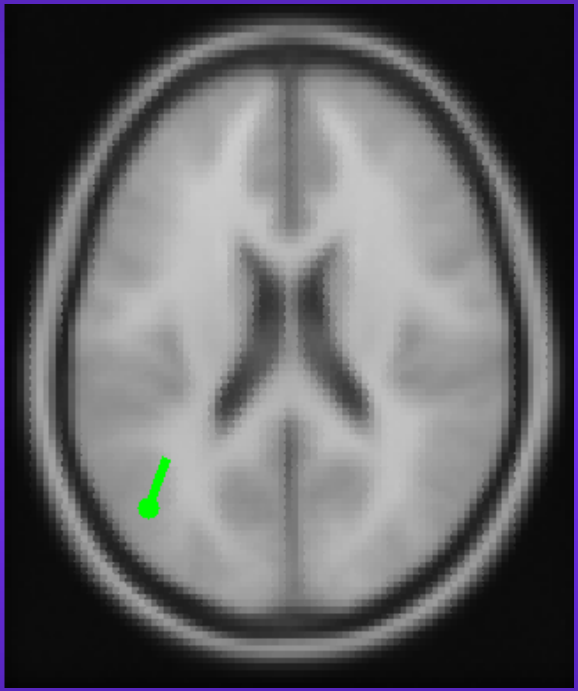
Compared with Mesh 4_2

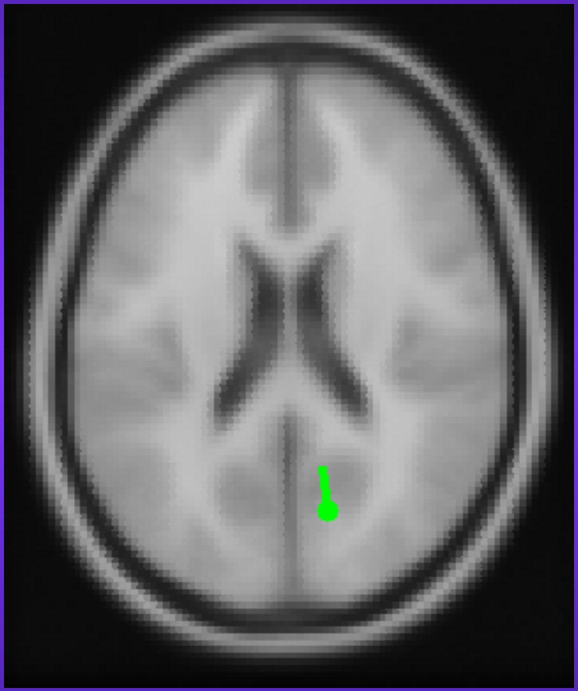
Source Localization Comparison

- 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 rv=0.0376 rv=0.0419

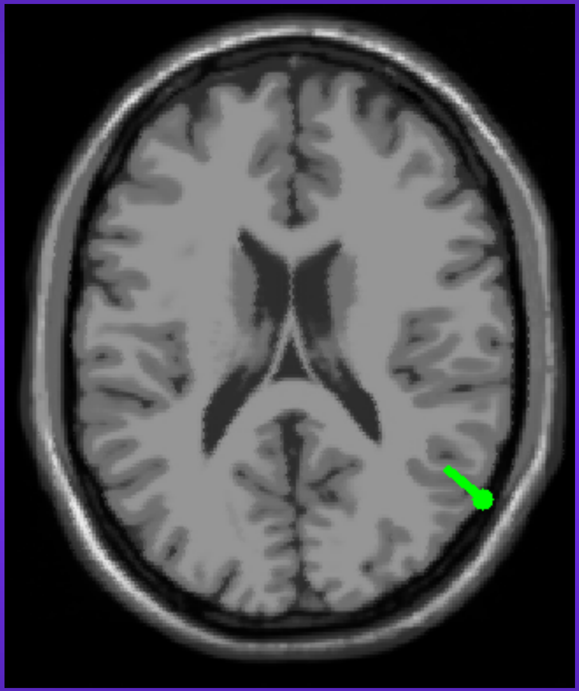
coord_transform =[0 0 0 0 0 0 930 1050 969]

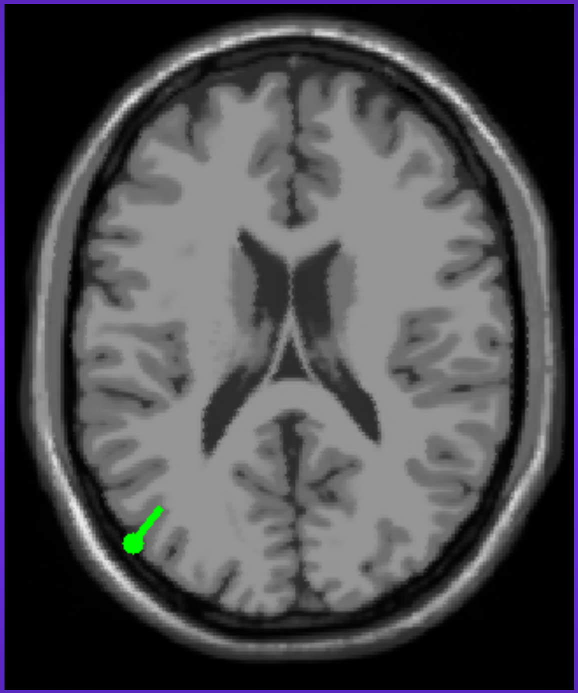
MNI Source Localization

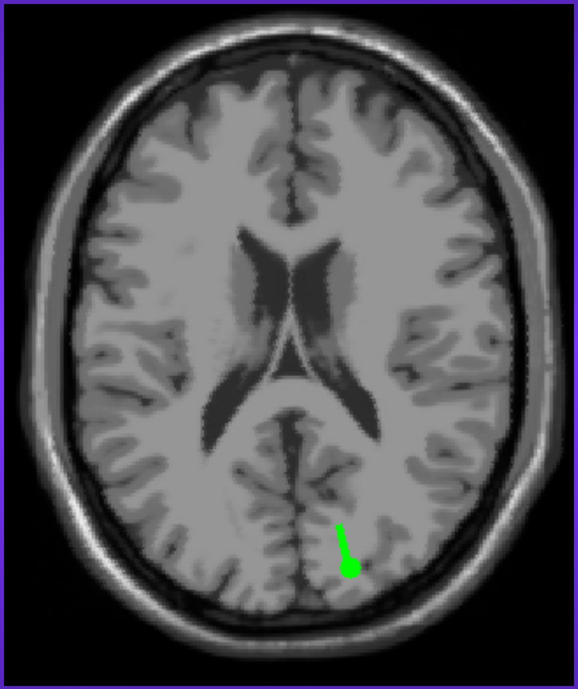
rv=0.0663 rv=0.0376 rv=0.0419

coord_transform =[0 0 0 0 0 0 930 1050 969]

Warped MNI sources





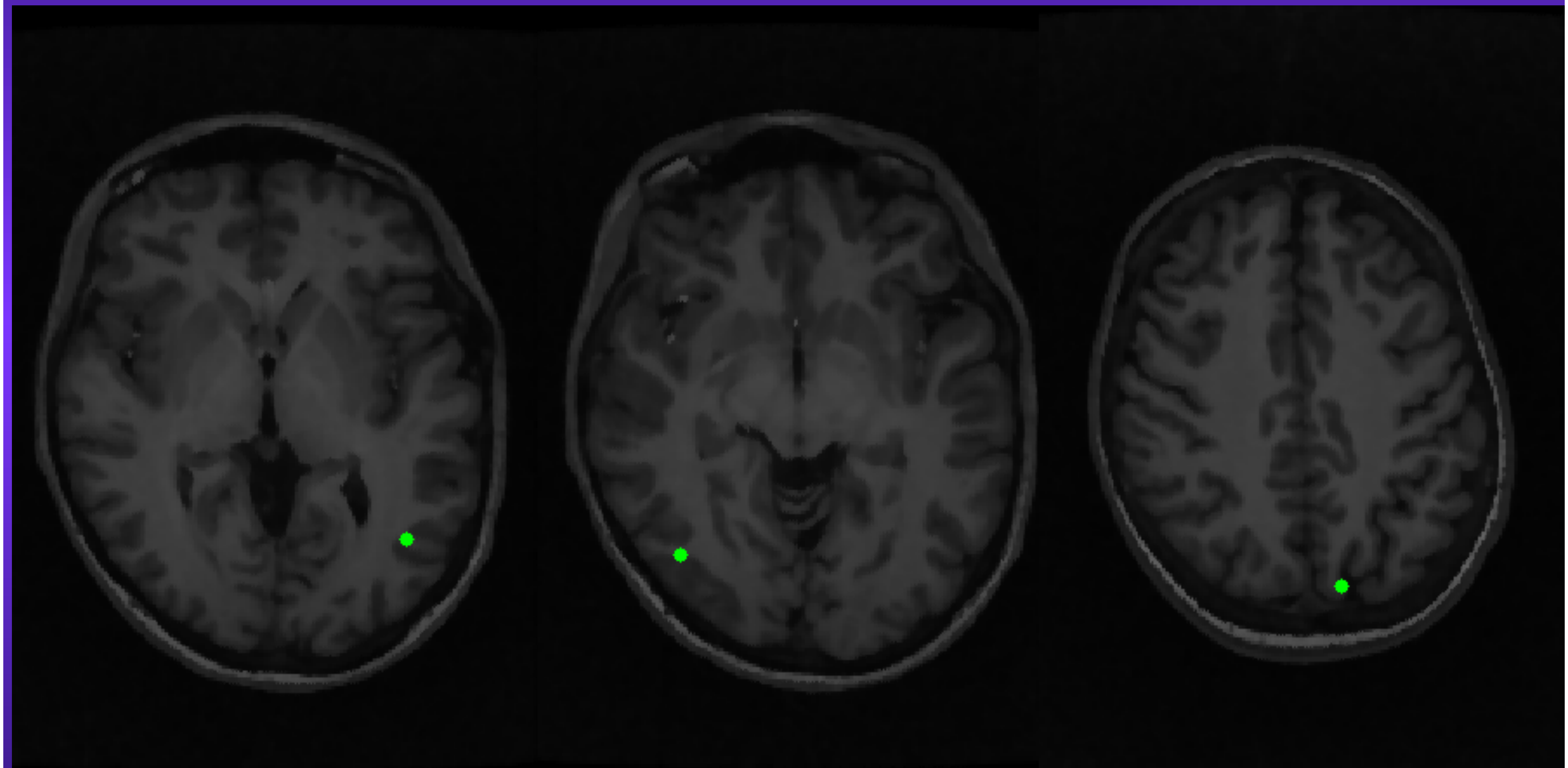


rv=0.0751
pos=[60.4 -64.4 8.45]
mom=[-53.1 43.9 -2.86]

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.