NA-MIC
National Alliance for Medical Image Computing
http://na-mic.org

Atlas/Label Fusion & Surface Registration

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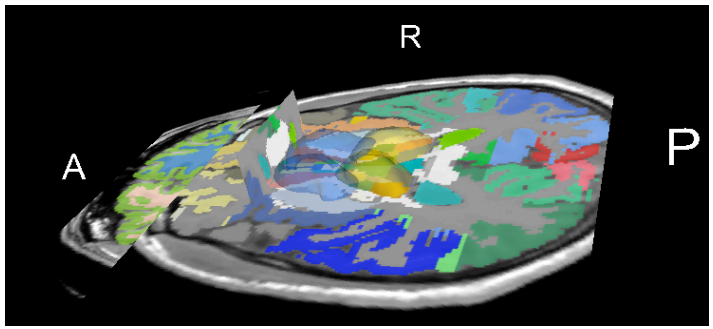
Learning Objective

In this tutorial you will learn about:

- grayscale images vs. labelmaps
- labelmaps vs. surface models
- thresholding
- registration

…..and the following methods:

- generate a surface model from a labelmap
- coregister two such models
- apply the transform to other objects



Overview

In this tutorial, we will perform the following:

- Building a surface model from a labelmap
- Visualizing the two models and their relative positions in space
- Co-registering surfaces
- Viewing result
- Applying result transform to labelmap image
- Saving your work

Pre-requisites

- this tutorial shows every step, but it helps if you're familiar with basic slicer functions, as taught in the "Slicer3Visualization Tutorial" by Sonia Pujol, Ph.D., found here:

  http://www.slicer.org/slicerWiki/index.php/Slicer3.6:Training

- You will need the tutorial dataset. If not yet downloaded and unzipped, please go to:

  http://na-mic.org/Wiki/index.php/Projects:RegistrationLibrary:RegLib_C11#Download

AtlasMergeTutorial_SlicerScene.mrml	Slicer Scene File to load
A0_gray.nrrd, A1_gray.nrrd	grayscale images of both atlases
A0_label.nrrd, A1_label.nrrd	labelmap images of both atlases

- You will need Slicer 3.6, if you have an older version, download a current one here:
  http://www.slicer.org/pages/Special:SlicerDownloads

Disclaimer: *It is the responsibility of the user of Slicer to comply with both the terms of the license and with the applicable laws, regulations, and rules.*

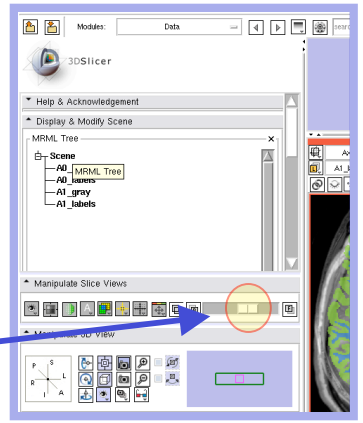
Platform

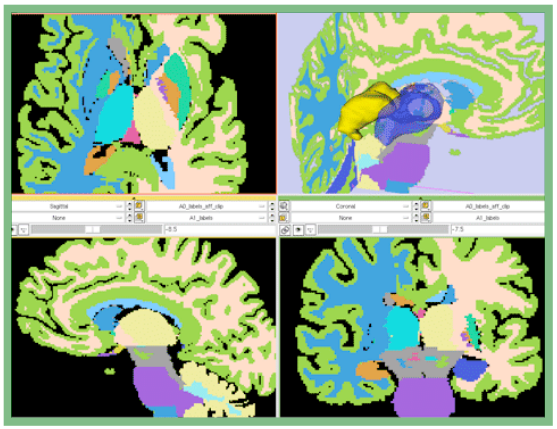
- This tutorial was developed and tested on a 64 bit linux computer and tested on an Intel MacBookPro.
- If you experience different performance on other platforms, please let us know:
  mailto: slicer-users@bwh.harvard.edu

Tutorial Format

A few layout explanations about the slides:

- we use screen snapshots with arrows and highlighted circles to indicate where to find buttons, menus etc.
- Figure borders, arrows and explanatory text will have a the same color to indicate what goes together.
- Some figures are animated gifs that must be viewed in Presentation mode. These figures have a caption underneath.
- when an icon is shown at the left margin of the slide, it indicates what module or button the explained actions belong to. For most icons this is also the shortcut button in the main Slicer toolbar that takes you to the corresponding module.





animated gif, view in presentation mode

Introduction / Scenario

We have two anatomic atlases, obtained from two separate individuals by expert radiologist tracing. We refer to them as A0 (“old atlas”) and A1 (“new atlas”)

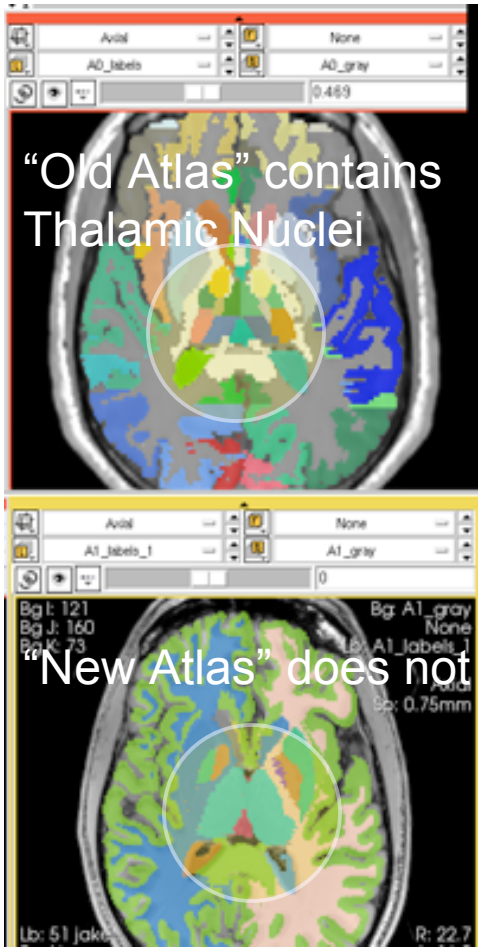
The “old atlas” A0 contains labels for 25 thalamic nuclei and substructures that are not present in the “new atlas” A1.

We want to transfer these labels from A0 -> A1, i.e. obtain a best possible estimate about the thalamic nuclei in A1 based on the information in A0

To this end we co-register the two atlases such that the thalamus of both align as good as possible. Then we merge the two label maps.

Because the two atlases hail from different individuals, no perfect alignment can be expected.

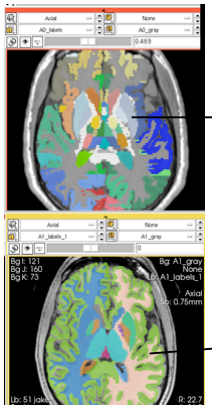
Because we’re interested only in the thalamus, we seek optimal alignment there and do not care much about the rest of the brain.



Strategy Overview

use merged volume to mask out all other labels

To accomplish this task we will follow the following plan:



Merge all labels of thalamic nuclei into a single label.

Build Surface Model

Merge all labels of left & right thalamus into a single label.

Build Surface Model

Automated Surface Registration

Apply registration transform to old atlas image.

Apply registration transform to merged thalamus mask image.

mask transformed labelmap with thalamus mask.

Merge transformed labelmap with new atlas.

Modules used…

Load Scene…

Add Data…

Threshold Image

Editor: Change Island

Model Maker

Models

Surface Registration

Resample Scalar Image

Mask Image

Image Label Combine

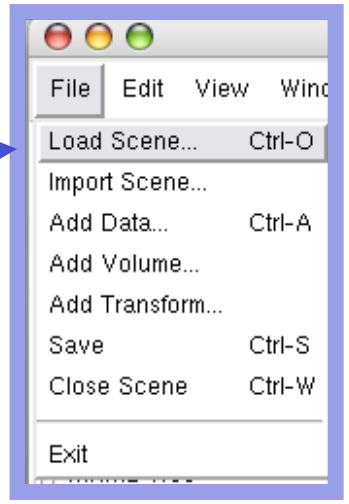
Save…

Loading Example Dataset

1. To get the Example Dataset loaded into Slicer:

File

2. Menu: File: Load Scene…



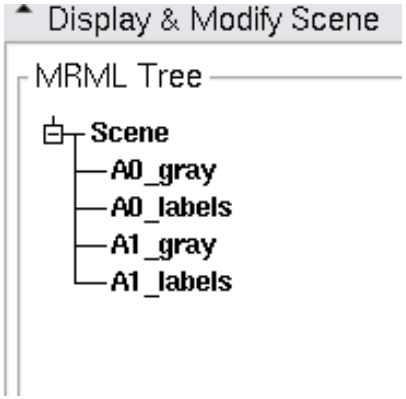
Select the Slicer Scene file that comes with the downloaded example dataset, called: AtlasMerge_SlicerScene.mrml

This will load all the necessary images. It will also set the views as explained below. If you wish to retrace how to set up the views, perform the steps below:

3. Review Loaded Content: next slide

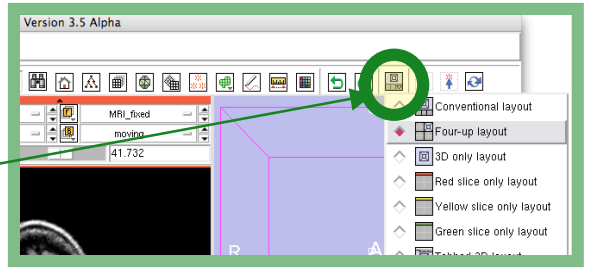
Review Loaded Content

1. To get a quick overview of what was loaded with the scene, go to the “Data” module.
2. You will see the “MRML” *(speak “Murrmul”)* tree that shows all loaded data content.
3. In this case we have 4 images loaded, 2 grayscale atlases A0_gray and A1_gray, and two associated labelmaps A0_label and A1_label.
4. The difference between a labelmap and a grayscale image is within slicer and found as a checkbox in the “Info” tab of the “Volumes” module.

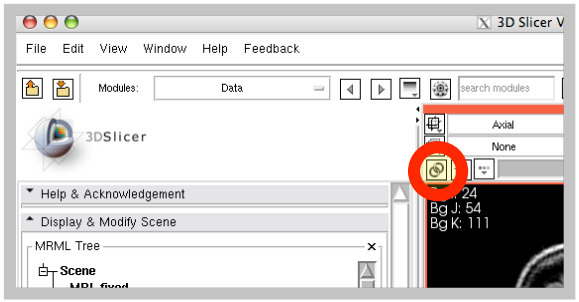


Adjust Views

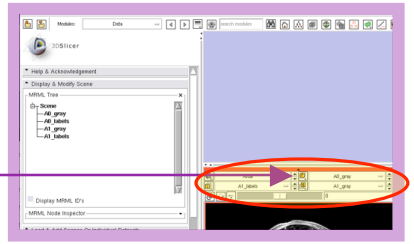
1. Select Layout: From the icon bar, click on the Layout menu and select “Conventional Layout”.



2. Link Views: Click on the Ring Icon in any of the slice views to link all the views together. This will save you the work of making selections for each slice window separately.



3. Choose Background: A1_gray:
note Slicer chooses the field of view based on the background image. Thus if you have two images of different spatial extent, place the larger in the background to see them both.



4. Choose Foreground: A0_gray

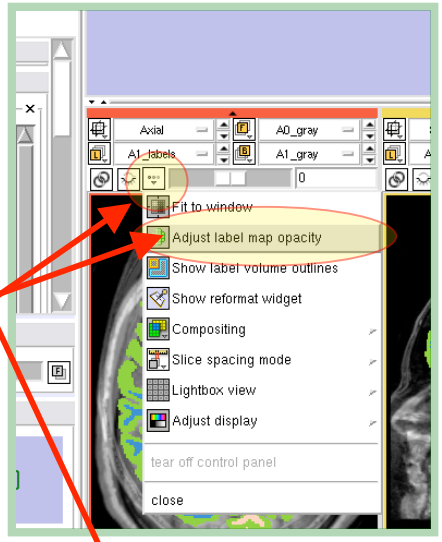
5. Choose Labelmap: A1_labels

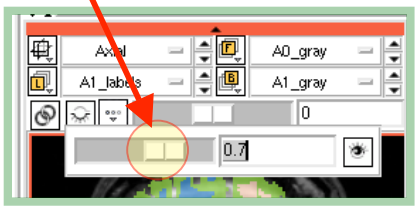
Adjust Views (2)

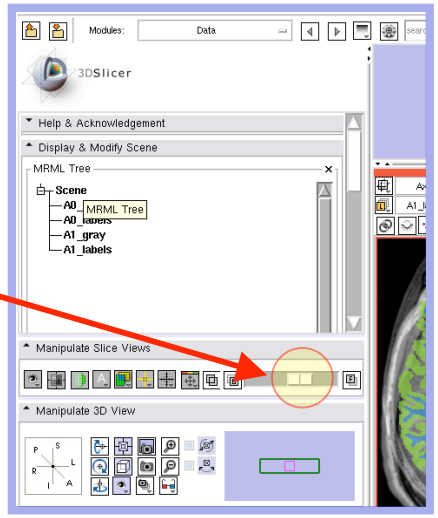
To get an idea of the initial data and misalignment, perform the following to see both datasets in one image:

1. Adjust the labelmap opacity to see both the grayscale image and the labelmap.Set the slider to about 0.7

2. Set Visibility Slider to halfway between foreground and background. This allows you to see both atlases. You can see the initial misalignment.



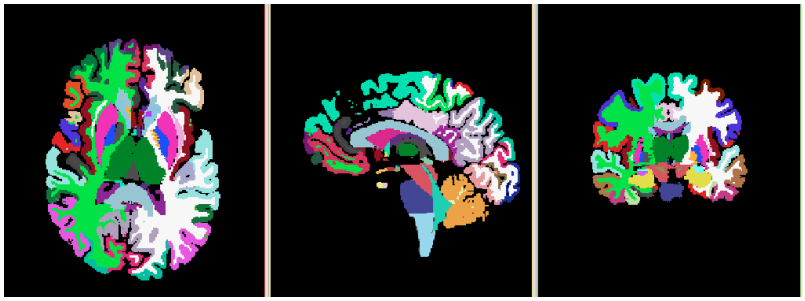




Assigning a Colormap

A labelmap contains discrete values that are assigned to a text label and a color. This is commonly stored in a color table (also referred to as LookUp Table or LUT). This assignment of the labelmap volume to a color table was already stored in the scene you loaded.

If you newly load or create a labelmap you need to perform this assignment manually. That is done in the “Display” tab of the “Volumes” module.



You can find more information about such LUTs in this tutorial:

http://www.slicer.org/slicerWiki/images/c/c9/3DDataLoadingAndVisualization_Slicer3.6_SoniaPujol.pdf

Build Thalamus Mask

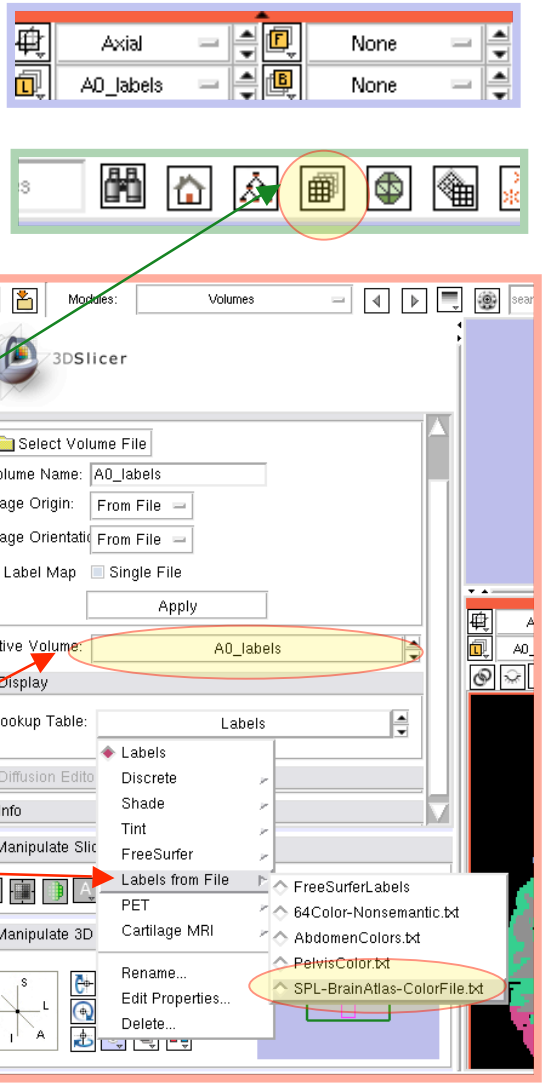
The old atlas A0 contains only 1 label for the entire thalamus. The new atlas A1 defines the thalamus as a set of nuclei. For registration we need two models of the entire thalamus. Hence we must first merge the labels of all the nuclei in A1:

1. Turn off all display other than A0_labels, i.e. select “None” for fore- & background.

2. The current colormap shows all nuclei labels as green. To see the individual structures, we select a new colormap: Go to the Volumes Module.

3. As “Active Volume” select “A0_labels”

4. Under “Lookup Table”, select “Labels From File” and “SPL-BrainAtlas-ColorFile.txt”



Build Thalamus Mask (2)

5. Via the right mouse button, zoom in. You should see the individual nuclei. If you hover the mouse over each, the label and number are displayed under "Lb: "

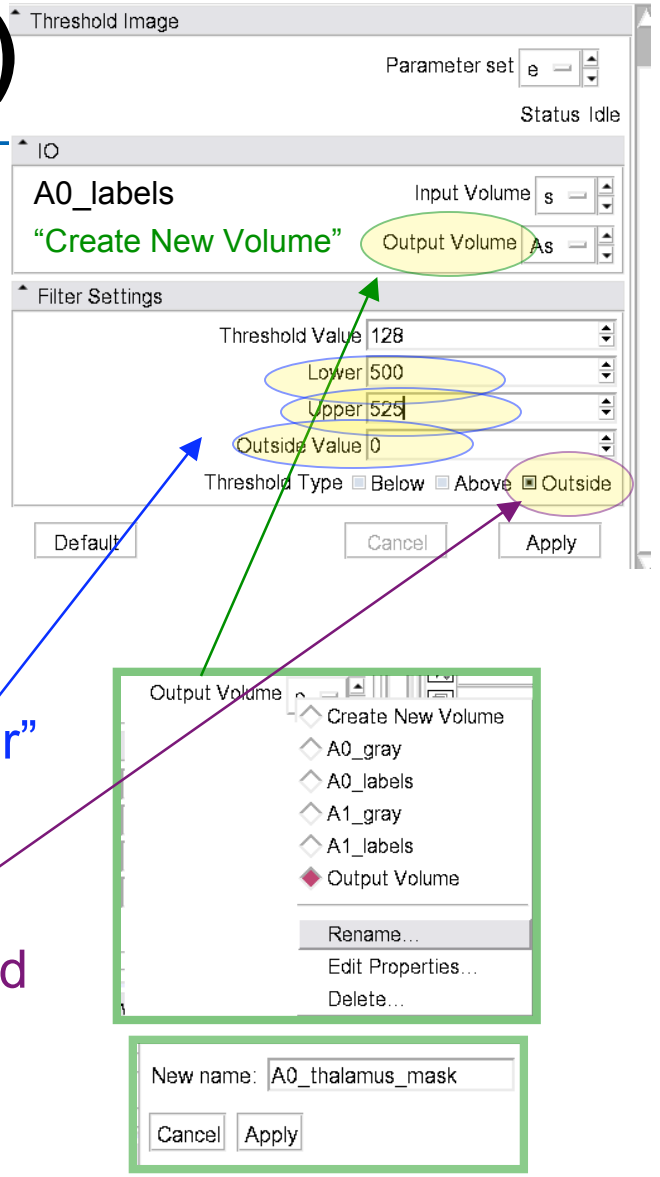
6. All thalamic structures have labels from 500-525. We use this to merge them into a single mask volume.

Build Thalamus Mask (3)

Here we show how to extract labels via the Threshold module. There are other alternatives we'll discuss later. The key advantage of this approach is that we can operate on the label image directly and merge all labels in two steps:
1. set all values outside of the thalamus label range to zero
2. Set all values inside the thalamus label range to 1

Modules: Threshold Image

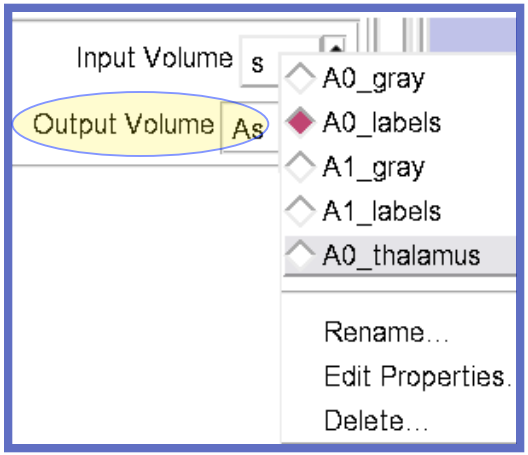
7. Go to the "Threshold Image" module
8. For Input Volume, select "A0_labels"
9. For Output Volume, select "New Volume", then rename that to "A0_thalamus_mask"
10. Set the "Lower" threshold to 500, the "Upper" to 525, and the "Outside" value to 0.
11. select the "Outside" checkbox. This will preserve all values in the range 500-525 and will set everything else to zero.
12. Click Apply.



Thalamus Mask (4)

When switching your axial view to the newly created “A0_thalamus_mask” you should see something like the image on the right.

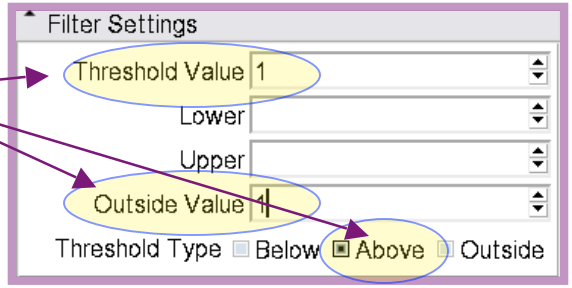
Now we set all values **inside** the thalamus label range to 1:
Do not forget to switch the input volume for this operation!



13. For Input Volume, select “A0_thalamus_mask”

14. For Output Volume, leave “A0_thalamus_mask”

15. Set the “Threshold Value” to 1 and “Output Value” to 1. (the “Upper” and “Lower” entries do not matter at this point.)



16. Click Apply. The volume “A0_thalamus_mask” should change from its previous look (top) to a solid color as shown on the right.

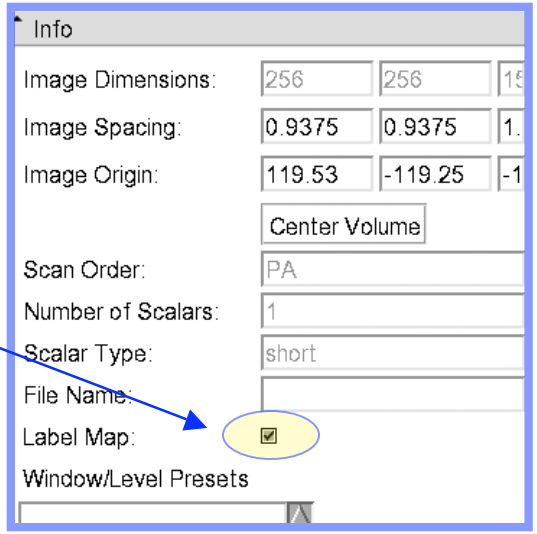
Threshold Image

Modules:

Thalamus Mask (5)

We now have a mask for the thalamus. Last step is to turn it into a labelmap:

17. Go to the “Volumes” module. Select “A0_thalamus_mask” for active volume, then in the “Info” tab, check the box for “Labelmap”

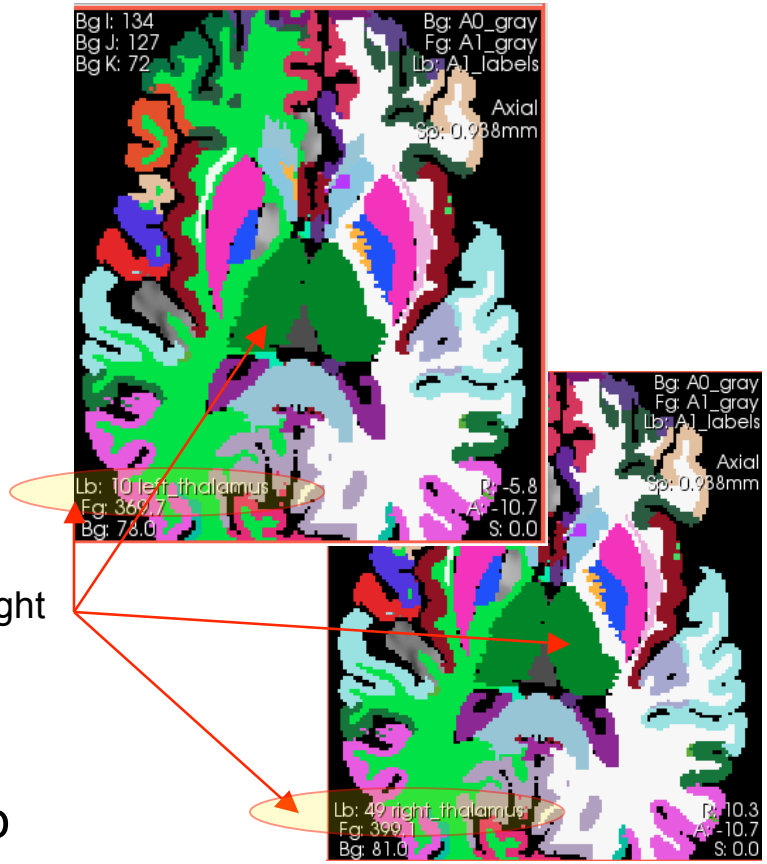


Merge labels in 2nd Atlas

The new atlas has just 2 labels for the thalamus: one for left and right side, respectively. Since we want a model for the entire thalamus, we merge the two.

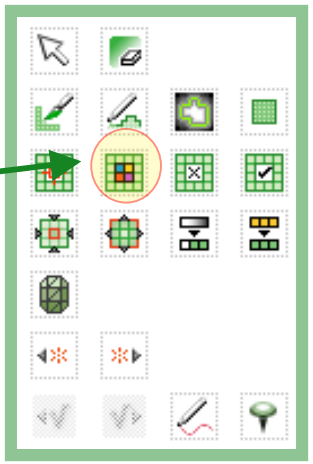
We could do this in the same fashion as before, but because we only change 1 label, we use a faster alternative: the “Change Island” tool in the Editor:

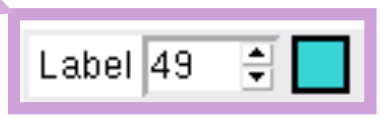
1. Go to the “Editor” module
2. As “Active”, select “A1_labels”
3. Move the cursor over the thalamus region (in green). When over the left and right thalamus, the values 49 and 10, respectively, and label names are displayed at the bottom. Now we know the label values to change.
4. We choose to change all label 10 to label 49:
5. In the label field, type/select the value 49.

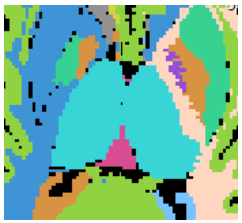


Change labels…

1. From the Editor tool palette, choose the "Change Island" tool. 
2. In the Label field, enter the value 49
3. Move the mouse over the left thalamus, make sure you see the label 10 displayed.
4. Click the left mouse button in the area. This will change all labels connected to the place you clicked to the value 49.
5. If you now move the mouse over the thalamus, it will always show the same name & label.





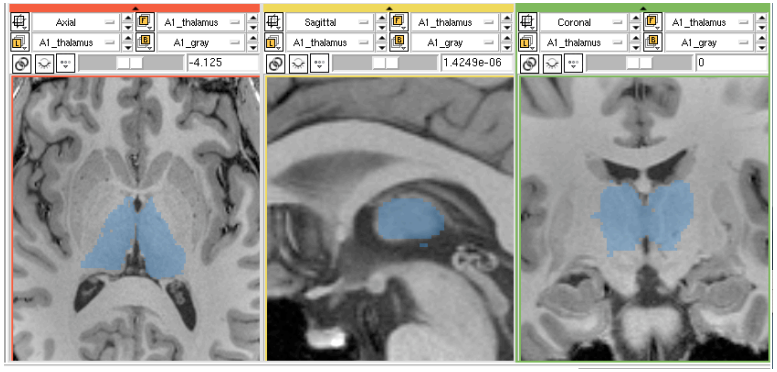


Build Mask for New Atlas (2)

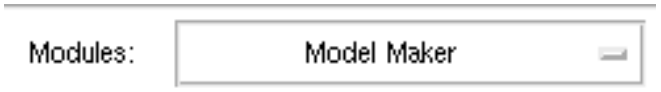
Now we repeat the thresholding in slide 16 to extract only label 49.

We now have label volumes for the thalamus in both atlases.

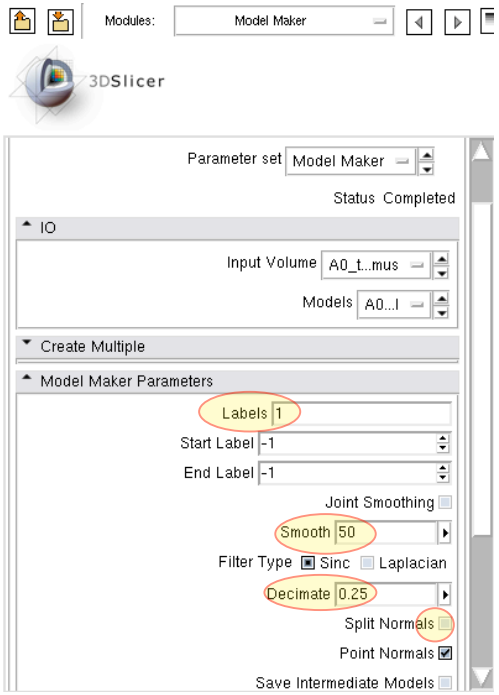
Next we build models for both.

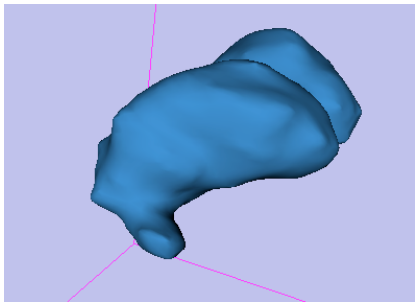


Build Thalamus Models

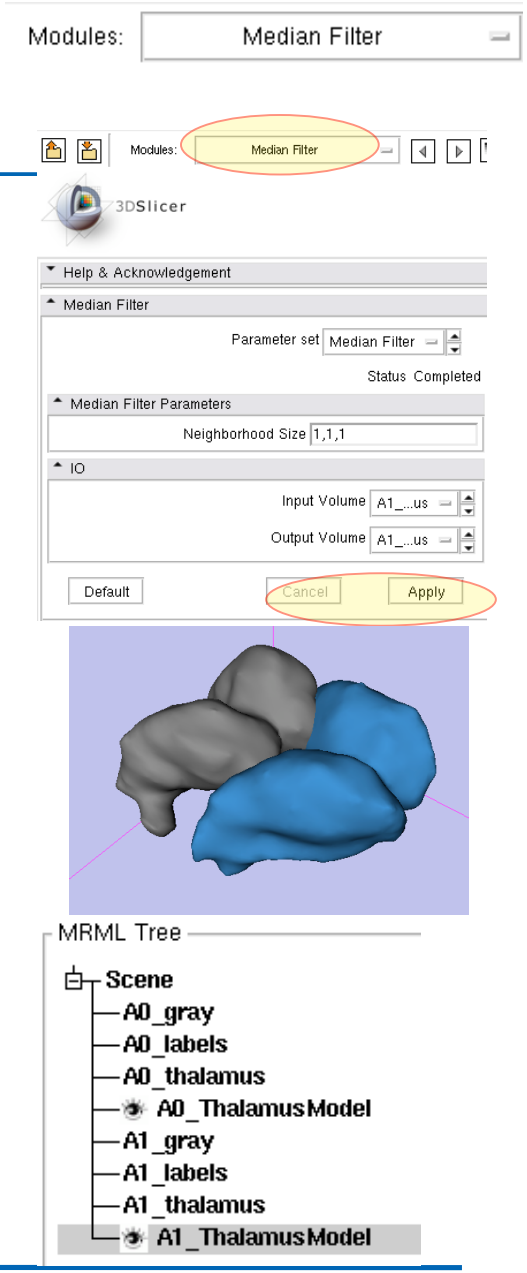


1. Go to the “Model Maker” Module (under Surface Models).
2. For “Input Volume”, select “A0_thalamus”
3. For “Models”, select “Create New Model Hierarchy”, then select “Rename” and enter “A0_ThalamusModel”
4. In the “Labels” field, enter 1.
5. Set the “Smooth” iterations field to 50
6. Leave the “Decimate” field at the default of 0.25
7. Turn off “Split Normals” checkbox
8. Click “Apply”
9. After a few seconds of processing, you should see a model appear in the 3D view.





Build Thalamus Models (2)

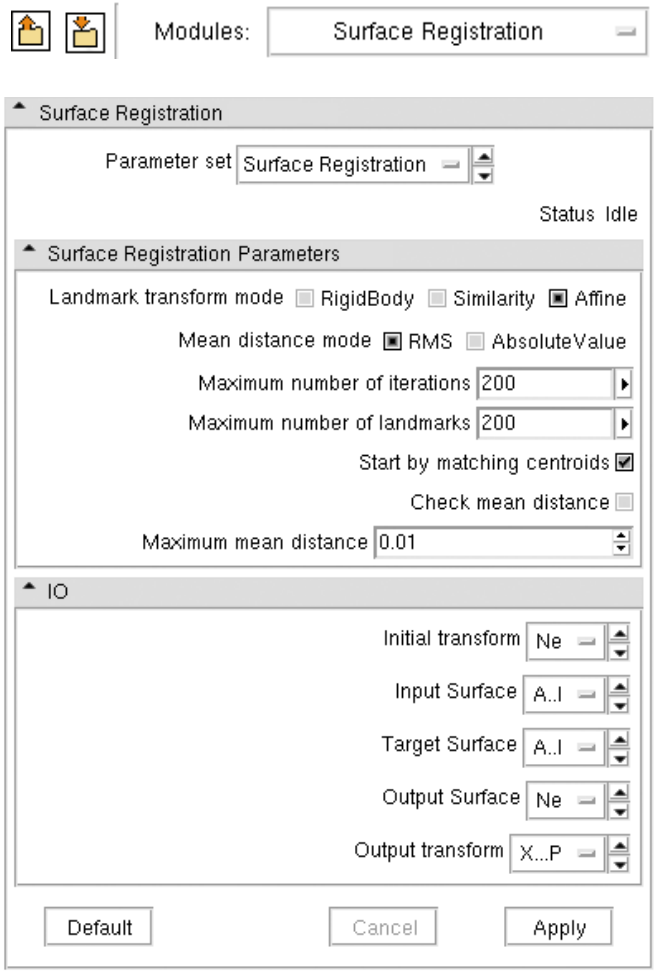


Modules: Median Filter

10. Before we build the second model, we apply some morphological cleanup to the second labelmap: Go to “Filtering / Denoising / MedianFilter” module. Select “A1_thalamus” as both input and output, leave defaults and click apply. The jagged edges at the surface will disappear.
11. We now Repeat the steps 1-9 on the previous slide for the second atlas, i.e. create “A1_ThalamusModel” from the “A1_thalamus” volume.
12. You should now have 2 models for each atlas, as seen on the right.

Register Thalamus Model Surfaces

1. Go to the “Surface Registration” module
2. Select “Affine” and “RMS” and “Start by matching centroids”
3. For “maximum number of iterations” and “landmarks”, set 200 each.
4. Input Surface: A0_ThalamusModel
   Target Surface: A1_ThalamusModel
5. Output transform: “Create New Linear Transform”, then select “Rename” and rename to “Xform_A0affine_ICP”
6. Click “Apply”.



Register Thalamus Model Surfaces (2)

1. Go to the “Data” module

2. Select the node “A0_ThalamusModel” and drag it on top of the “Xform_A0affine_ICP” node

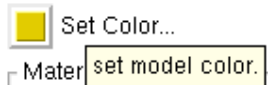
3. Click in the 3D view to force a redraw. You should now see the two models on top of each other.

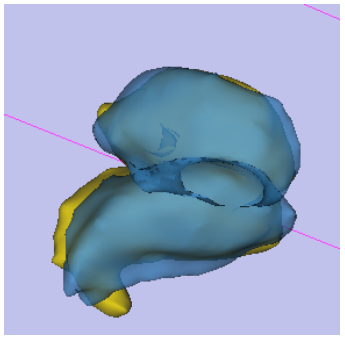
4. Go to the “Models” volume.

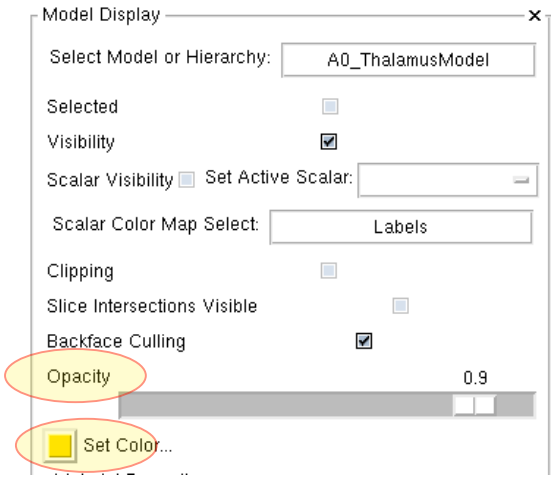
5. Select “A0_ThalamusMode” from the menu, click on the “Set Color” button and change color to yellow.

6. Set the opacity slider to 0.9

7. Select “A1_ThalamusModel” and set the opacity to 0.7

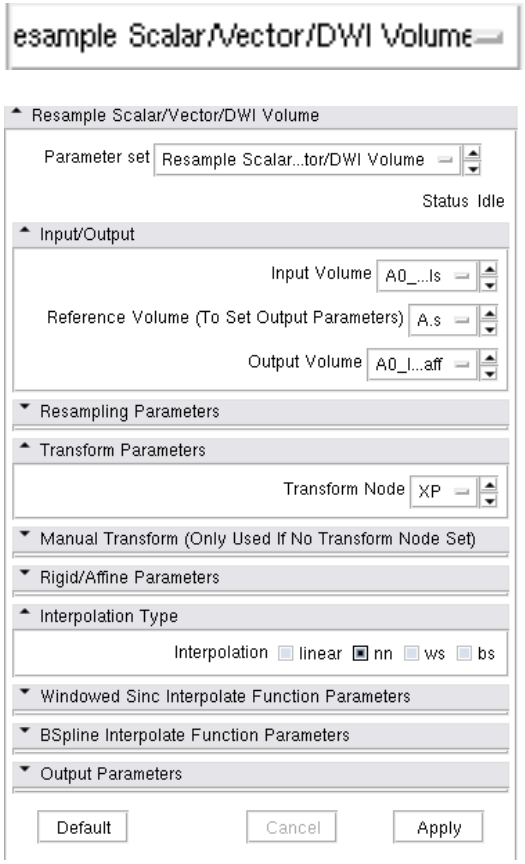






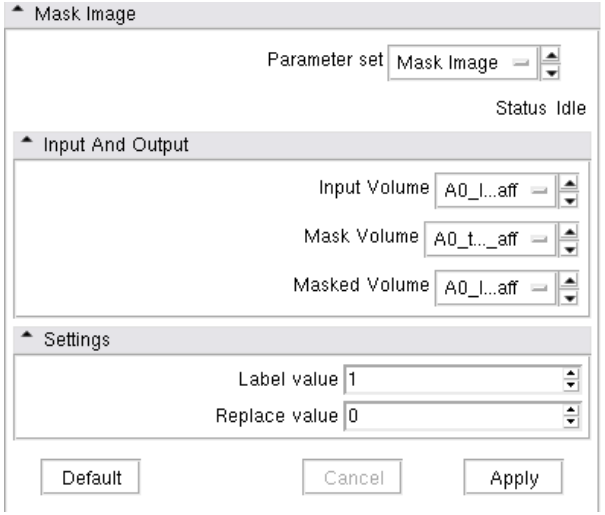
Apply Registration to LabelMap

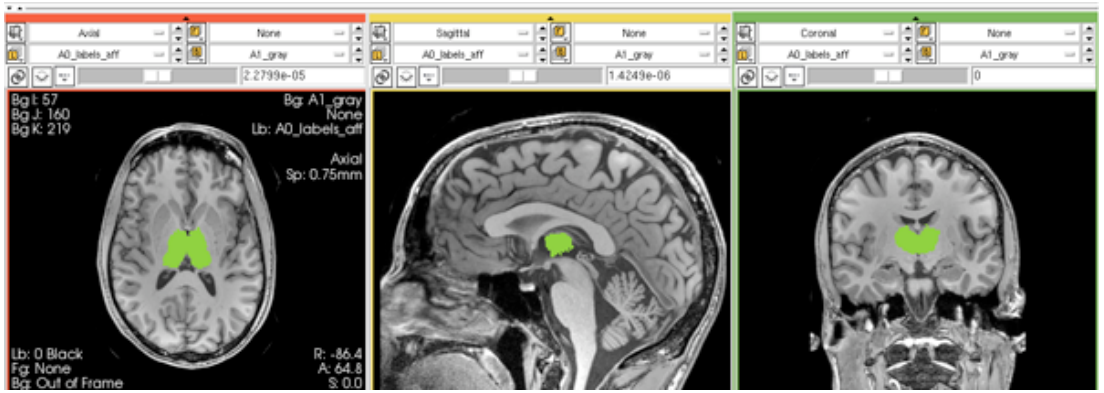
1. Go to the “Resample Scalar/Vector/DWI Volume” module
2. Input Volume : “A0_labels”
   Reference Volume : “A1_labels”
   Output Volume : “Create New Volume”, rename to “A0_labels_aff”
3. Transform Node: “Xform_A0Affine_ICP”
4. Interpolation Type: “nn”
5. Click “Apply”.
6. Repeat for the “A0_Thalamus” volume, i.e. create a new “A0_Thalamus_aff”
7. Go to the “Volumes” module, select the newly created “A0_labels_aff” and “A0_thalamus_aff”, then check the “Labelmap” box.



Mask New Labelmap

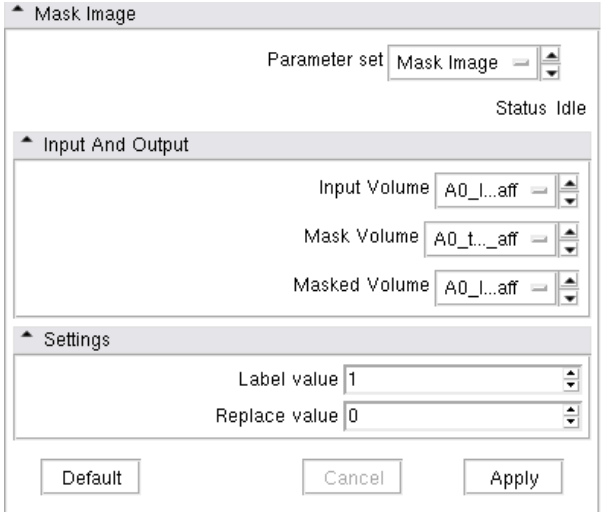
1. From the new labelmap we want to keep only the thalamic structures:
2. Go to “Mask Image” module
3. Input Volume: “A0_labels_aff”
   Mask Volume: “A0_thalamus_aff”
   Masked Volume: “A0_labels aff”
   (Note we overwrite the volume with the masked one, if you get an error at this step you need to repeat the previous resampling step)
4. Click “Apply”.





Mask New LabelMap (2)

Finally we mask again with the thalamus of the new (target) atlas. This is to prevent replacing labels other than the thalamus in places where the registered volume extends beyond the target. In other words we clip off anything “sticking out” beyond the boundaries of the A1 thalamus:

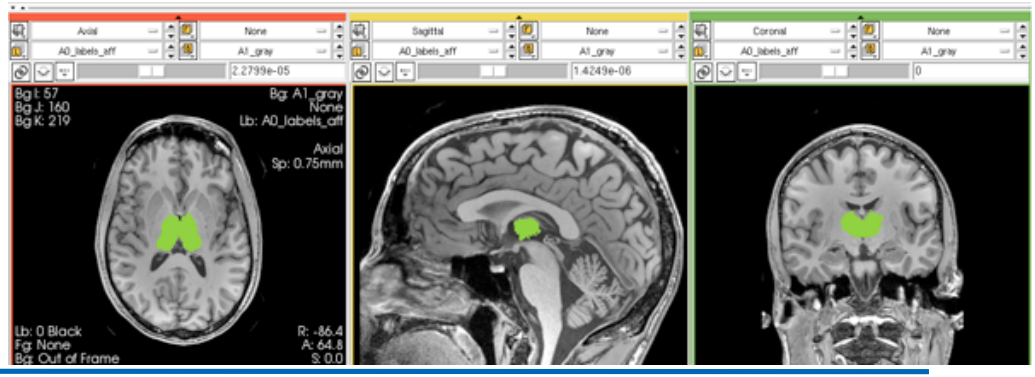


Modules: Mask Image

1. Go to the “Mask Image” module

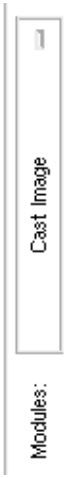
2. Input Volume: “A0_labels_aff”
   Mask Volume: “A1_thalamus_aff”
   Masked Volume: “Create New Volume”, rename to “A0_labels aff_clip”

3. Click “Apply”.

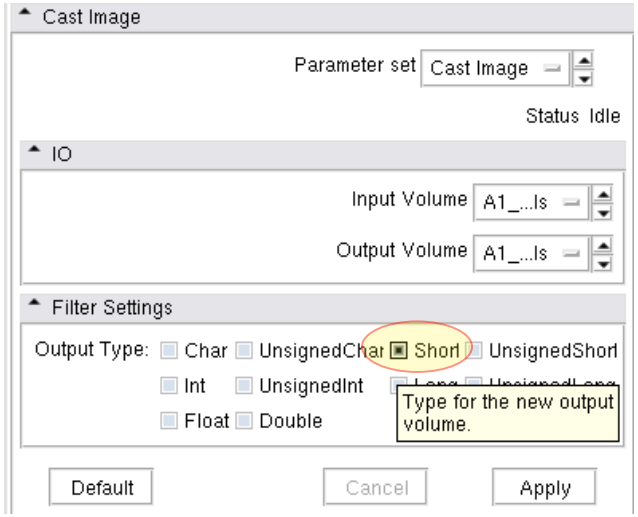


Type Cast Atlas Labelmap

Some labelmaps can have different datatypes, which can cause problems when merging. To ensure both volumes to be merged have the same datatype we check the info in the “Volumes” module. To change we use the “Cast Volume” module”:

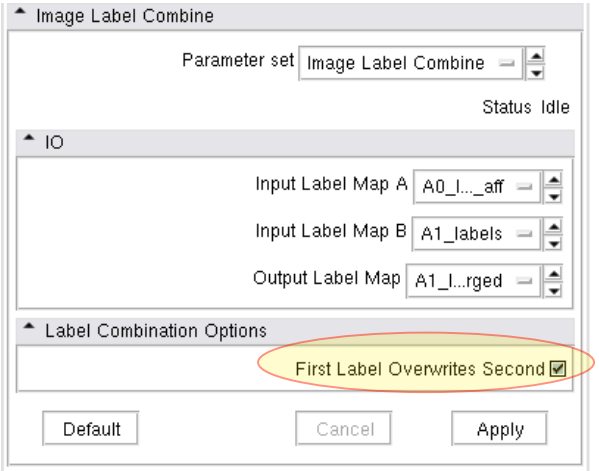


1. Go to the “Cast Image” module
2. Input Volume: “A1_label”
   Output Volume: “A1_label”
   Output Type: “short”
3. Click Apply



Merge Labelmaps

1. Last step is to transfer the Thalamic Nuclei labels into the A1 labelmap.



2. Go to the “Image Label Combine” module

3. Input Label Map A: “A0_label_aff_clip”
   Input Label Map B: “A1_labels”
   Output Label Map: “Create New Volume”, rename to “A1_labels_merged”

4. Check box: First label overwrites second.

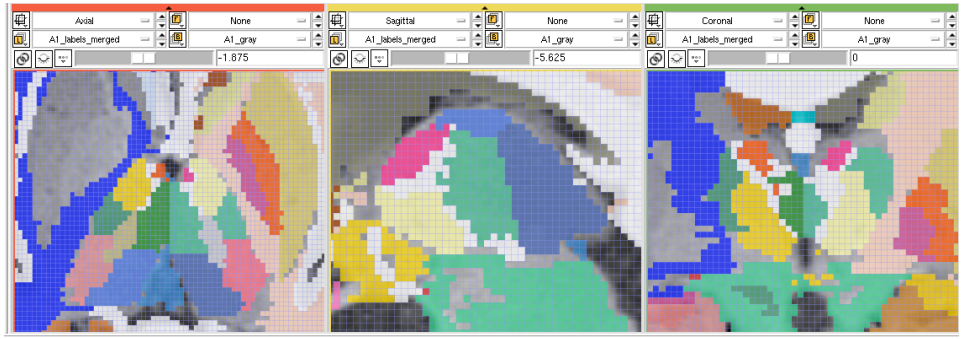
5. Click Apply

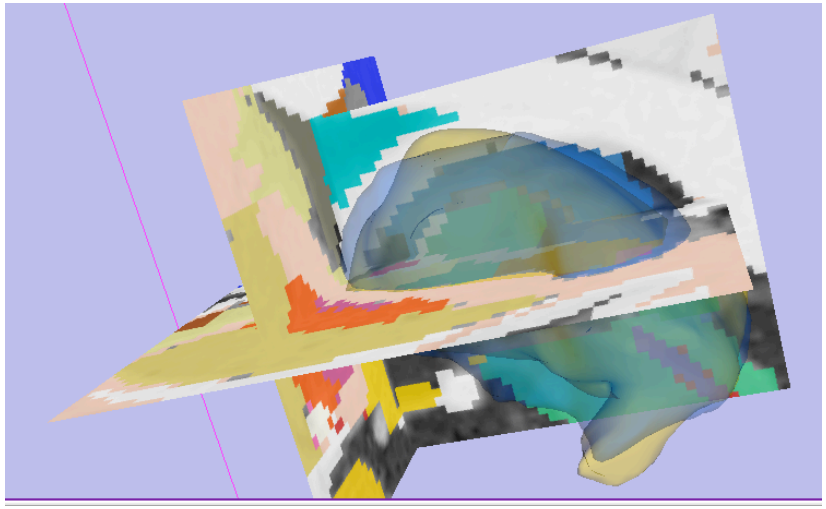
6. Go To “Volumes” module, select the new “A1_labels_merged” and check the “Labelmap” box.

View Result

1. Go to the “Volumes” module, select “A1_label_merged”. Under “Display”, select a new colormap: “Labels from File / SPL-BrainAtlas-2009-ColorFile.txt”
2. In the slice view, select “A1_gray” for for background, “A1_labels_merged” for labelmap.
3. Set the labelmap opacity to ~0.7

Lookup Table: SPL-BrainAtlas-2009-ColorFile





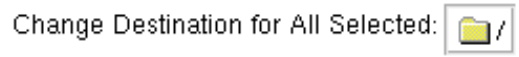
Save

Select “Save” from the File Menu.

Check all boxes except the original input images
“A0_gray”, “A0_labels” etc.

Create a new output directory, and select it via the
“Change Destination For All Selected” button.

click “Save Selected”.



What Next

Try the Manual Registration Tutorial or one of the tutorials from the Registration Case Library.

http://www.slicer.org/slicerWiki/index.php/Slicer3.6:Training

http://na-mic.org/Wiki/index.php/Projects:RegistrationDocumentation:UseCaseInventory

http://www.slicer.org/slicerWiki/index.php/Slicer3:Registration#Registration_in_3D_Slicer|Main

Feedback: anything amiss? If you have suggestions on how we can improve this and other documentation, please let us know: visit:

http://na-mic.org/Wiki/index.php/Projects:RegistrationDocumentation

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