Slicer3 Training Tutorial

Centerline Extraction of Coronary Arteries in 3D Slicer using VMTK based Tools

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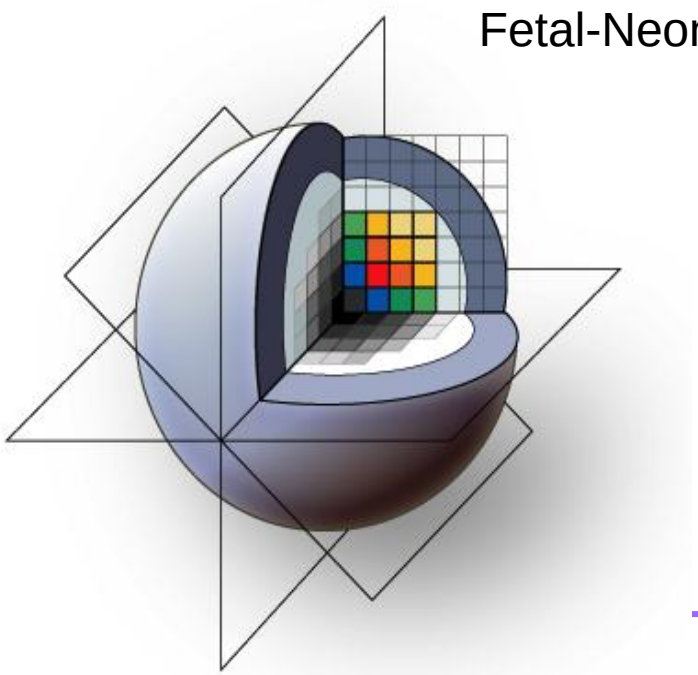

Updated for Slicer3 Version 3.6 by:

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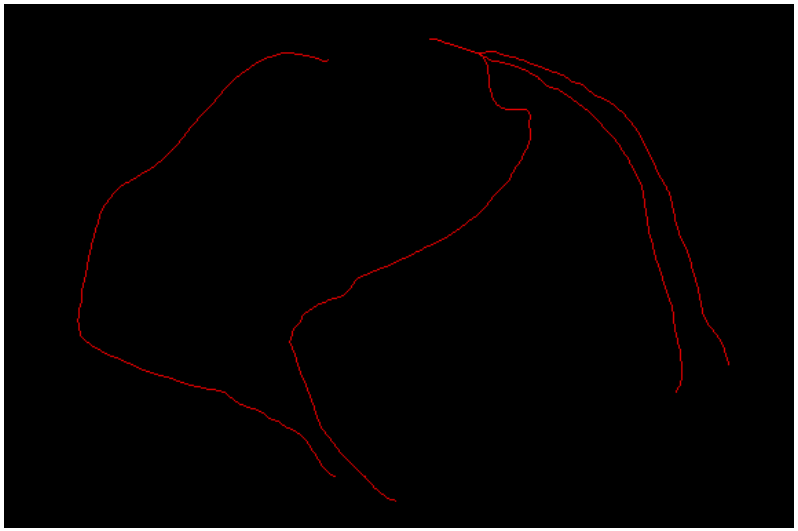
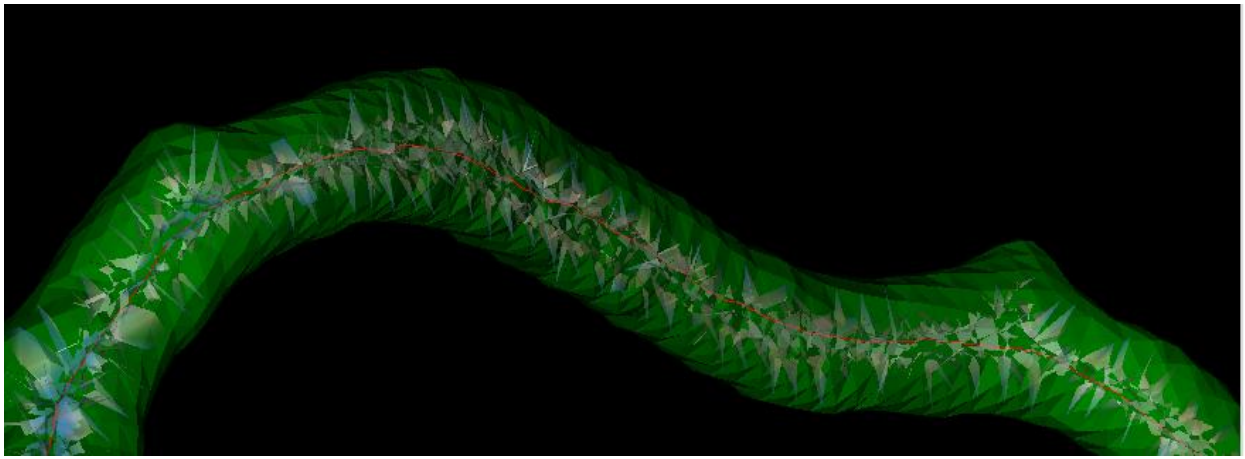
Modeling and Simulations Engineer
Open Source Medical Software Corporation

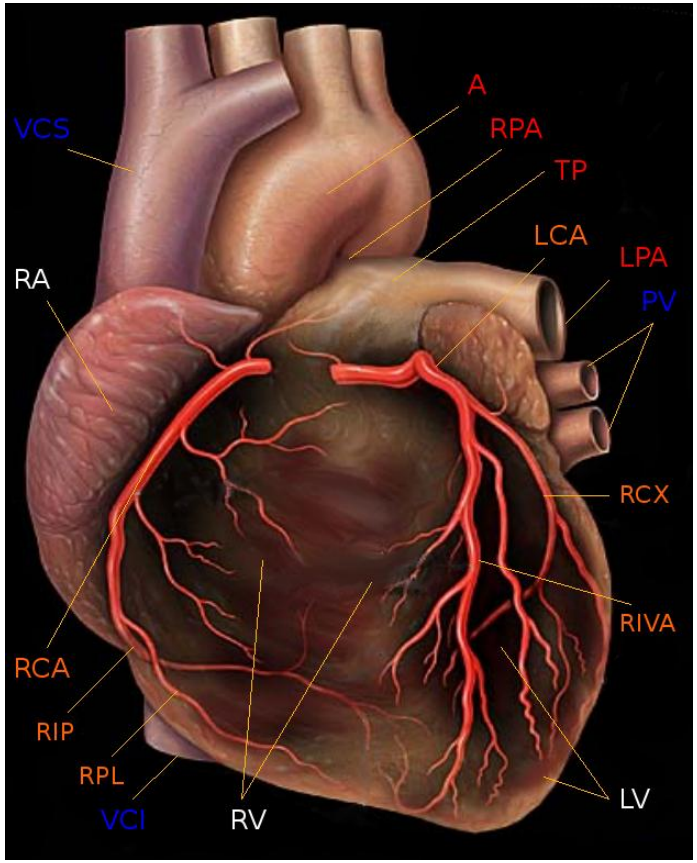
Learning Objective



Guiding you step by step through the process of centerline extraction of Coronary Arteries in a cardiac blood-pool MRI using VMTK based Tools.



Background



Human Heart with Coronaries, Author: Patrick J. Lynch (1999), Creative Commons License

Coronary heart disease (CHD) is the leading cause of death in high-income countries and one of the main causes of death worldwide*.

The primary cause for CHD is atherosclerosis of the coronary arteries and is called coronary artery disease (CAD).

The extraction of the central lumen line (centerline) of coronary arteries is helpful for visualization purposes, stenosis quantification or further processing steps.

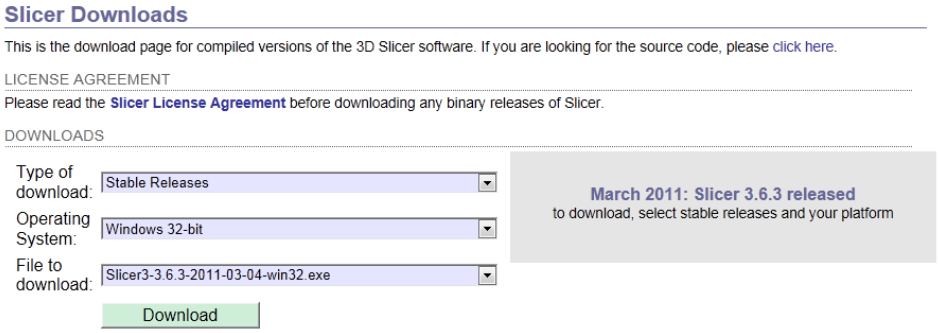
* WHO Fact Sheet 310: http://www.who.int/mediacentre/factsheets/fs310/en/index.html

Materials

This tutorial requires the installation of the **Slicer3** software and the tutorial dataset. They are available at the following locations:

- **Slicer3** download page (***Slicer 3-3.6.3-2011-03-04-win32.exe***)

http://slicer.org/pages/Special:SlicerDownloads



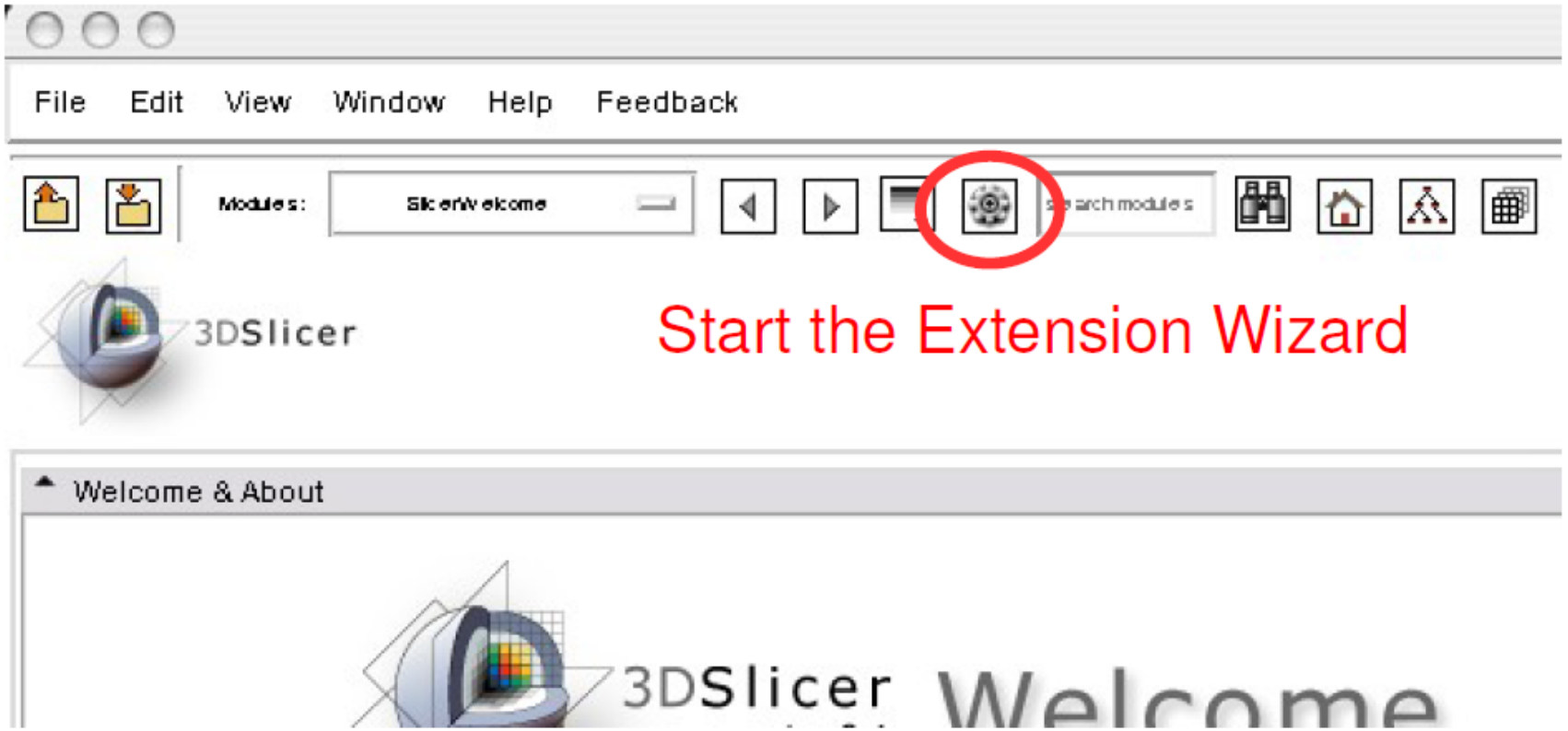
- **Tutorial MRI data** (3 files)

http://www.na-mic.org/Wiki/index.php/File:TutorialVMTKCoronariesCenterlinesMRI_Data_Winter2010AHM.zip

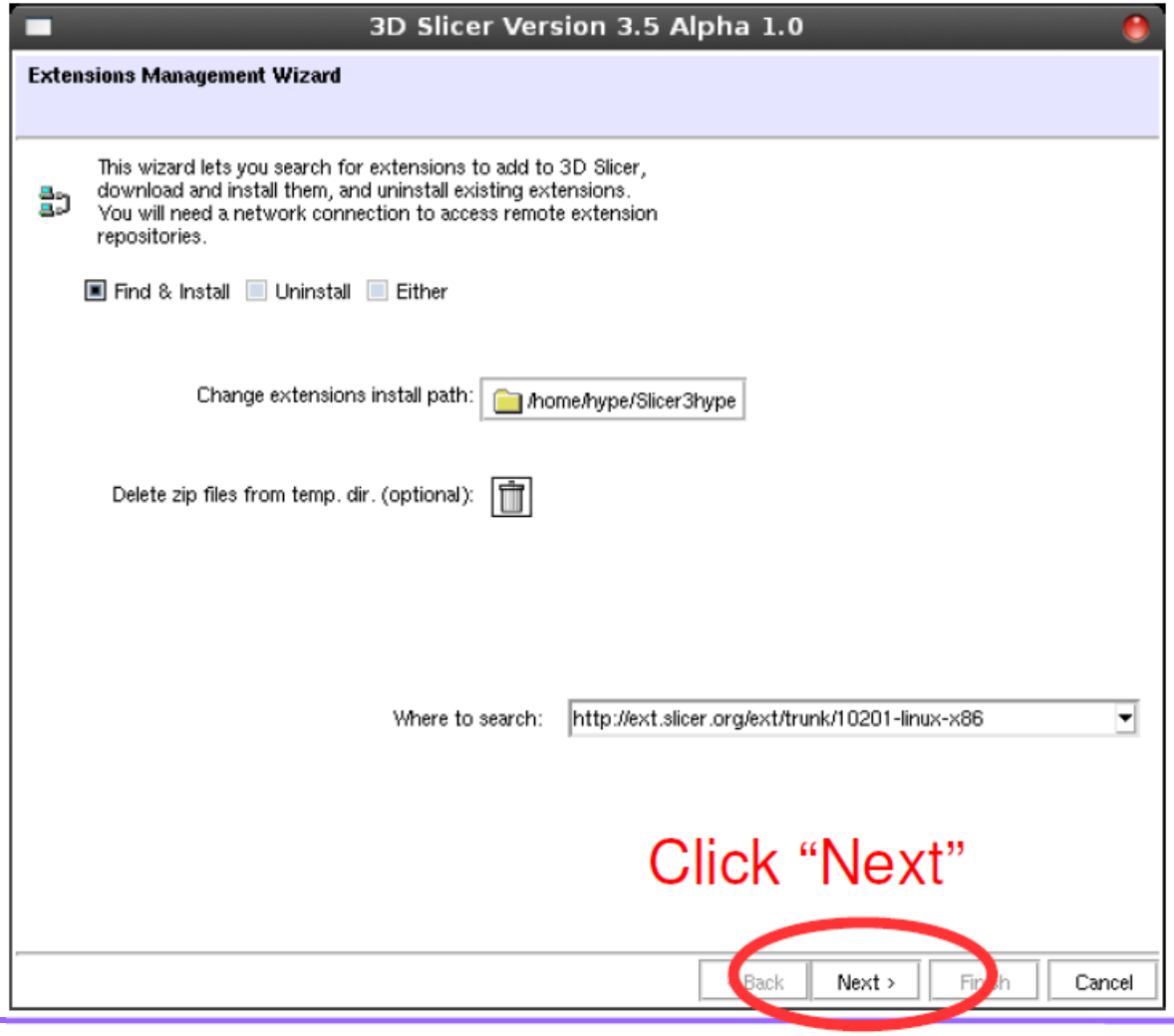
Disclaimer: *It is the responsibility of the user of Slicer to comply with both the terms of the license and with the applicable laws, regulations, and rules.*

Overview

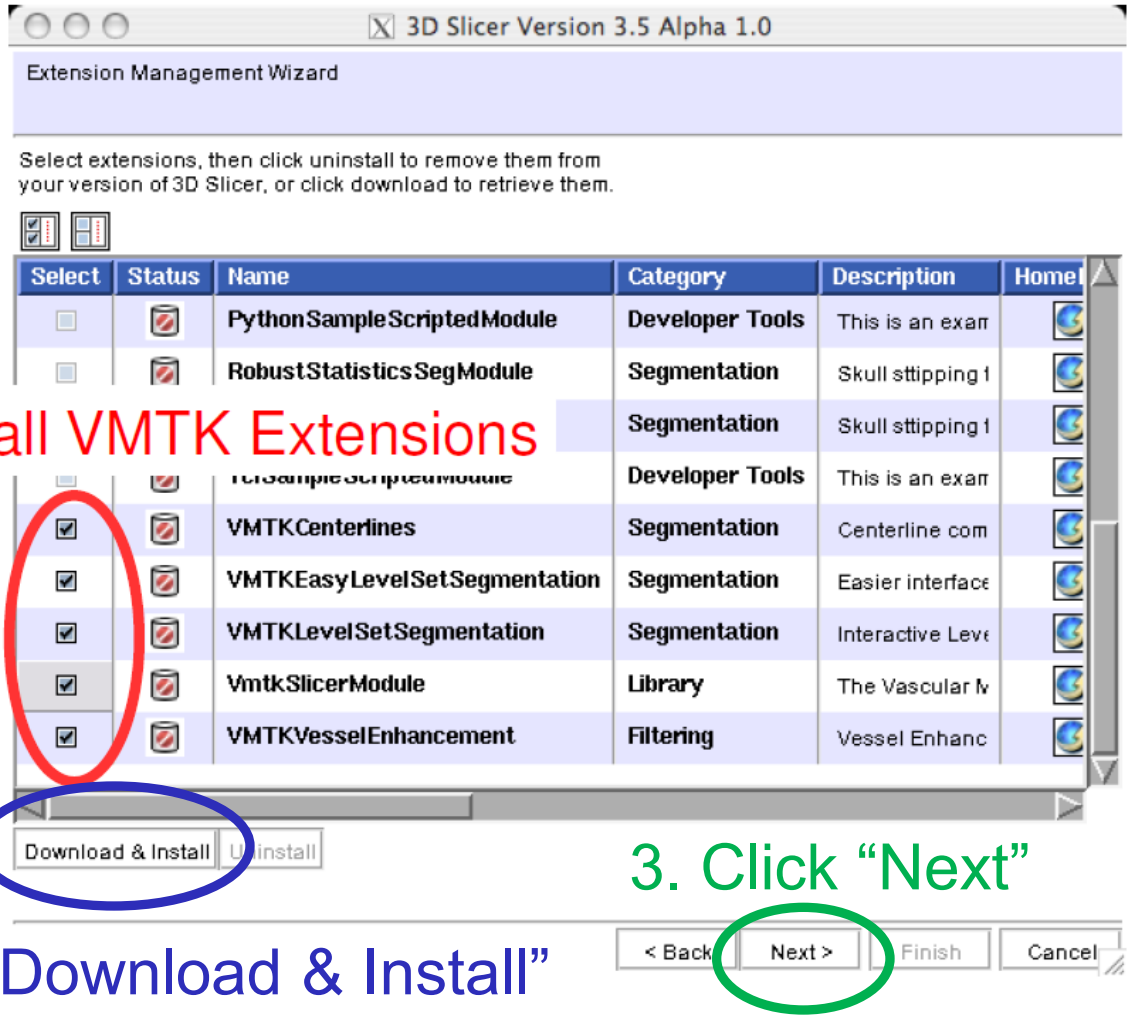
Installing VMTK in 3D Slicer



Installing VMTK in 3D Slicer



Installing VMTK in 3D Slicer

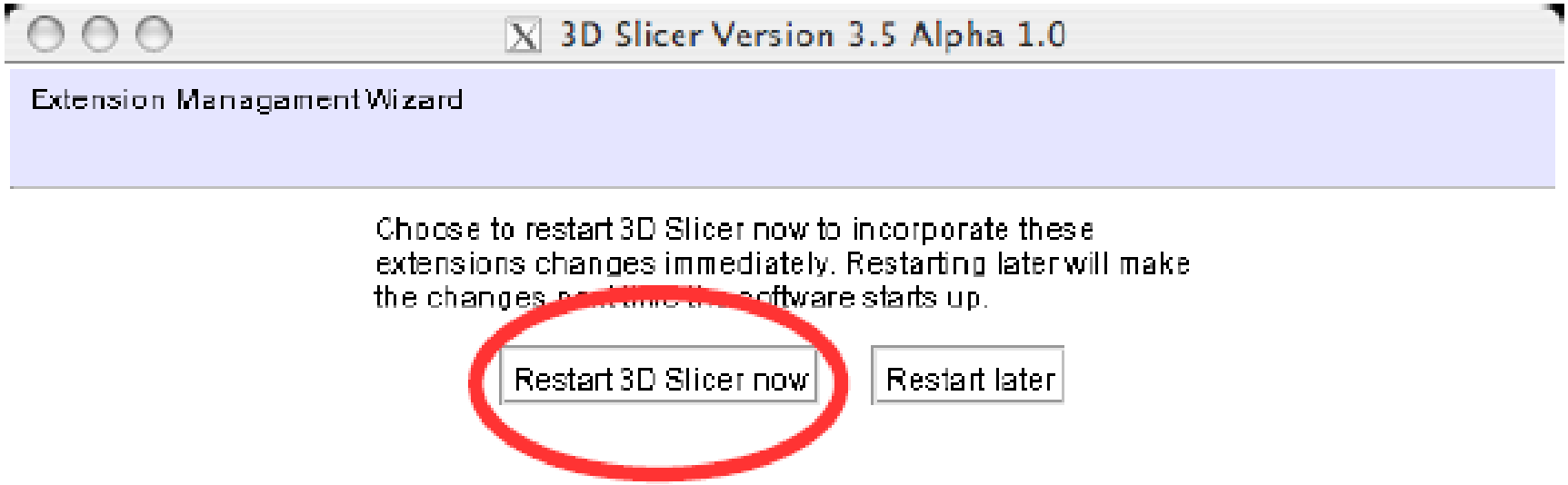


1. Select all VMTK Extensions

2. Click “Download & Install”

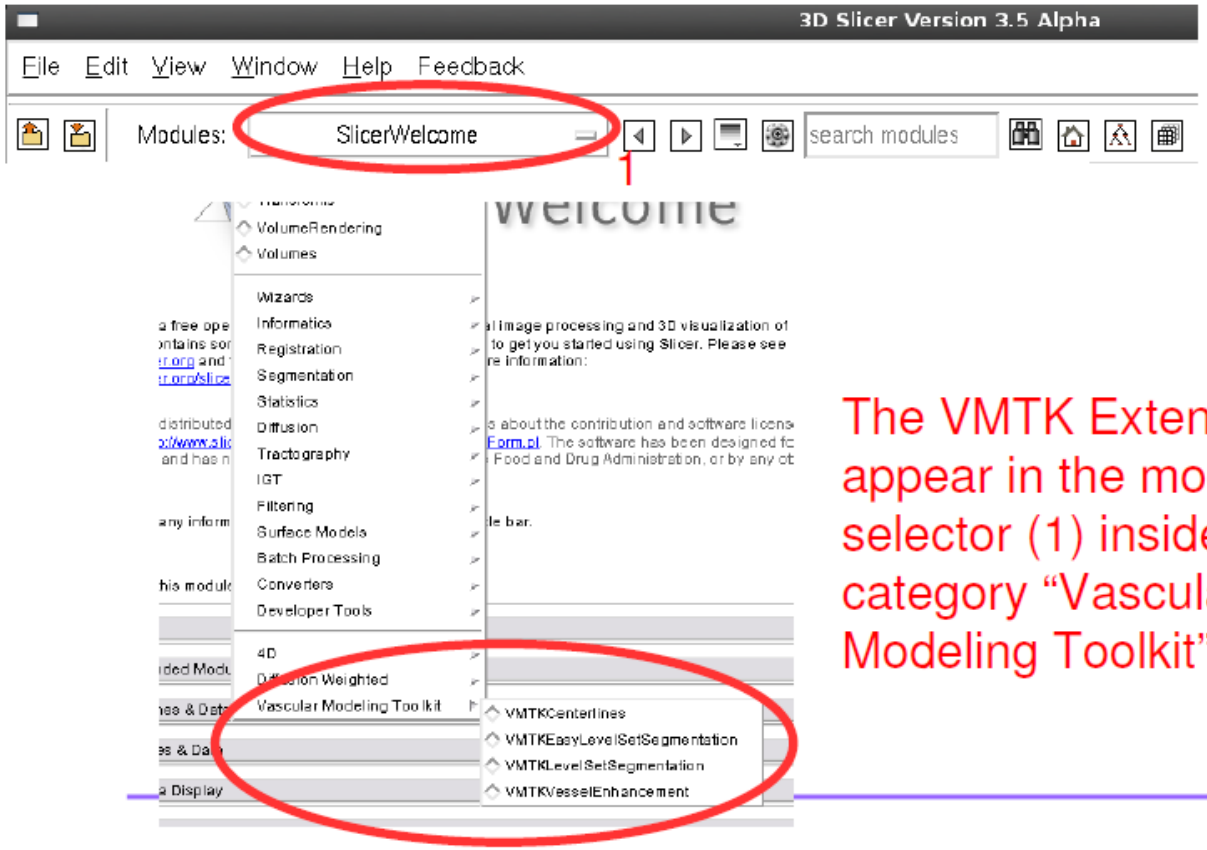
3. Click “Next”

Installing VMTK in 3D Slicer



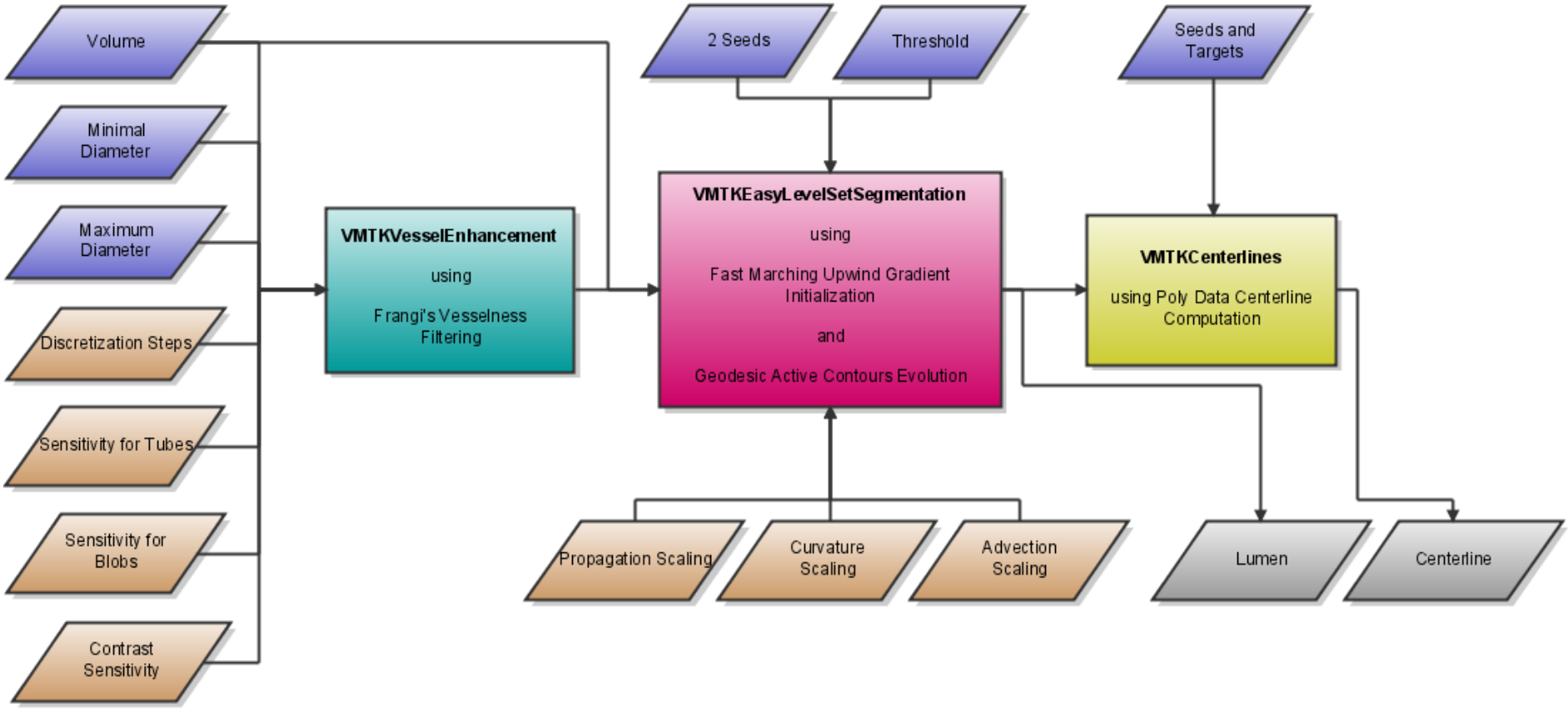
Restart 3D Slicer

Installing VMTK in 3D Slicer

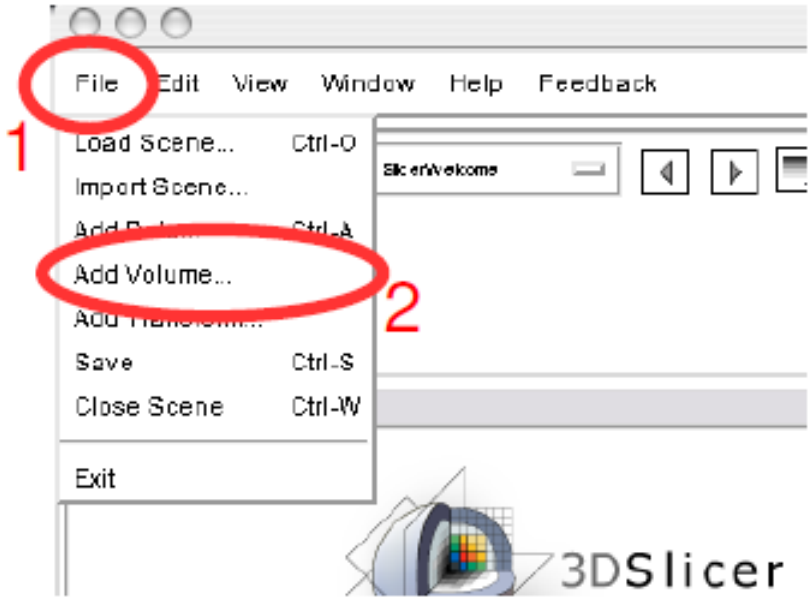


The VMTK Extensions appear in the modules selector (1) inside the category “Vascular Modeling Toolkit”

The Pipeline

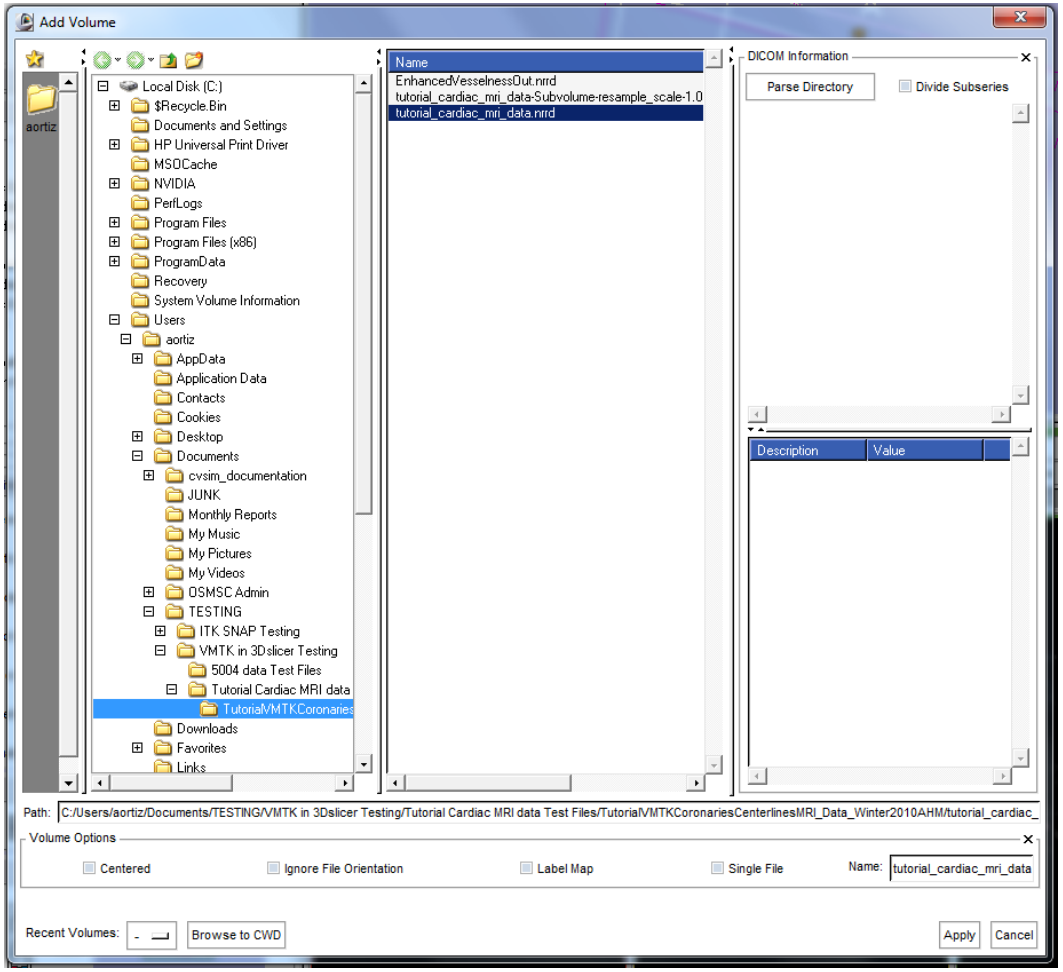


Loading Data



To load the tutorial data, choose the “File” menu (1) and select “Add Volume...” (2)

Loading Data

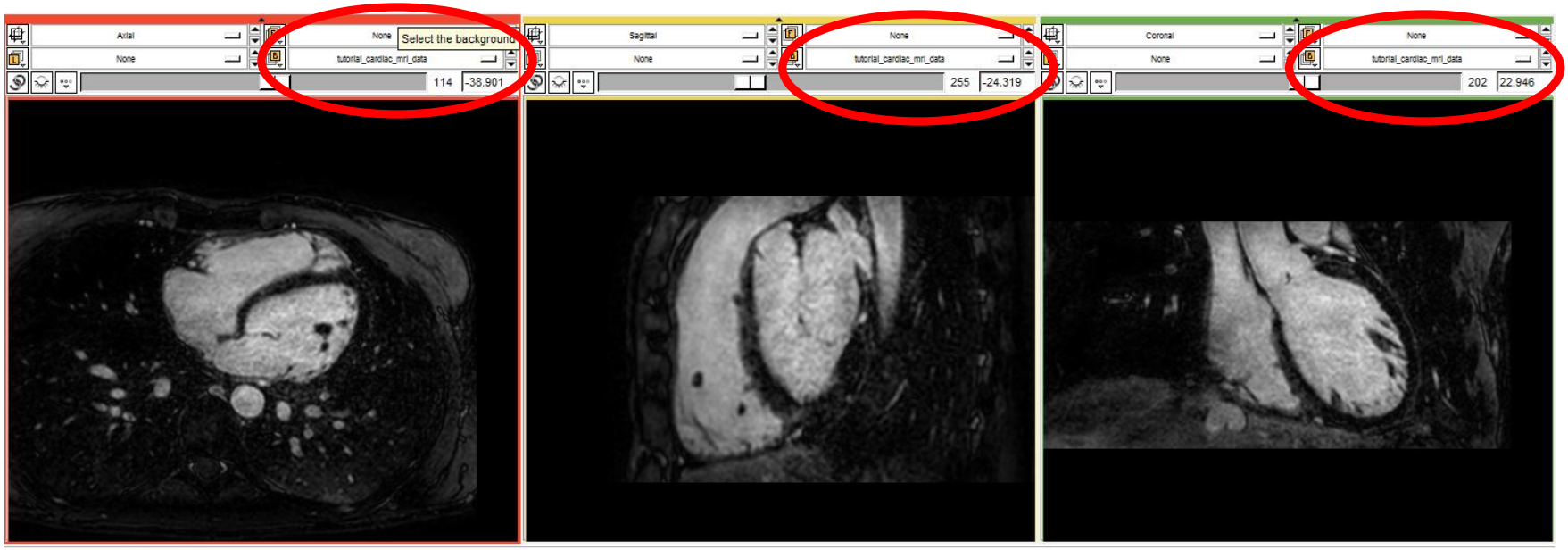


Select the file "tutorial_cardiac_mri_data.nrrd" and press Apply.

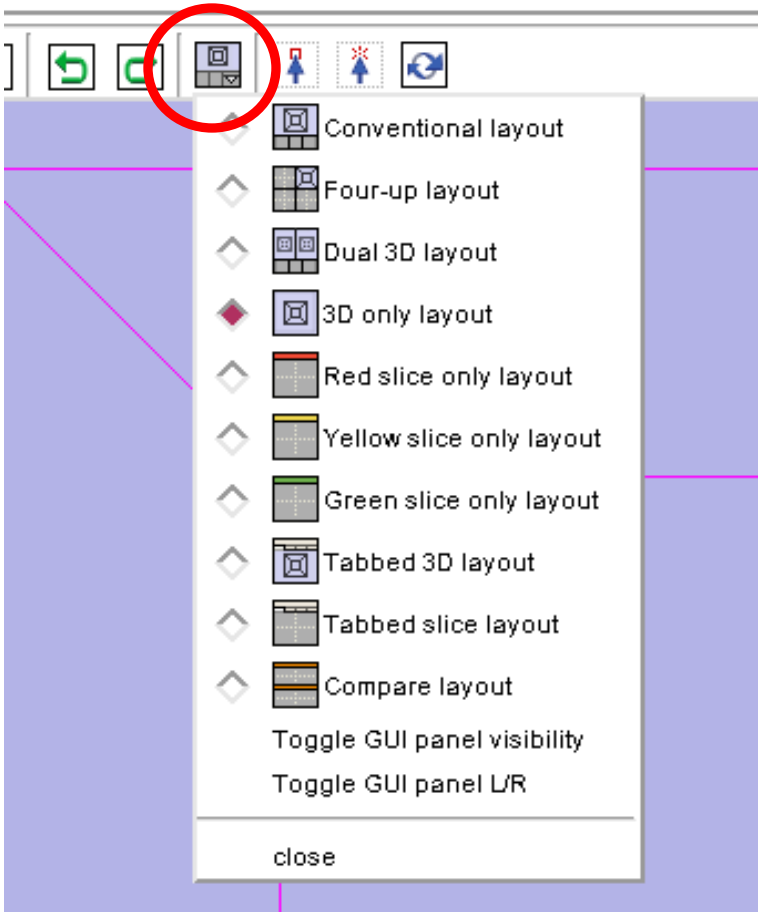
Repeat this for the other two files: "tutorial_cardiac_mri_data-Subvolume-resample_scale-1.0.nrrd" and "EnhancedVesselnessOut"

Viewing Data

Make sure you are viewing the “tutorial_cardiac_mri_data.nrrd” data by selecting that file on each slice window as shown.



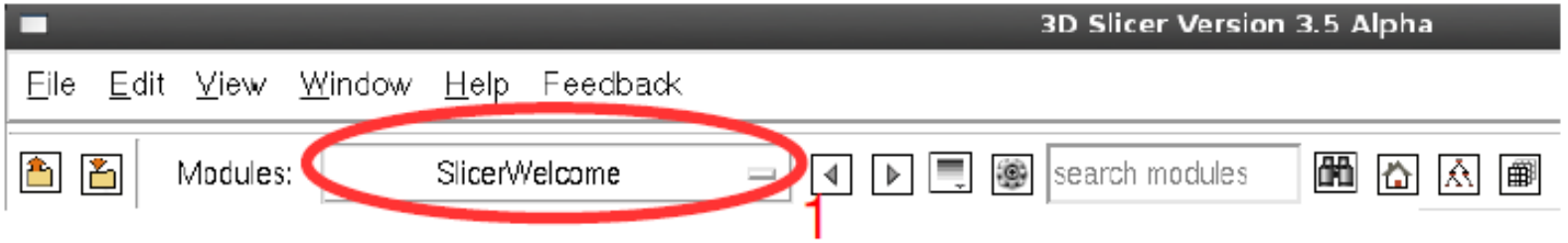
Viewing Data



The layout selector will allow you to choose the desired window(s) of interest for viewing. Start off with the "Conventional layout"

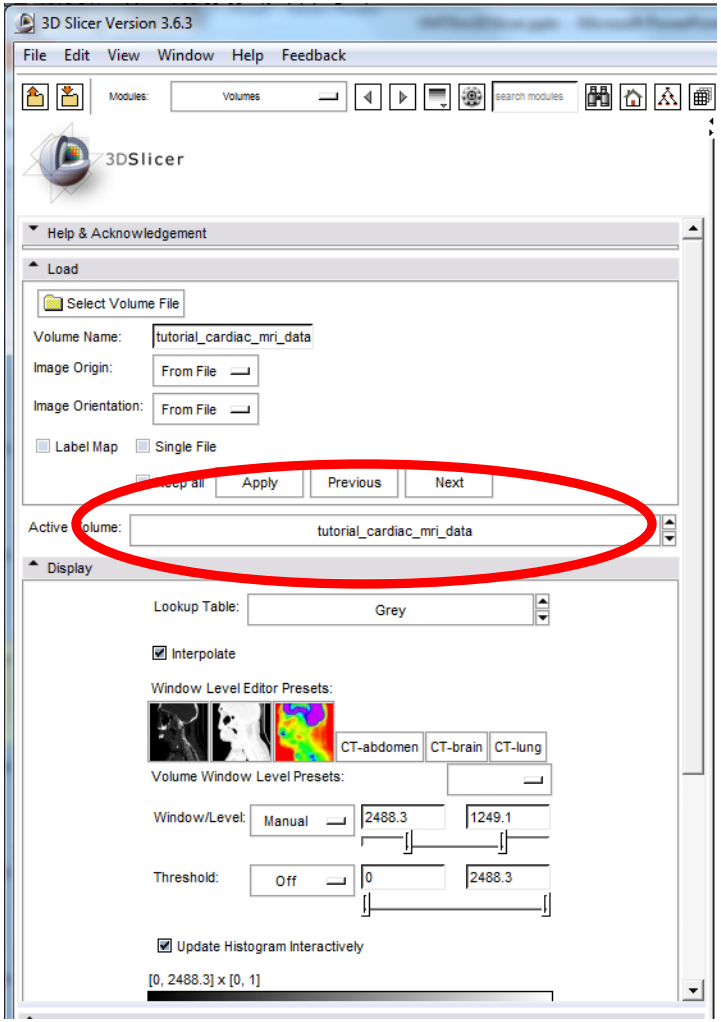
Your layout preference will depend on the task that you are performing. You might want to use the "Red slice only layout" for segmentation or the "3D only layout" for centerline computation

Active Volume



Use the modules selector (1) to navigate to the “Volumes” module (2)

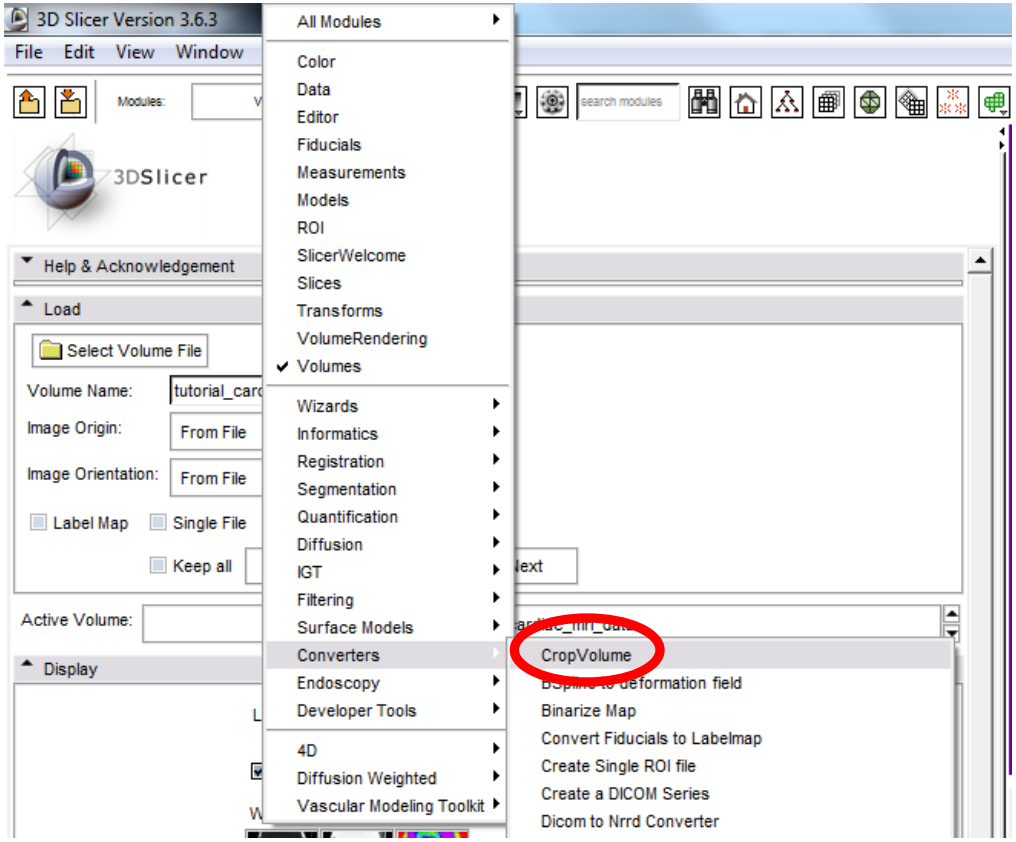
Active Volume



Make sure that the **Active volume** is the “tutorial_cardiac_mri_data” file.

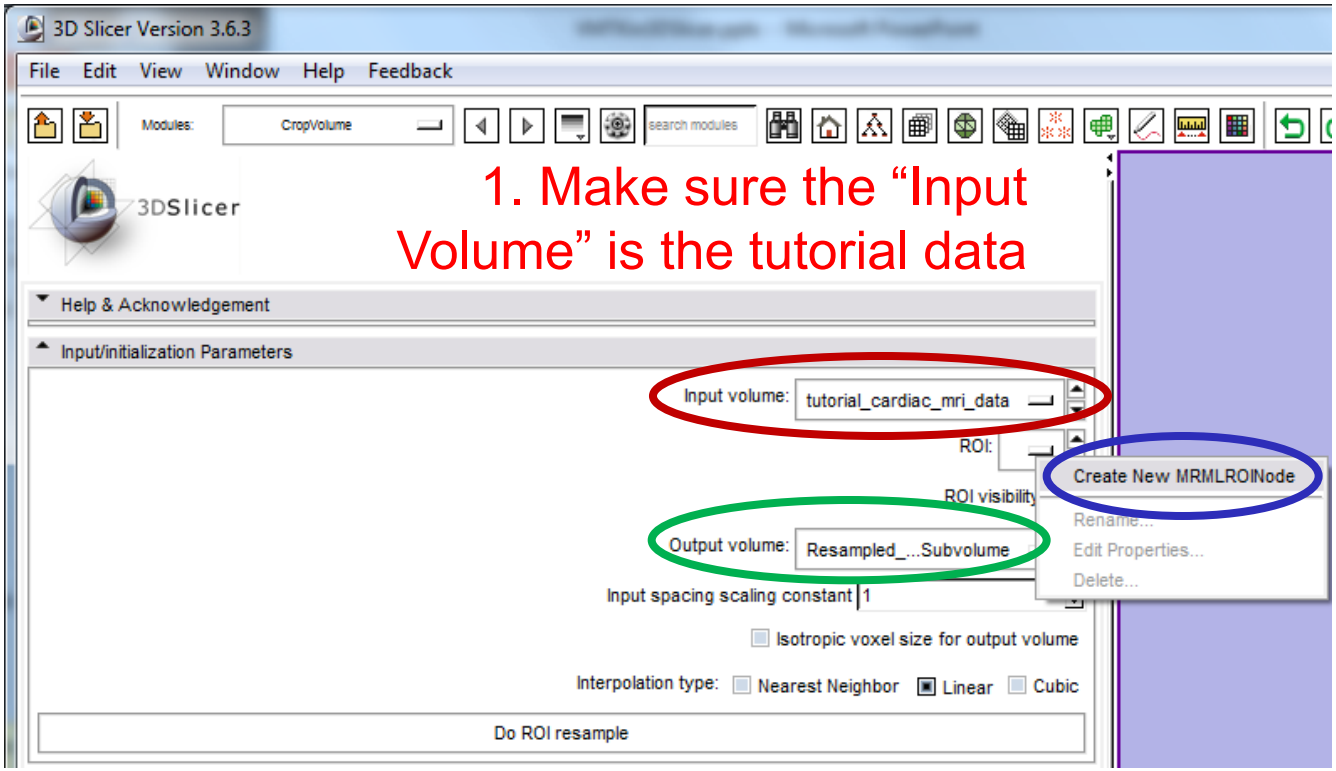
You will need to make sure that you have the correct data file as the **Active Volume** at each step: Extracting ROI, Vesselness Filtering, Level Set Segmentation, and Centerline Computation.

Extracting the ROI



Use the modules selector to start “CropVolume” under the “Converters” menu

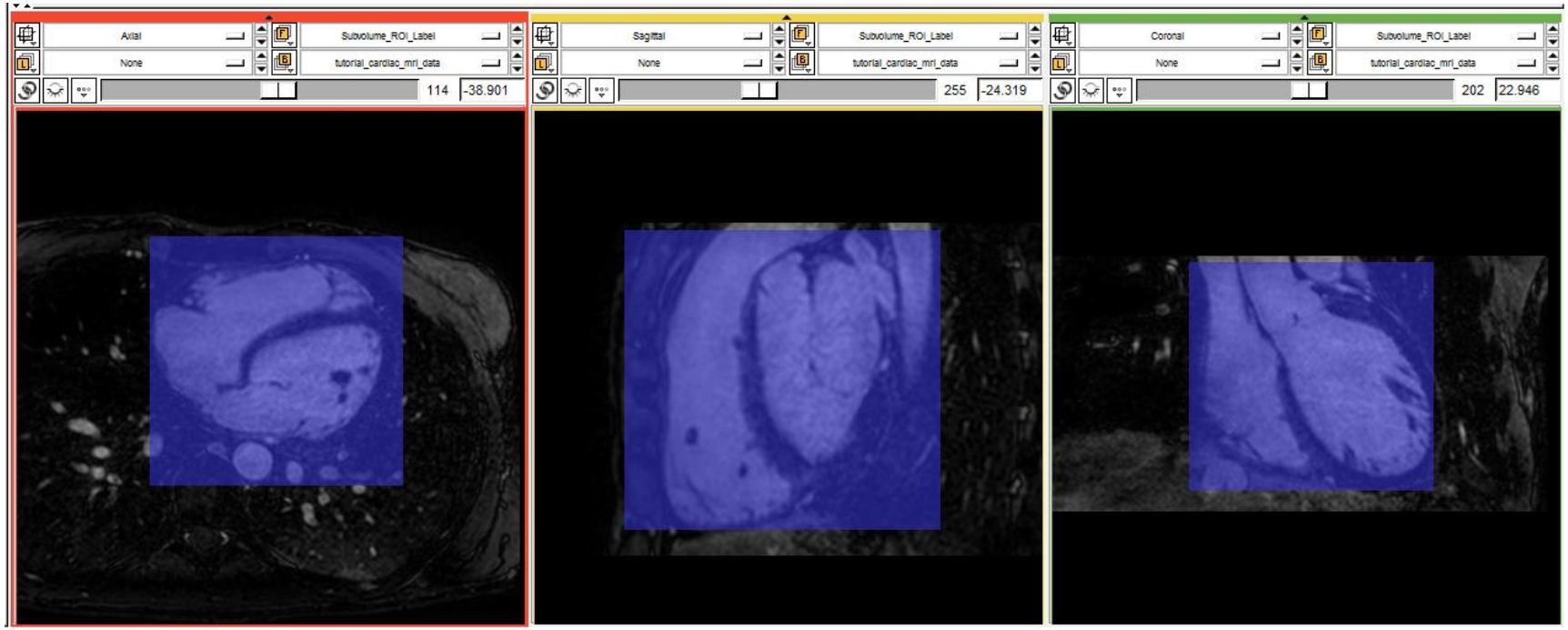
Extracting the ROI



2. Create a new MRRLROINODE under "ROI:"

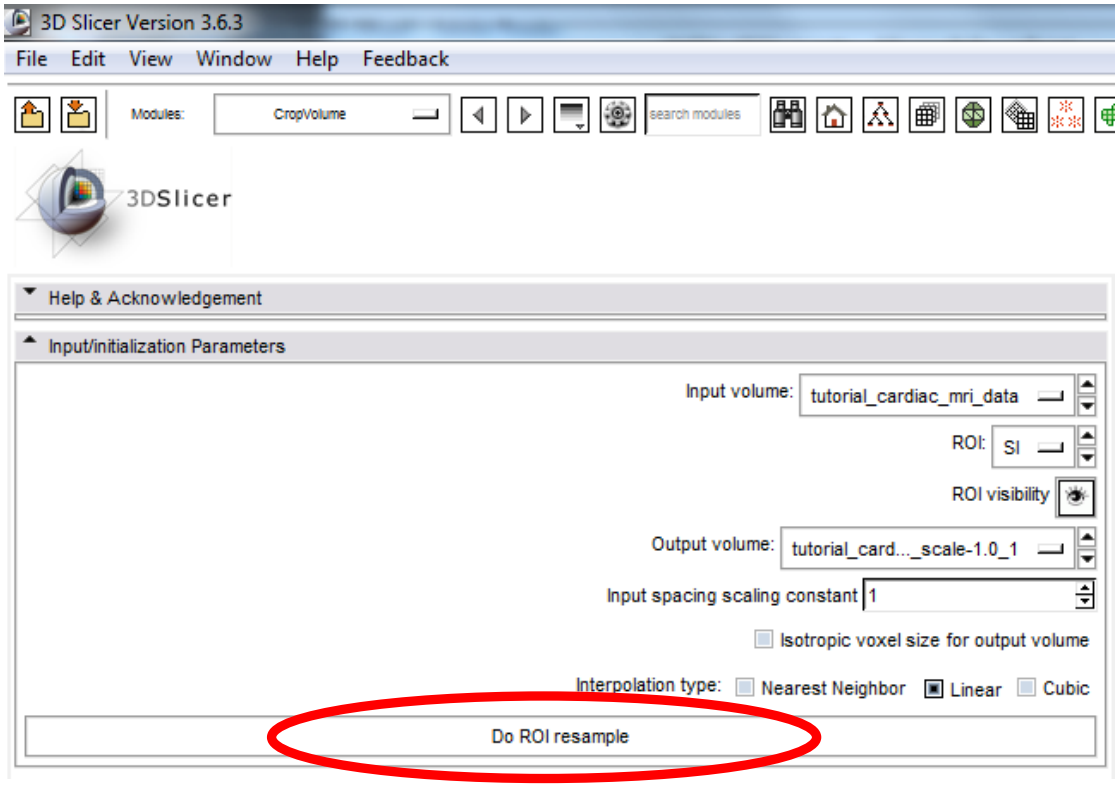
3. Create a new volume as the "Output Volume"

Extracting the ROI



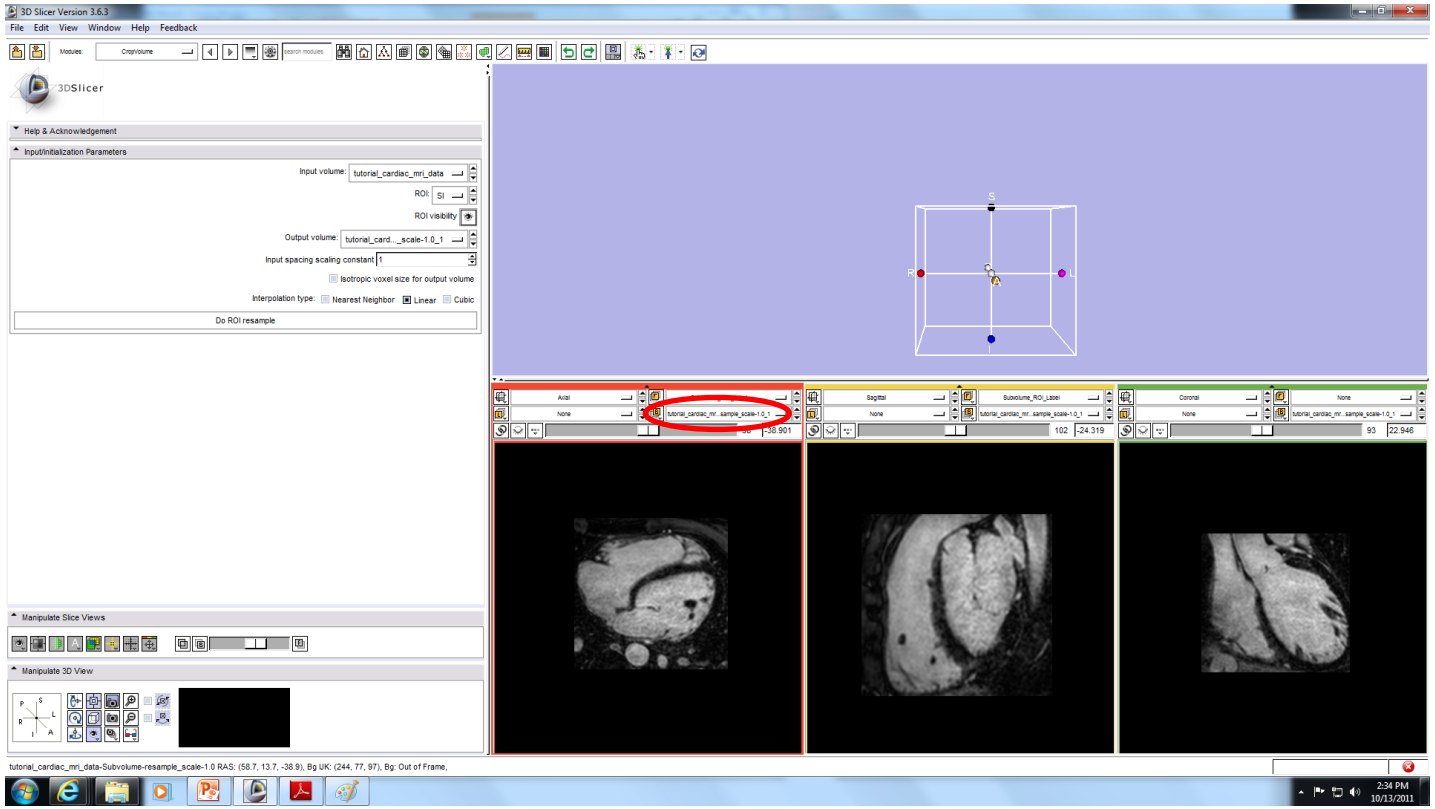
Now click around the heart in the slice views to select the subvolume. The selection is shown in transparent blue above.

Extracting the ROI



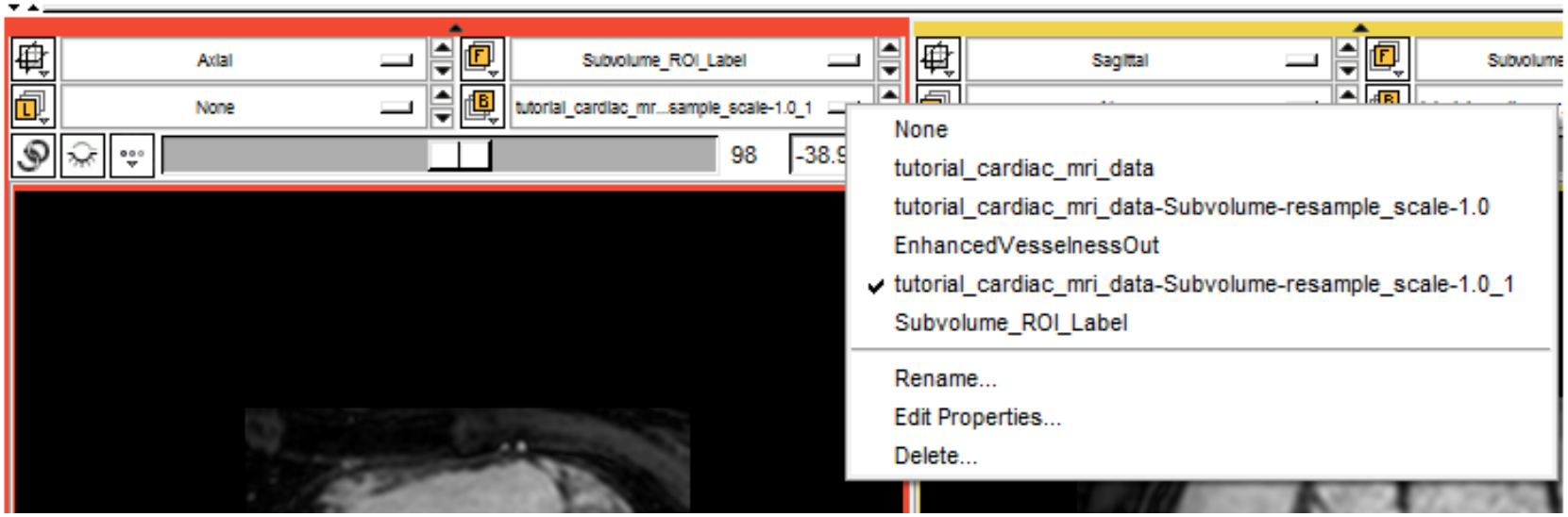
Click “Do ROI resample” to extract the subvolume.

Extracting the ROI



Your red, yellow, and green slice windows should now show the subvolume. If not…

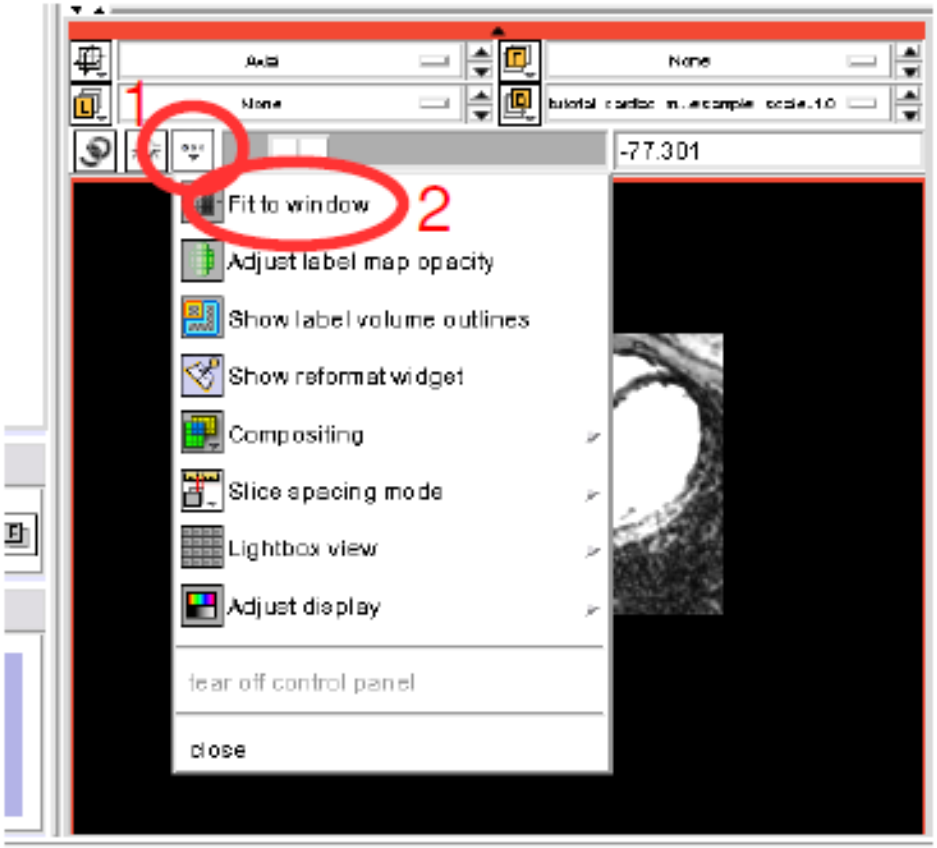
Extracting the ROI



If not, you should be able to change the data in view to the subvolume that you extracted, **"tutorial_cardiac_mri_data-subvolume-resample_scale-1.0_1".**

Alternatively, you can use the subvolume that you initially loaded, **"tutorial_cardiac_mri_data-subvolume-resample_scale-1.0".**

Extracting the ROI

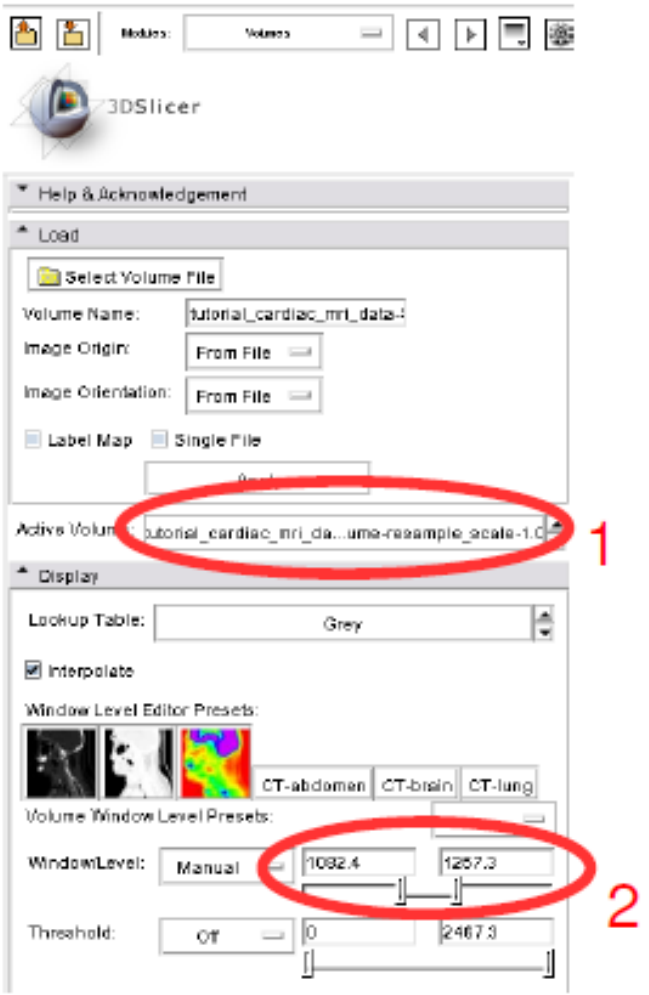


Fit the volume to the window by using the options icon (1) and selecting “Fit to window” (2)

Change Active Volume

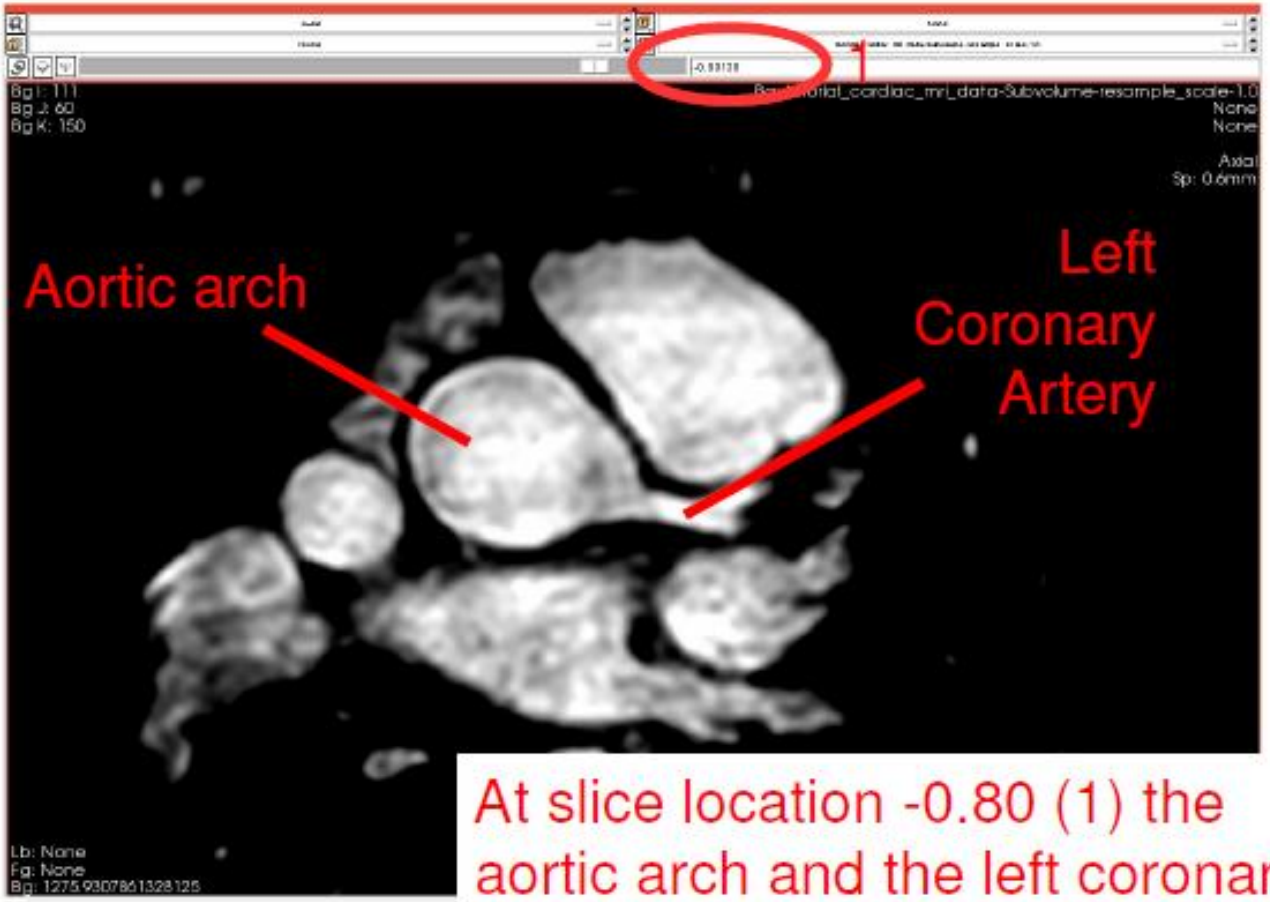
Use the modules selector (1) to navigate to the “Volumes” module (2)

Change Active Volume

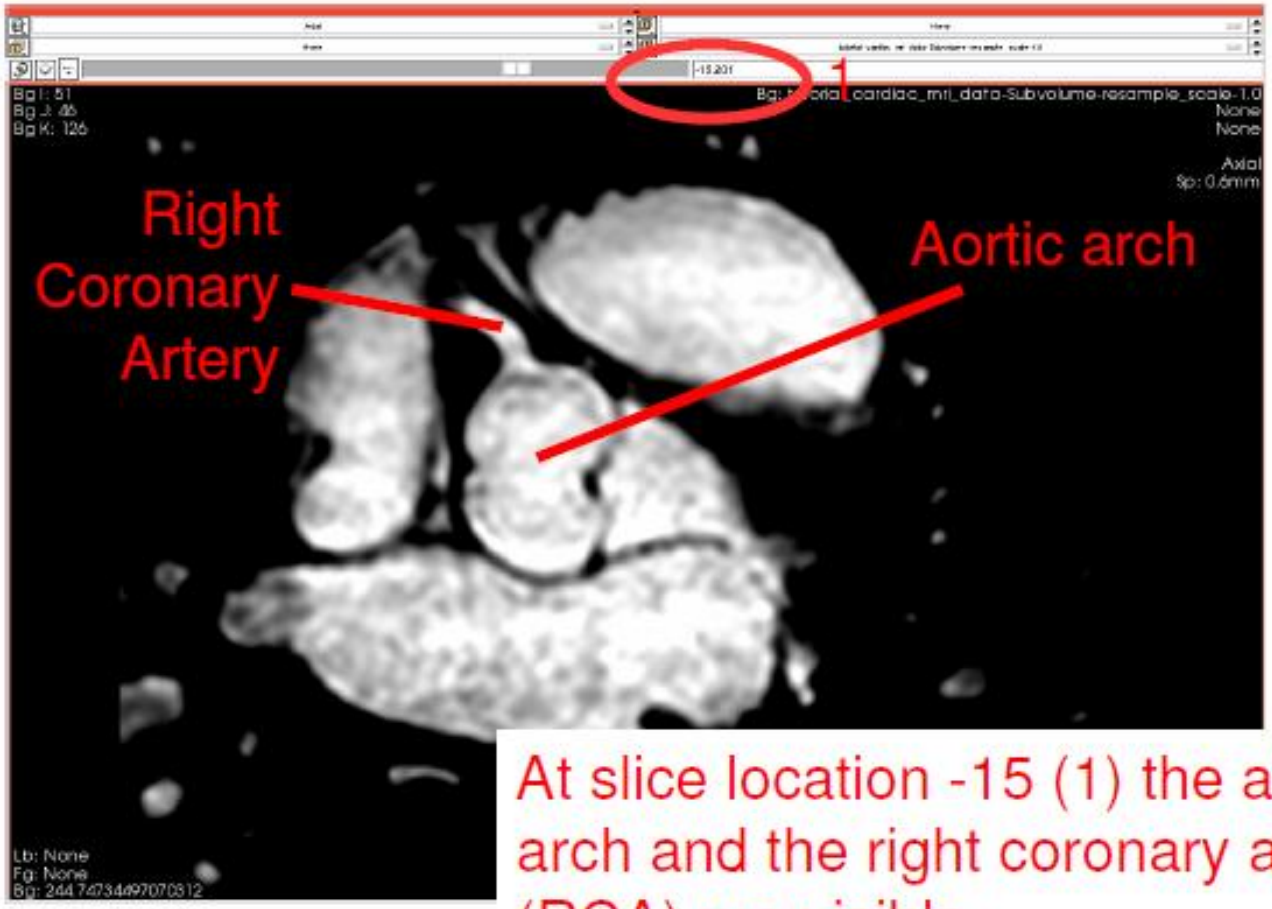


1. Be sure the subvolume that you selected for viweing, either the **"tutorial_cardiac_mri_data-subvolume-resample_scale-1.0_1"** or the **"tutorial_cardiac_mri_data-subvolume-resample_scale-1.0"** is the Active Volume.

2. If you adjust the Window/Level setting to 1082 and 1257 you get a better visualization

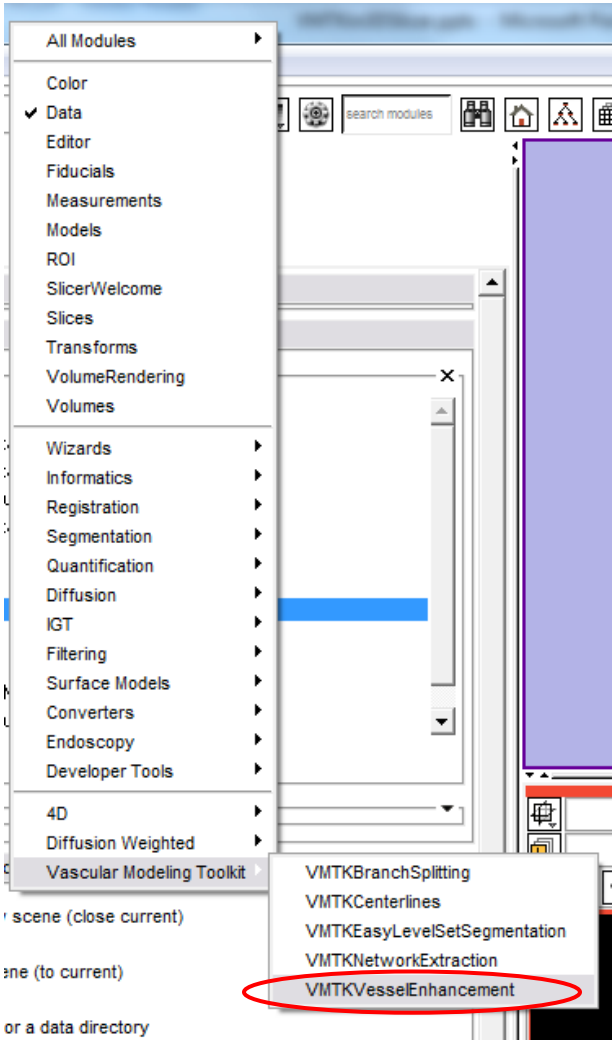


At slice location -0.80 (1) the aortic arch and the left coronary artery (LCA) are visible



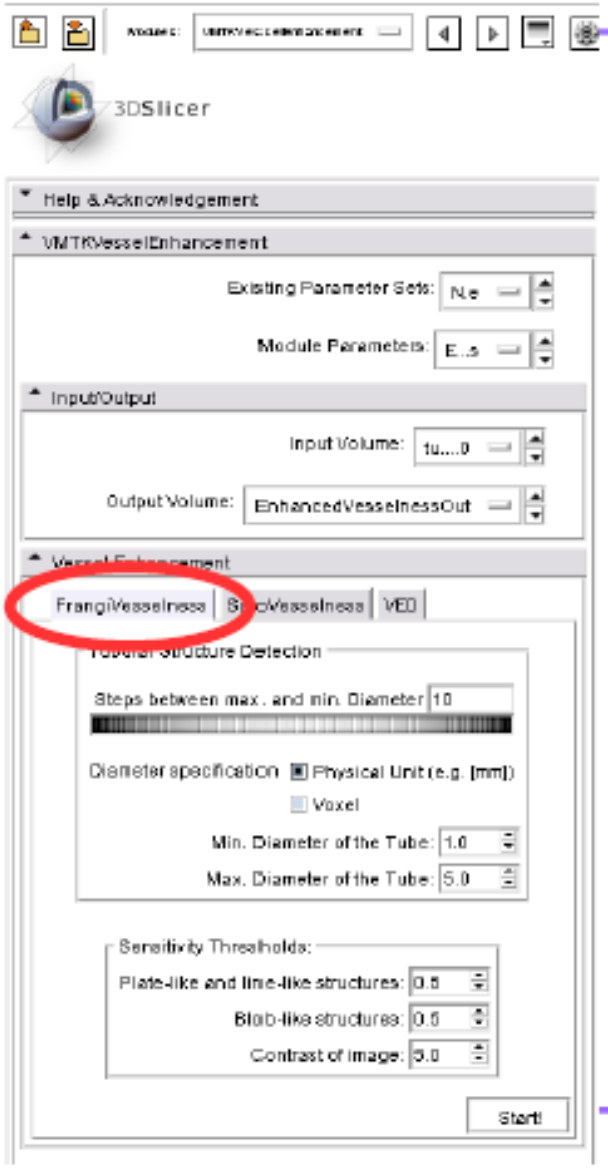
At slice location -15 (1) the aortic arch and the right coronary artery (RCA) are visible

Vesselness Filtering



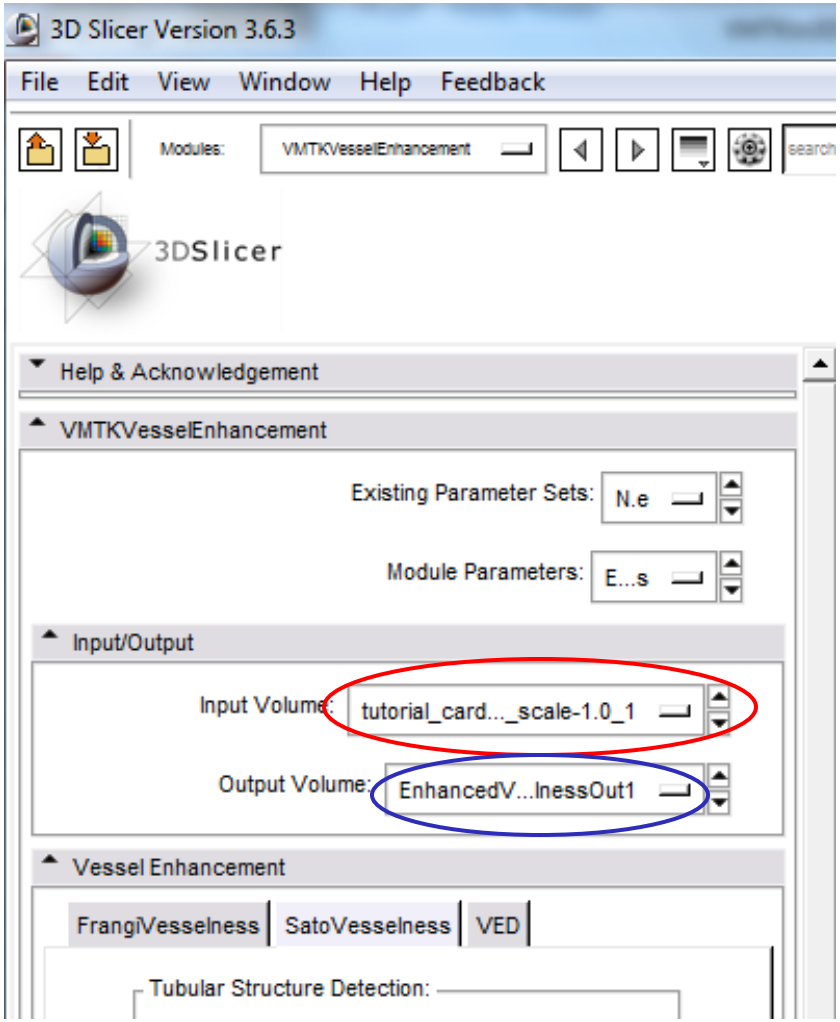
Navigate to the VMTKVesselEnhancement module under the “Vascular Modeling Toolkit” Menu using the modules selector

Vesselness Filtering



This panel appears. Switch to "FrangiVesselness".

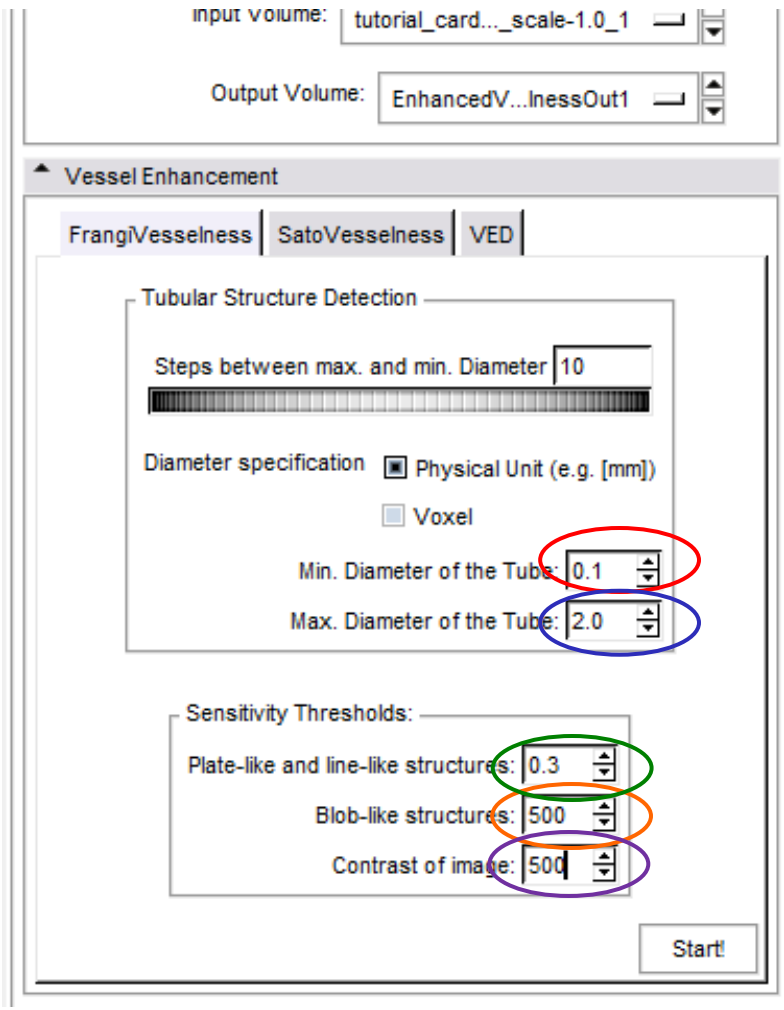
Vesselness Filtering



1. Select the desired subvolume as your “Input Volume”

2. Make sure that the “Output Volume” is a new file with the file name starting with “EnhancedVesselnessOut…” and NOT any other file that would potentially be overwritten

Vesselness Filtering



1. Enter “0.1” (unit: mm) as the minimal diameter of tubular structures to detect

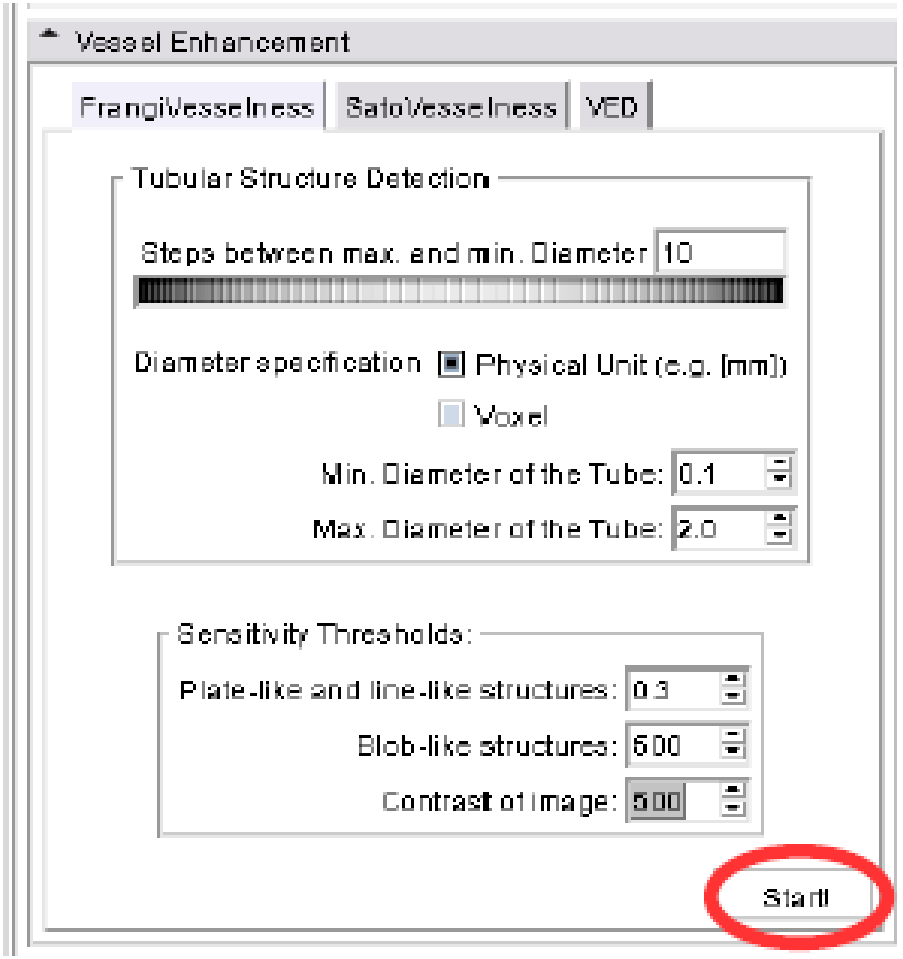
2. Enter “2.0” (unit: mm) as the maximum diameter of tubular structures to detect

3. Choose a low threshold of “0.3” to detect line-like rather than plate-like structures

4. *A* higher threshold of “500” limits the detection of bloblike Structures

5. The contrast of the vessels in comparison to the background in the tutorial data is very high, so set a higher threshold of “500” to detect only well visible structures

Vesselness Filtering



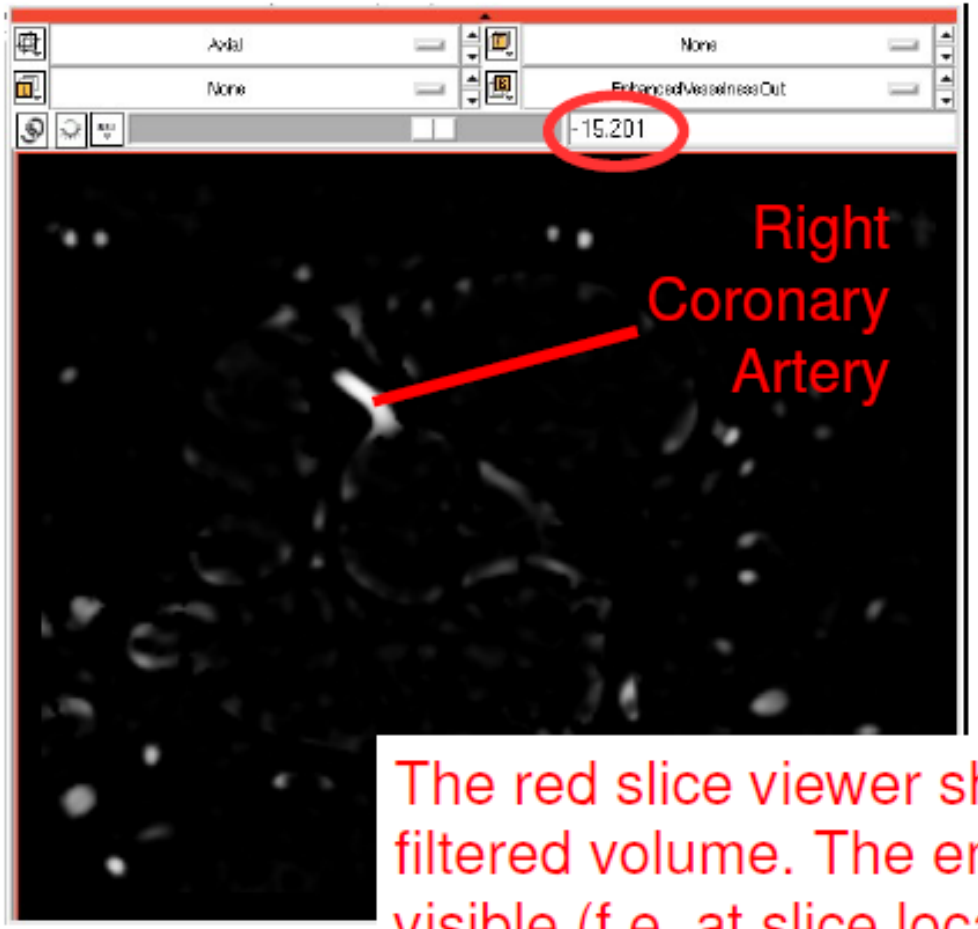
Click “Start!”

Vesselness Filtering

After you Click Start, the software may appear as “Not responding”. Don’t worry, it should still be working!

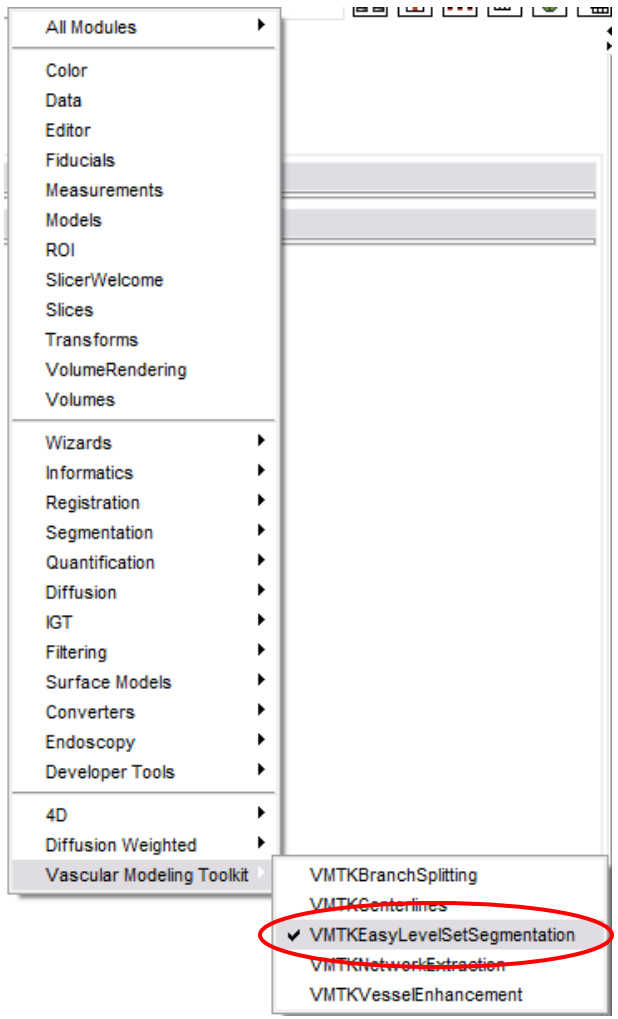
In fact, any time you click on a button to perform a task, the software may appear as not responding, but should be performing the task indicated.

Vesselness Filtering



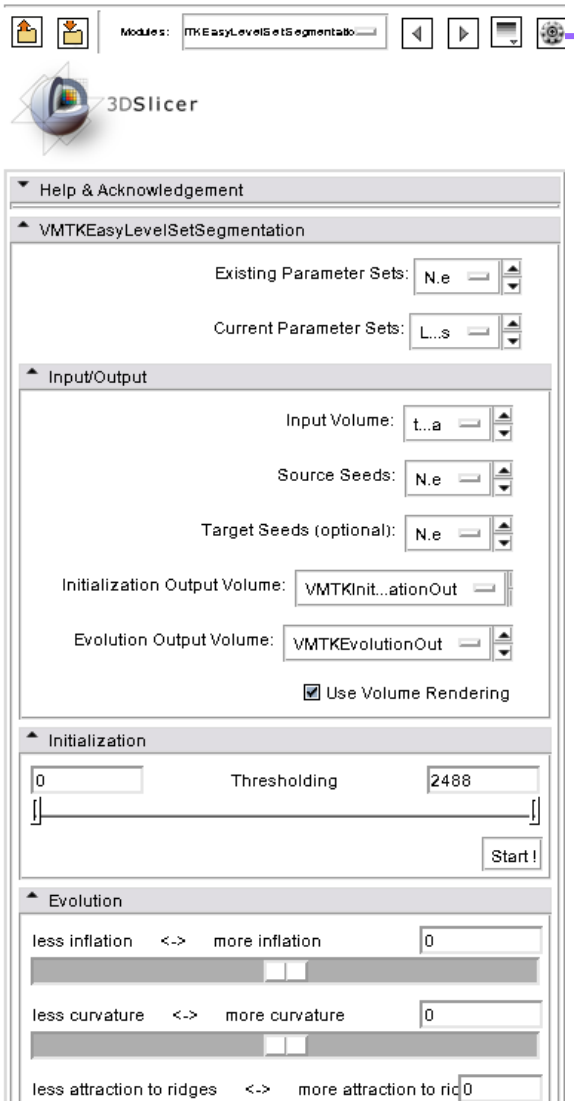
The red slice viewer shows the vesselness filtered volume. The enhanced tubes are visible (f.e. at slice location -15).

Level Set Segmentation



Navigate to the VMTKEasyLevelSetSegmentation module under the "Vascular Modeling Toolkit menu using the modules selector

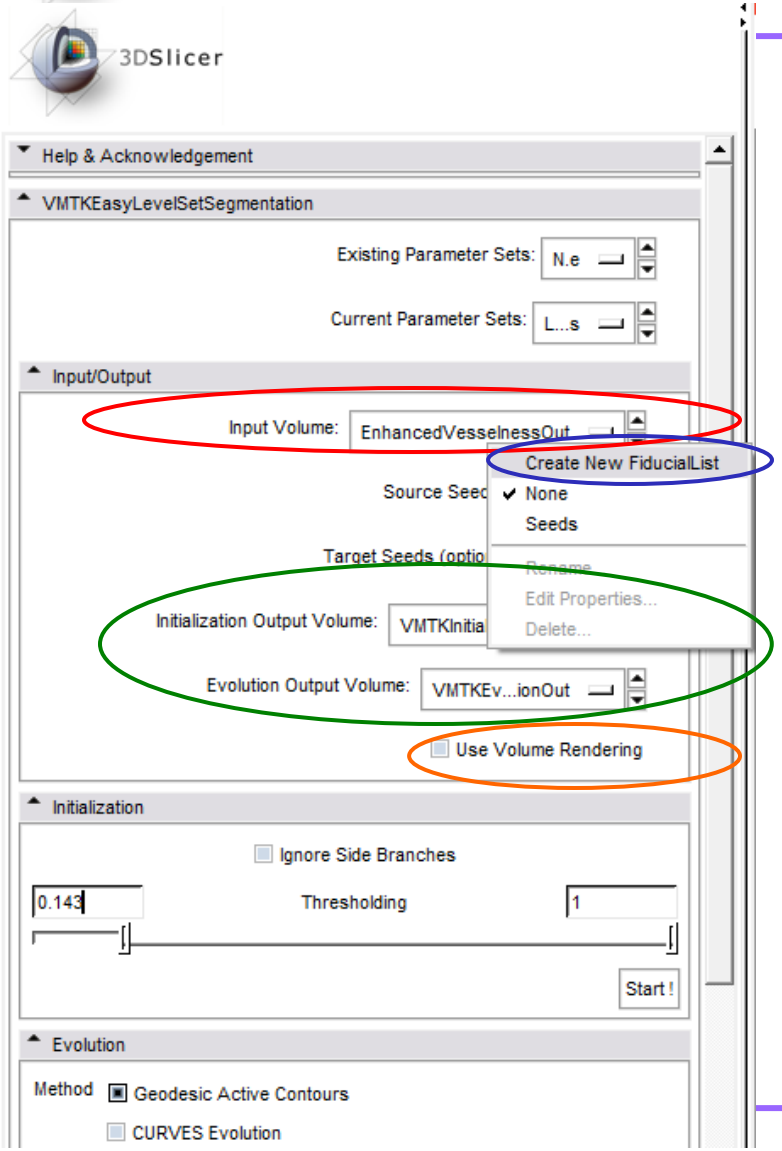
Level Set Segmentation



This panel now appears.

The Level Set Segmentation process consists of two steps: Initialization and Evolution

Level Set Segmentation



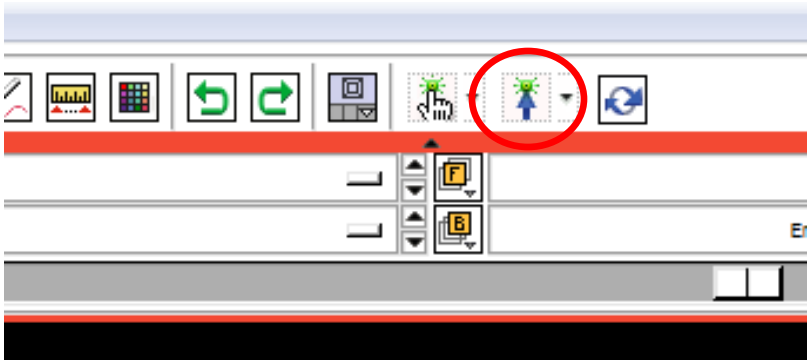
1. Select the "EnhancedVesselnessOut" volume as the "Input Volume"

2. Use the "Source Seeds" selector to "Create New Fiducial List"

3. Make sure that both "Output volumes" are new files that begin with "VMTKInitialization…" and "VMTKEvolution…" and NOT existing files that can potentially be overwritten

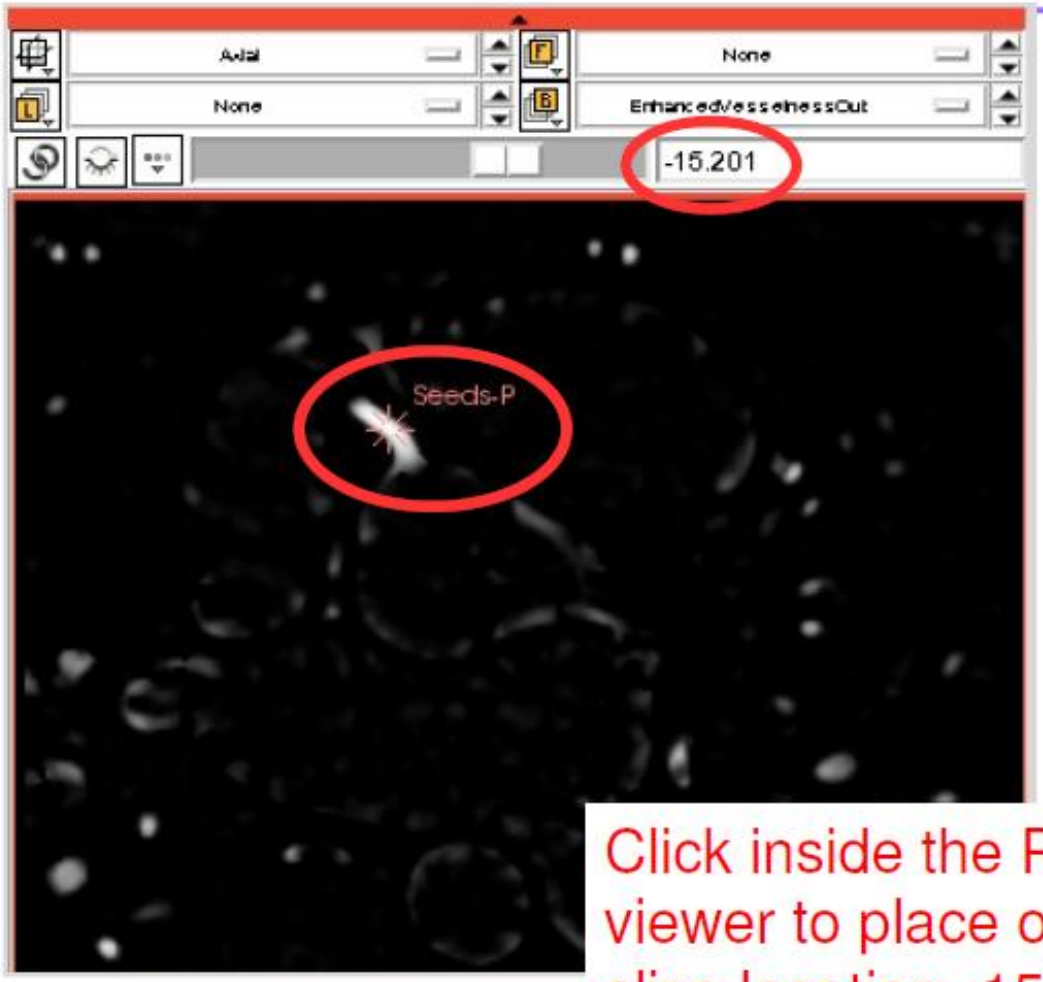
4. Deactivate "Use Volume Rendering" because Polydata is needed later

Level Set Segmentation



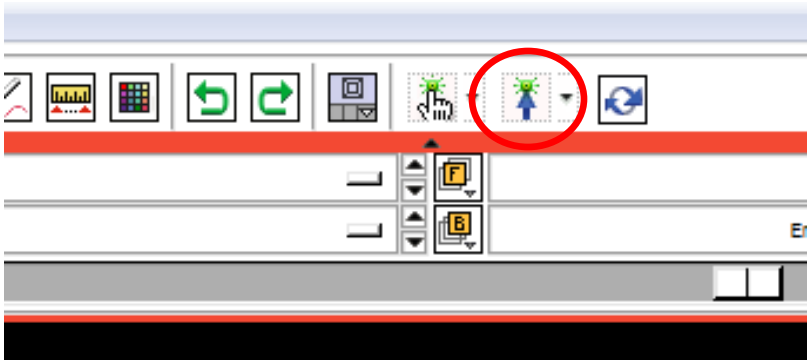
Switch to “Place mode by using the icon in the toolbar shown above.

Level Set Segmentation



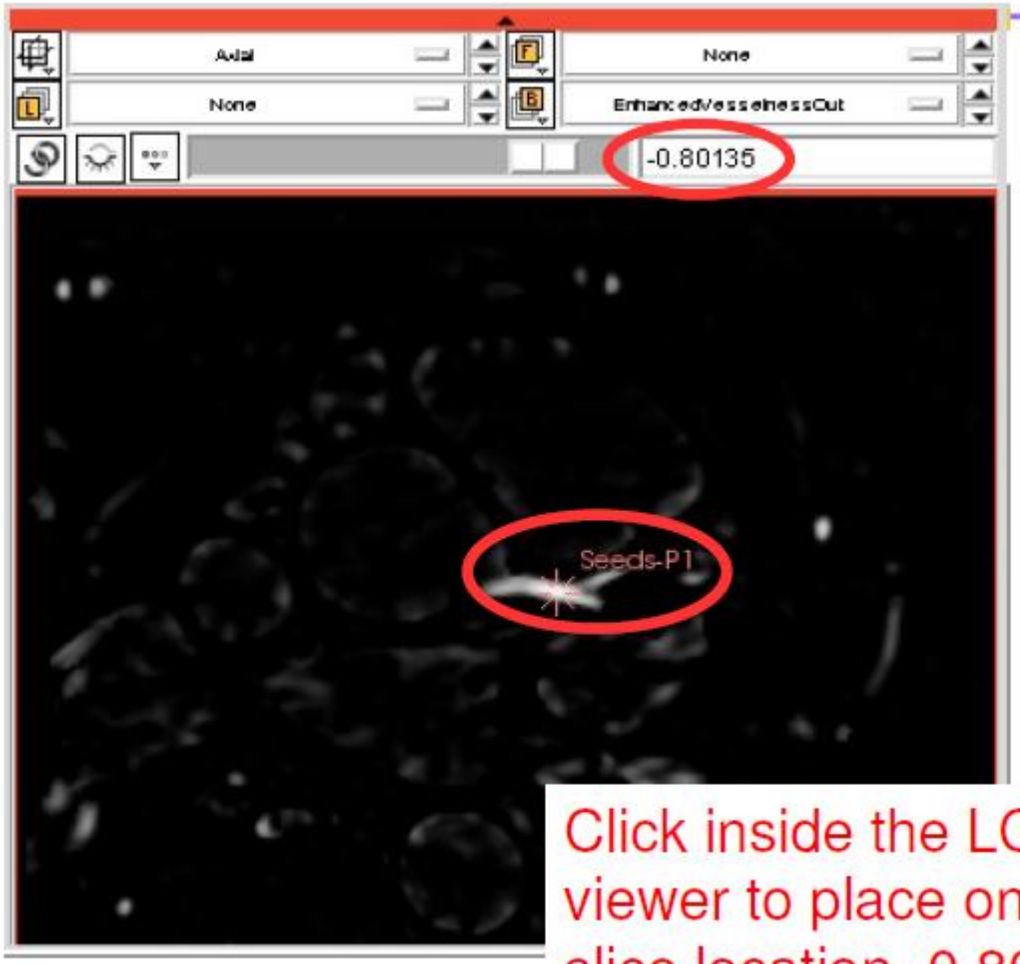
Click inside the RCA on the red slice viewer to place one seed point (f.e. at slice location -15)

Level Set Segmentation



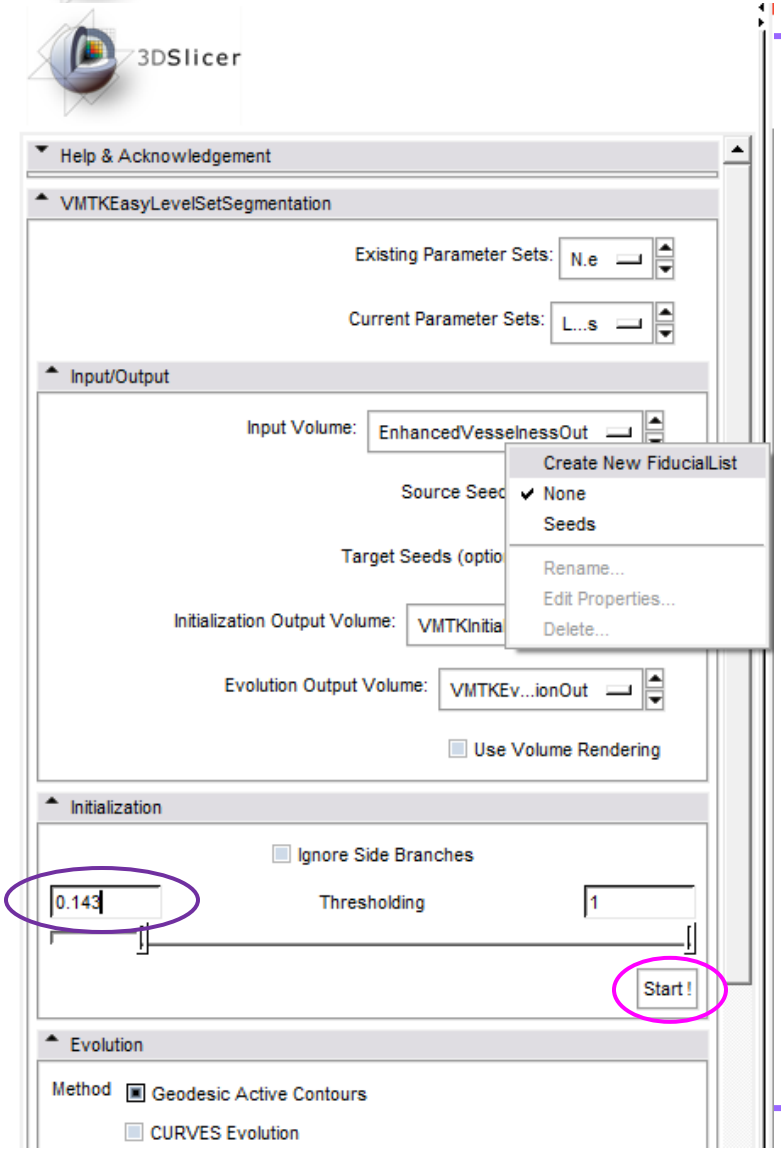
Change to switch to
“Place” mode again!

Level Set Segmentation



Click inside the LCA on the red slice viewer to place one seed point (f.e. at slice location -0.80)

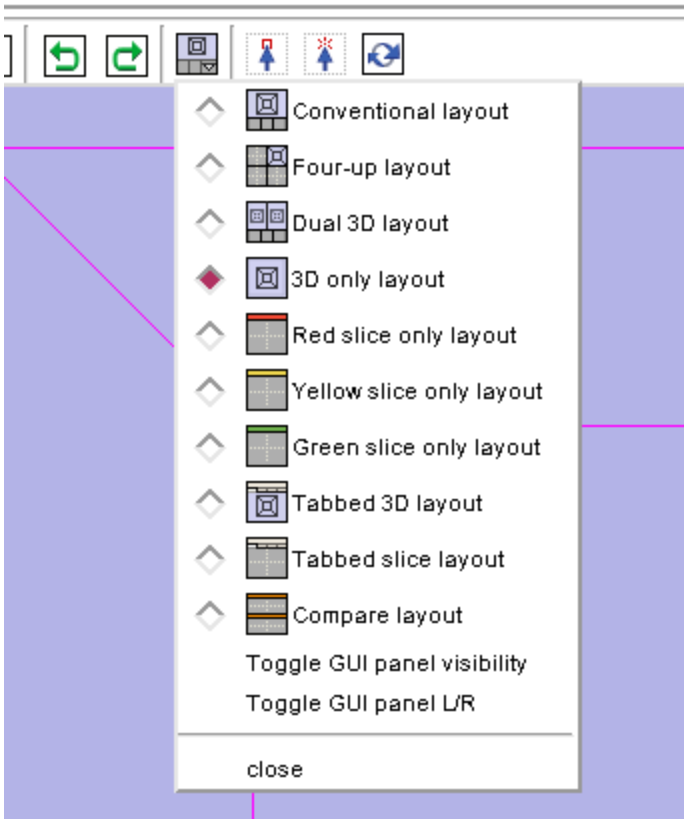
Level Set Segmentation



5. Set a lower threshold of “0.143”

6. Click “Start!

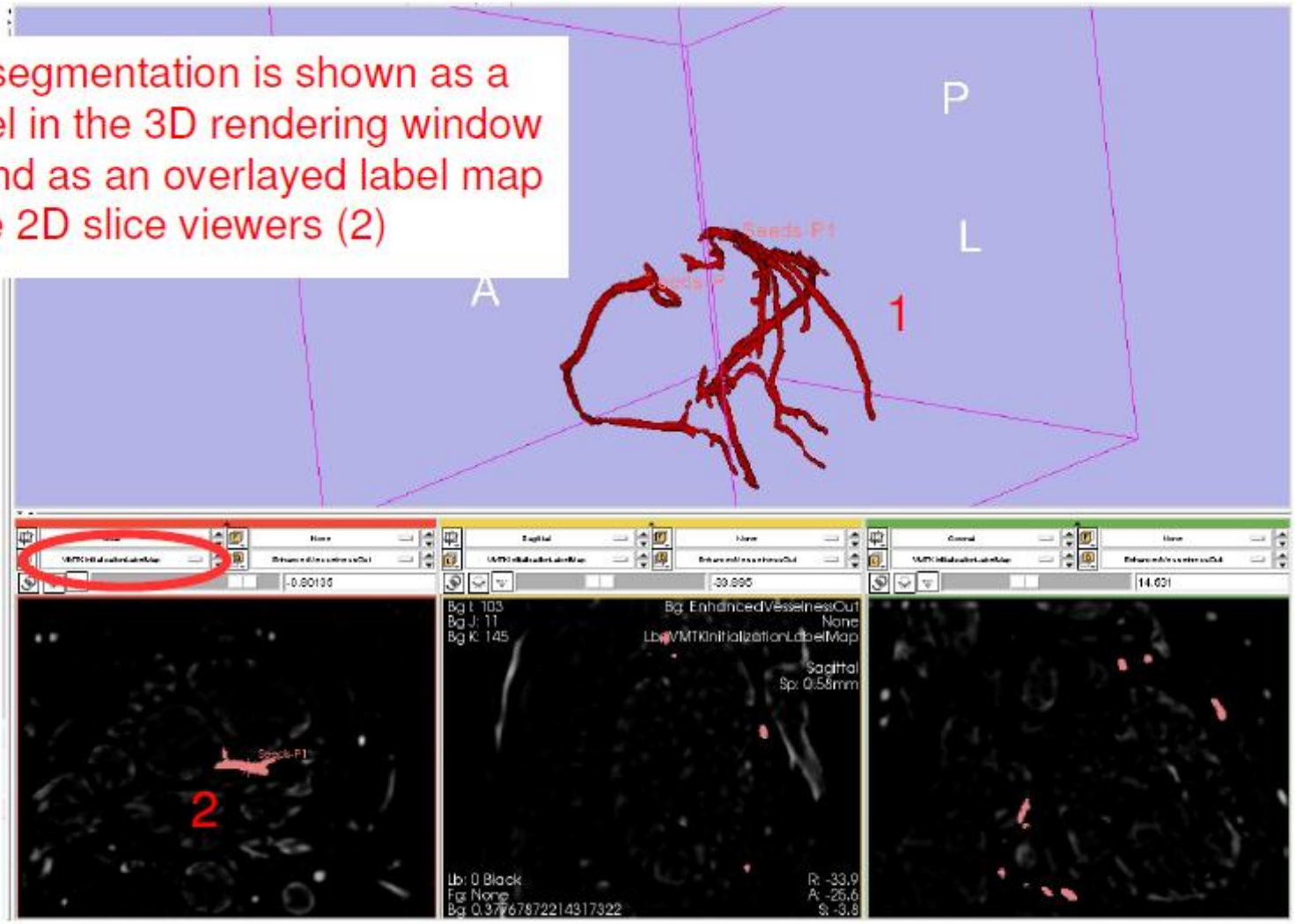
Level Set Segmentation



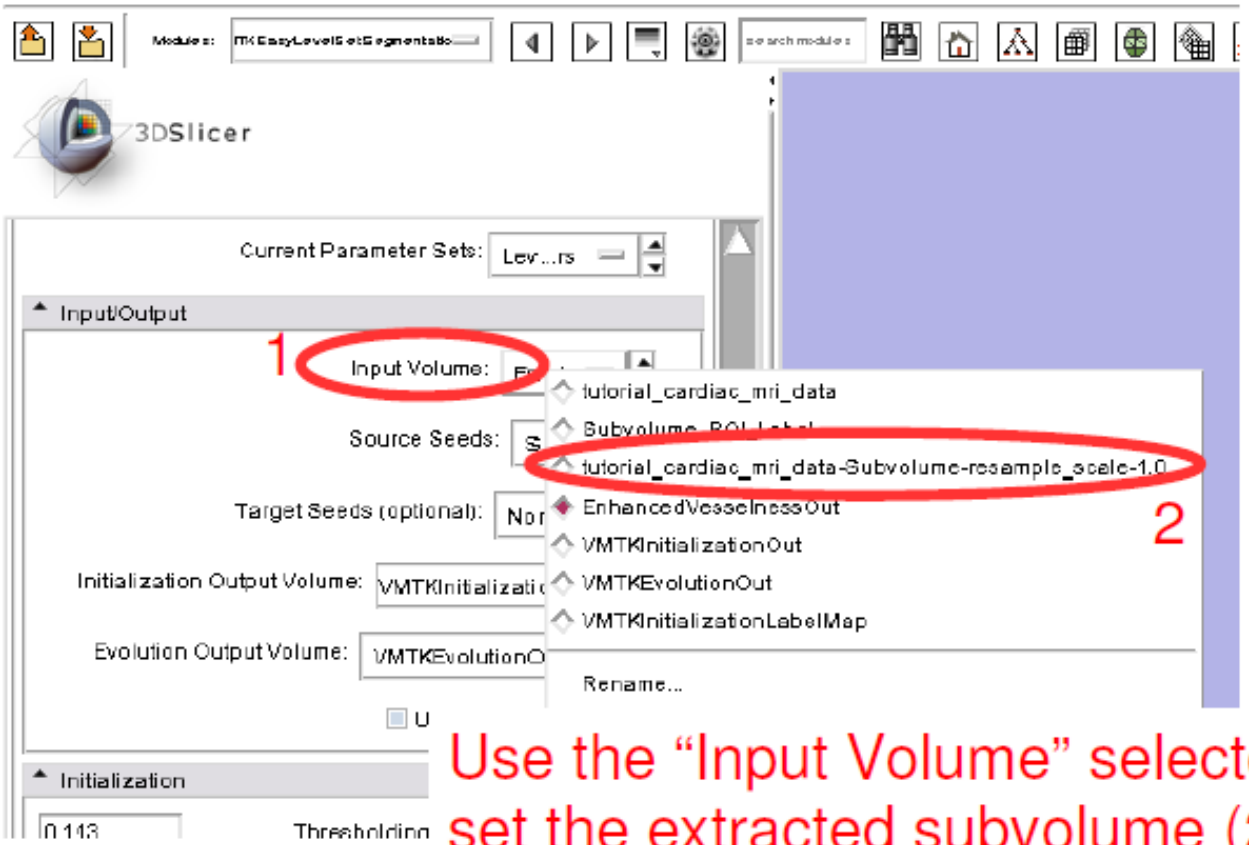
If you are not already in "Conventional Layout," switch to conventional layout to see the 3D rendering of the model you just created!

Level Set Segmentation

The segmentation is shown as a model in the 3D rendering window (1) and as an overlayed label map in the 2D slice viewers (2)

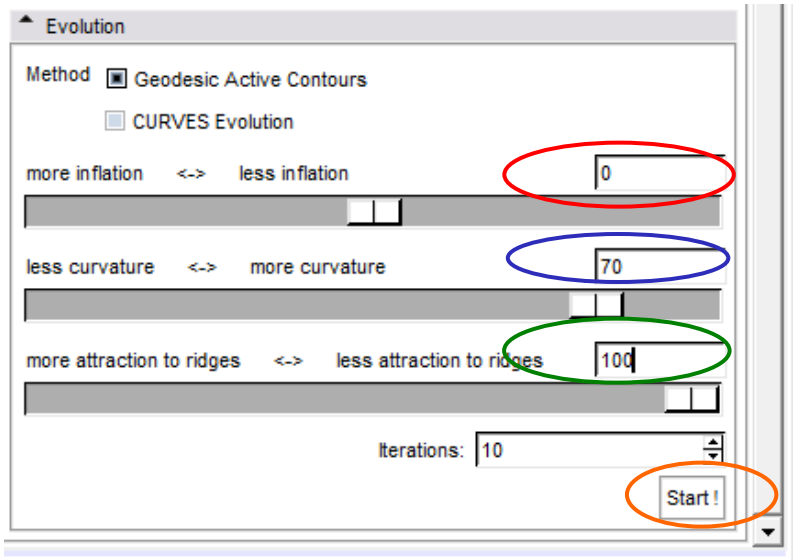


Level Set Segmentation



Use the “Input Volume” selector (1) to set the extracted subvolume (2) as the input for the evolution stage

Level Set Segmentation



1. The initialization is already close to the edges of the vessels so no inflation in needed

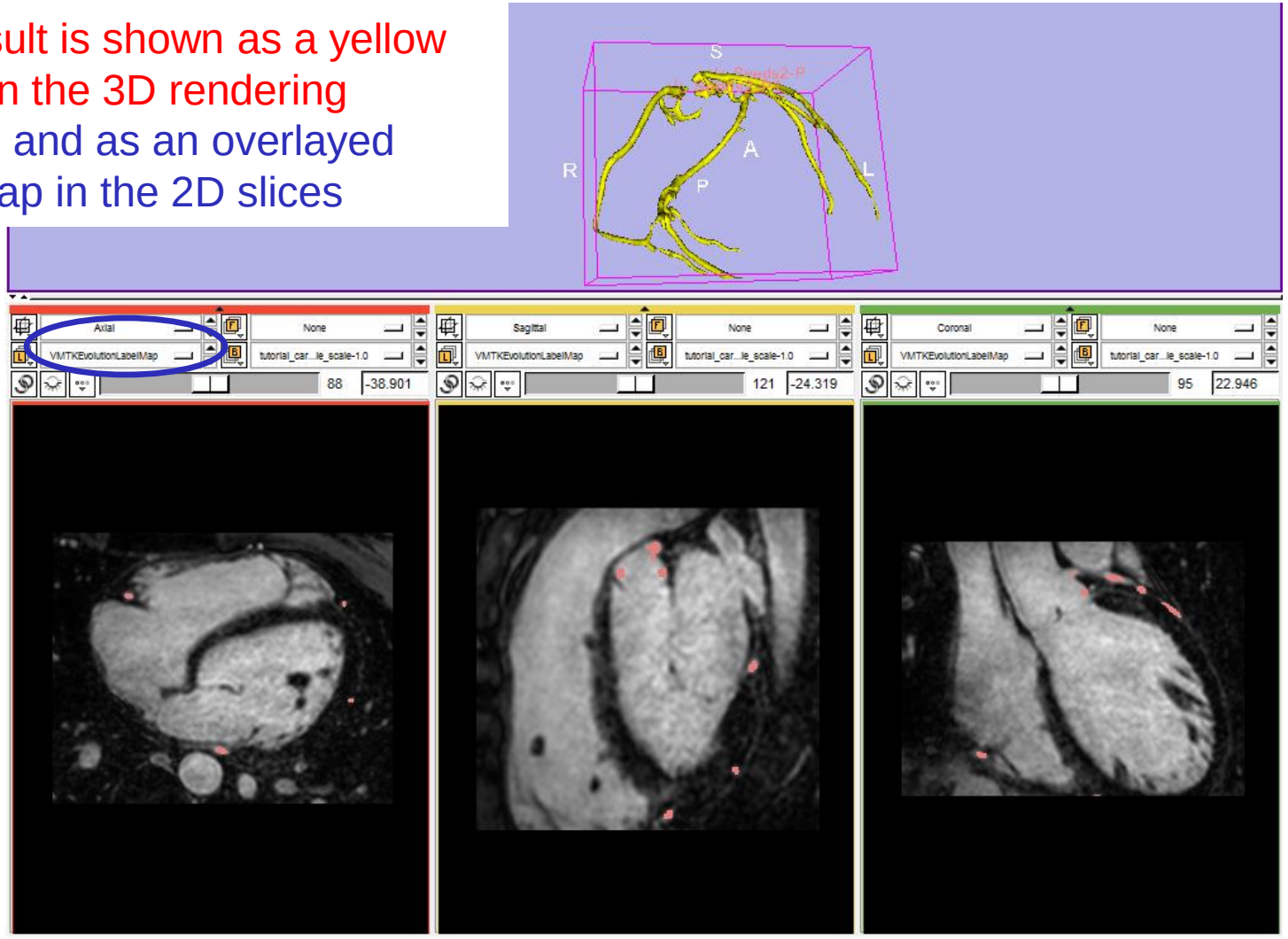
2. To get a smooth surface a higher curvature weight of “70” is important

3. To attract the segmentation to the gradient ridges a high attraction weight of “100” is necessary

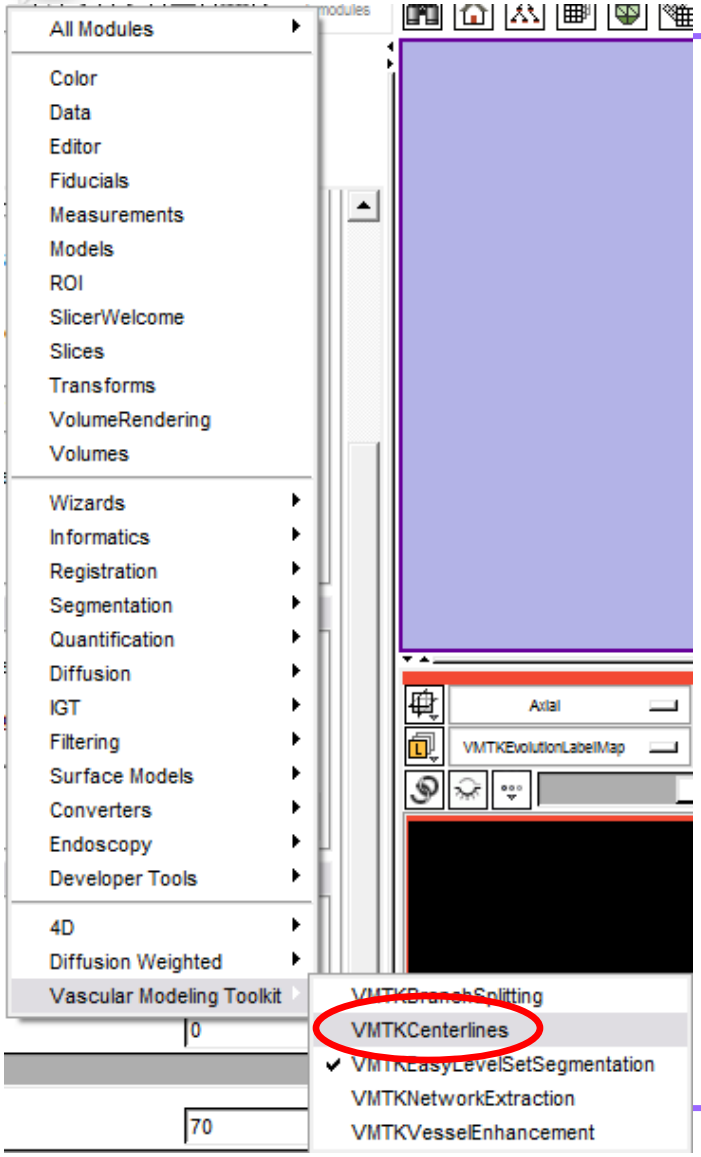
4. Now Click “Start”!

Level Set Segmentation

The result is shown as a yellow model in the 3D rendering window and as an overlayed label map in the 2D slices

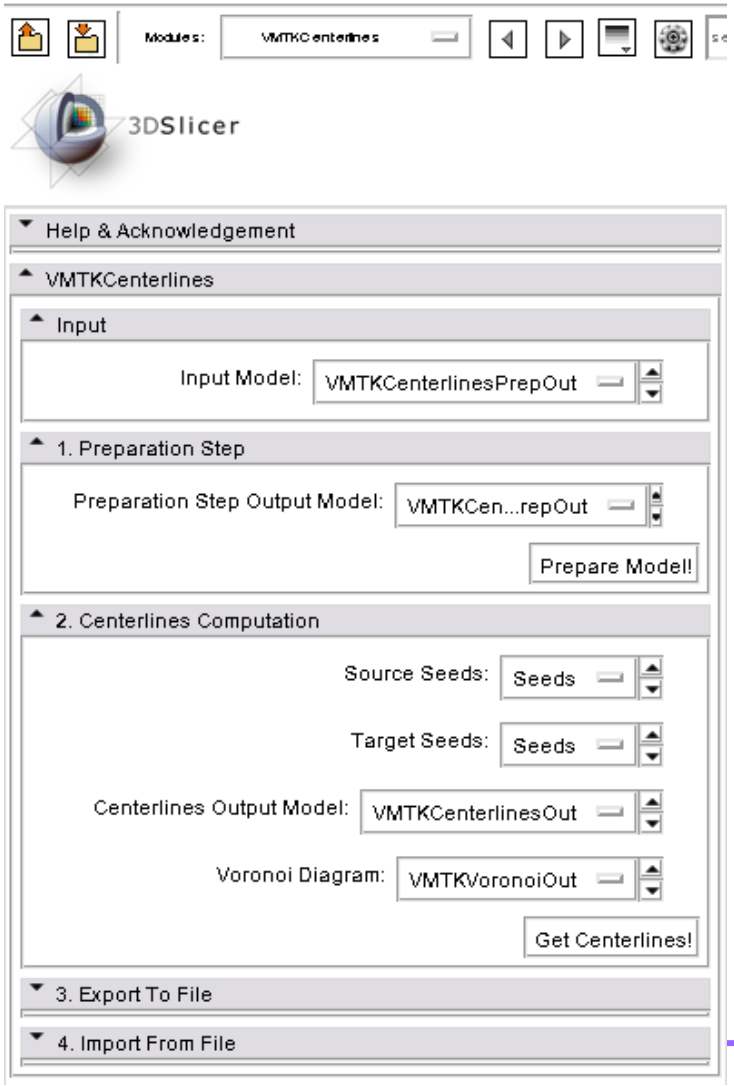


Centerline Computation



Navigate to the VMTKCenterlines module under the “Vasculas Modeling Toolkit” using the modules selector

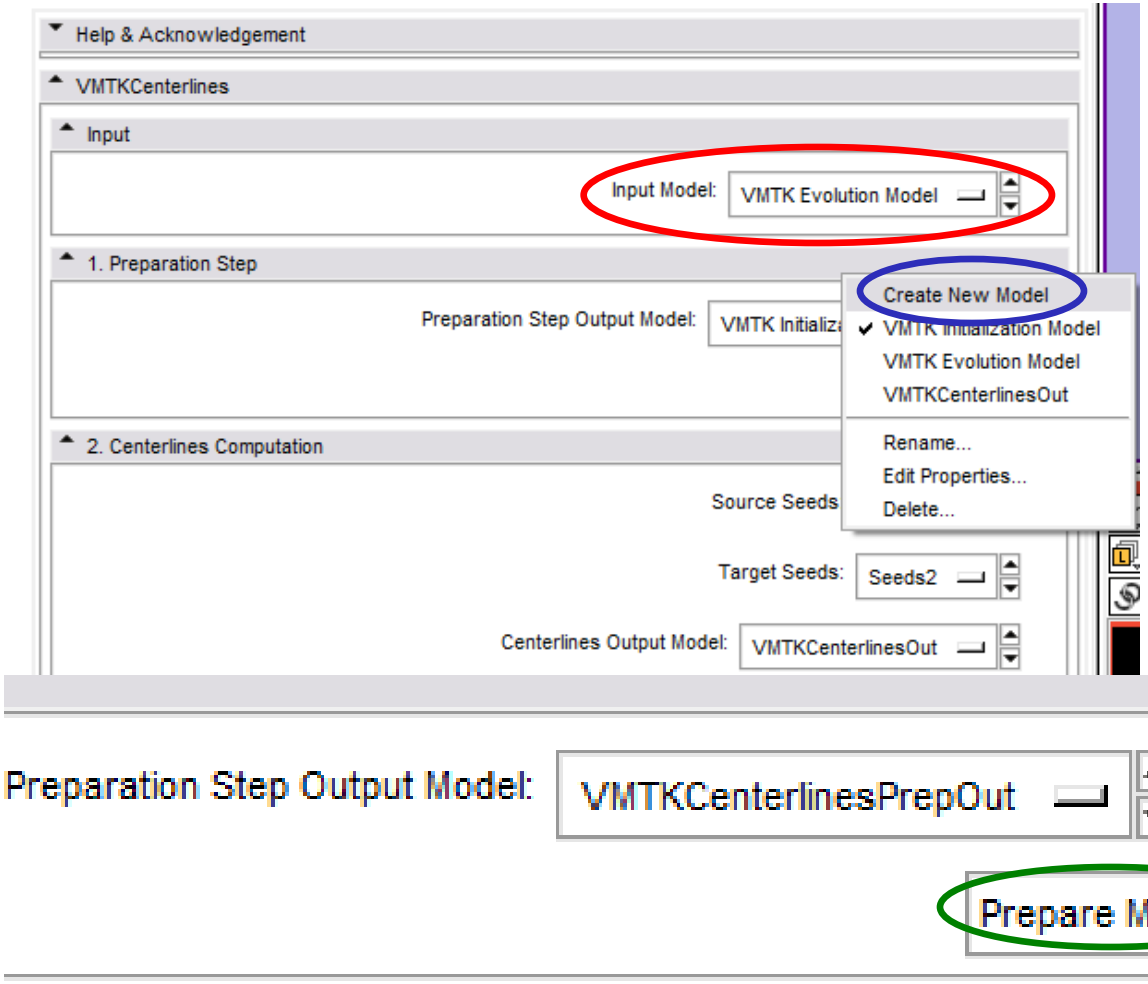
Centerline Computation



This panel now appears.

The Centerlines extraction consists of two steps: Model preparation and Centerline Computation

Centerline Computation

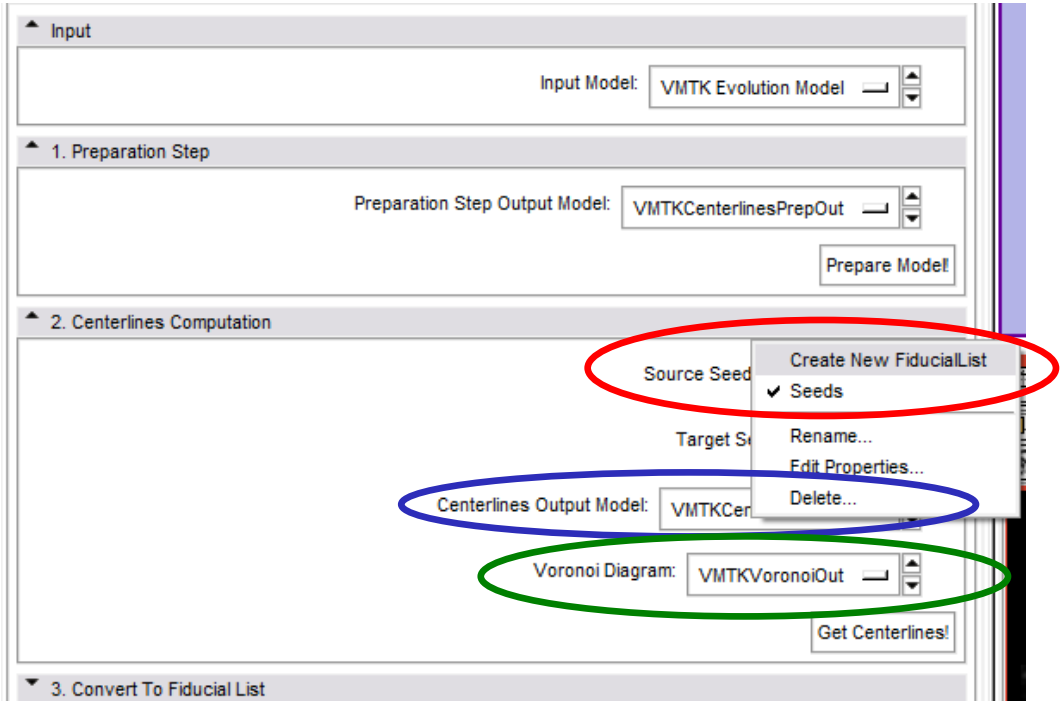


1.Set the "VMTKEvolution Model" as the "Input Model"

2. "Create New Model" for the Preparaton Step Output Model. This will create a model called "VMTKCenterlinesPrepOut"

3. Click "Prepare Model!" The blue model in the 3D Rendering Window turns green

Centerline Computation



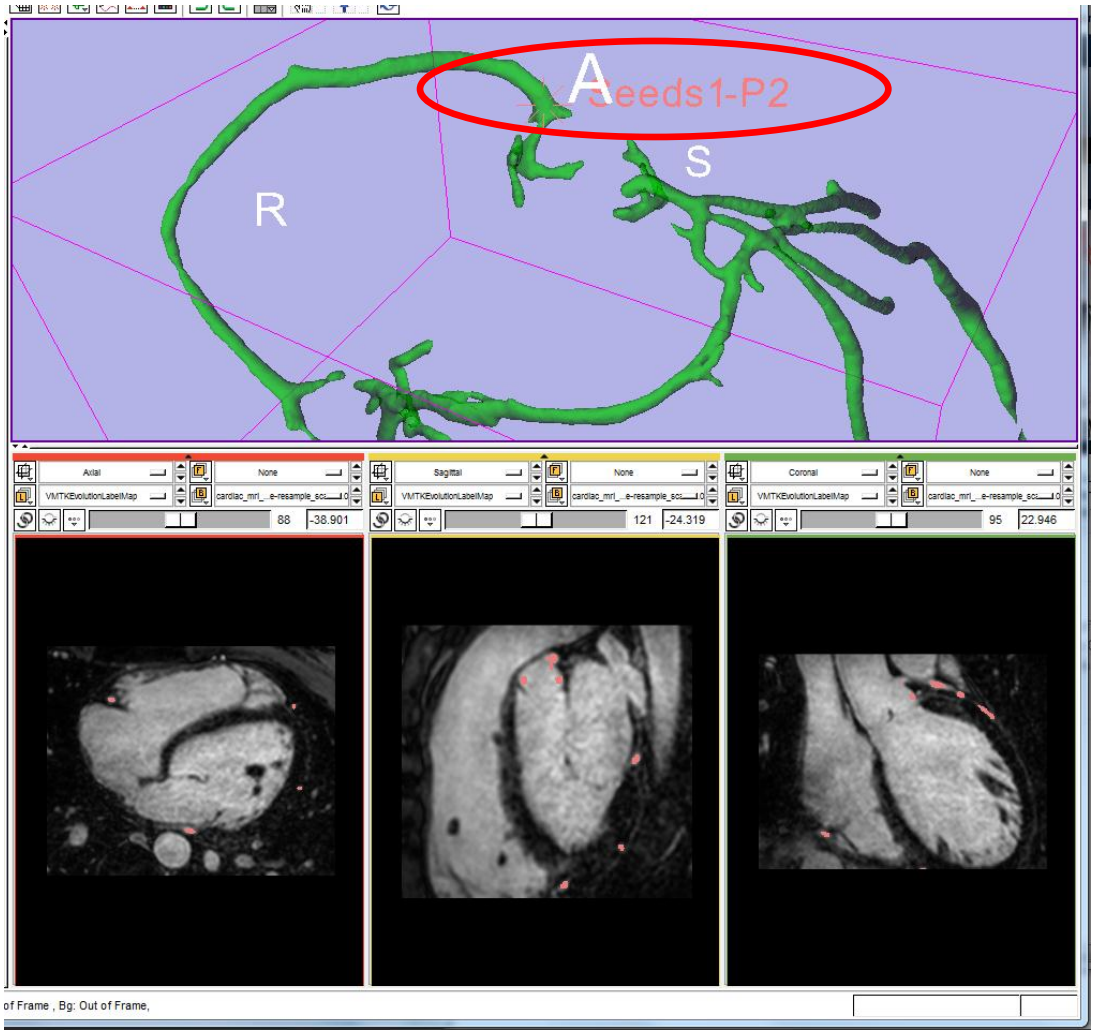
1.Use the “Centerlines Computation” panel to delete the “Seeds” FiducialList and “Create New FiducialList.” This will create a fiducial list named “Seeds1”

2. “Create New Model” for the Centerlines Output Model. This will create a model called “VMTKCenterlinesOut”

3. “Create New Model” for the Voronoi Diagram. This will create a model called “VMTKVoronoiOut”

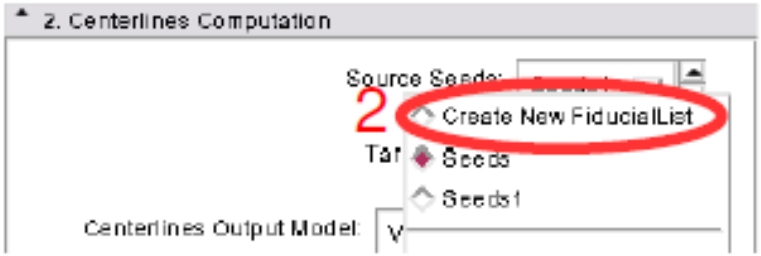
DON’T CLICK “GET CENTERLINES!” YET

Centerline Computation



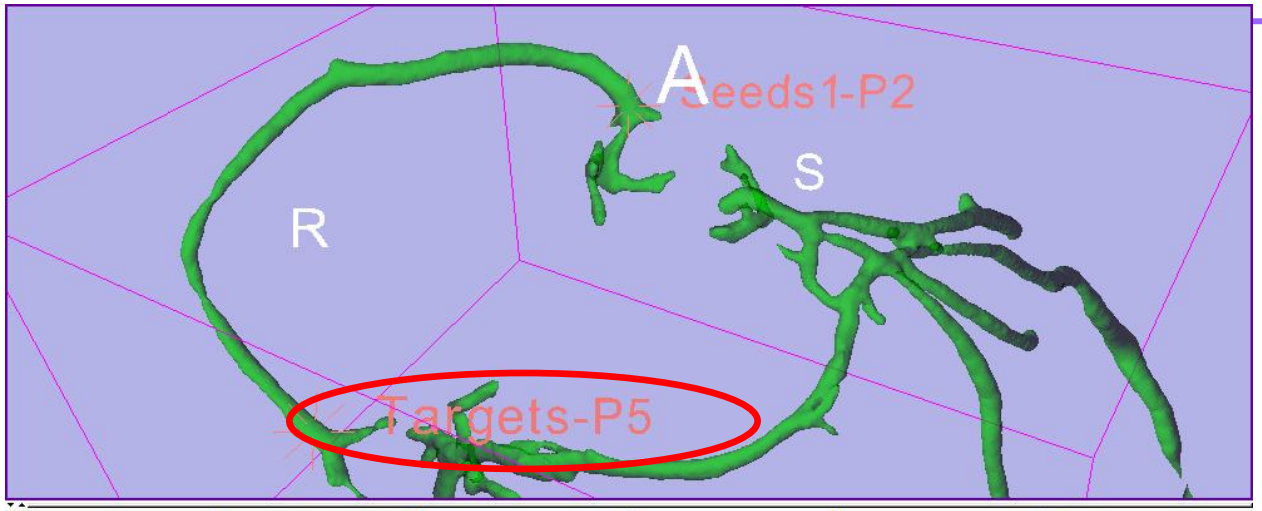
Place a Seed in the 3D Rendering Window directly on the green model where the desired Centerline path will start

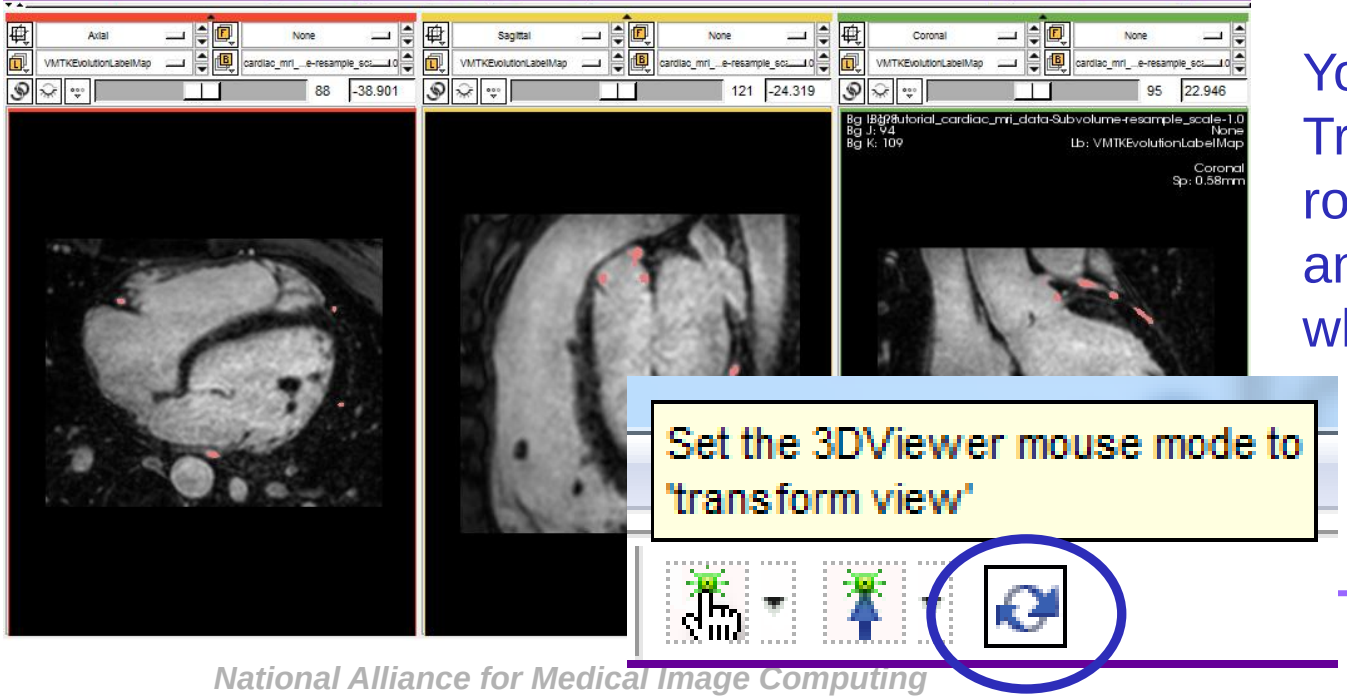
Centerline Computation



Use the “Target Seeds” selector (1) to create a new Fiducial list (2)

Centerline Computation

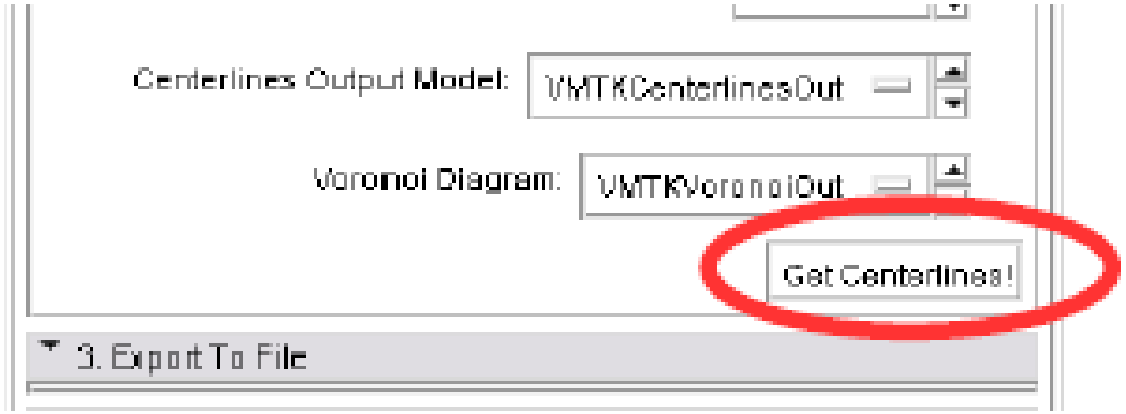




Place a “Target” Seed in the 3D Rendering Window directly on the green model where the desired Centerline path will end.

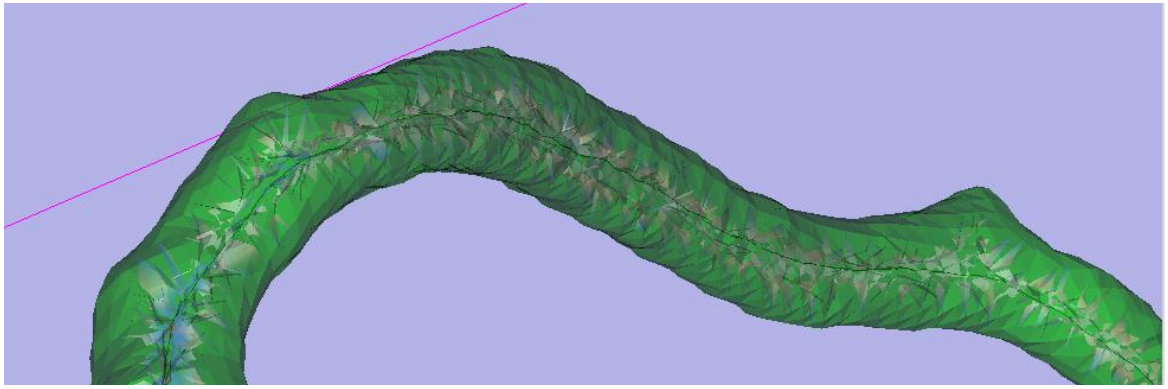
You can switch to Transform mode to rotate the model and place the seeds where desired

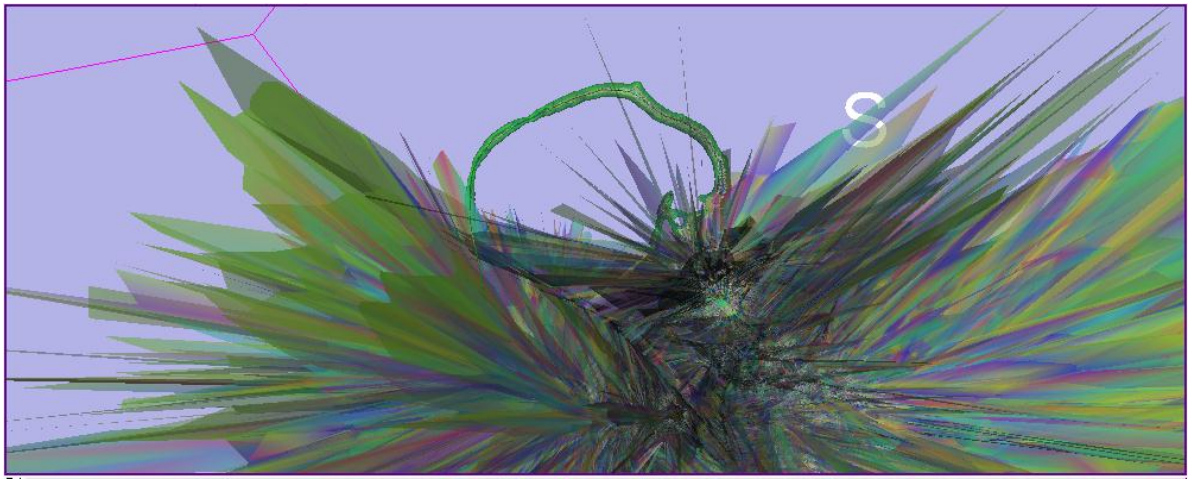
Centerline Computation



Click “Get Centerlines!”

Centerline Computation

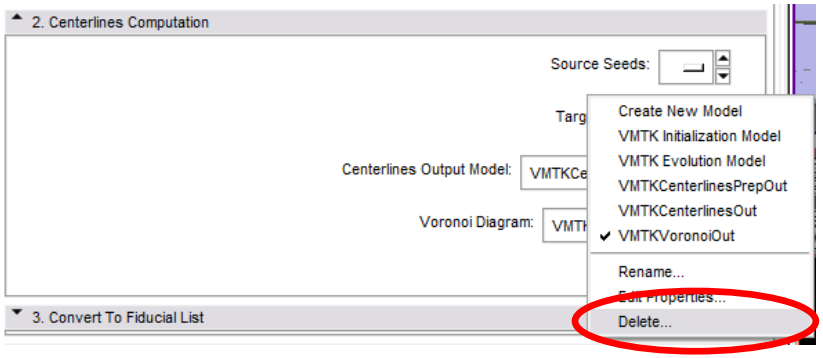


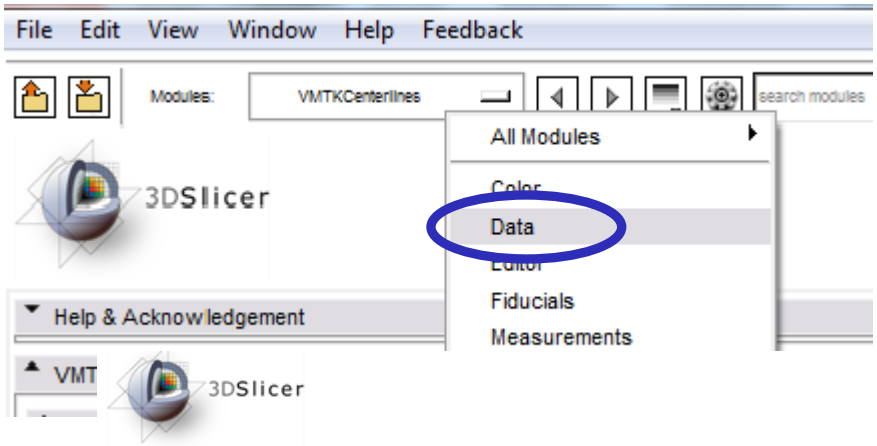


You should have gotten a centerline for the selected path and a Voronai diagram for the entire segmented area. It looks like figure 1.

If you got something that looks like figure 2, then something went wrong when computing the Voronoi diagram. We can just delete or make the voronoi diagram invisible for now….

Centerline Computation

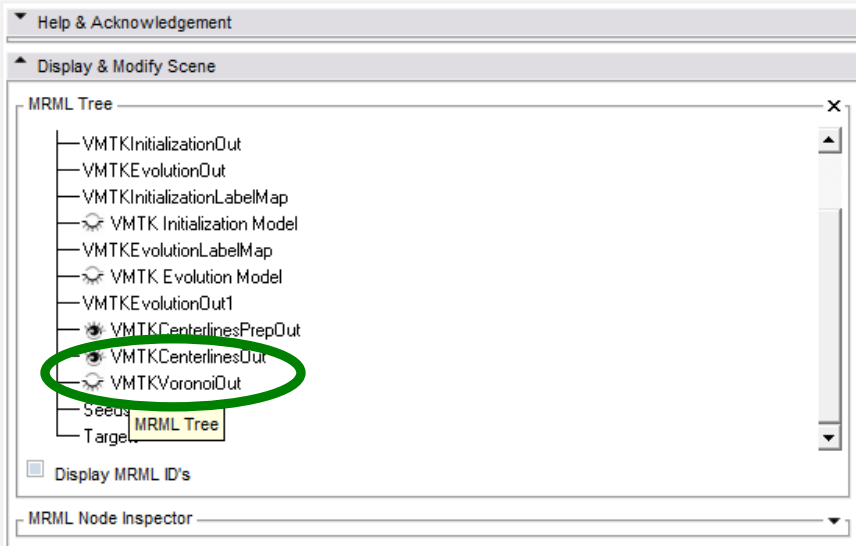




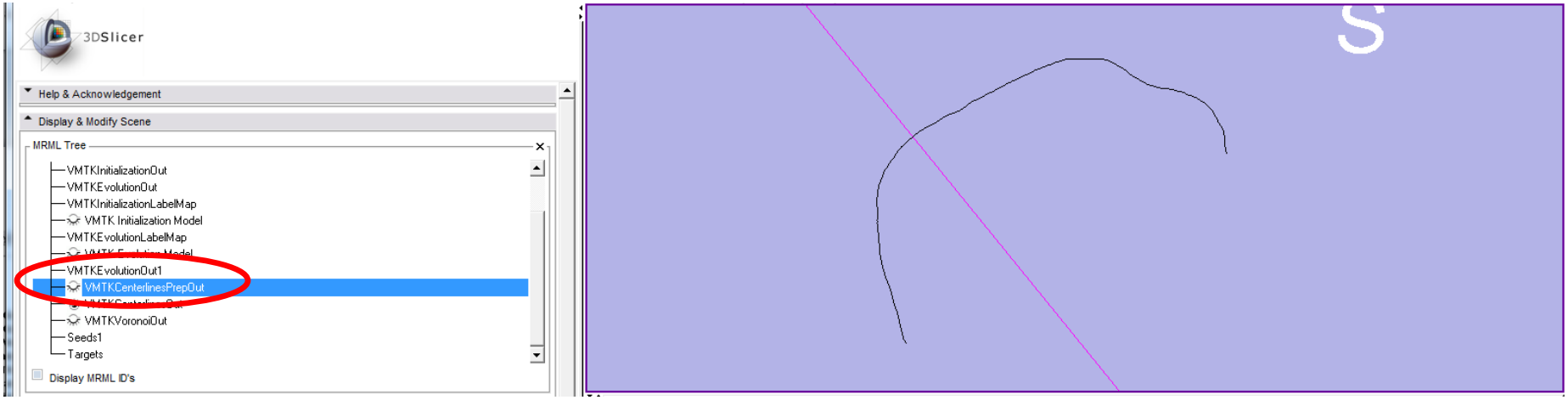
You can delete the Voronoi diagram by opening the “Voronoi Diagram” menu under the Centerlines Computation panel. Make sure the “VMTKVoronoiOut” file is selected and choose delete

If instead you want to make the Voronoi diagram invisible open the “Data” module.

Then scroll down on the “Display & Modify Scene” Panel and click on the eye next to the “VMTKVoronioOut” file to close the eye and make it invisible.

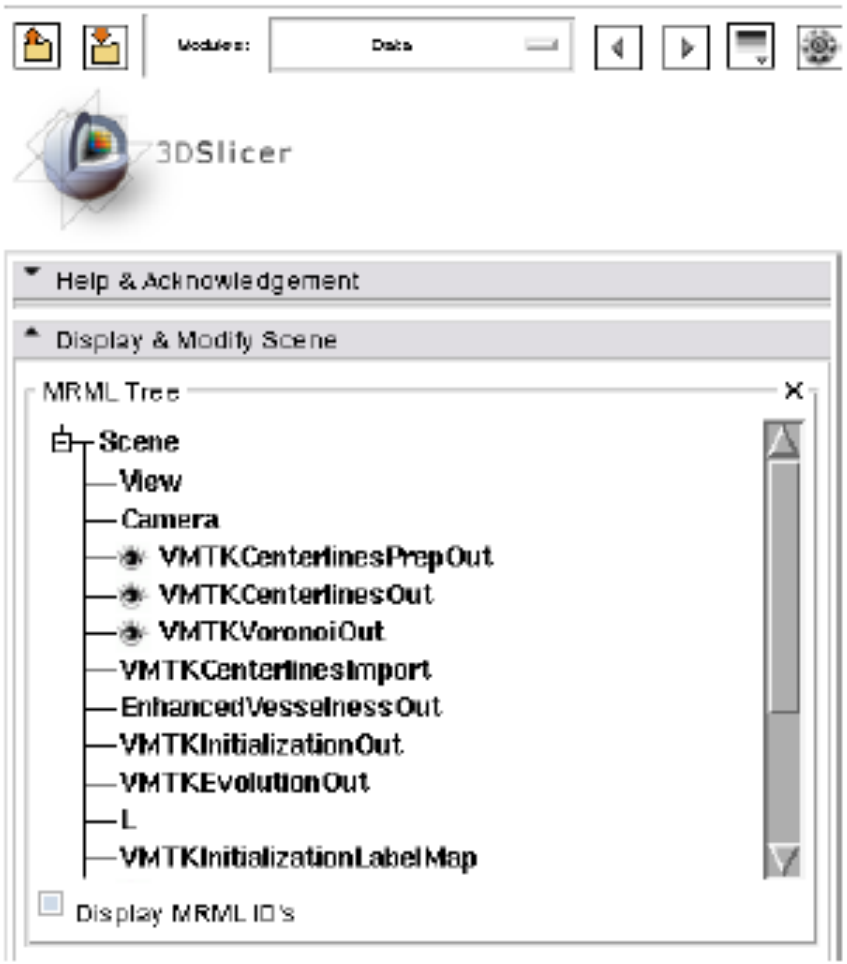


Results



You can also turn off the VMTKCenterlinePrepOut model to see just the Centerline path that you created in the 3D rendering Window.

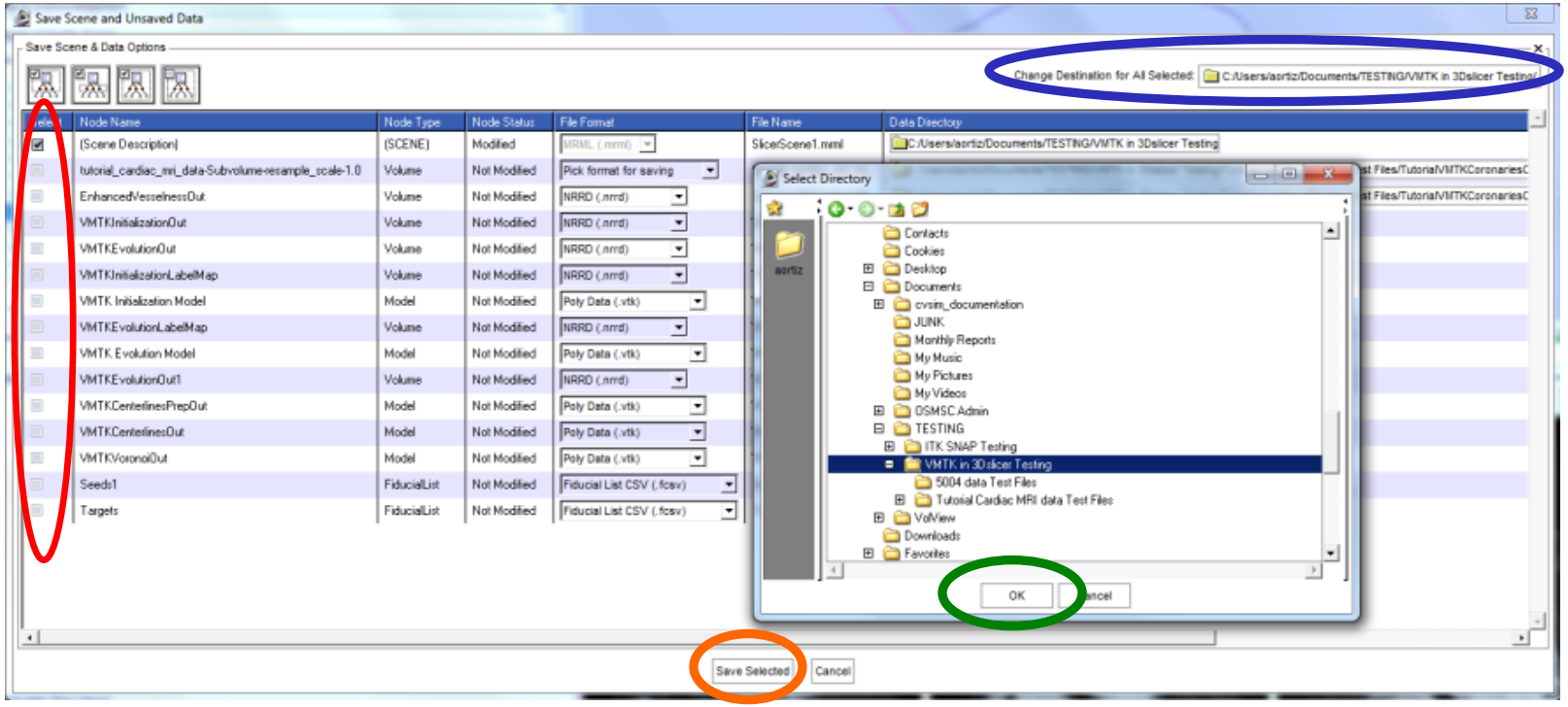
Results



All segmentation parts are available as MRML nodes in the current scene. The "Data" module shows the MRML tree.

In general you can come back to the data module at any time to turn on and off segmentation parts conveniently.

Saving Files



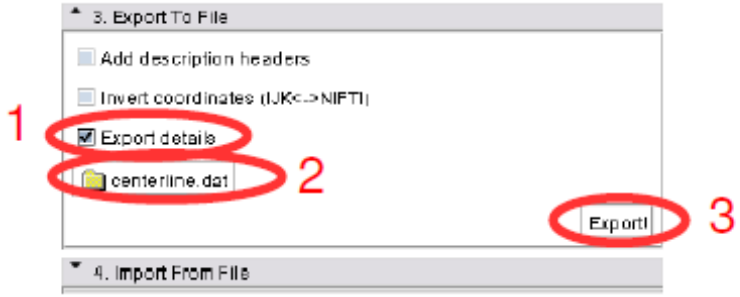
1. Now is a good time to save your work…when saving, select all of the files that you would like to save

2. Select the directory that you would like to save the checked files in.

3. Click "OK"

4. Then Click "Save Selected"

Saving Files



The VMTKCenterlines module supports the export of extracted Centerlines as clouds of points to the filesystem.

To export details like the maximum inscribed sphere radius activate the checkbox (1), choose a destination (2) and click “Export!” (3).

Make sure that, when you choose a destination and enter a file name, you include the file extension type to save as a “.dat” file

Saving Files

centerline.dat

```
-43.5243453979 23.6248474121 -2.82282710075 1.3566731871 83156.0 74764.0 0.076
-43.5672912598 23.6453384291 -2.81163999557 1.34768368553 83687.0 74764.0 0.848
-44.3442382812 23.8746795654 -3.1158893108 1.31434156682 83606.0 83606.0 0.0
-44.6662406921 23.9847869873 -3.34564328194 1.31296327481 81841.0 81841.0 0.0
-44.7168263062 24.0004348755 -3.36283813553 1.31391.0 84189.0 0.06
-45.0118713379 24.0653190613 -3.42026376724 1.36677139288 84284.0 84284.0 0.0
-45.1805908385 24.090881239 -3.53823828697 1.42 82318.0 82318.0 0.0
-45.3257102966 24.1287307739 -3.57551217079 1.44477739523 67865.0 67865.0 0.0
-45.3494758606 24.1336631775 -3.5815103054 1.45031551176 82928.0 82938.0 0.72
-45.4003161621 24.1486034393 -3.61397314072 1.45145492922 59494.0 82920.0 0.872
-45.5894927979 24.1538124084 -3.6366481781 1.45485727223 82684.0 82699.0 0.104
-45.8841552734 24.2133865356 -3.7017223835 1.45863325172 82693.0 82693.0 0.0
-45.9728851318 24.2313556671 -3.73139214516 1.46847106443 54075.0 54075.0 0.0
-45.9736022949 24.2315006256 -3.73163151741 1.475319183 54075.0 81328.0 0.992
-46.1253738403 24.3120250702 -3.77564024925 1.47537432912 81328.0 81328.0 0.0
-46.2832069397 24.3910942078 -3.82611846924 1.46098955773 81335.0 83671.0 0.576
-46.5725059509 24.5075893402 -3.93619441986 1.45986542314 83675.0 83671.0 0.736
-46.5947151184 24.5178642273 -3.94453046706 1.47386688327 83672.0 83675.0 0.852
-46.6676940918 24.5478881727 -3.9686293602 1.47718453884 83732.0 83732.0 0.0
-46.7952346802 24.5904388428 -4.08715827942 1.48837306238 83731.0 83728.0 0.312
-46.8497428894 2
-47.119460869 24
-47.4573402405 2
-47.7022323608 2
-47.7347488403 2
-48.2051200867 2
-48.295879364 25
-48.3784751892 2
-48.4057388306 2
-48.4948959351 2
-48.6587406267 2
-48.765625 25.25
-48.8883724976 2
```

1

2

The exported file includes the world coordinates (1) of the Centerlines and also the Maximum Inscribed Sphere Radius (2) for each point.

ANA: I HAVE NOT CHECKED TO SEE IF FILES WERE SAVED CORRECTLY

References

Luca Antiga, Marina Piccinelli, Lorenzo Botti, Bogdan Ene-Iordache, Andrea Remuzzi, and David A Steinman. An image-based modeling framework for patient-specific computational hemodynamics. *Med Biol Eng Comput*, 46(11):1097–1112, Nov 2008.

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