Cortical Thickness

Pipeline v1.0 Overview

Usage

Setup

SET BASE_PATH indicating the path to CorticalThickness folder.

Example:

```
BASE_PATH=${1:-"/neuro/labs/grantlab/research/MRI_processing/jose.cisneros/CorticalThickness"}
```

Usage without Docker.

```
(base) [jose.cisneros@hanyang:x86_64-Linux]...rticalThickness$>python code/corticalThickness.py  -h
usage:    ==========   Cortical Thickness Pipeline by Jose Cisneros (May 5, 2022 ver.1)   ==========

      [-h] -ca CASE [-bp BASE_PATH] [-im IN_MRI] [-is IN_MRI_SEG] [-se ENABLE_SURFACE_EXTRACTION]
      [-ir ENABLE_INTENSITY_REFINEMENT] [-do OUTSIDE_DOCKER] [-rp RESULTS_PREFIX] [-icm INTENSITY_CLUSTERING_METHOD]

optional arguments:
  -h, --help            show this help message and exit
  -ca CASE, --case CASE
                        Subject id
  -bp BASE_PATH, --base-path BASE_PATH
                        Path containing code & resources.
  -im IN_MRI, --input-mri IN_MRI
                        Input MRI .nii file path.
  -is IN_MRI_SEG, --input-segmented IN_MRI_SEG
                        Input MRI segmented .nii file path.
  -se ENABLE_SURFACE_EXTRACTION, --surface-extraction ENABLE_SURFACE_EXTRACTION
                        Enable Surface Extraction (default: True)
  -ir ENABLE_INTENSITY_REFINEMENT, --intensity-refinement ENABLE_INTENSITY_REFINEMENT
                        Enable Intensity Clustering for CP external boundary refinement. (default: True)
  -do OUTSIDE_DOCKER, --outside-docker OUTSIDE_DOCKER
                        Flag indicating if script running outside docker. (default: True)
  -rp RESULTS_PREFIX, --results-prefix RESULTS_PREFIX
                        Prefix for Results folder. (default: )
  -icm INTENSITY_CLUSTERING_METHOD, --intensity-clustering-method INTENSITY_CLUSTERING_METHOD
                        Soft Clustering Method use for Intensity Refinement. Options: GMM, FCM, sFCM (default: sFCM)
```

Output Folder: {BASE_PATH}/Results/{CASE}

Example:

```
${BASE_PATH}/code/corticalThickness.py \
   -ca FCB028 \
   -im ${BASE_PATH}/Samples/FCB028/recon_to31.nii \
   -is ${BASE_PATH}/Samples/FCB028/segmentation_to31_final.nii
```

Usage with Docker.

```
(base) [jose.cisneros@hanyang:x86_64-Linux]...rticalThickness$>python code/corticalThicknessDocker.py  -h
usage:    ==========   Cortical Thickness Pipeline using Docker by Jose Cisneros (May 9, 2022 ver.1)   ==========

      [-h] -ca CASE [-bp BASE_PATH] -im IN_MRI -is IN_MRI_SEG -o OUTPUT [-se ENABLE_SURFACE_EXTRACTION]
      [-ir ENABLE_INTENSITY_REFINEMENT] [-icm INTENSITY_CLUSTERING_METHOD]

optional arguments:
  -h, --help            show this help message and exit
  -ca CASE, --case CASE
                        Subject id
  -bp BASE_PATH, --base-path BASE_PATH
                        Path containing code & resources.
  -im IN_MRI, --input-mri IN_MRI
                        Input MRI .nii file with path.
  -is IN_MRI_SEG, --input-segmented IN_MRI_SEG
                        Input MRI segmented .nii file with path.
  -o OUTPUT, --output-folder OUTPUT
                        Output folder containing all generated files.
  -se ENABLE_SURFACE_EXTRACTION, --surface-extraction ENABLE_SURFACE_EXTRACTION
                        Enable Surface Extraction
  -ir ENABLE_INTENSITY_REFINEMENT, --intensity-refinement ENABLE_INTENSITY_REFINEMENT
                        Enable Intensity Clustering for CP external boundary refinement.
  -icm INTENSITY_CLUSTERING_METHOD, --intensity-clustering-method INTENSITY_CLUSTERING_METHOD
                        Soft Clustering Method use for Intensity Refinement. Options: GMM, FCM, sFCM
```

Example:

```
${BASE_PATH}/code/corticalThicknessDocker.py \
   -ca FCB028 \
   -im ${BASE_PATH}/Samples/FCB028/recon_to31.nii \
   -is ${BASE_PATH}/Samples/FCB028/segmentation_to31_final.nii \
   -o ${BASE_PATH}/Results
```

Useful information about Docker.

Setup:

- Option1: Get Docker Image building it with Dockerfile
  - `docker build -t cortical-thickness ${BASE_PATH} -f ${BASE_PATH}/deploy/Dockerfile`
- `Option2: Get latest Docker Image published.`
  - `docker pull ghcr.io/josecisneros001/fnndsc-cortical-thickness`
  - `docker tag ghcr.io/josecisneros001/fnndsc-cortical-thickness  cortical-thickness`

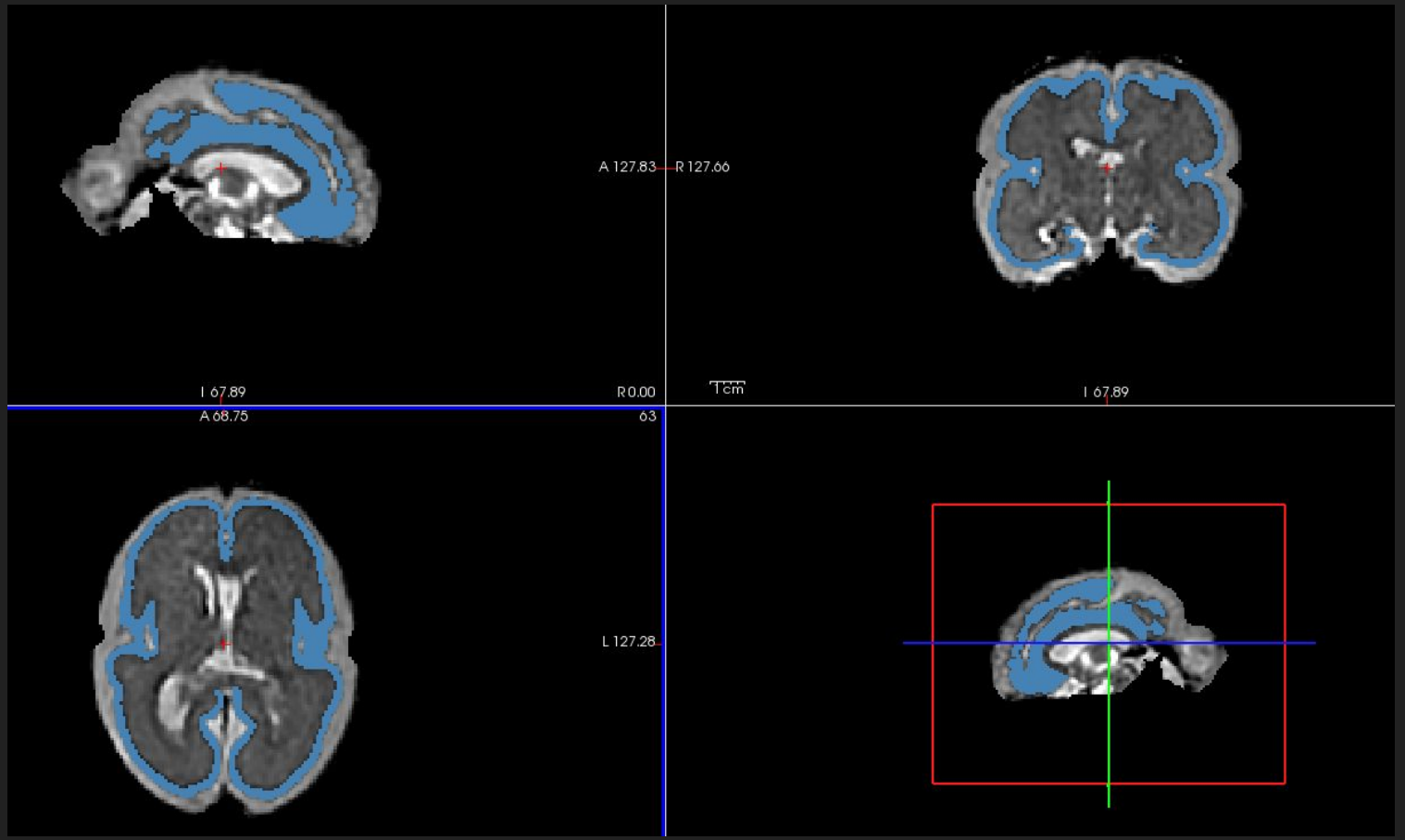
Publish new Docker Image

- `docker login ghcr.io`
- `# Build your image if it doesn't exist yet.`
  - `docker build -t ghcr.io/josecisneros001/FNNDSC-Cortical-Thickness .`
- `# Tag it if already exists.`
  - `docker tag cortical-thickness ghcr.io/josecisneros001/fnndsc-cortical-thickness`
- `docker push ghcr.io/josecisneros001/fnndsc-cortical-thickness`

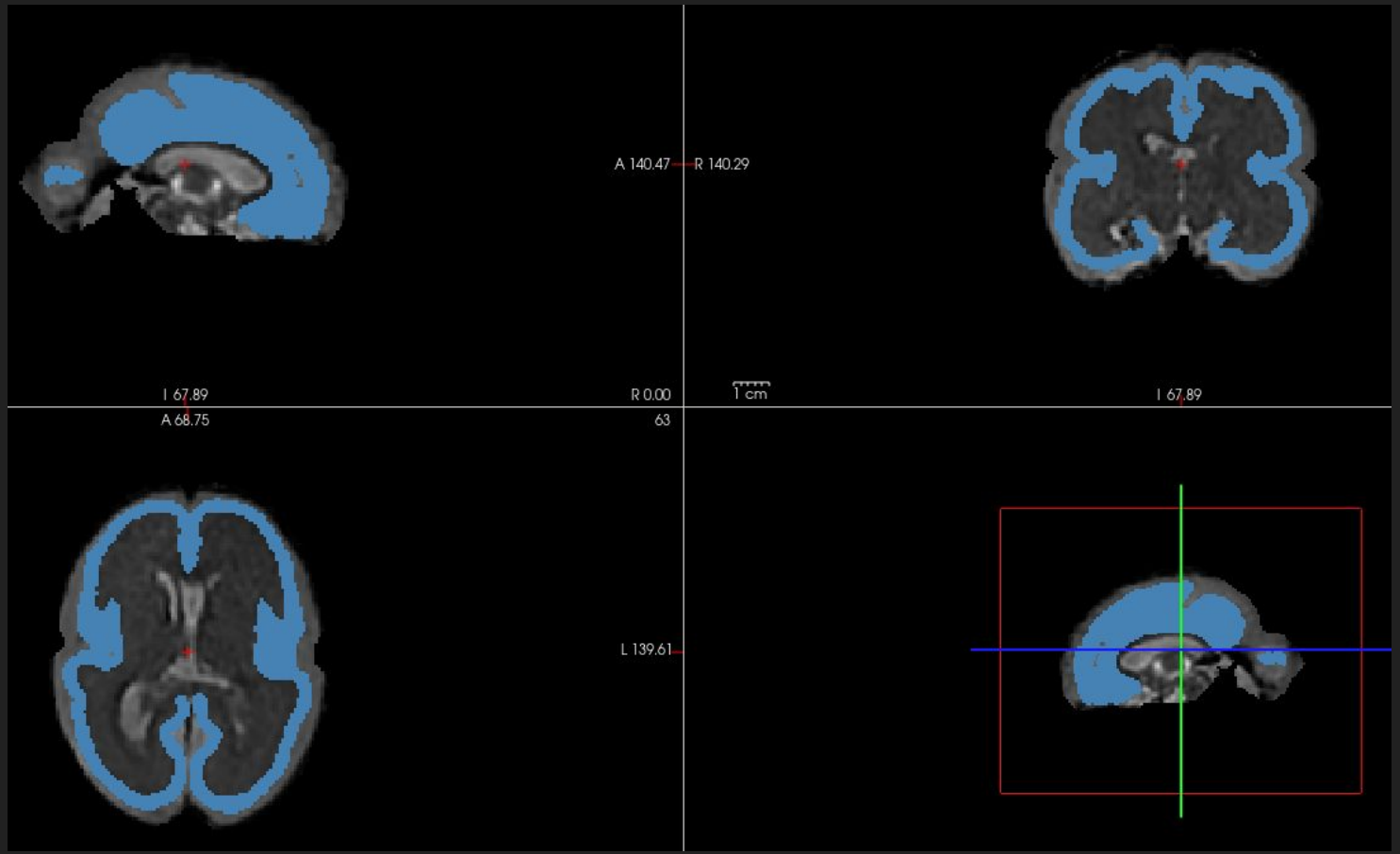
Code - Pipeline

Processing Step

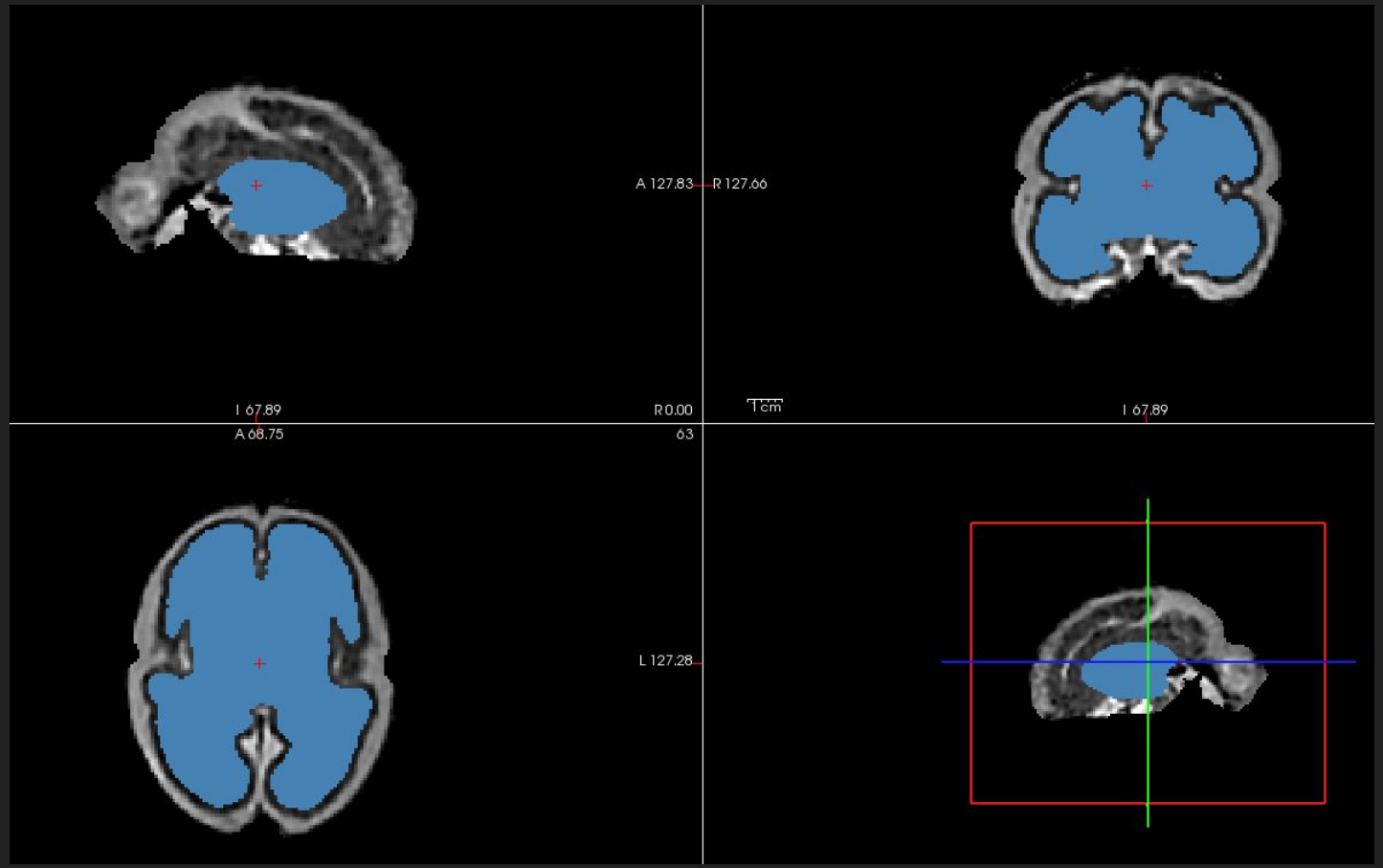
```
# Segment and Join Cerebral Exterior Labels 1 & 42. Obtained from deep learning segmentation.
${TARGET_DIR}/${CASE}/temp/cerebral_ext.mnc
```



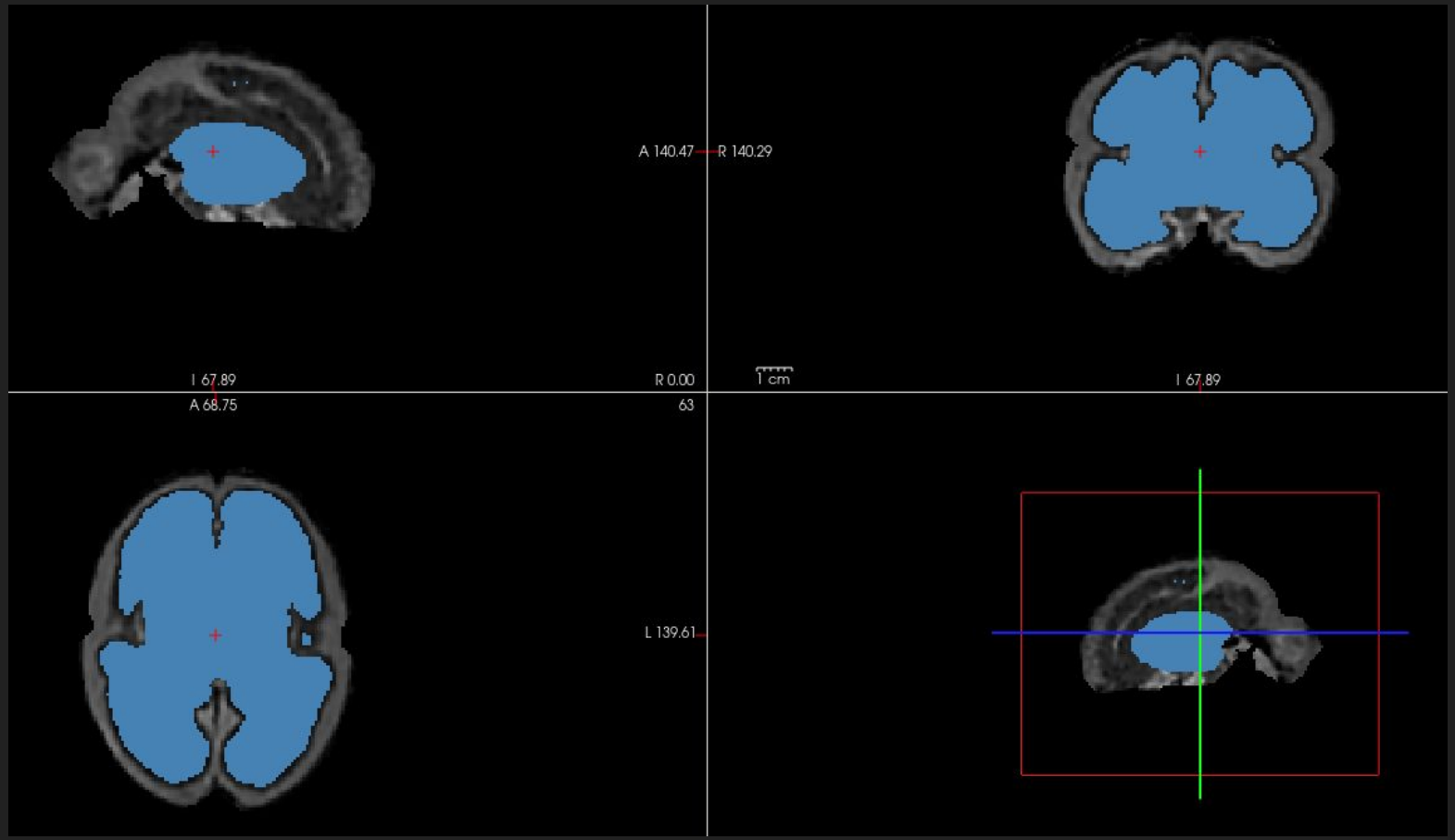
```
# Dilation Cerebral Exterior
${TARGET_DIR}/${CASE}/temp/cerebral_ext_d.mnc
```



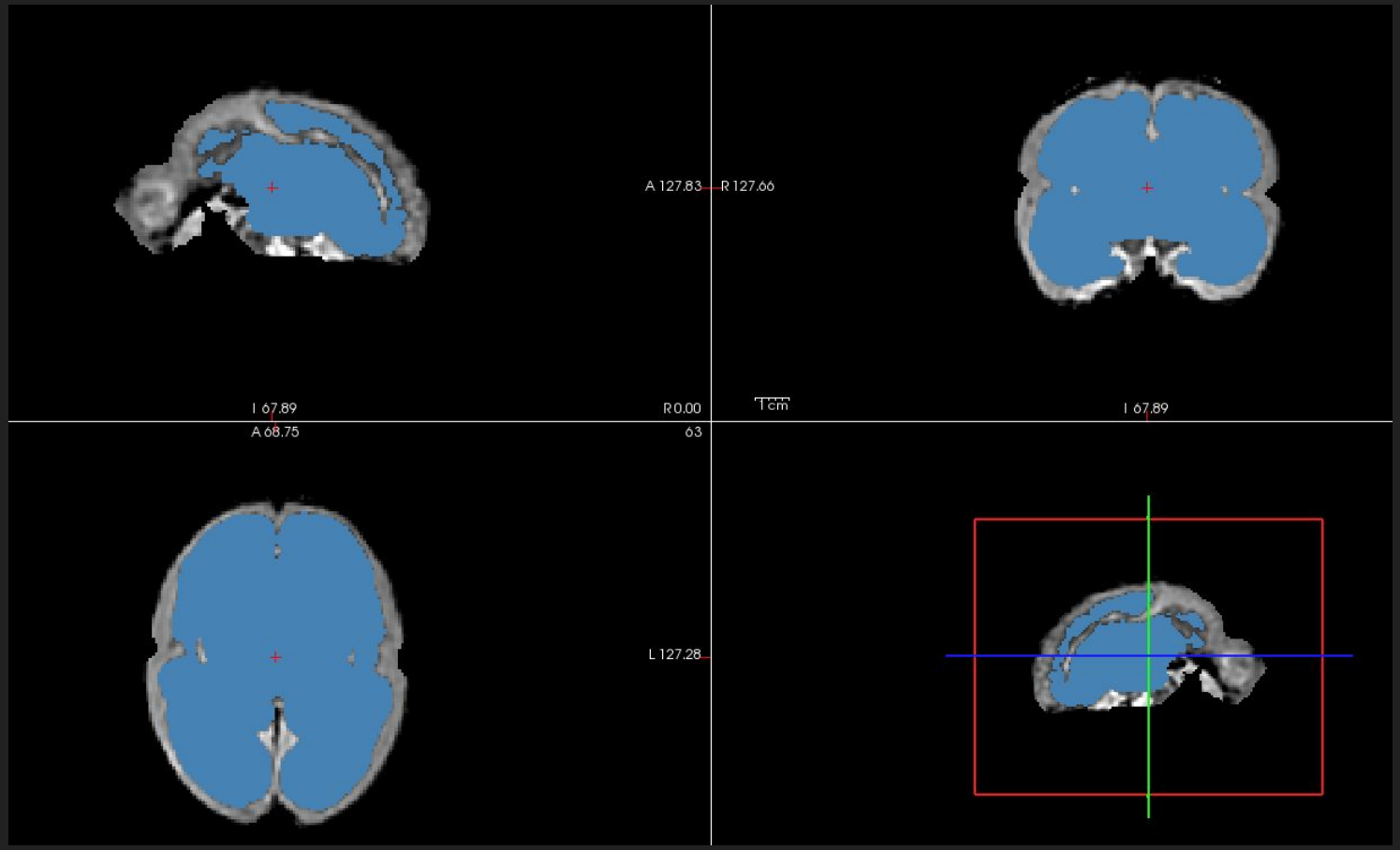
```
# Segment and Join Cerebral Interior Labels 160 & 161. Obtained from deep learning segmentation.
${TARGET_DIR}/${CASE}/temp/cerebral_int.mnc
```



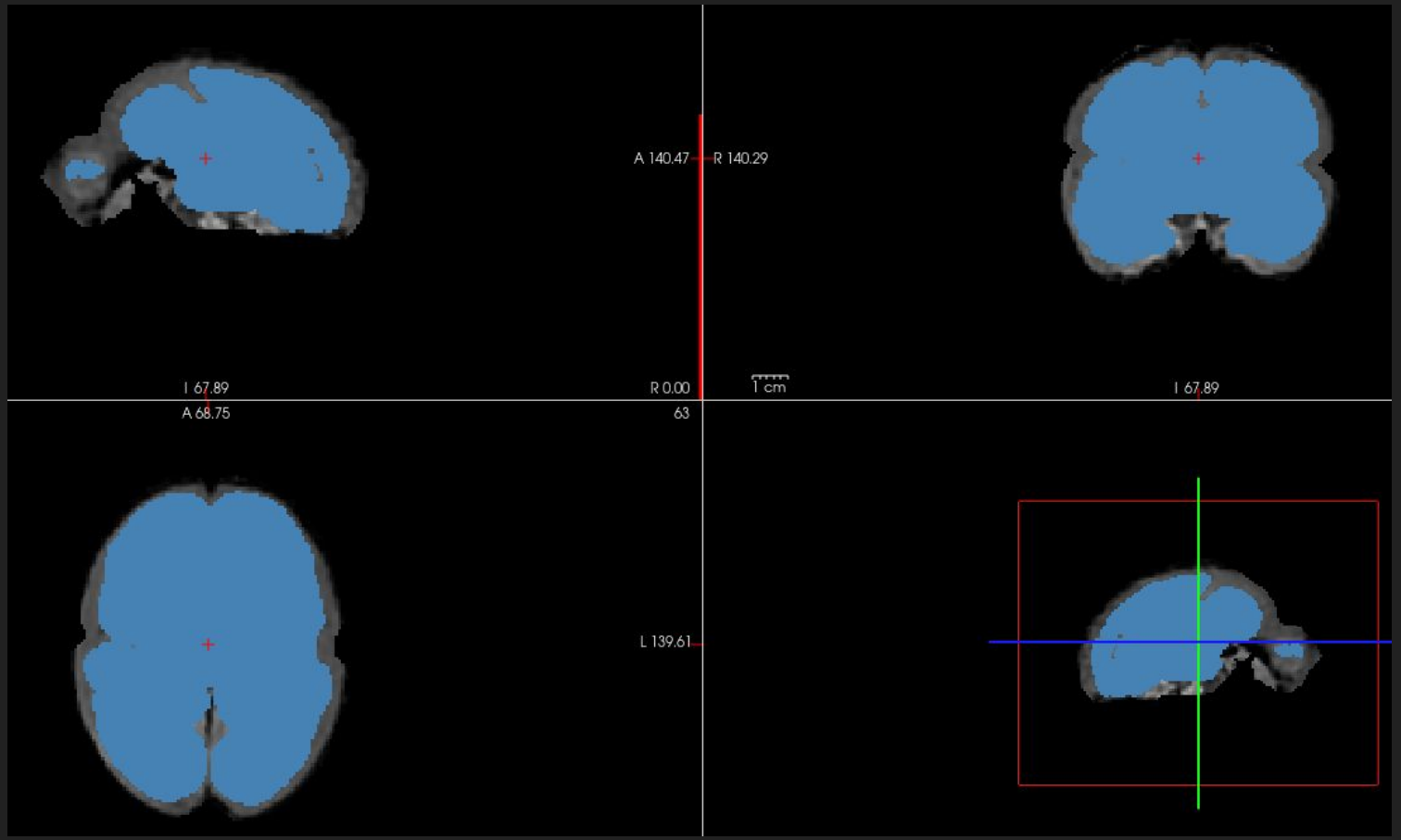
```
# Dilation Cerebral Interior
${TARGET_DIR}/${CASE}/temp/cerebral_int_d.mnc
```



```
# Binarize all segmentations [from 1 to 161] Obtained from deep learning segmentation.
${TARGET_DIR}/${CASE}/temp/initial_segmentations.mnc
```

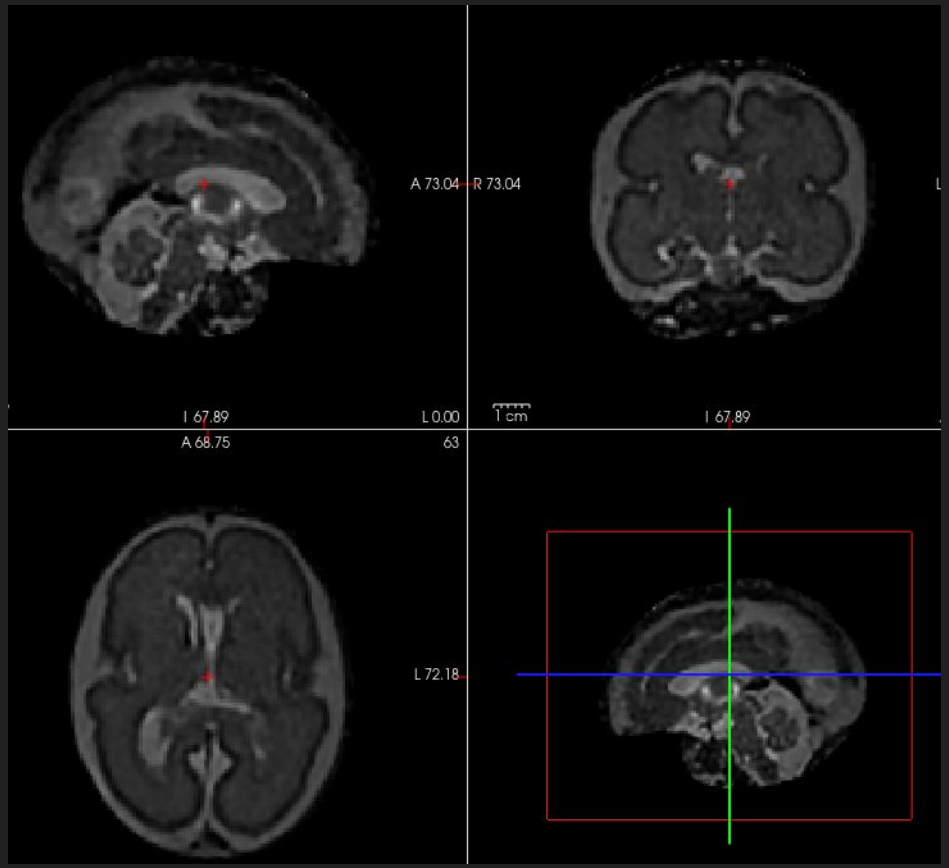


```
# Dilation Initial Segmentations
${TARGET_DIR}/${CASE}/temp/initial_segmentations_d.mnc
```

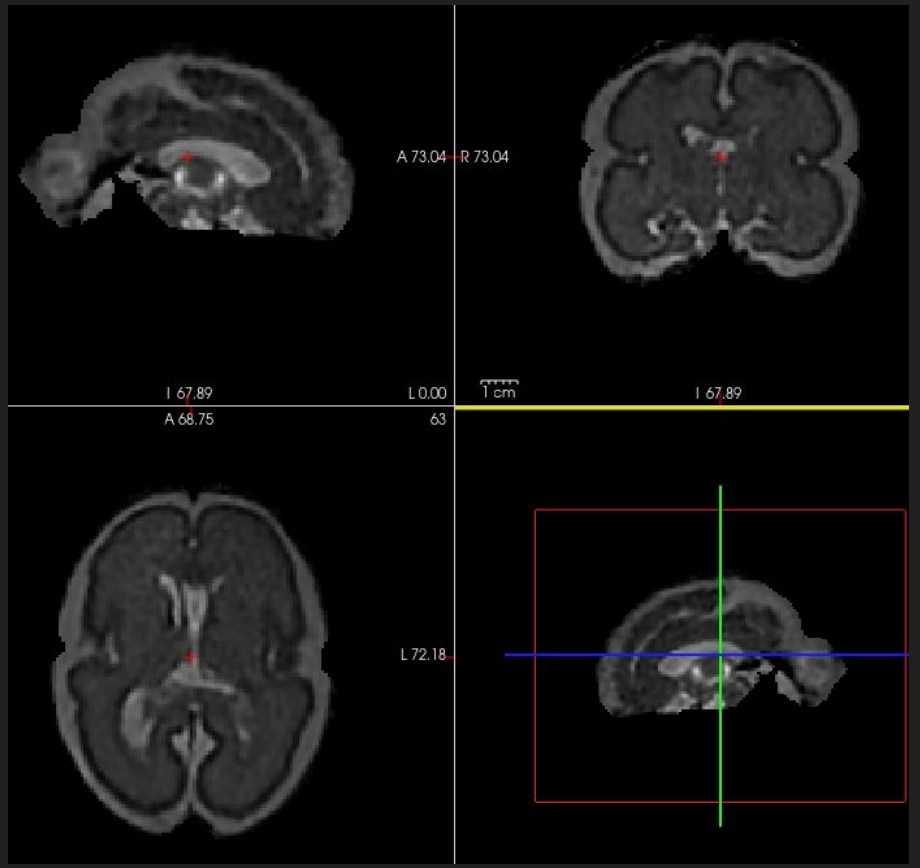


```
# Remove Cerebellum for next steps.
${TARGET_DIR}/${CASE}/input/input_mri_processed.mnc
```

Before:



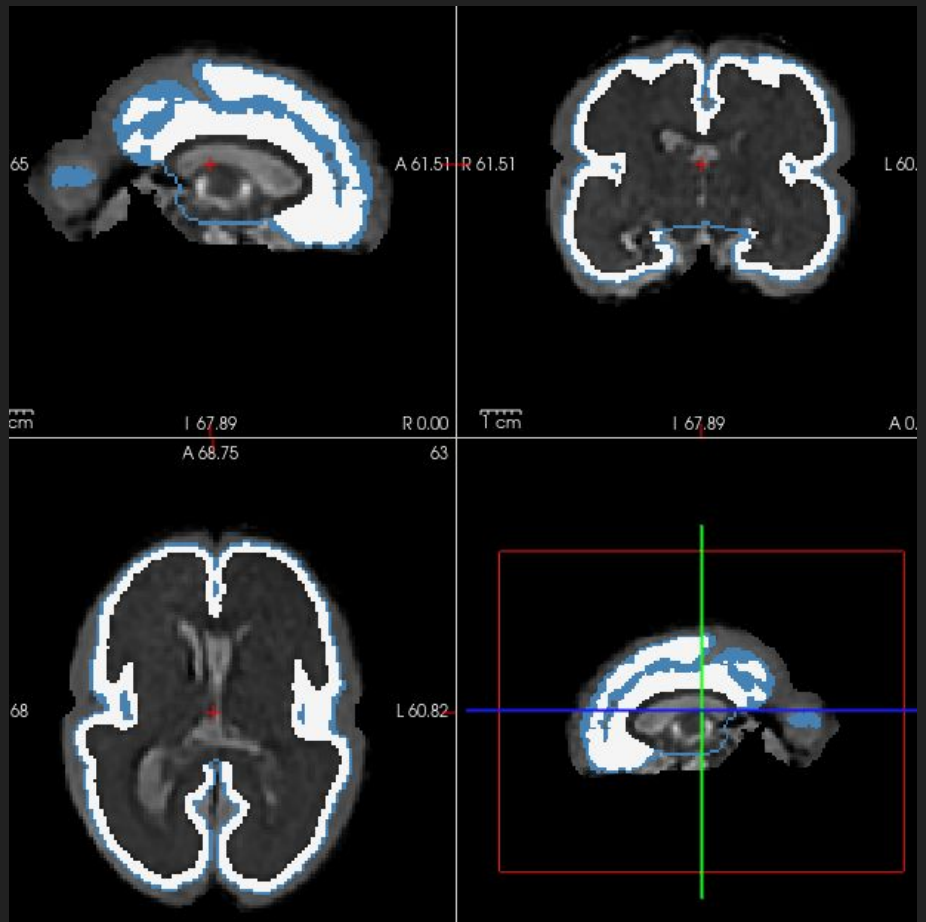
After:



Code - Pipeline

Skeletonization Step

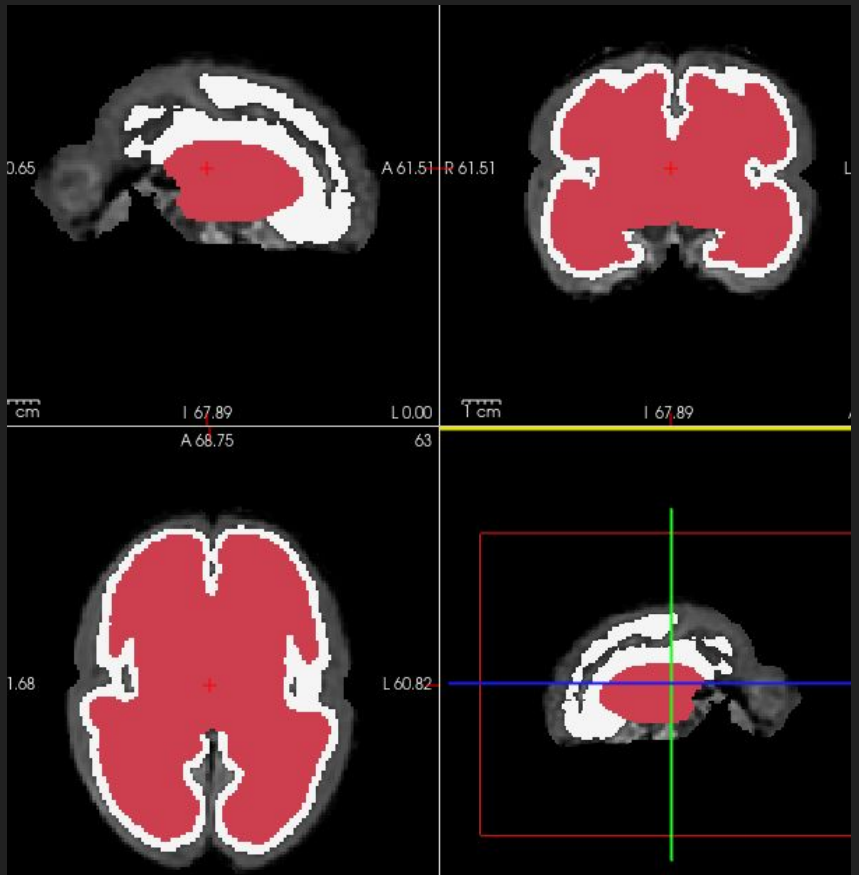
```
# GM External Boundary - 1 voxel apart.
${TARGET_DIR}/${CASE}/temp/cerebral_ext.mnc -> White (Input)
${TARGET_DIR}/${CASE}/temp/gm_ext.mnc -> Blue (Output)
```



```
# Join GM and WM, labeled, not binarized
${TARGET_DIR}/${CASE}/temp/gray.mnc (Input)
${TARGET_DIR}/${CASE}/temp/cerebral_int.mnc (Input)
${TARGET_DIR}/${CASE}/temp/wm_and_gm.mnc -> White (GM) & Pink (WM) (Output)
```

GM with GM/CSF outer boundary + WM

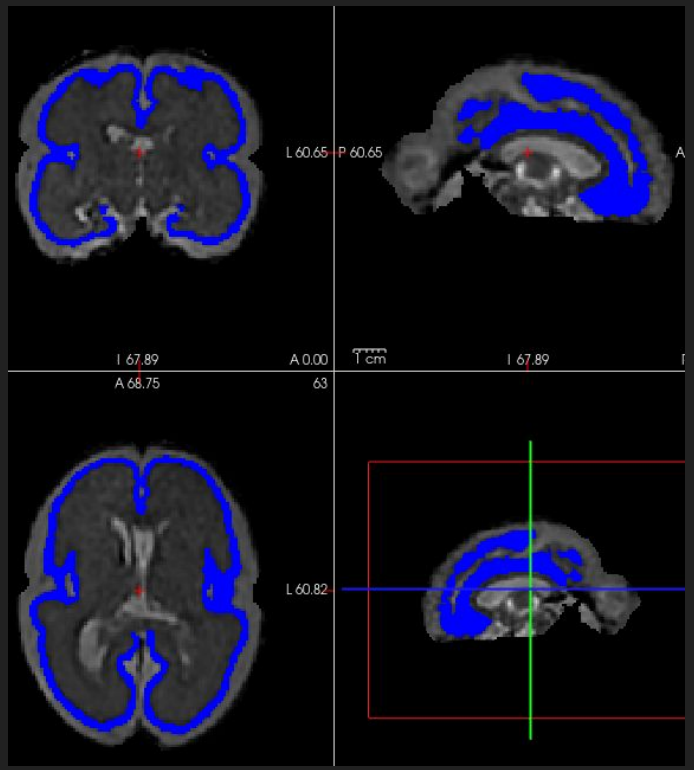
Important detail to consider for the skeleton input. GM and WM need to have different labels, that's why the output has two different colors (Pink & White).

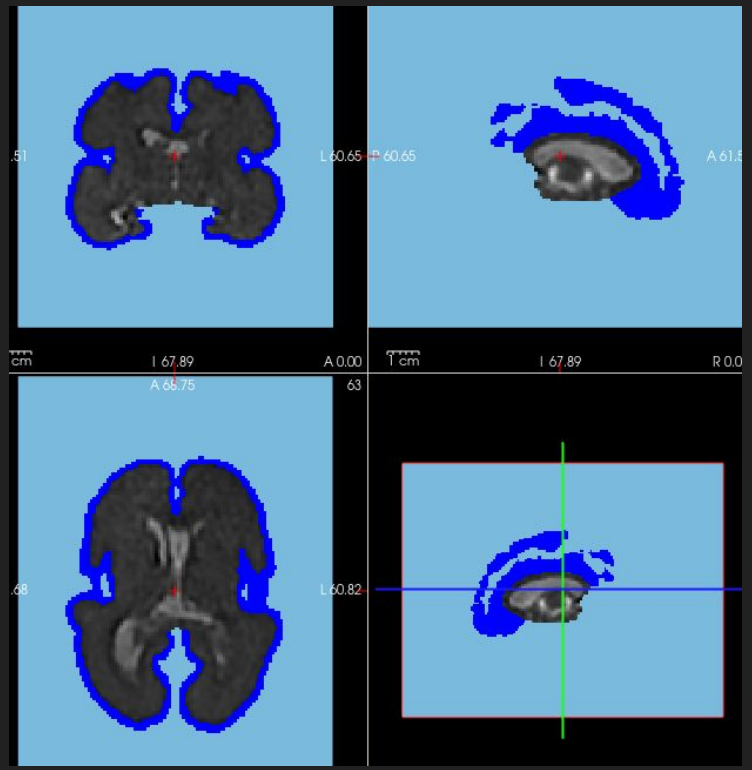


```
#### Prepare Skeleton Gray Scale input.
#### 11-Outside GM, 0 - WM, 255 - GM.
${TARGET_DIR}/${CASE}/temp/cerebral_ext.mnc (Input)
${TARGET_DIR}/${CASE}/temp/cerebral_int.mnc (Input)
${TARGET_DIR}/${CASE}/temp/gm_grayscale.mnc -> Blue (GM), Dark (WM) & lightBlue (outside) (Output)
```

CSF obtained with CP dilation + GM

Important detail that lightblue is everything the skeleton don't need to consider. First Image doesn't hide lightblue to show that there are parts of the brain not considered in skeleton.



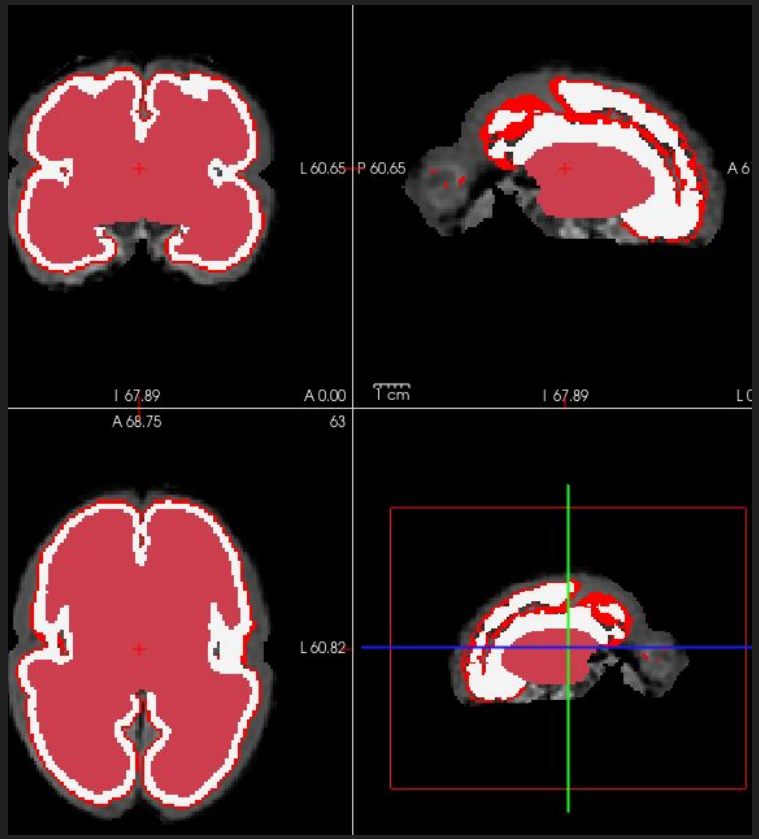


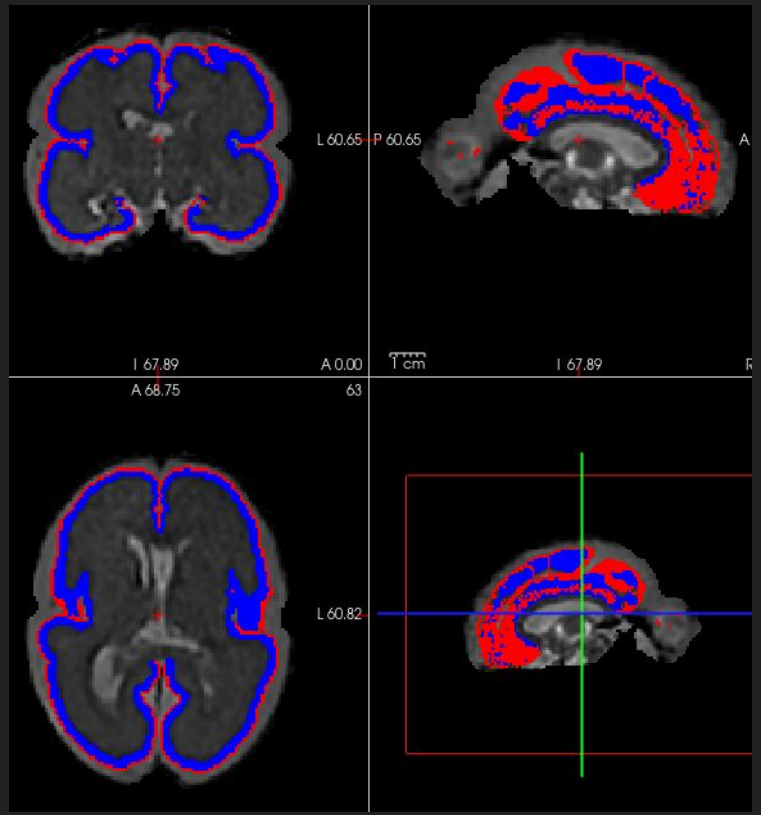
Skeleton

${TARGET_DIR}/${CASE}/temp/gm_grayscale.mnc (Image 2 Blue) (Input)

${TARGET_DIR}/${CASE}/temp/wm_and_gm.nii (Image 1 White & Pink) (Input)

${TARGET_DIR}/${CASE}/temp/skeleton_1_corr.nii -> (Image 1&2 Red) (Output)



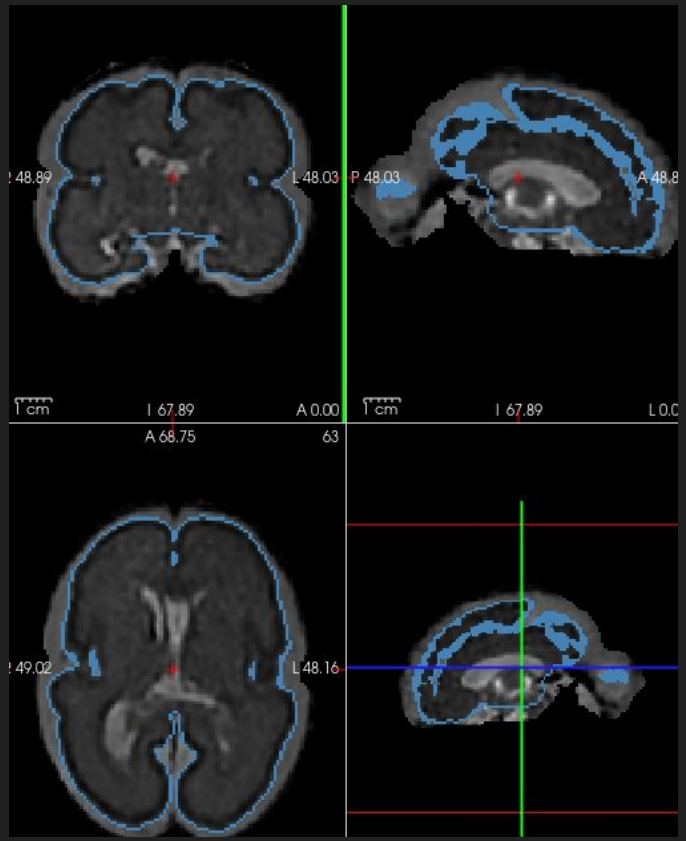


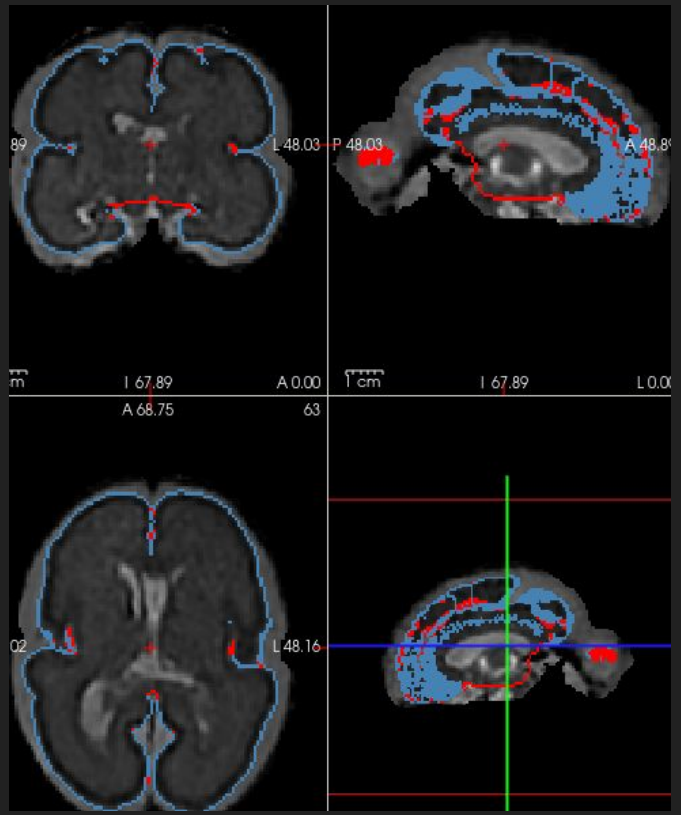
Join Skeleton with GM external boundary.Skeleton follows External boundary limited by DeepLearning in a 100%.

${TARGET_DIR}/${CASE}/temp/gm_ext.mnc (Input First Image)

${TARGET_DIR}/${CASE}/temp/skeleton_1_corr.nii (Input Second Image Blue)

${TARGET_DIR}/${CASE}/temp/skeleton_corr.nii -> (Output Second Image Blue + Red)





Code - Pipeline

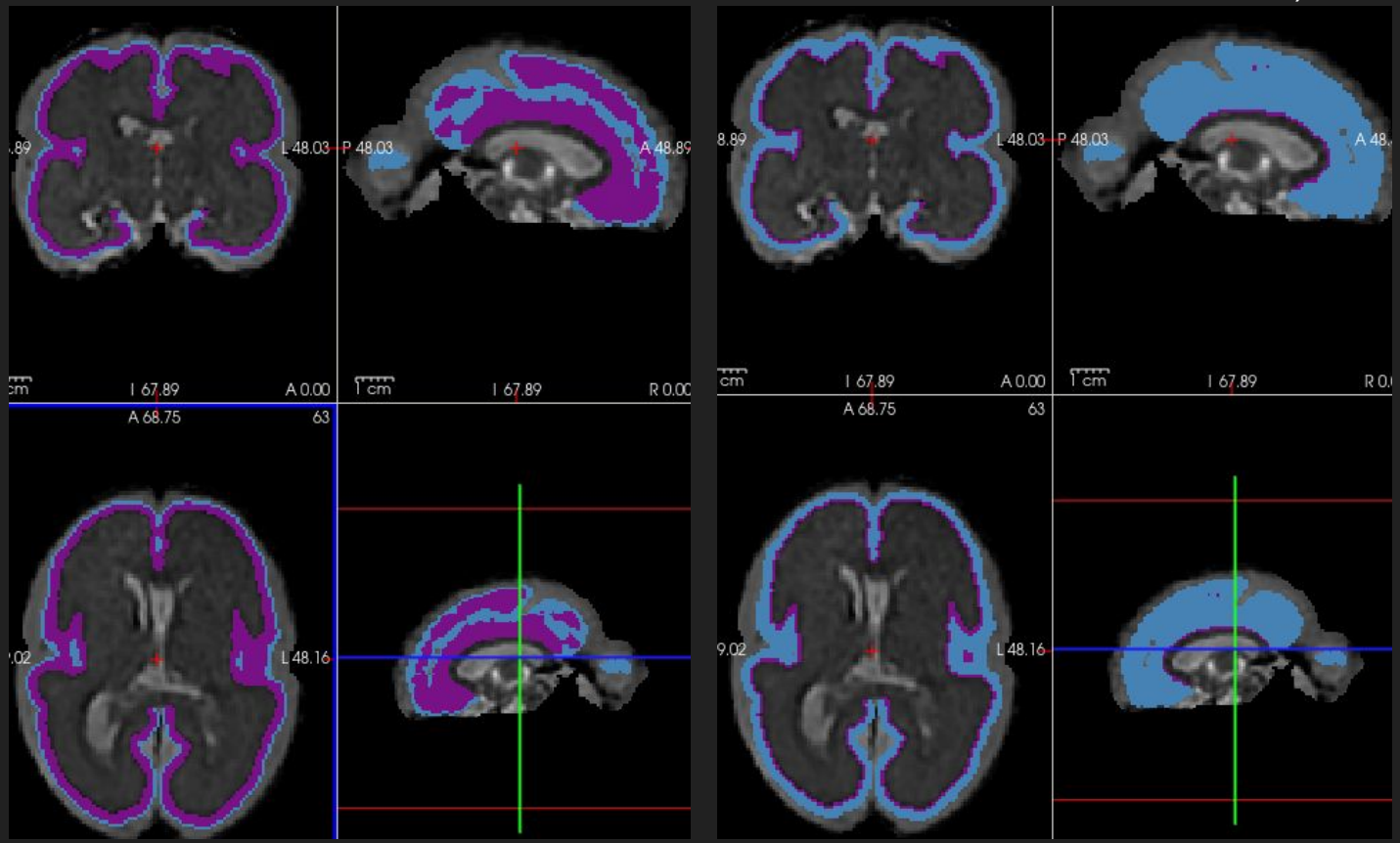
Intensity Refinement (Optional)

Clustering Input Volume: GM -> 1 extra outer voxel and without 1 inner voxel.

${TARGET_DIR}/${CASE}/temp/clustering_input.mnc (Blue)

Purple - GM.

Input for Soft clustering method, divide voxels in two groups (Bright & Dark).

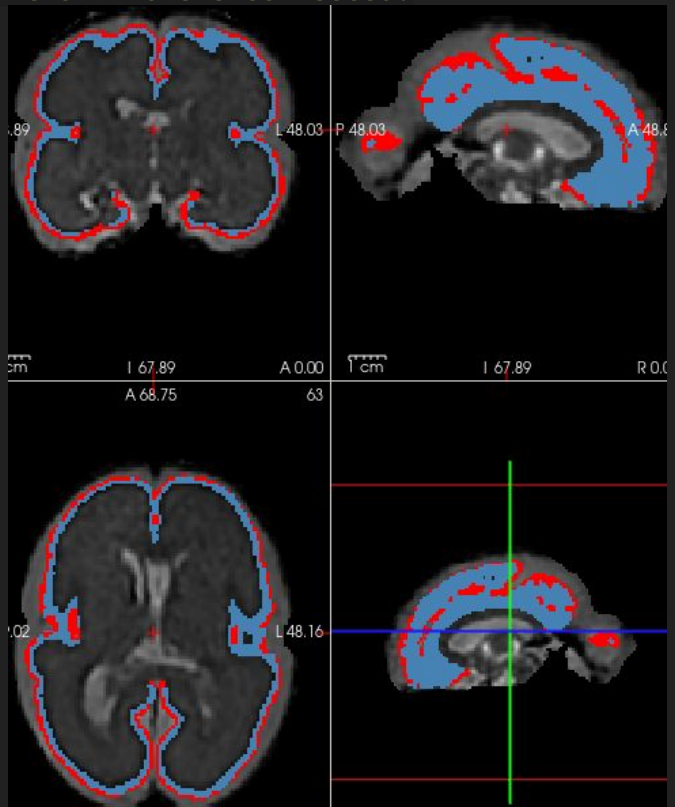


Current Pipeline has three soft clustering methods implemented. Choose by cmdline argument.

- Gaussian Mixture Model (GMM)
- FCM (Fuzzy c-Means)
- sFCM (Spatial Fuzzy c-Means)

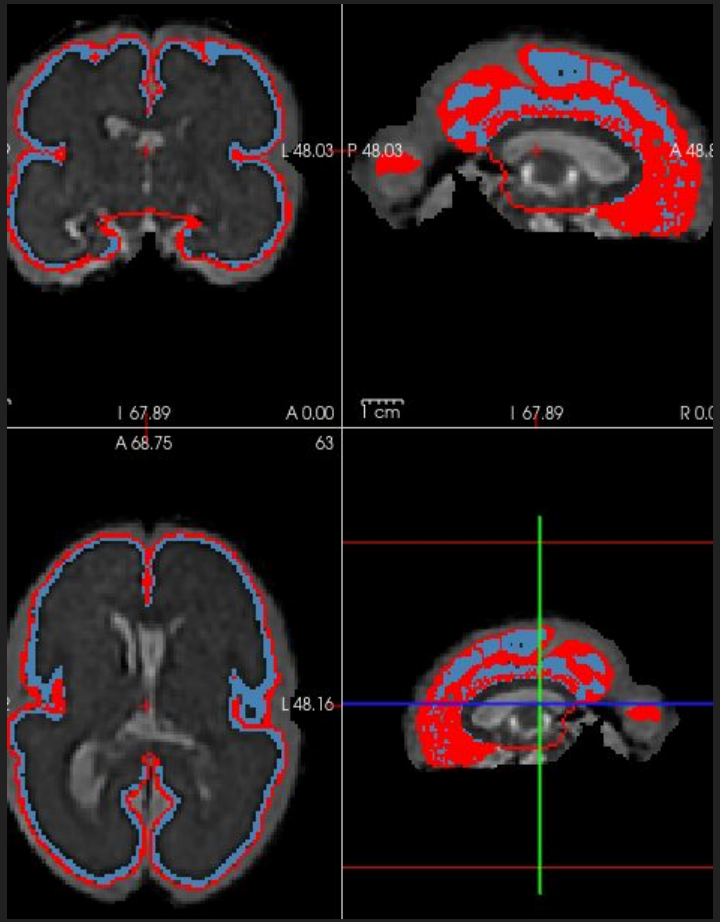
GMM & FCM are based only in Intensity, sFCM considers neighboring intensity, for this reason it has a better performance against noise and tends to have all voxels connected.

sFCM example:

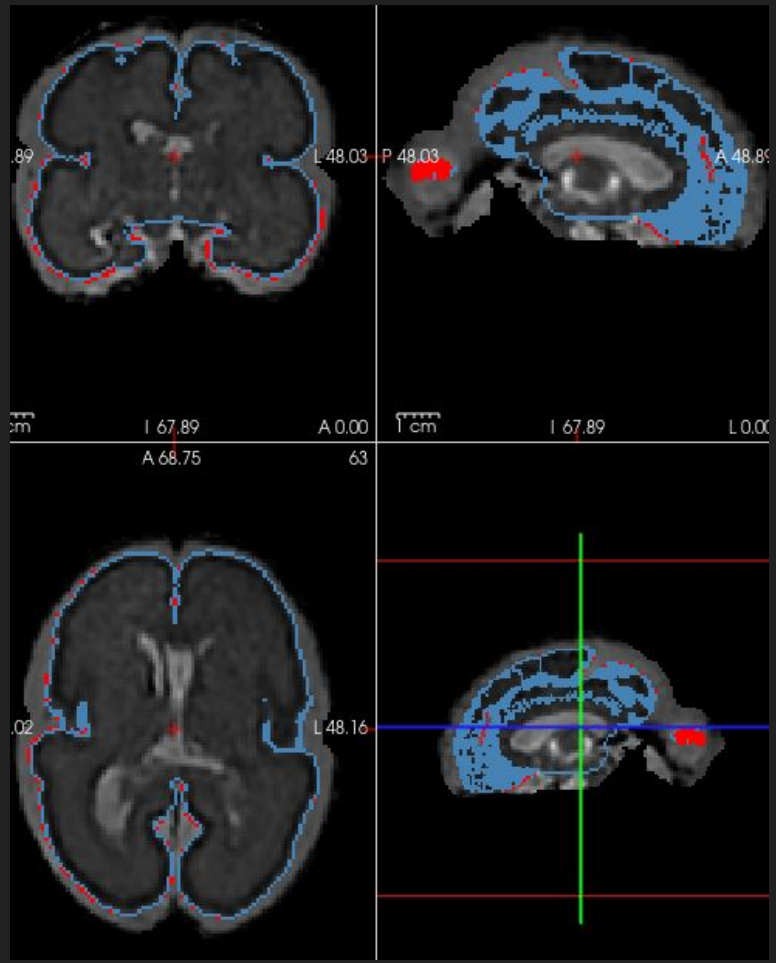


Join Clustering Output with Skeleton limiting inner boundary to skeleton.

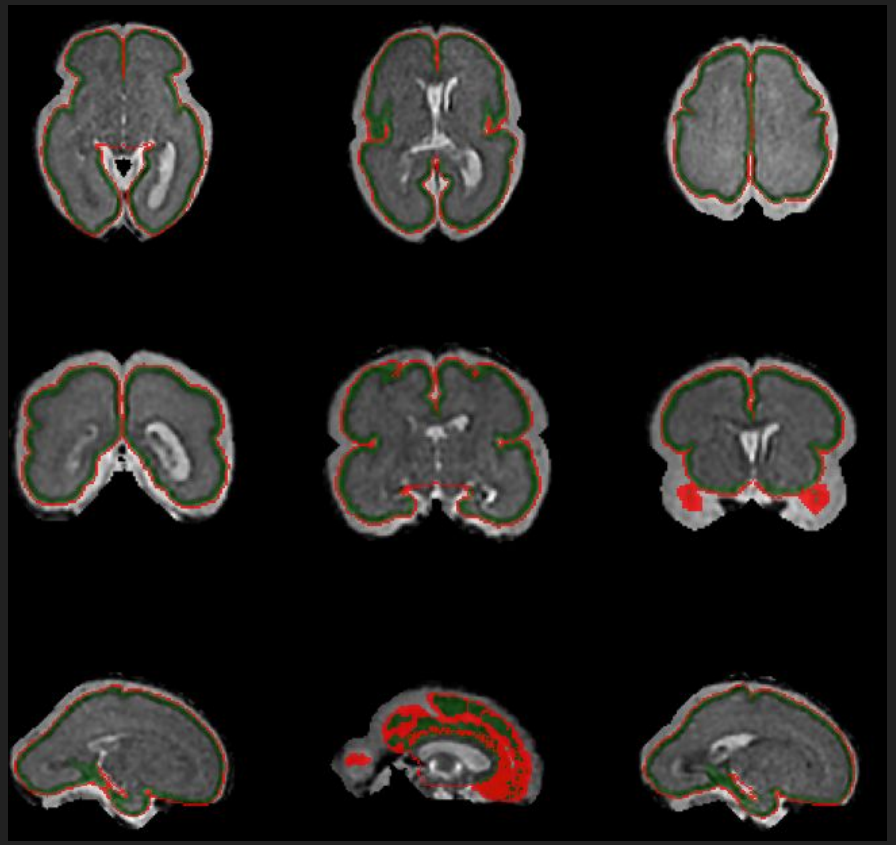
${TARGET_DIR}/${CASE}/temp/ps2_csf.mnc (Red)



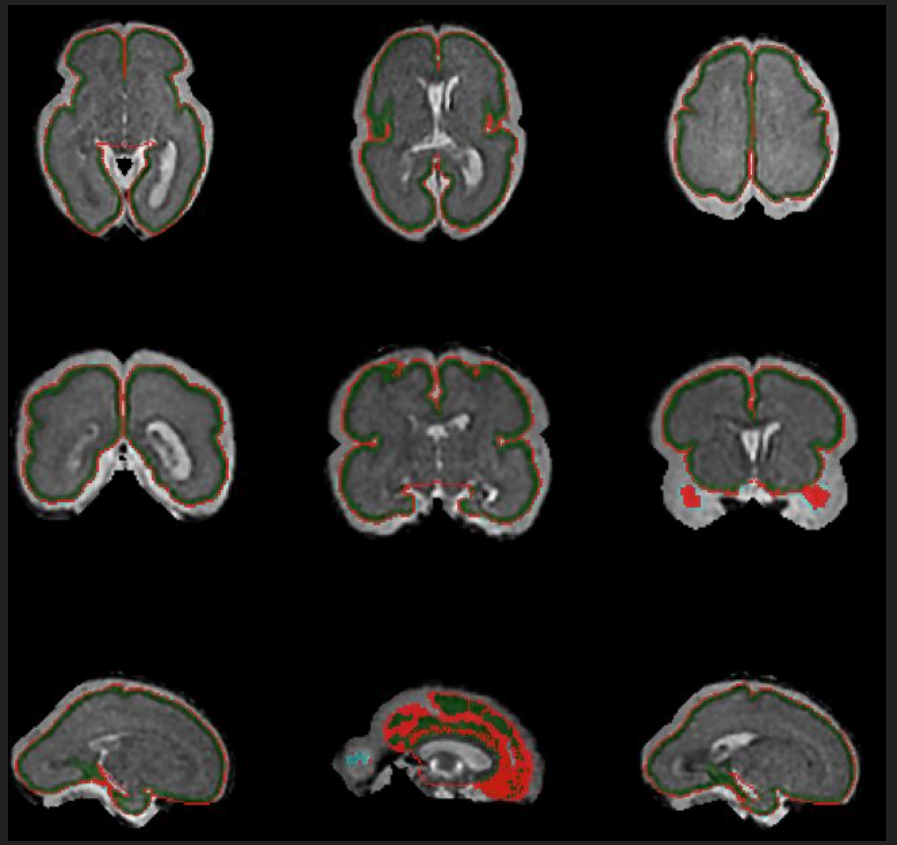
```
#### Get inner boundary.
${TARGET_DIR}/${CASE}/temp/ps2_csf.mnc (Red)
Red Inner Boundary:
${TARGET_DIR}/${CASE}/output/ps2.nii (Blue)
also called as:
${TARGET_DIR}/${CASE}/output/skeleton_output.mnc
```



Skeleton



Skeleton + Intensity Refinement

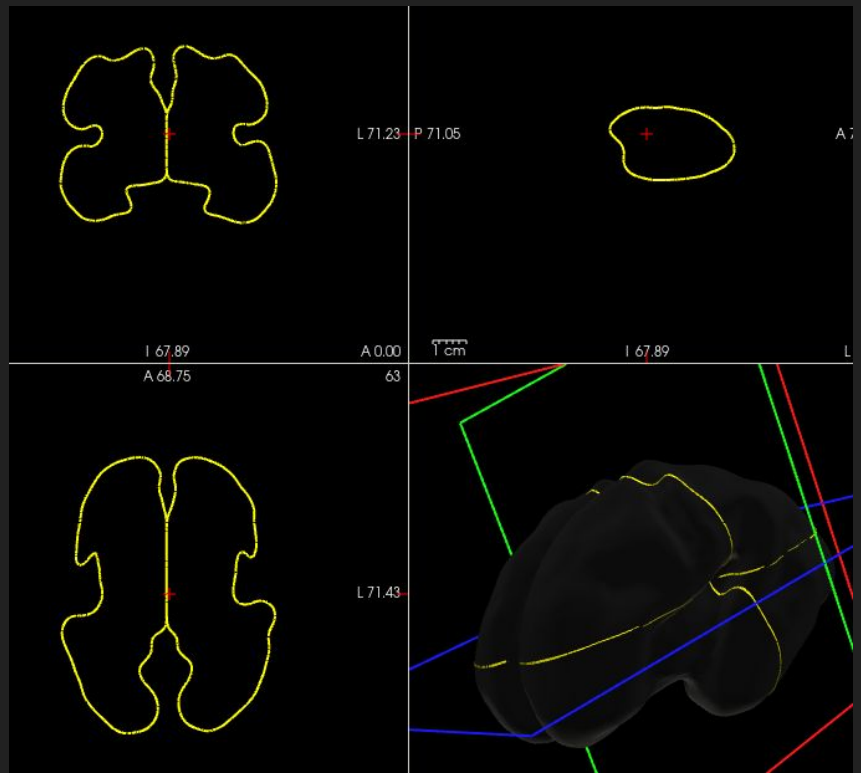


Code - Pipeline

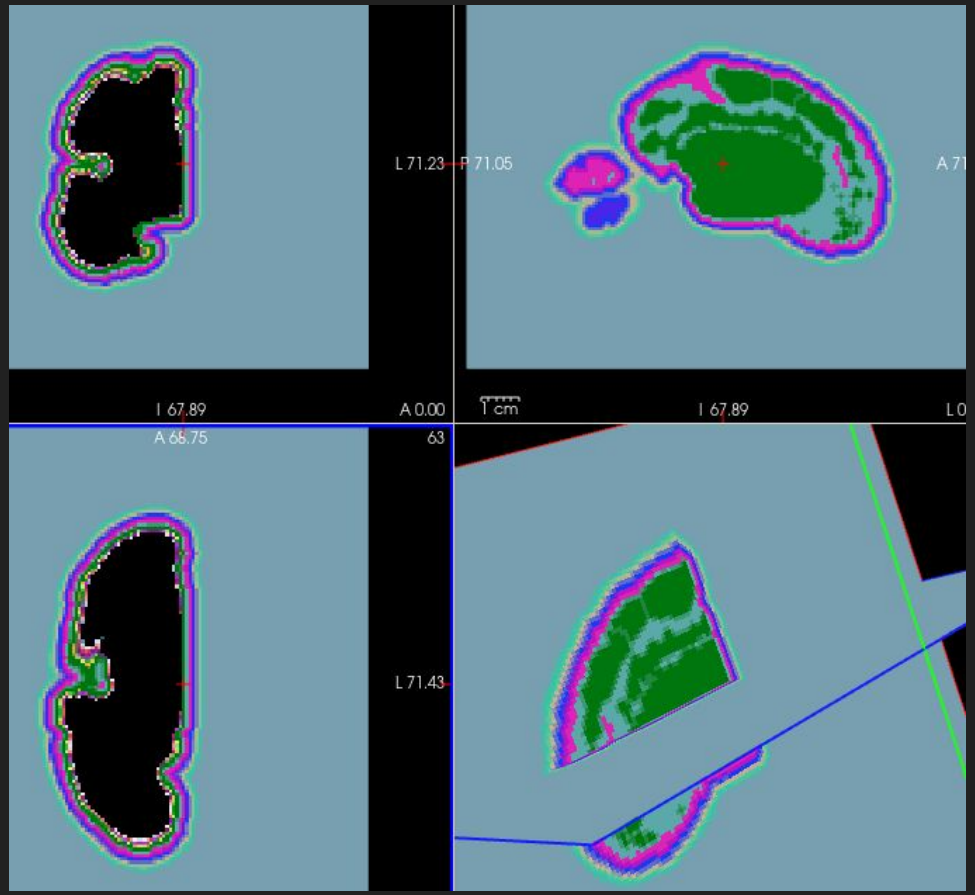
Surface Extraction

```
#### White Inner Extraction
${TARGET_DIR}/${CASE}/surfaces/lh.smoothwm.native.obj
${TARGET_DIR}/${CASE}/surfaces/lh.smoothwm.native.asc

${TARGET_DIR}/${CASE}/surfaces/rh.smoothwm.native.obj
${TARGET_DIR}/${CASE}/surfaces/rh.smoothwm.native.asc
```

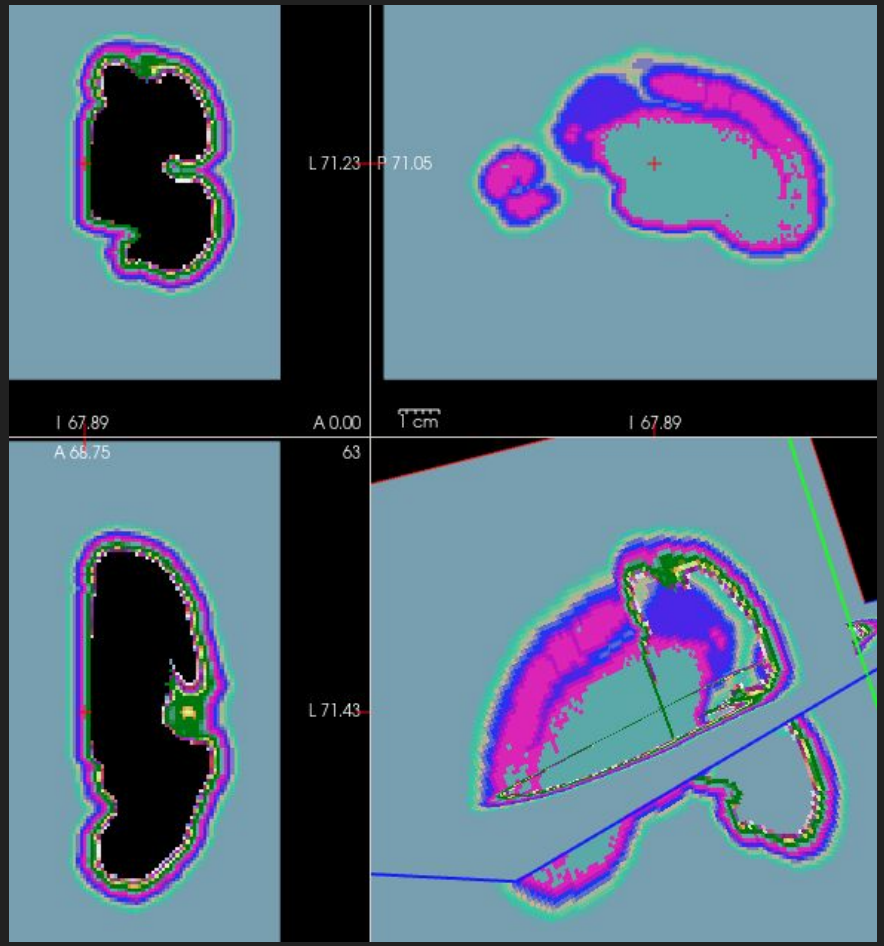


```
#### Generate Laplace Field for outer extraction.
${TARGET_DIR}/${CASE}/surfaces/laplacian_to31_left_fixed.mnc
```



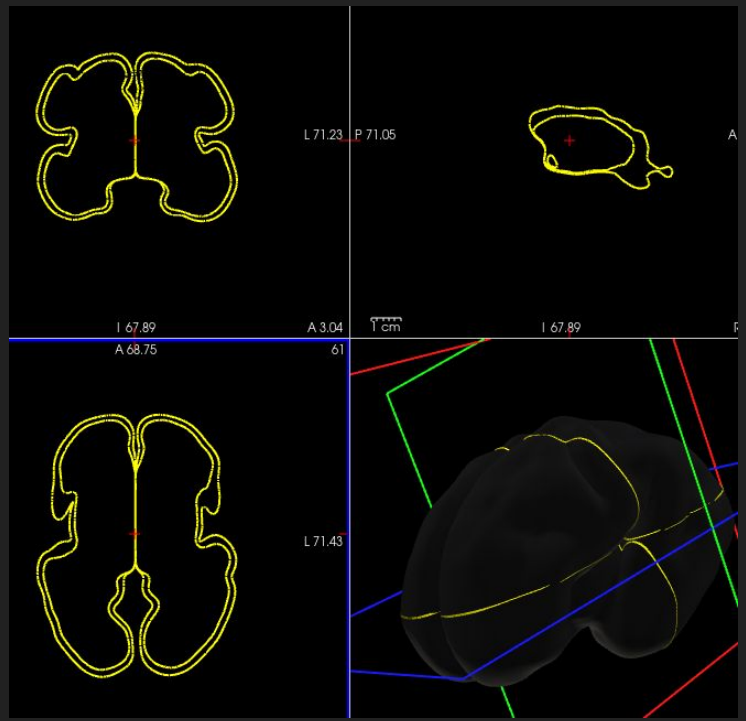
Generate Laplace Field for outer extraction.

${TARGET_DIR}/${CASE}/surfaces/laplacian_to31_right_fixed.mnc



```
# Expand White Matter till Laplace Field, CP Surface Extraction
${TARGET_DIR}/${CASE}/surfaces/lh.pial.native.obj
${TARGET_DIR}/${CASE}/surfaces/lh.pial.native.asc

${TARGET_DIR}/${CASE}/surfaces/rh.pial.native.obj
${TARGET_DIR}/${CASE}/surfaces/rh.pial.native.asc;
```

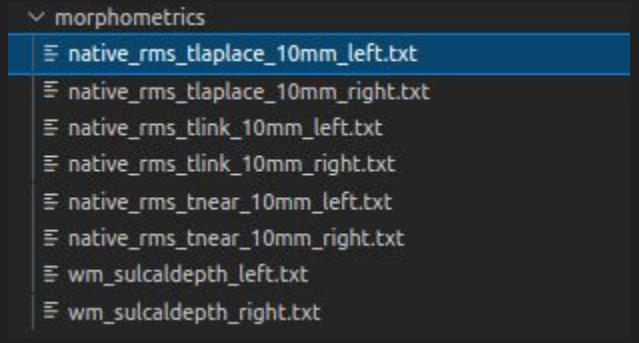


Code - Pipeline

Morphometrics Measurement

```
# Cortical Thickness Calculations with three methods (same as Mengting Pipeline) (3 .txt files per side generated.)
  -   tlink      use t-link method for thickness
  -   tnear      use t-near method for thickness
  -   tlaplace   use t-Laplace method for thickness
# Depth Potential Calculations. (1 .txt file per side generated.)

Results/FCB028/morphometrics/*
```



Format:

```
1   15.021
2   27.0097
3   28.6648
4   27.4705
5   47.6426
6   55.6526
7   46.3256
8   54.2754
9   28.0118
10  33.8271
11  32.9404
12  24.1953
13  22.9465
14  18.7177
15  10.2492
16  52.3813
17  39.4696
18  33.0017
19  36.0228
20  40.8147
21  18.3901
22  56.9144
23  36.5423
24  48.1512
25  26.8554
26  40.9527
27  25.3158
28  44.0519
29  39.5022
30  36.461
31  36.4782
32  34.0717
33  17.2389
34  23.7858
35  7.52124
36  43.3553
37  61.2423
38  46.7108
39  47.5814
40  32.8099
```