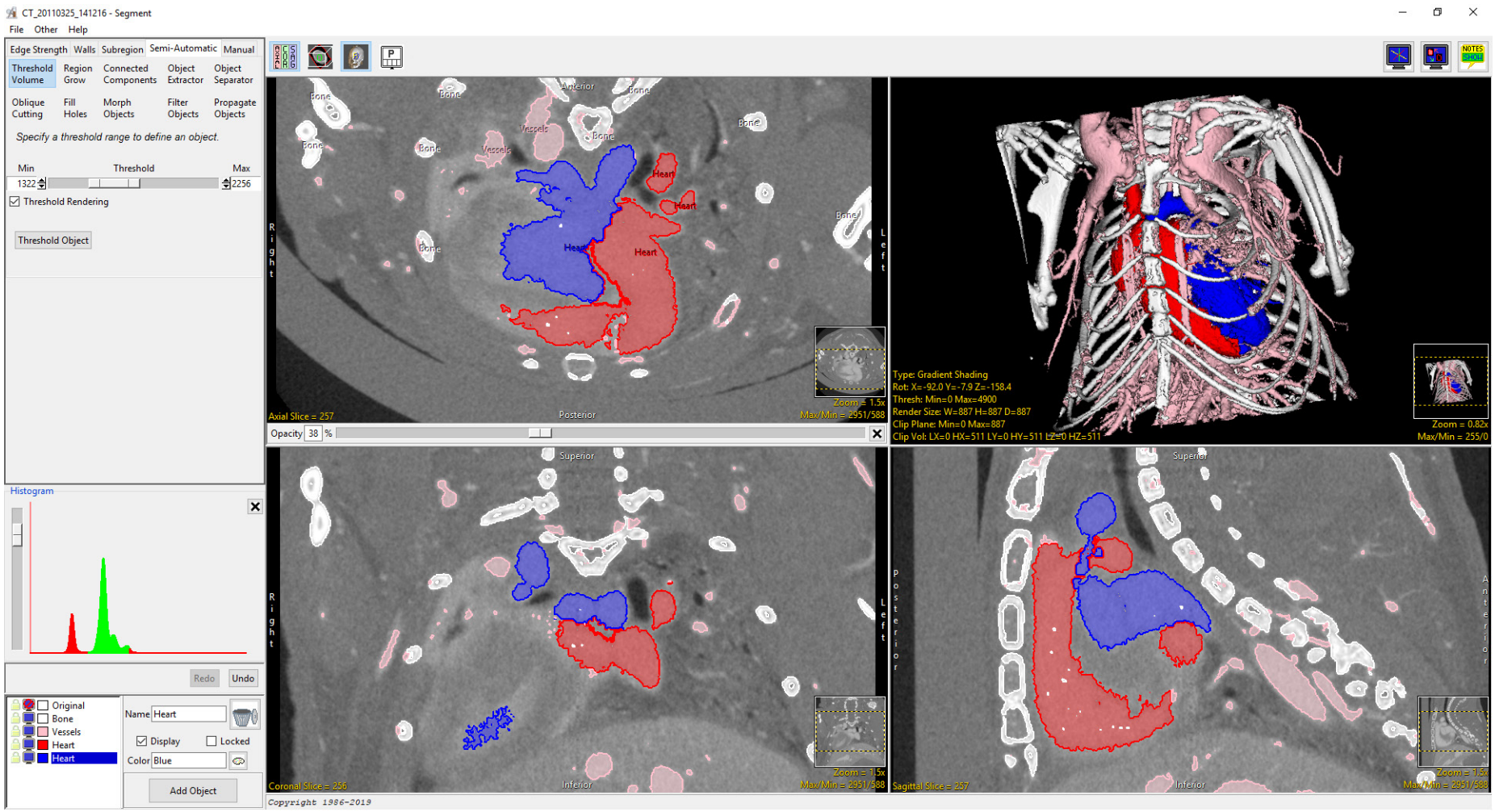
Segment

Introduction

The goal of segmentation is to partition an image into regions, or objects, that are homogeneous with respect to one or more characteristics or features. Segmentation is a critically important tool for the processing of image data and is often the precursor to other applications such as measurement, visualization, surface-based registration and surface extraction.



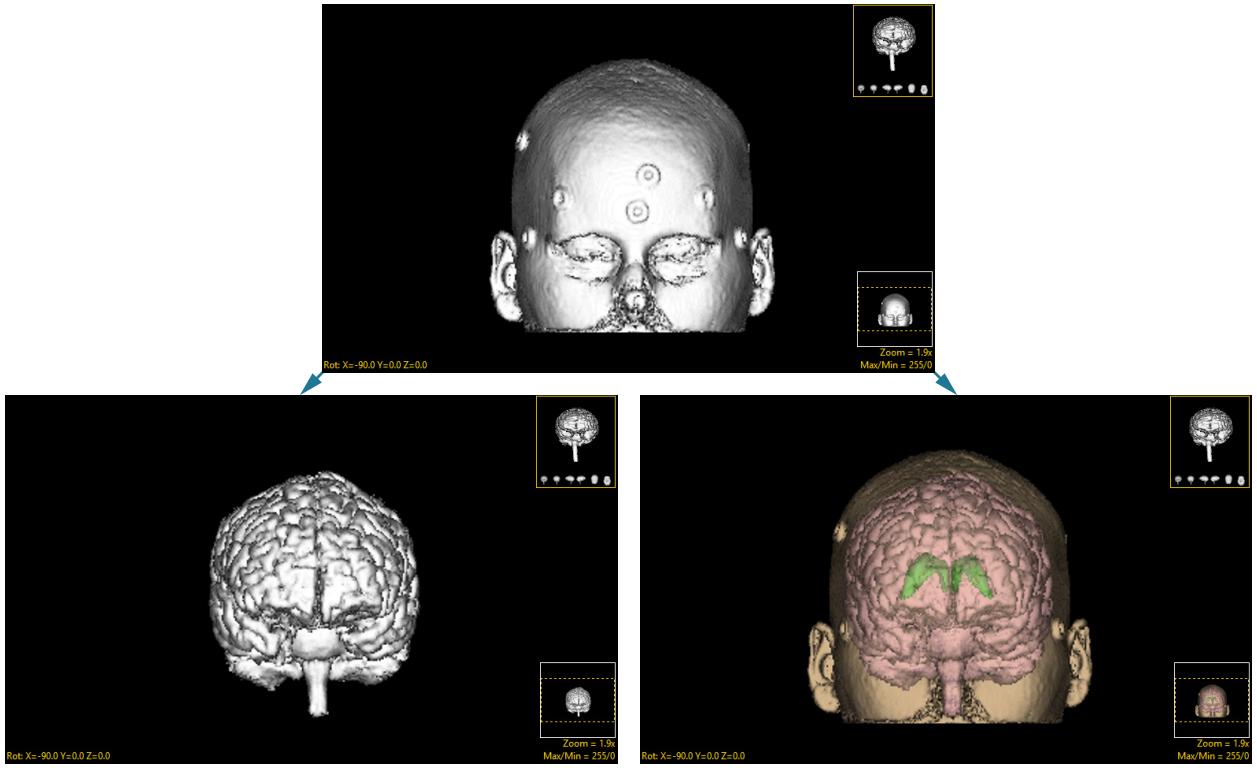
Object Maps

Analyze uses a file called an object map to partition image data into groups of voxels within a segmentation component map. After creation of the object map through segmentation, it can be used to drive visualization, registration, surface generation and statistical analysis.

The object map is an associated volume with the same dimensions as the image data. Each voxel of the object map contains an 8-bit value which encodes it as belonging to 1 of 256 total possible objects. Every voxel in the data set is initially assigned to the first object (Original), leaving 255 additional objects that can be used for 2D region or 3D volume of interest definition.

Object maps are loaded separately from the image data to which they are associated using the File > Load Object Map option in each functional module. When the object map is loaded, the objects defined in it are overlaid on the image data.

Object Map Segmentation vs. Grayscale Segmentation



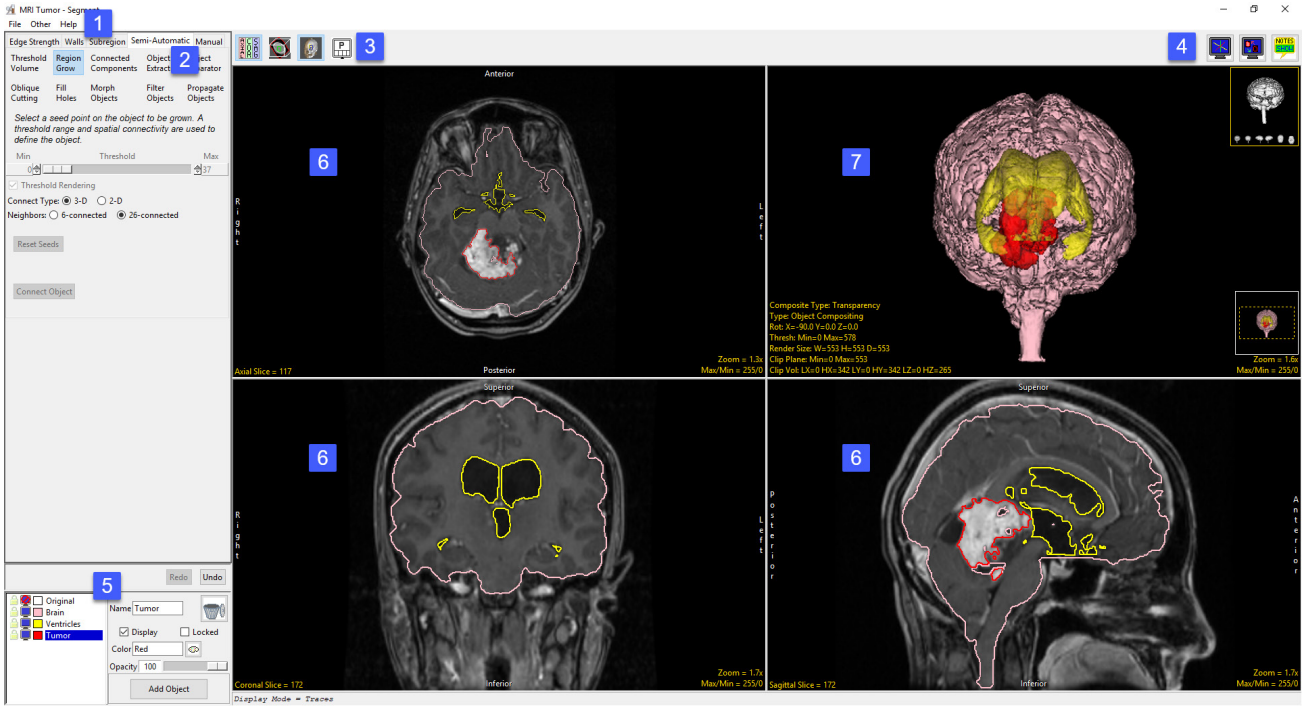
Grayscale segmentation destroys all voxels that are not part of the object of interest.

Object maps preserve the original data by assigning the segmented voxels to objects.

Segment Module Interface

The Segment Module interface is divided into the following areas: [1] Menu, [2] Segmentation Options, [3] Display Controls, [4] Tools, [5] Object Control Window, [6] Orthogonal Image Display, and [7] Rendering Window.

Each of the Segment Module Interface areas are now described:



Menu

The Menu provides access to the File, Options and Help menus.

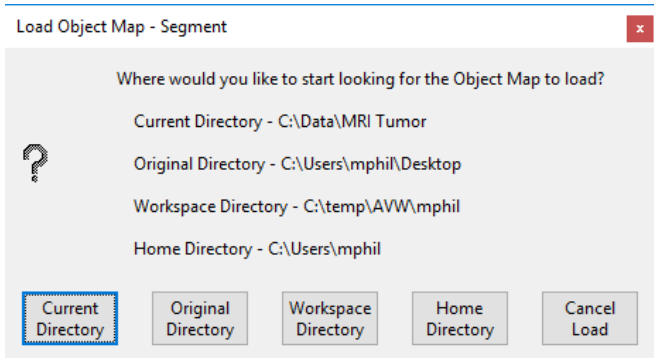
File

The File menu allows users to load and save object maps for the loaded data set. The File options include:

Input/Output Ports: Displays a Volume area at the bottom of the Segment module window. This area facilitates the dragging and dropping of image data into the module and the loading of a related image data set, see Dual Input Segmentation for additional information.

Load Object Map: When selected opens a Load Object Map window allowing users to navigate to, select and load an object map file. The following options are available:

- Current Directory: Takes user to the current directory, the current directory is set by right-clicking in the main Analyze 14.0 window and then choosing Current Directory from the menu. See section 1. Analyze Basics for additional information.
- Workspace Directory: Takes user to the current Workspace directory.
- Home Directory: Takes user to the user's Home directory.
- Cancel Load: Cancels the load of the object map.

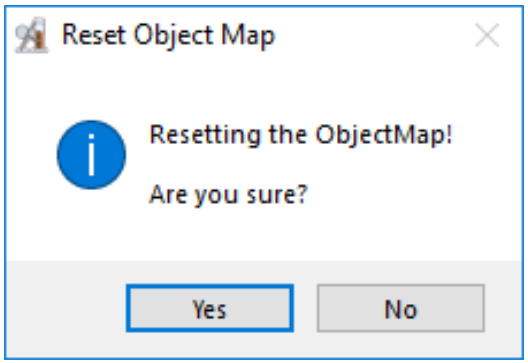


Menu (continued)

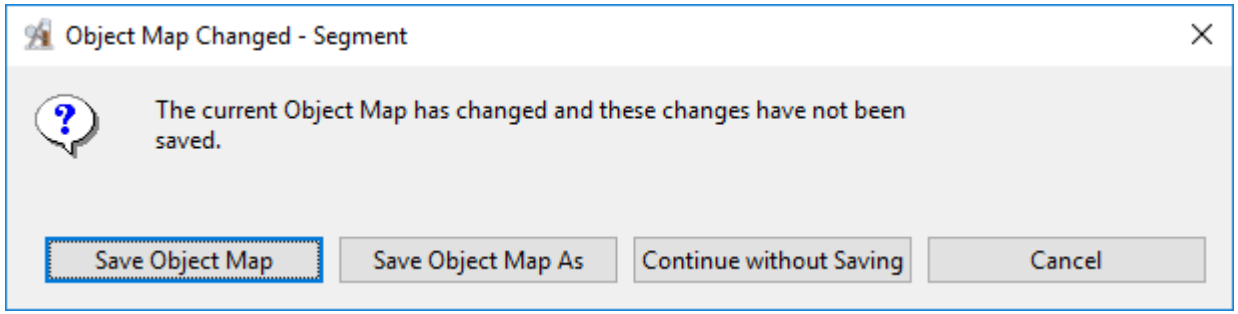
Save Object Map: When selected opens a Save Object Map window allowing users to navigate to name the object map and select a location to save the object map file.

Save Object Map As: Allows users to save a copy of the current object map without overwriting the original object map file.

Reset Object Map: Resets the current loaded object map, deleting all defined objects. When this option is selected a prompt will be returned asking you to confirm the reset. Select 'Yes' to continue or 'No' to cancel.



If the object map has not been saved or changes to an object map have not been saved when the Rest Object Map option is selected an Object Map Changed prompt will be returned providing the opportunity to save the object map.



Exit: Closes the module

Menu (continued)

Other

The other menu provides access to additional module options and configuration of the tools area.

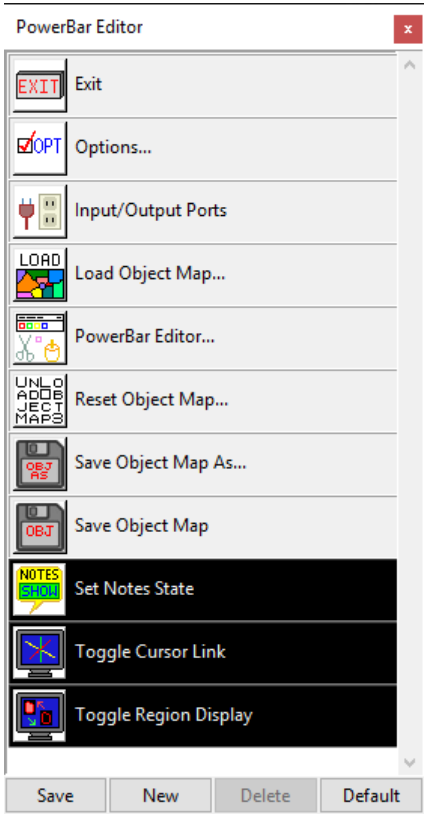
Options: When selected opens the Options menu providing access to Module configuration options, including:

- Intensities Linked: Allows users to enable or disable linked intensity adjustment. When linked any adjustment an images intensity display will be applied to all grayscale slices displayed. When disabled image intensities can be adjusted individually.
- Fast Object Rendering: Enables/Disabled Fast Object Rendering.
- Show Cursor Coordinates: Allows users to Enable/Disable the display of the linked cursor coordinates and voxel grayscale value displayed in the lower left-hand corner of the display window.
- Auto Note Update: Allows the Auto Note Update option to be enabled or disabled.
- Auto Cursor Link: Allows the Auto Cursor Link option to be enabled or disabled.
- Remember Layout: When enabled the module will remember changes made to the layout and will open with this layout in the future. When disabled the module will open with the default layout.
- Threads: Allows users to specify the number of threads used in a multi-threaded rendering process. By default, the number of threads is set to the number of processors on the system.

Menu (continued)

Powerbar Editor

When selected opens the PowerBar editor allowing users to add additional shortcut buttons to the tools area of the Segment window. Add or remove the following shortcut buttons form the tools area: 1) Exit, 2) Options, 3) Input/Output, 4) Load Object Map, 5) PowerBar Editor, 6) Reset Object Map, 7) Save Object Map As, 8) Save Object Map, 9) Set Note Stat, 10) Toggle Cursor Link, 11) Toggle Region Display.



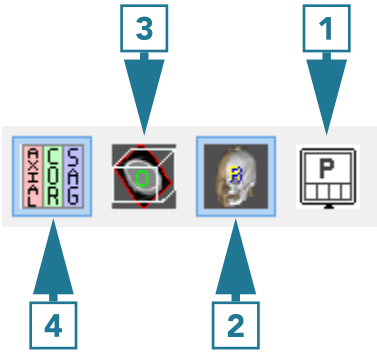
Help

The Help menu provides users with quick access to help resources including:

- About: View version, system and environment information.
- Users Guide: Opens the Analyze 14.0 User's Guide.
- Get Help: Opens the AnalyzeDirect Support Page.

Display Controls

The Display Control tools allow users to control and customize the layout of the Segment display area. Some of these control options are unique to Segment.



1 Control Layout

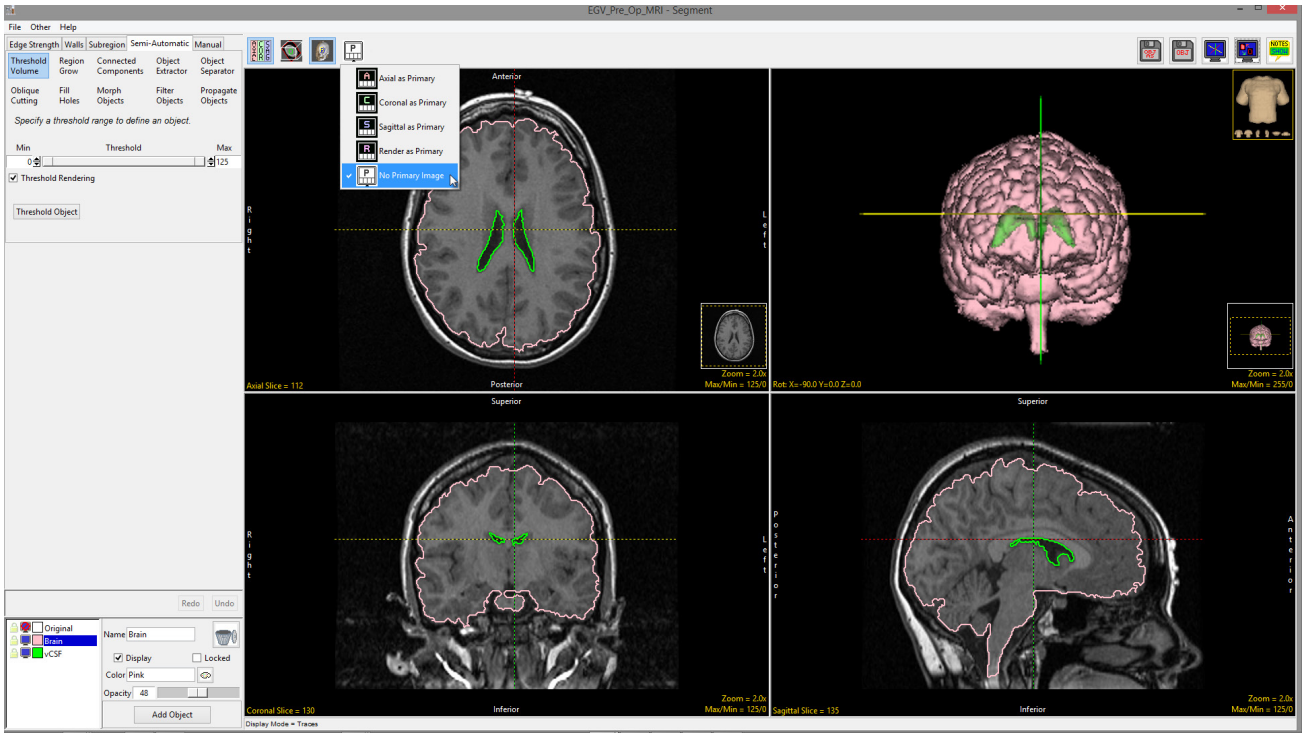
2 Toggle Rendering

3 Toggle Oblique

4 Toggle All Orientations

Control Layout

This option allows users to control the layout of the display. Choose from Axial as Primary, Coronal as Primary, Sagittal as Primary, Render as Primary or No Primary image.

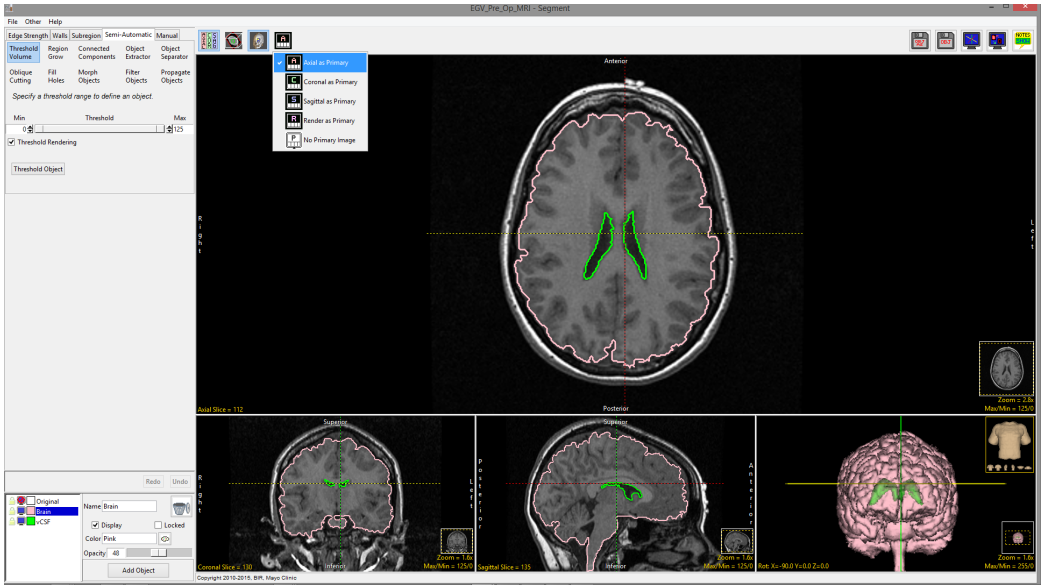


No Primary Image: This is the default selection.

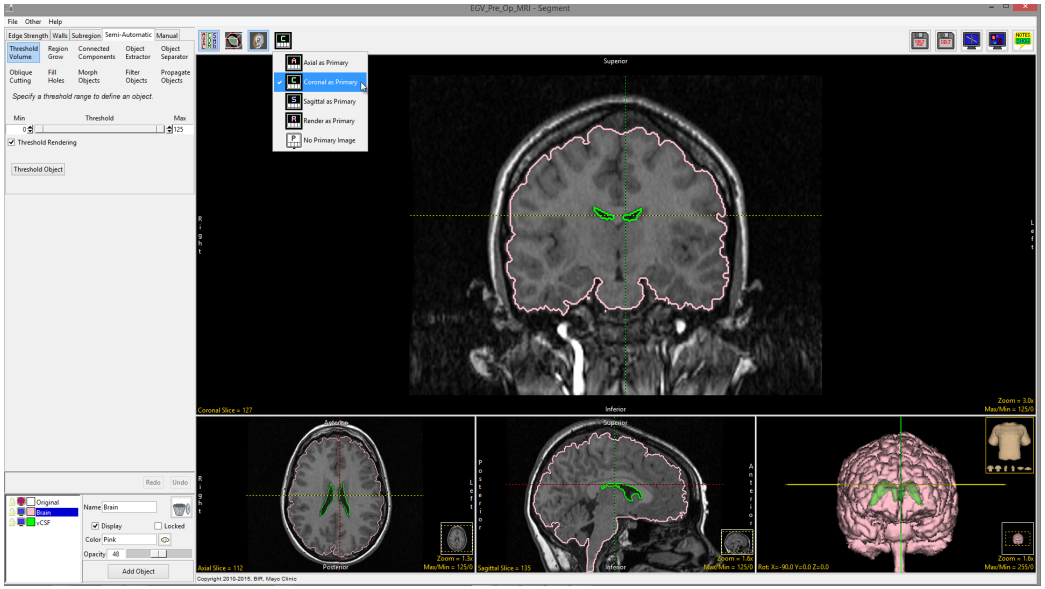
This option displays the rendering and three orthogonal views in four equally sized windows.

Display Controls (continued)

Axial as Primary: Focuses the display on the axial image. The coronal, sagittal and rendering windows are displayed below the axial window.

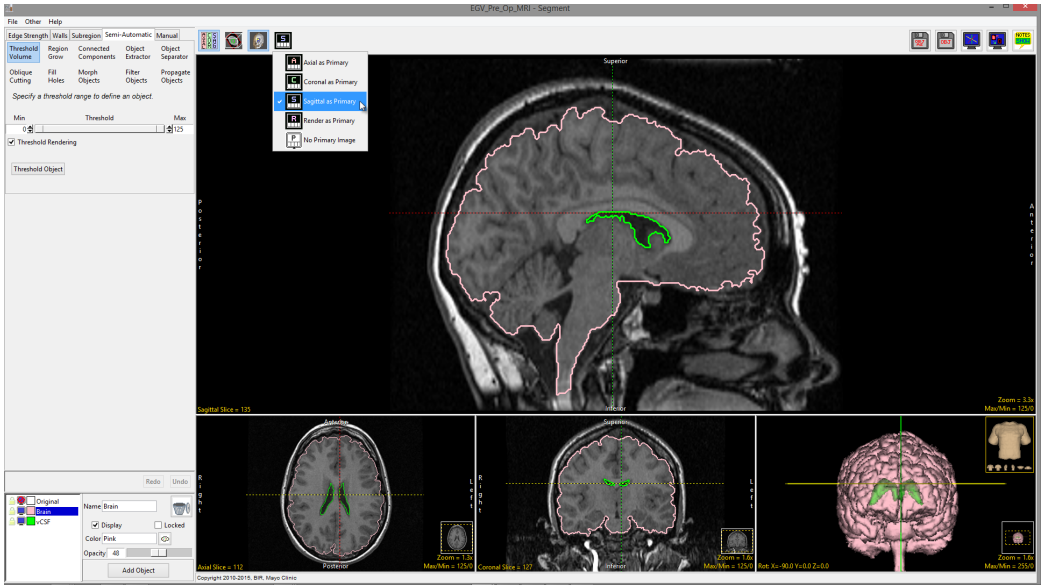


Coronal as Primary: Focuses the display on the coronal image. The axial, sagittal and rendering windows are displayed below the coronal window.

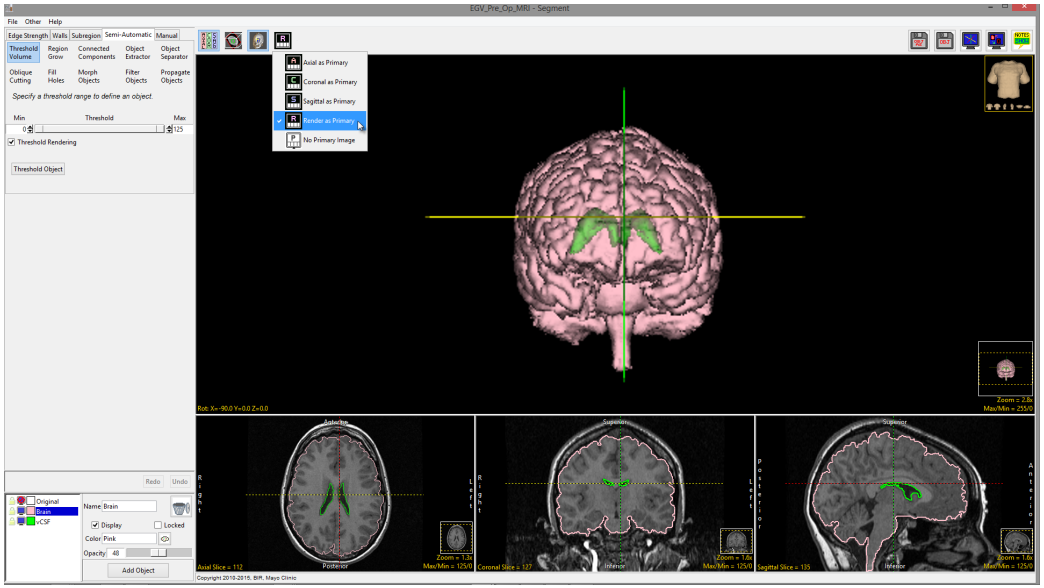


Display Controls (continued)

Sagittal as Primary: Focuses the display on the sagittal image. The axial, coronal and rendering windows are displayed below the sagittal window.



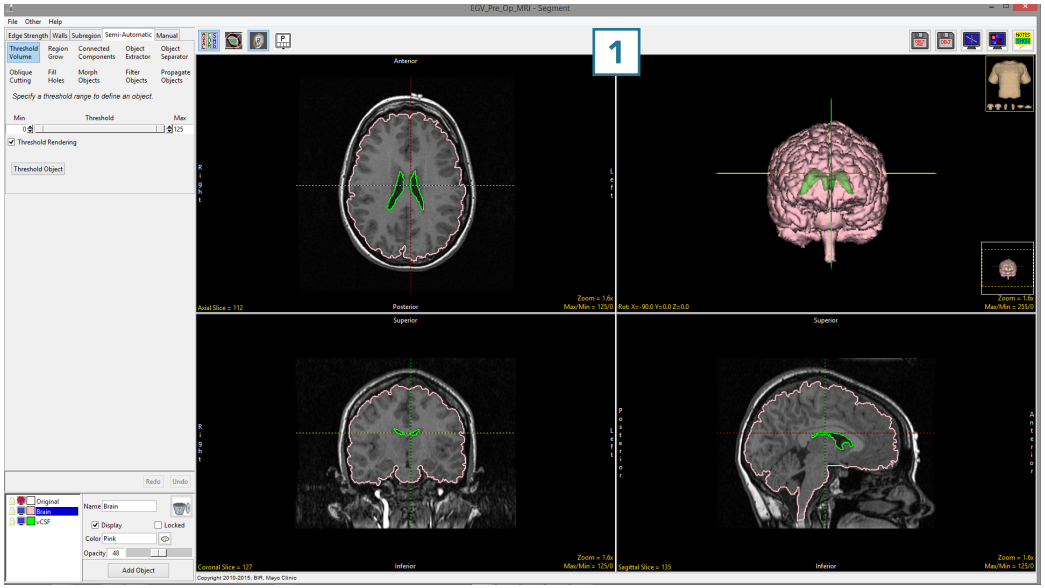
Render as Primary: Focuses the display on the rendering. The axial, coronal and sagittal windows are displayed below the rendering.

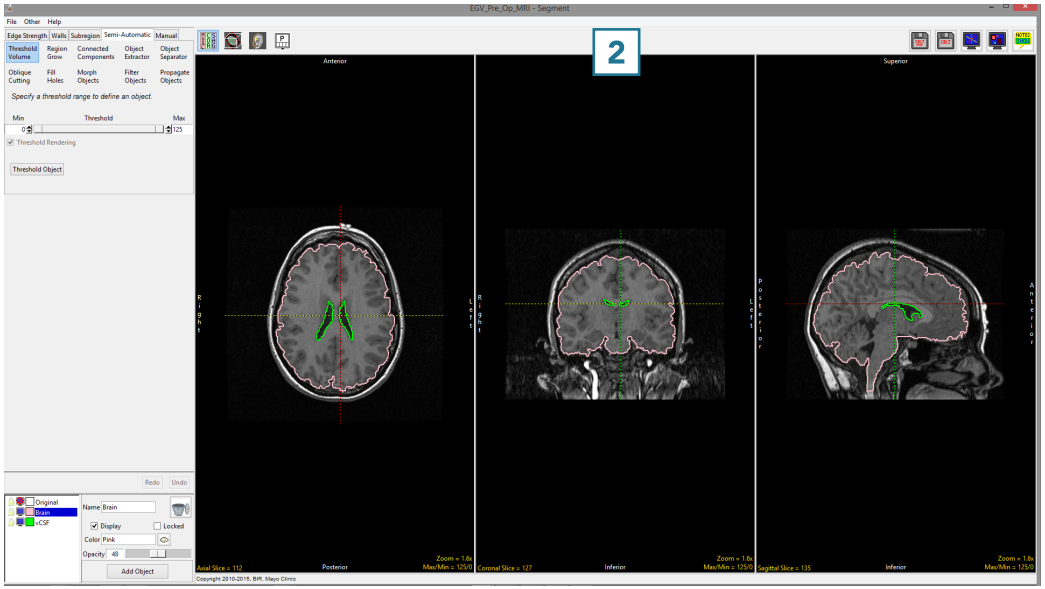


Display Controls (continued)

Toggle Rendering

The Toggle Rendering options allows users to switch the Render window on [1] and off [2].

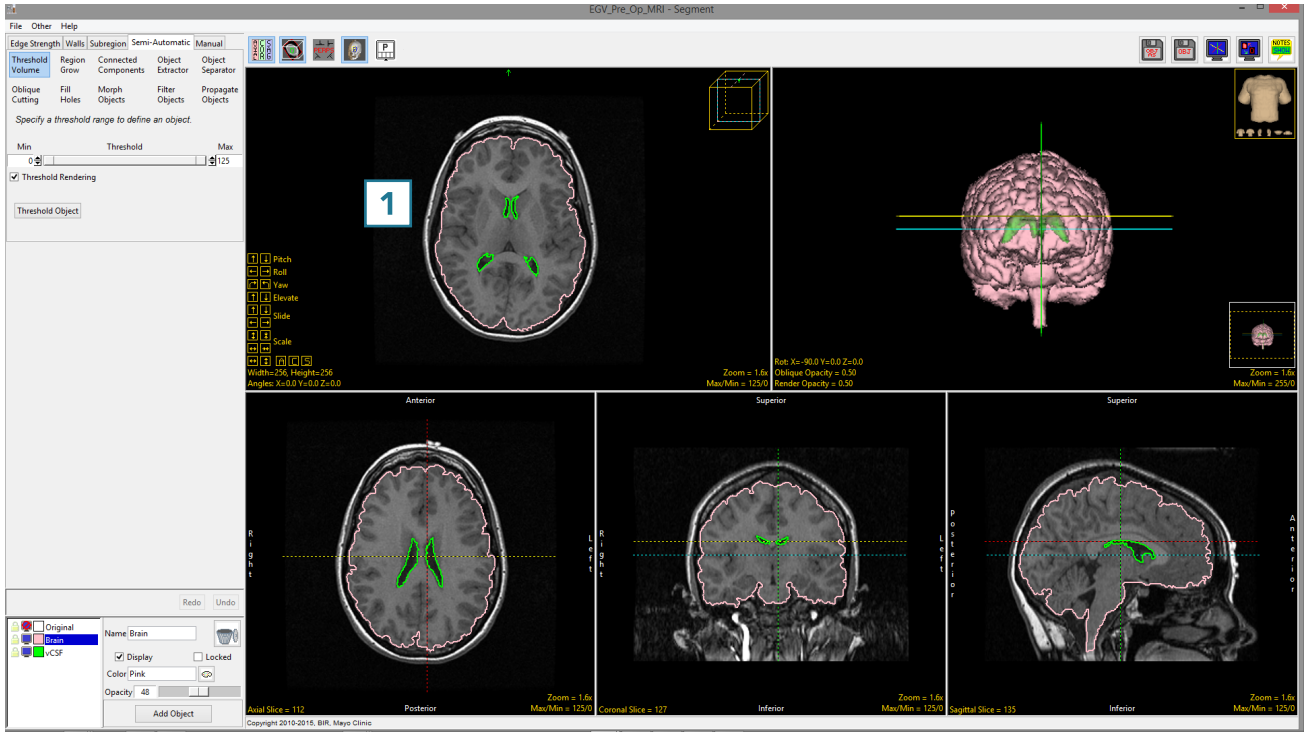




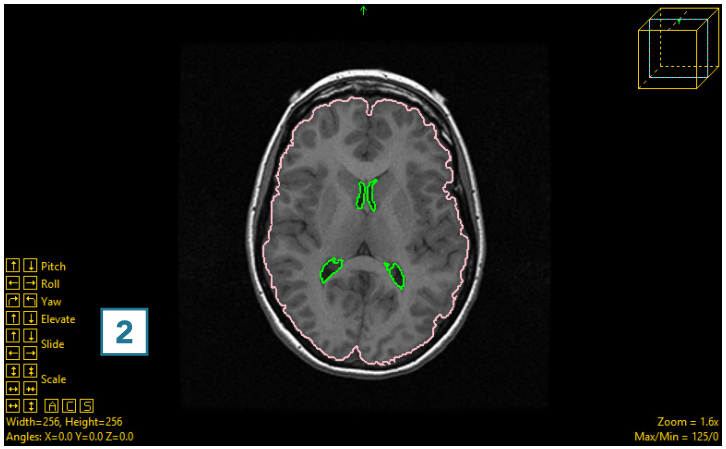
Display Controls (continued)

Toggle Oblique

The Toggle Oblique option allows users to switch the oblique display window [1] on and off.



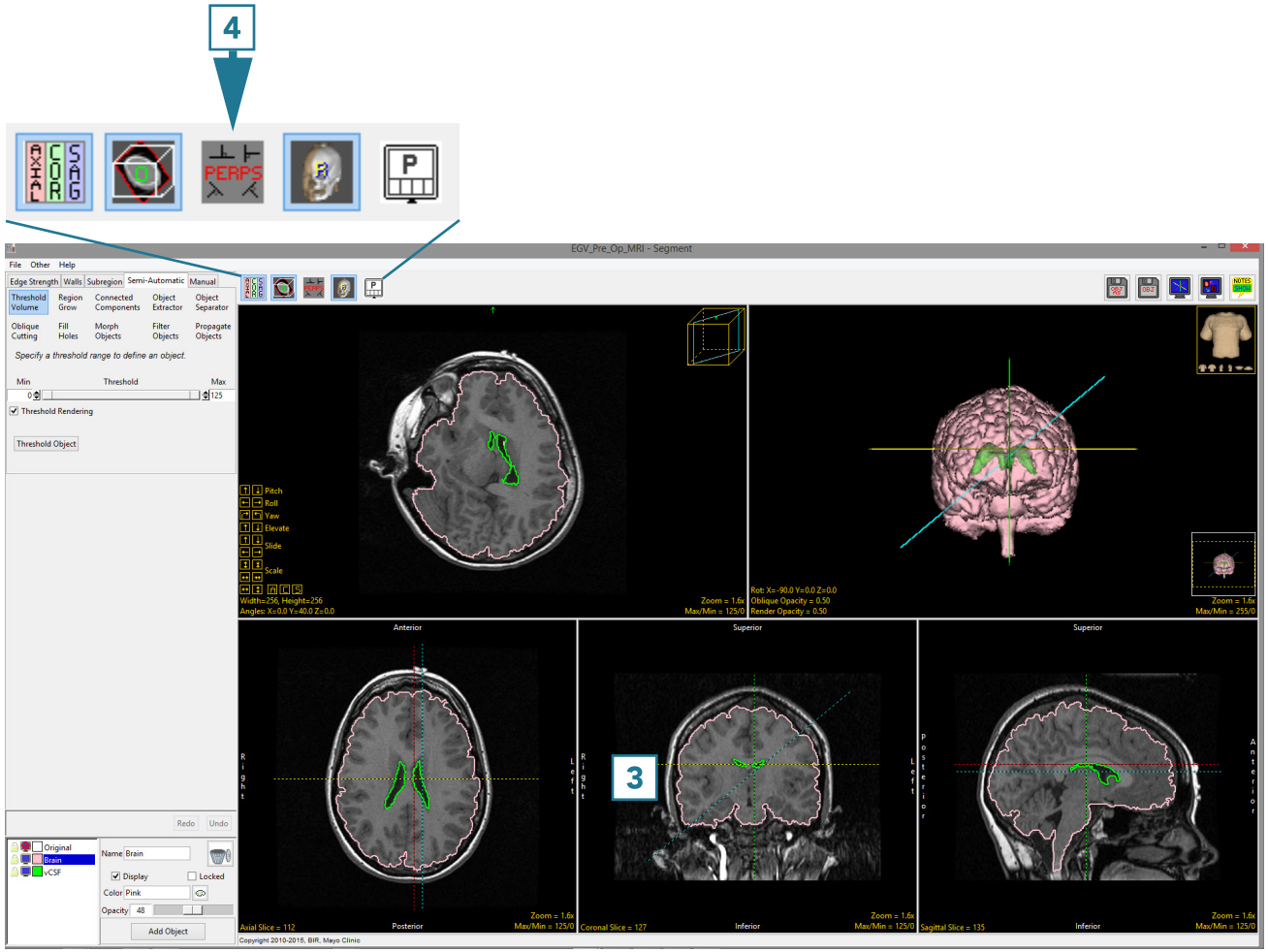
The oblique window provides users with the ability to create any arbitrary oblique plane on the fly, using the control tools [2] in the oblique window.



Display Controls (continued)

The oblique image can also be generated using the blue oblique reference line that appears in all of the other enabled windows [3].

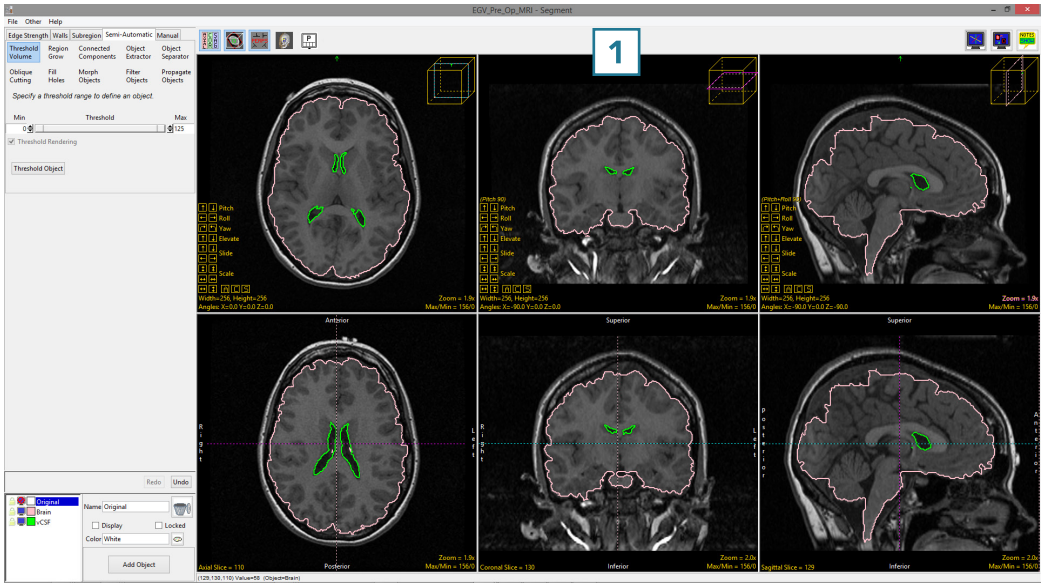
When the oblique image is enabled, an additional option becomes available: Toggle Perpendicular [4].



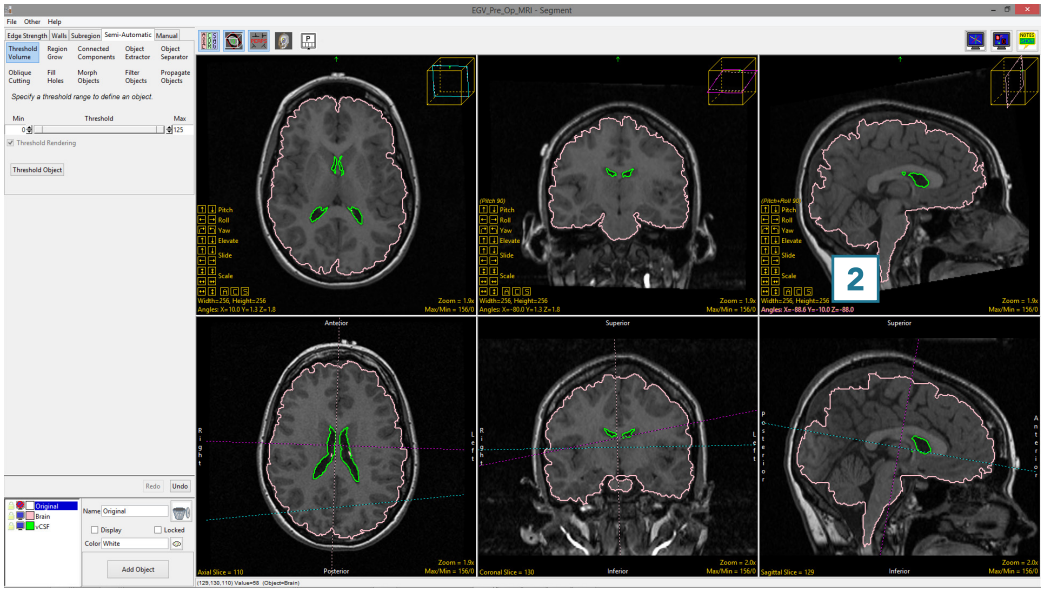
Display Controls (continued)

Toggle Perpendicular

The Toggle Perpendicular window provides an oblique control window for each orientation [1].

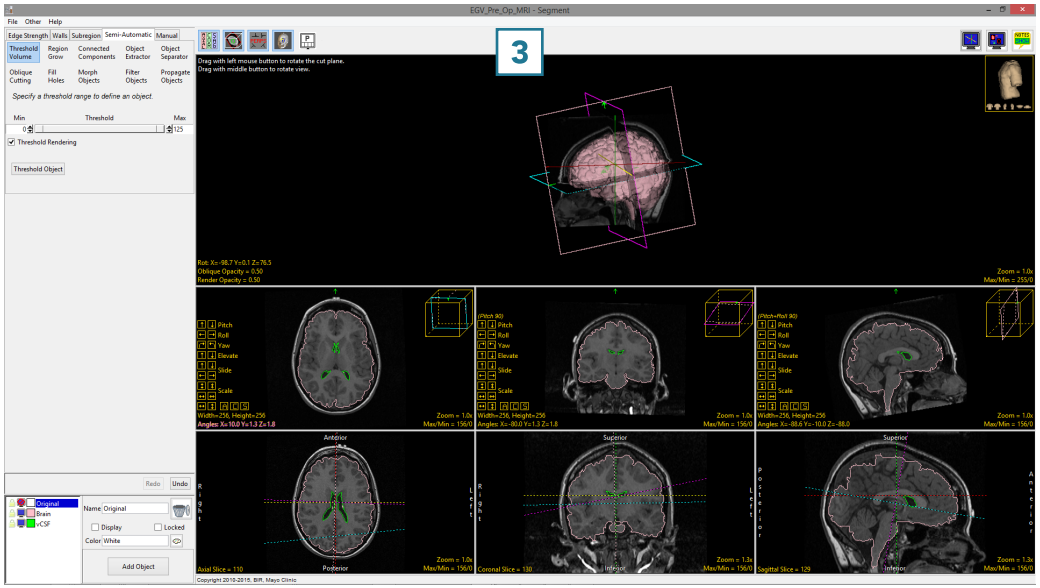


The control tools [2] can be used to manipulate each orientation to aid users with the generation of the desired oblique plane.

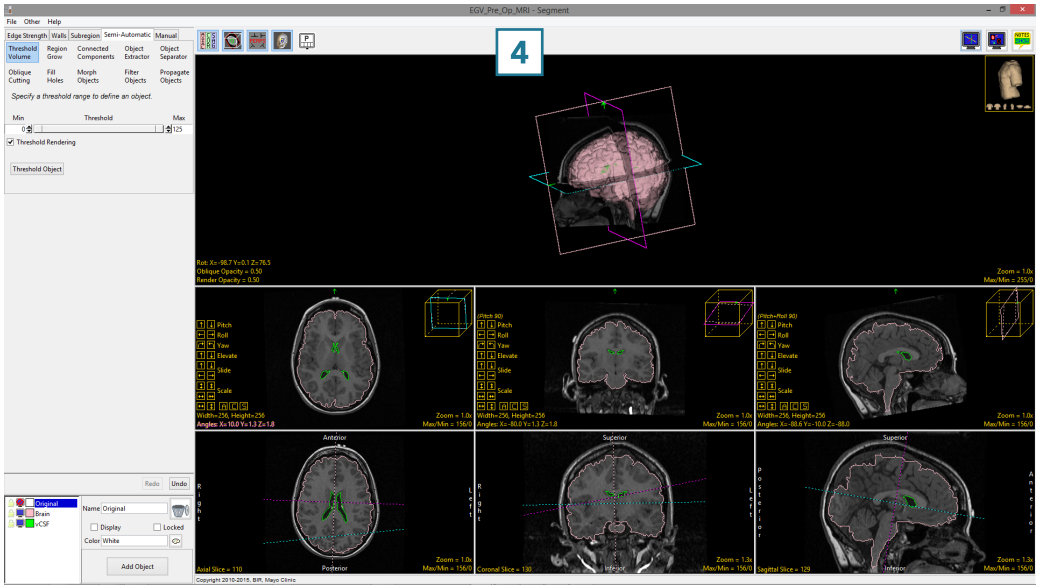


Display Controls (continued)

When enabled, the perpendicular displays can be viewed with the Rendering toggled on [3]. While this option is up to the user, some users find the oblique reference lines displayed on the 3D rendering helpful when manipulating the oblique plane in 2D.



Users may also find it useful to switch off the linked cursor tool [4] when using the oblique reference lines.

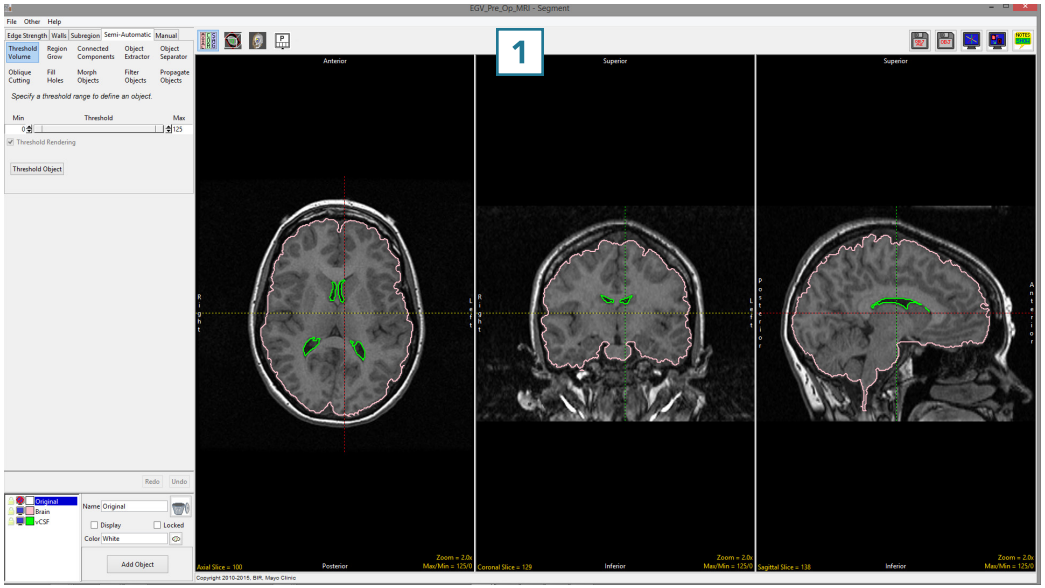


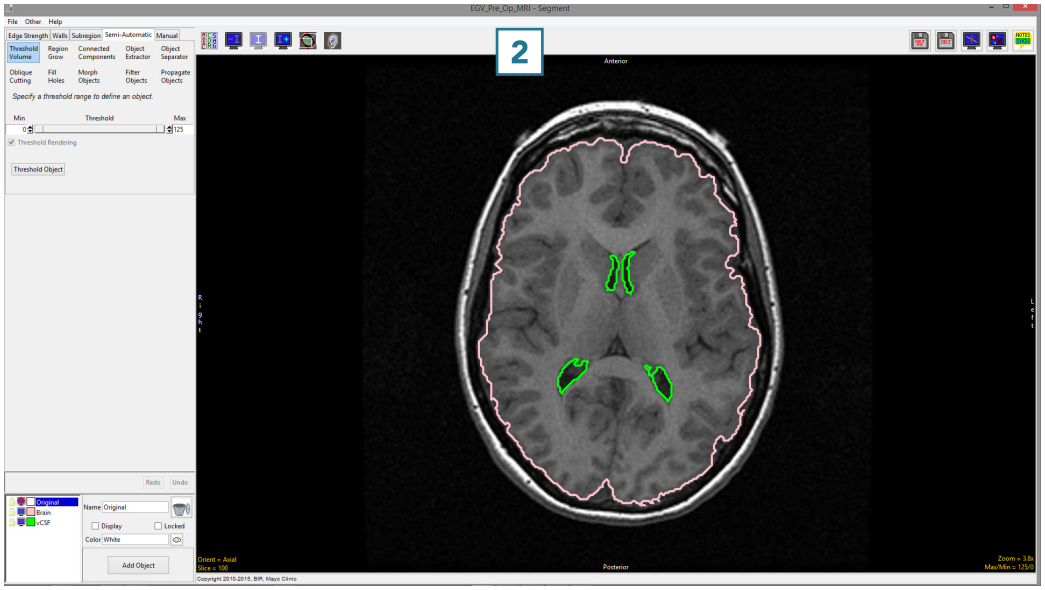
For more information about creating oblique planes, refer to the Apply Matrix exercise in the Transform section.

Display Controls (continued)

Toggle All Orientations

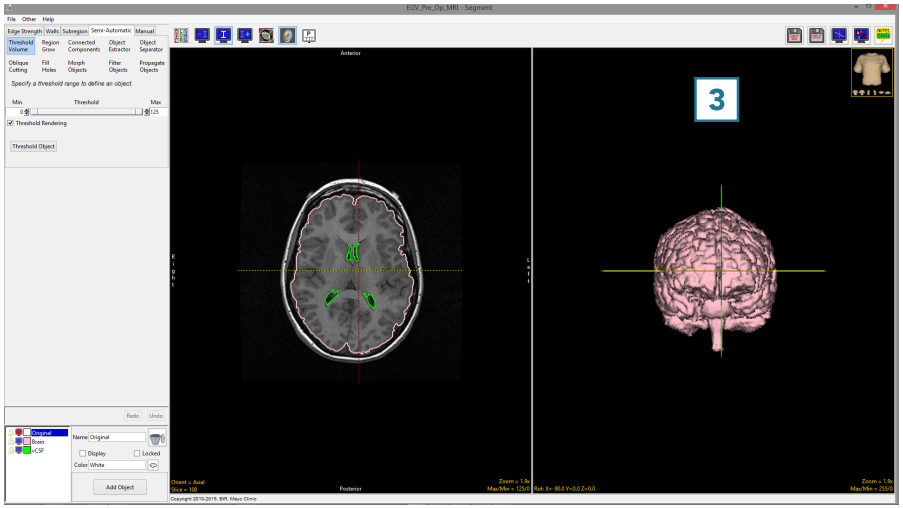
The Toggle All Orientations option allows users to switch between the display of the axial, coronal and sagittal [1] windows to a single image window [2].



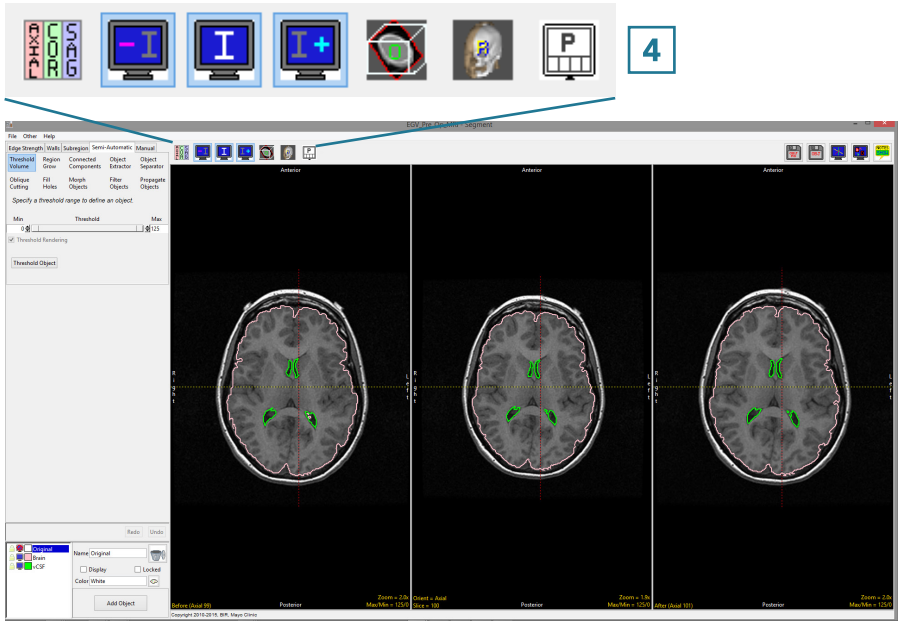


Display Controls (continued)

When the rendering is enabled, the 3D rendering will also be displayed [3].

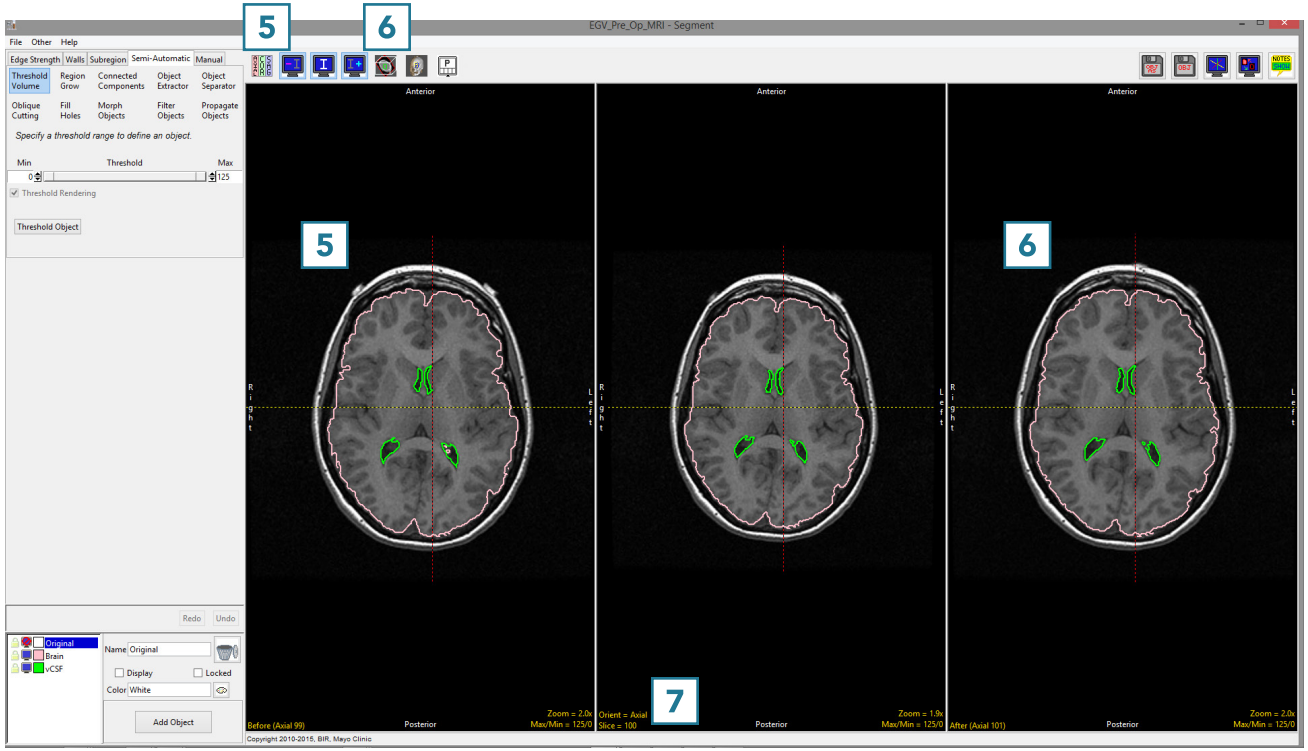


When display is toggled to single display mode, additional display options are enabled [4].



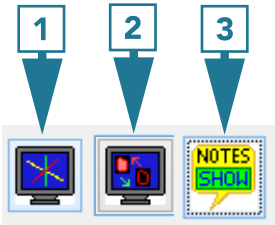
Display Controls (continued)

The additional options allow users to display the image before [5] and after [6] the current slice. To display another orientation, click on the Orient text [7] to cycle through the orthogonal orientation displays.



Tools

The Tools options in the top right hand corner of the Segment Module Interface, provide access to the Cursor Link, Toggle Region Display and the Set Note State tools.



1 Cursor Link

2 Toggle Region Display

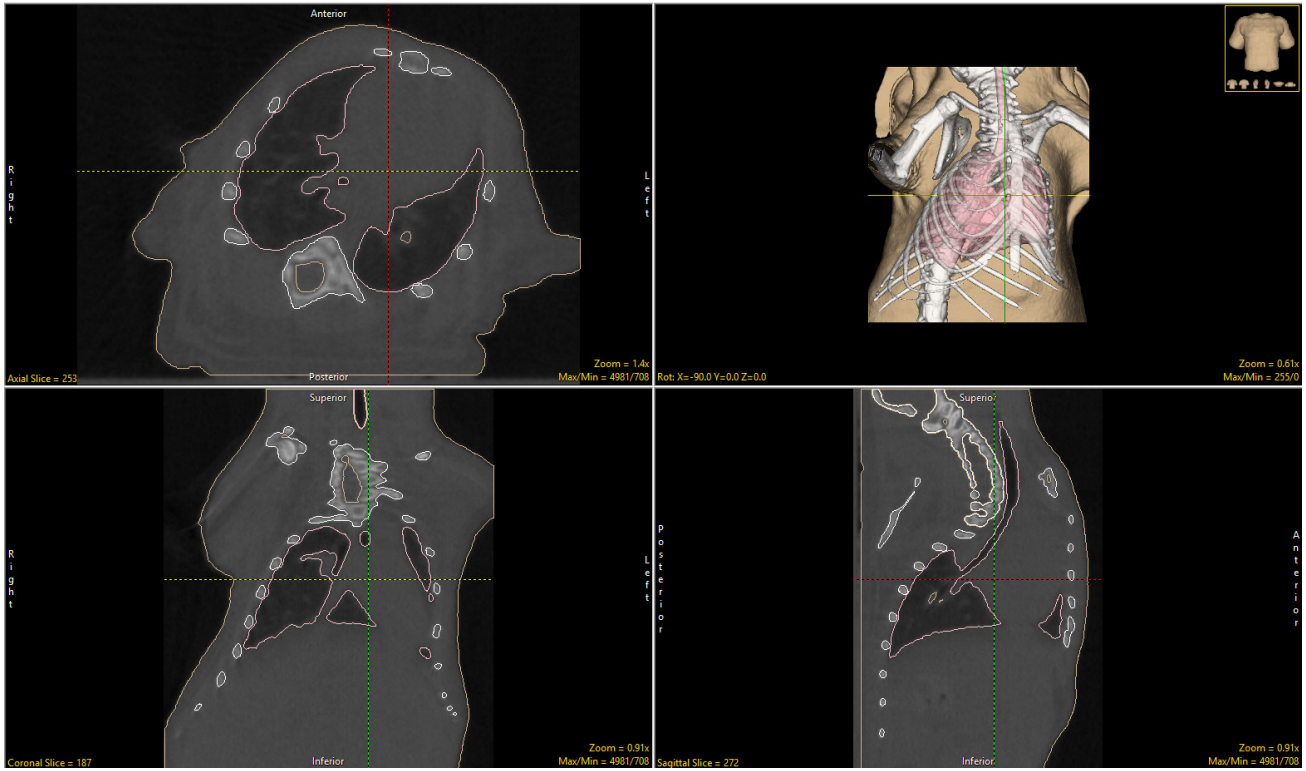
3 Set Note State

Cursor Link

The cursor link allows users to interactively navigate through the image data. The tool can be controlled

from any of the 2D orientations or from the 3D rendering. Moving the tool will interactively update the corresponding slice displays.

The linked cursor can be enabled or disabled using the Toggle Cursor Link button.

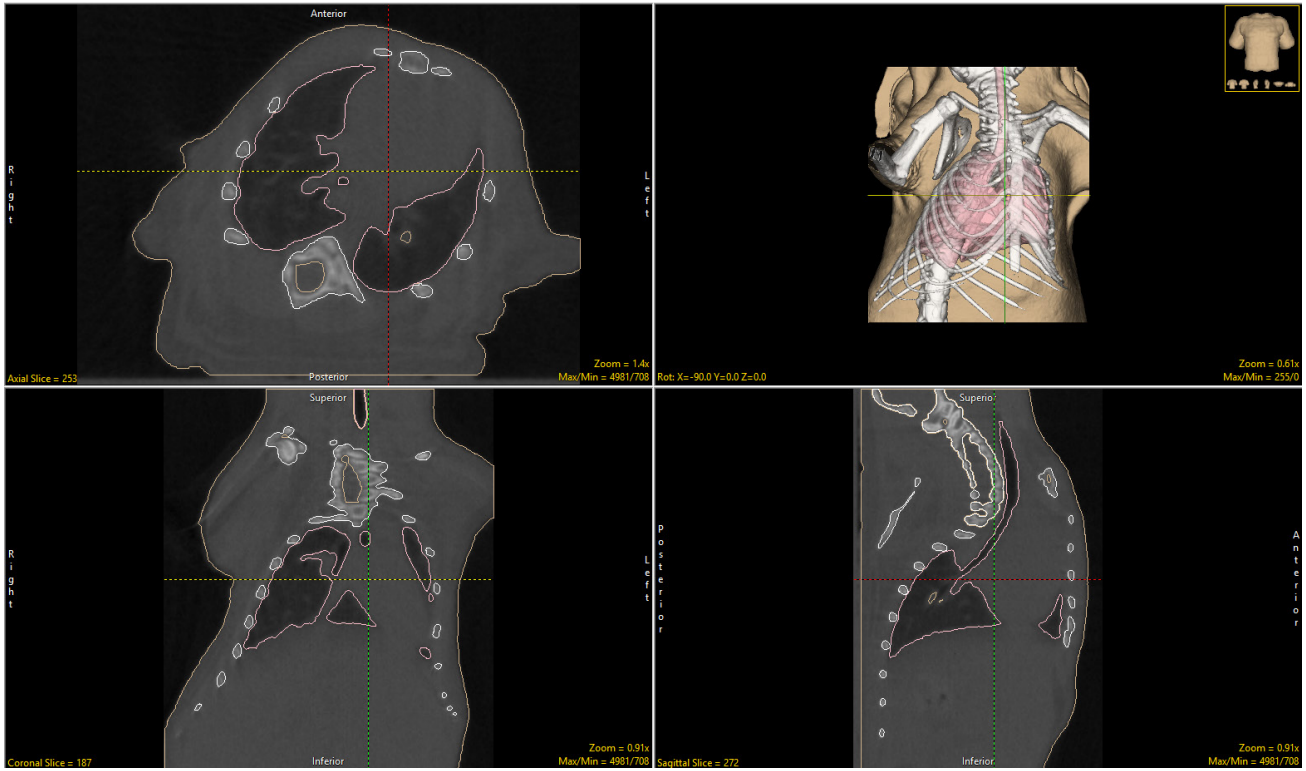


Tools (continued)

Toggle Region Display

Users have the option to change the display of objects on the 2D slices. Users can cycle through the various object display options using

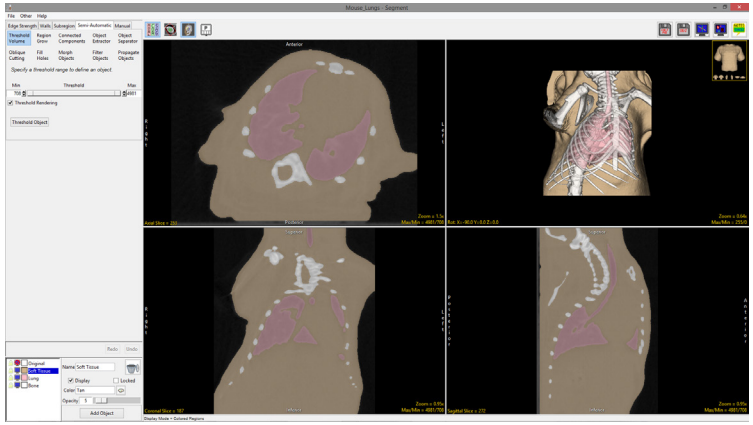
the Toggle Region Display button or using the t key.



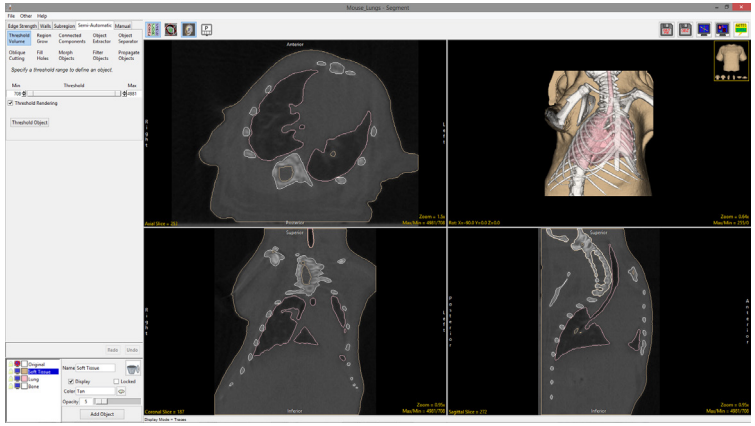
Tools (continued)

There are four object display options:

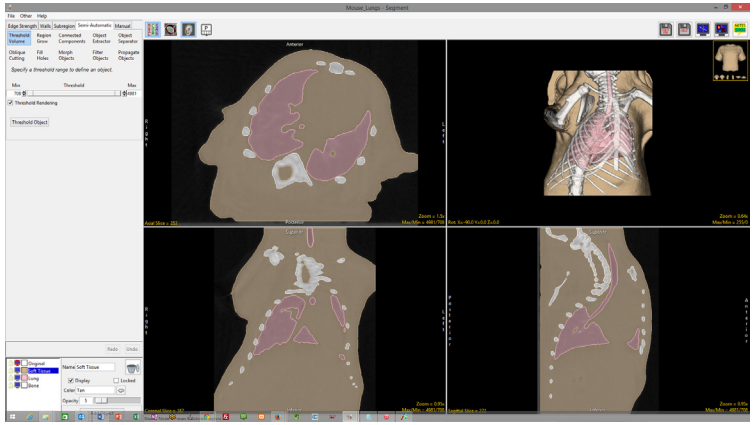
Filled Regions



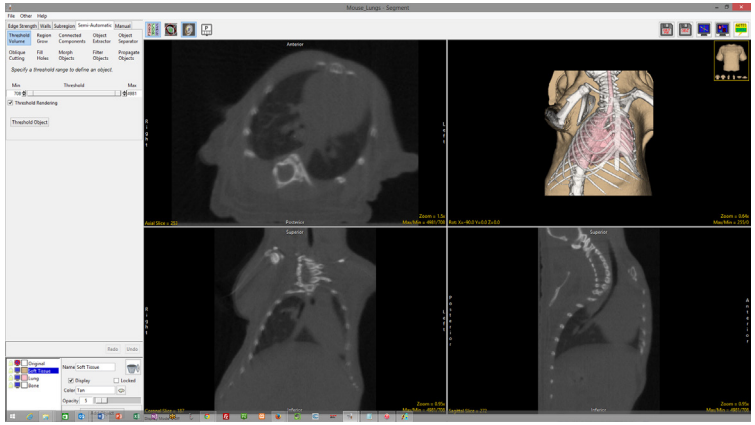
Edges



Filled Regions with Edges



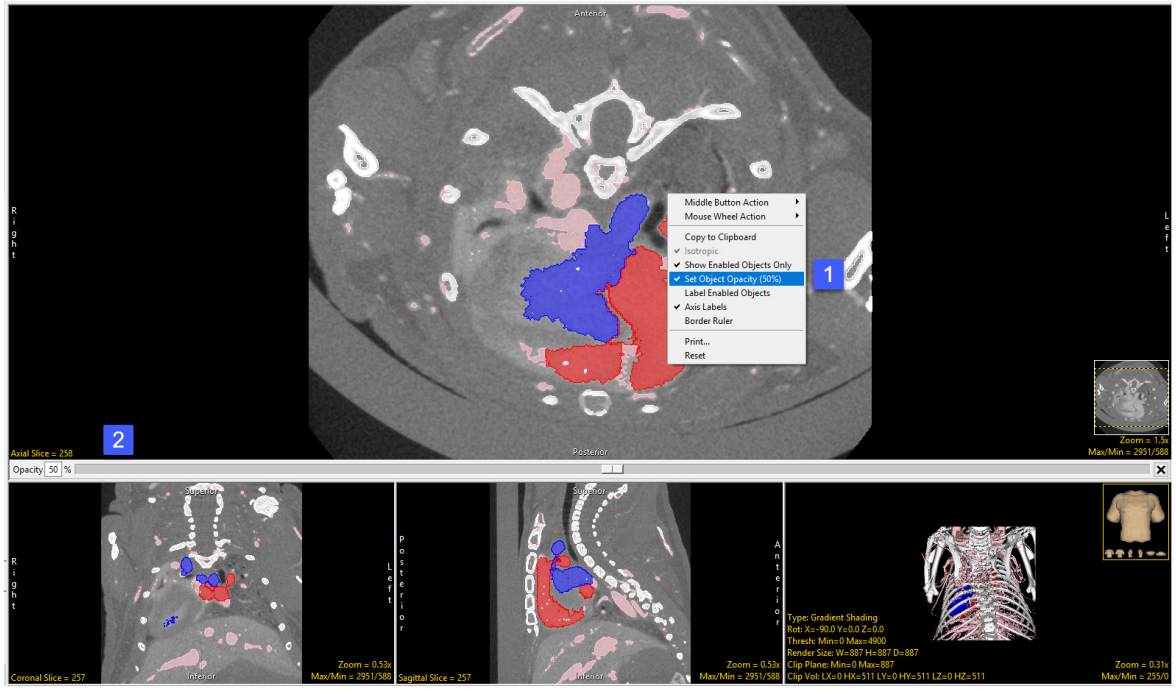
Off



Tools (continued)

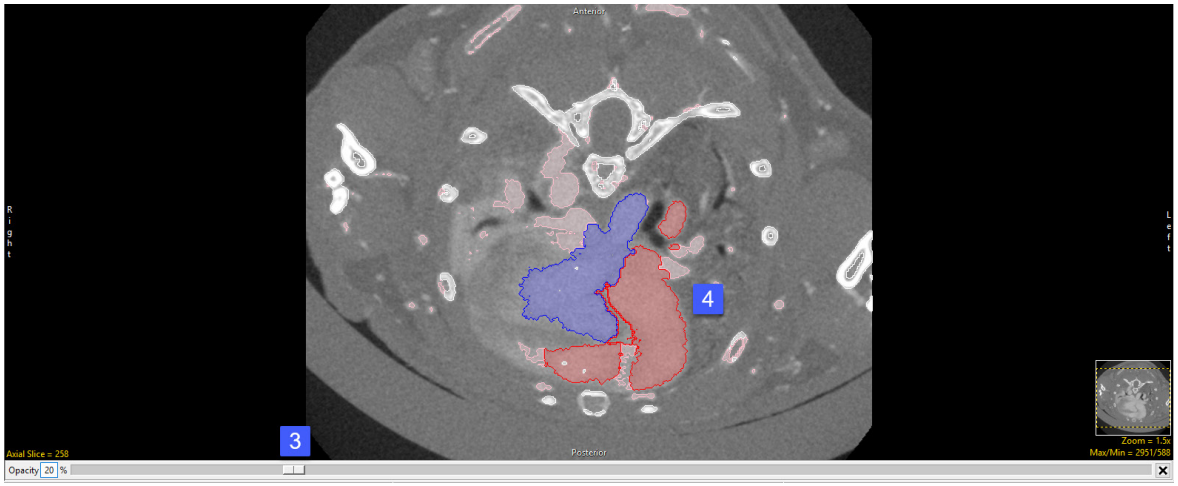
2D Object Opacity Display: It is possible to change object color alpha blend for the display of objects on the 2D slice data for the filled regions and filled regions with edges object display options. Adjusting the alpha blend allows users to visualize underlaying grayscale data while still seeing which voxels are assigned to objects.

To adjust the alpha blend right-click on any of the 2D slices displays and then choose the Set Object Opacity [1] option to enable it.



An Opacity slide will appear below the slice display window [2] allowing users to adjust the alpha blend of the objects on the image data. The default opacity value is 50%.

Use the slider to reduce the object opacity value [3] and review the effect [4].



Tools (continued)

Notes

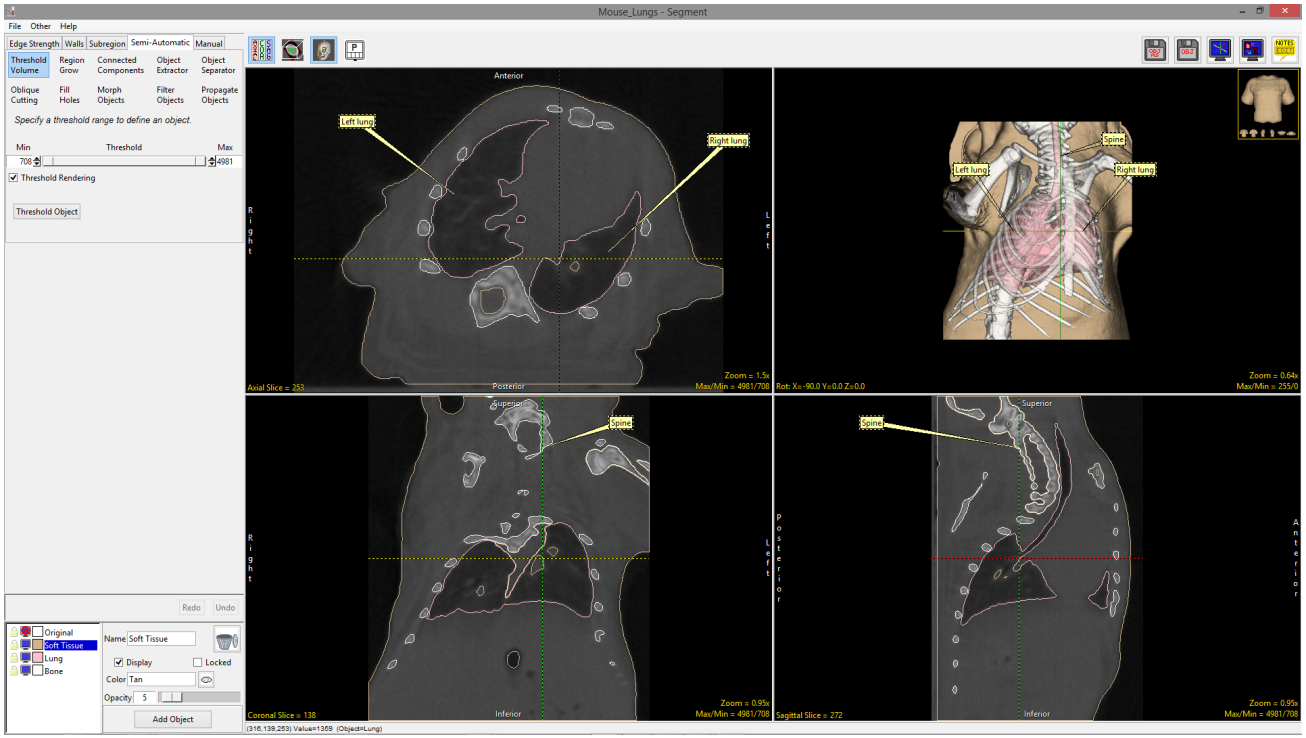
The Notes tool in Analyze allows users to annotate image data in 2D or 3D. Notes will be associated with the data set and can be loaded into other modules. Notes can be hidden or deleted at any time.

Shows notes (default).

Allows users to make and edit notes.

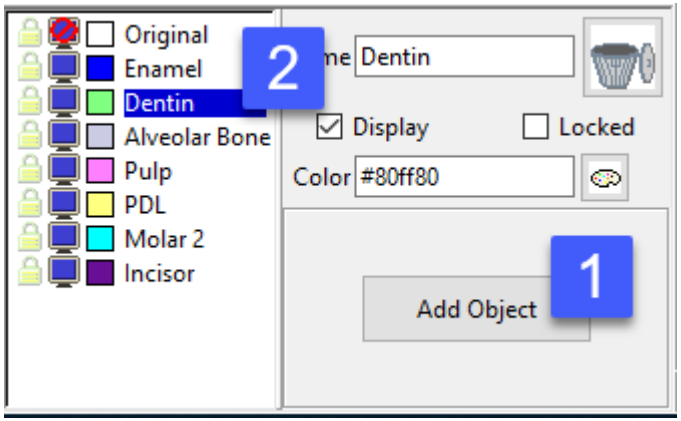
Hides notes.

To annotate a data set using notes click on the Notes button in the toolbar (note that the Edit mode will be activated.) Click on any 2D slice or the 3D rendering to create a note.



Object Controls Window

The Object Controls window allows users to add objects to the current object map. It also allows users to edit object properties. The Object Controls window provides users with the following object control options, functions, and productivity tools:

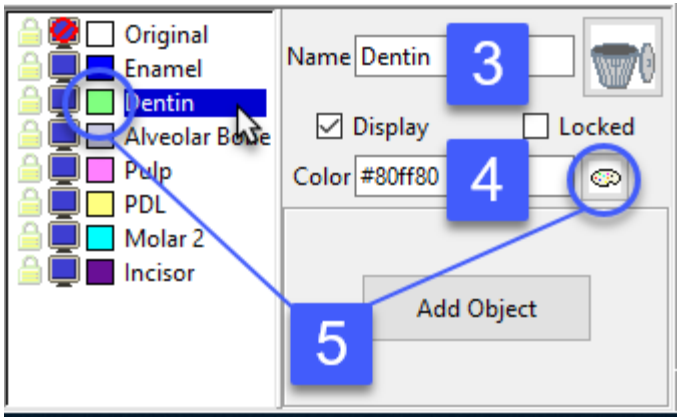


Add Object

The Add Object button [1] allows users to add new objects to the object map. Objects are show in the object list [2].

Name

The Name field [3] in the object attributes area allows users to modify the assigned object name to something applicable for the segmented object.



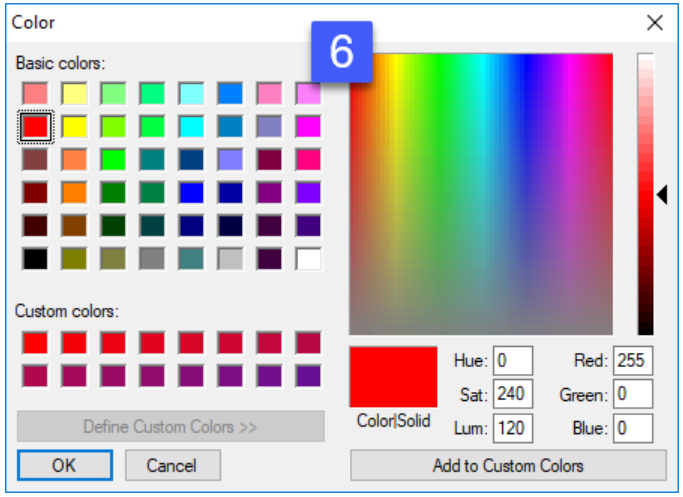
Color

Object color can be updated by entering the color name (e.g. Gray) or the hex color code (e.g. #808080) in the Color field. [4]

Object colors can also be interactively selected using an object color palette. To open the Color palette, click on the palette icon [5] next to the Color field or the colored square next to the object name in the object list.

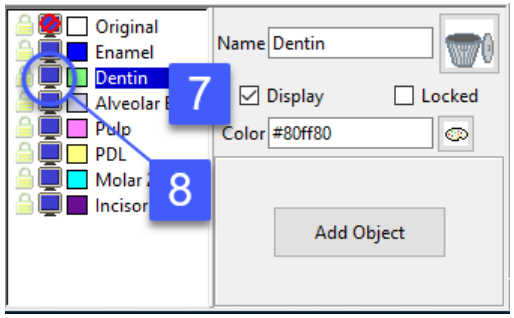
Object Controls Window (continued)

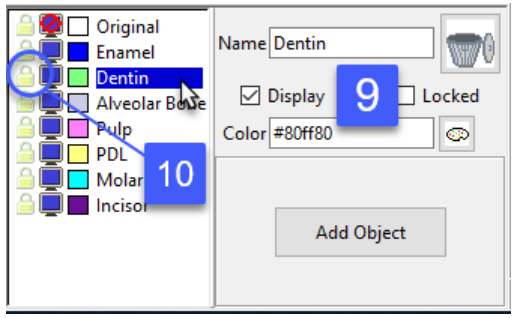
The Color selection palette [6] will open, select a basic color or use the color selector to choose a color. Color HSL and RGB values can also be input.



Display

The Display attribute for an object controls if the object is visible or not on the 2D slice displays and 3D rendering. To disable and enable the display of an object use the Display checkbox [7] in the object attribute are or click the screen icon next [8] to the object in the object list.





Object Lock

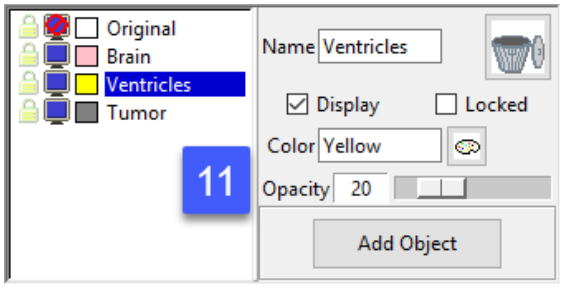
Object locking provides the ability to lock objects preventing the voxels assigned to the locked object from being edited. This is a powerful tool to aide segmentation, as locking an object protects objects from being written over. When an object is locked, the boundary of the object acts as a limit. This can be leveraged to help with the segmentation of objects that are spatially connected. However, some semi-automatic tools do not observe locked objects. Before such a tool is used, a dialog box will appear notifying the user of this.

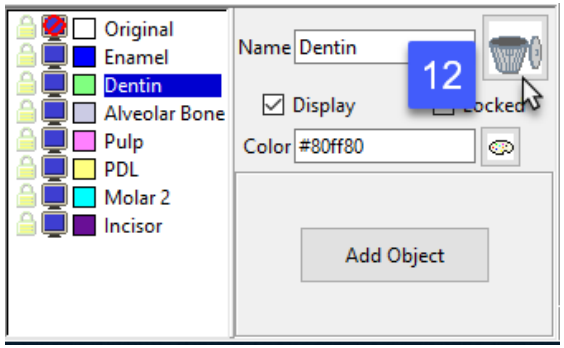
Objects can be locked and unlocked by checking the Locked checkbox [9] in the object attribute area or by clicking the lock icon [10] for the object in the object list.

Object Controls Window (continued)

Opacity

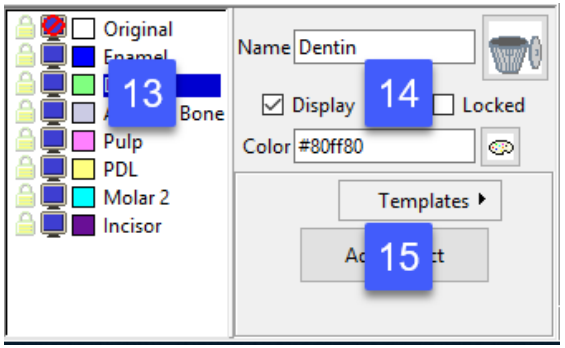
The Opacity option [11] is only available when the Transparency option is enabled. To enable the option right-click on the rendering and choosing Transparency form the menu. Adjusting object opacity levels allows users to enhance the rendered display of objects. Object opacity can be manipulated by using the opacity slider or by entering a value in the text field.





Delete

The delete button [12] allows users to remove objects form the object map. Voxels assigned to an object that is deleted are reassigned back to the Original object and the object is removed from the object list.

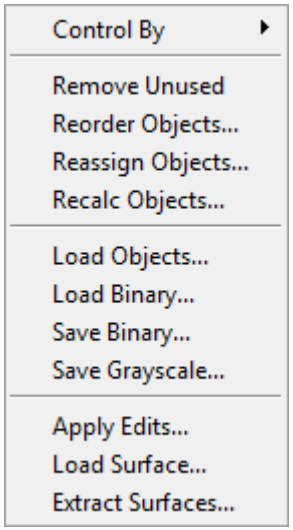


Right Mouse Menus

There are several right mouse menu options in the object controls window, and these menus are accessible by right-clicking in the object list [13], the object attribute area [14], and the area around the Add Object button. [15]

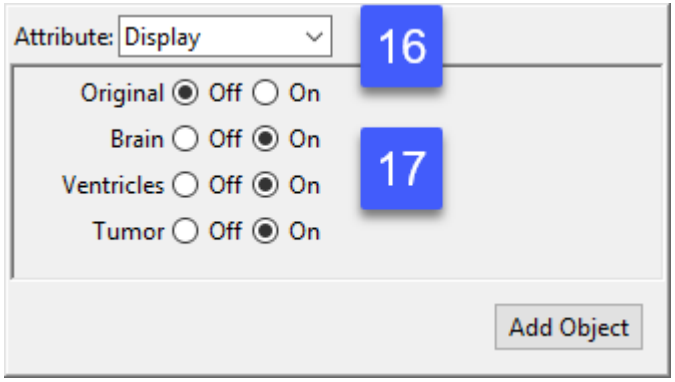
Object Controls Window (continued)

Object List Right Mouse Menu



Right click in the object list area to access additional object functionality from the right mouse context menu. These options include:

Control By: The Control By option allows users to set the control of object attributes by objects or by attribute. When set to Object users can modify all object attributes for a single object. When set to Attribute users can modify the selected attribute for all objects:

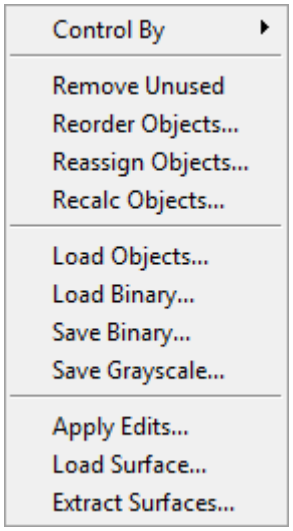


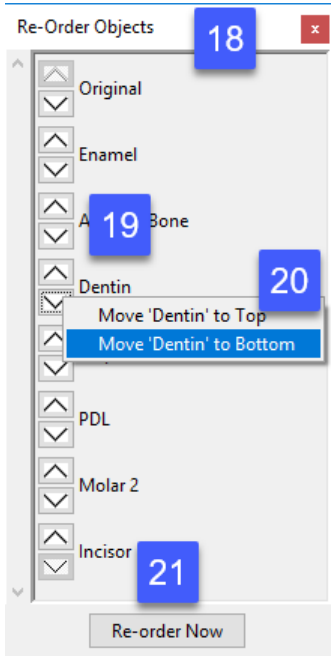
- Objects: Objects is the default control by option, displaying a list of objects. Attributes for each object can be edited in the object attribute area for each object.
- Attributes: When the Attributes option is selected the object list area updates providing an attribute drop down menu [16]. Users can select any of the object attributes to enable or disable for all the objects in the object map [17]. The attribute options include; Display, Lock, Name, Color, Shades, Neighbors Used, and Opacity. Controlling by Attribute is extremely useful when you need to modify attribute values for many objects. Right-clicking in the object area provides access to additional selection options to enable or disable attributes including All, None, and Invert.

Object Controls Window (continued)

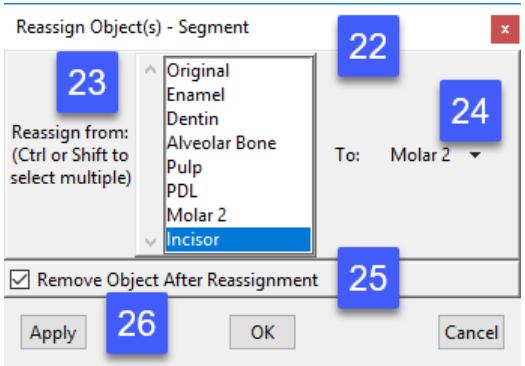
Remove Unused: allows users to quickly delete any object in the object list that doesn't have a voxel assigned to it. A helpful option for object map clean-up.

Reorder Objects: allows users to reorder objects in the object list. When selected a Reorder Objects window opens [18]. Objects can be moved up or down in the object list using the arrow keys next to the object [19]. Right-clicking on an object allows you to move the object to the top or bottom of the object list [20]. To apply changes in object order click the Re-order button [21].





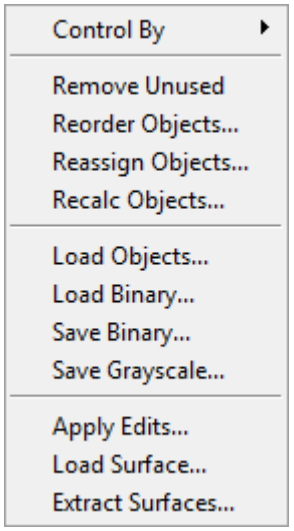
Reassign Objects: Selecting the reassign object option will open the Reassign Object(s) window enabling the reassignment of one or many objects to another. Select the object to reassign from the 'Reassign From' list [23] then set the object to reassign to from the 'To' drop down list. [24] Check or uncheck the Remove Object After Reassignment check box [25] and then click Apply. [26] All voxels assigned to the objects selected in the 'Reassign From' list will be assigned to the object in the 'To' list.

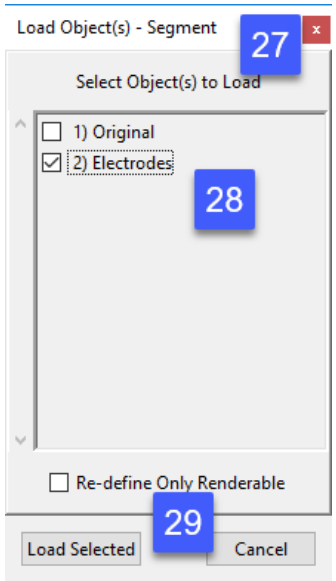


Recalc Objects: When this option is selected the module calculates and sets the minimum enclosing 3-D region for each object.

Object Controls Window (continued)

Load Objects: allows users to load objects from another object map into the current object map. For example, electrodes segmented from a CT data set could be loaded onto a brain object in a co-registered MRI data set. To use, right-click on the object list area and then choose Load Objects from the menu. In the window returned navigate to and select the object map that contains the object(s) you wish to load. Once select a Load Object(s) window [27] will open. Check the objects you wish to load [28] and then click Load Selected [29].

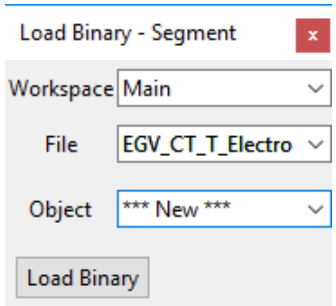




Please note, loaded objects will overwrite voxels assigned to other objects so consider the order that objects are loaded. For example, loading a hippocampus object into an object map that contains the whole brain would work fine, however, loading the whole brain into an object map that contains the hippocampus would not work, as the hippocampus object would be overwrote by the brain object.

Load Binary: allows users to create objects using a binary image. For example, electrodes segmented from a CT data set saved to the workspace as a binary image could be loaded onto a brain object in a co-registered MRI data set. The following options are available:

- Workspace: Select the workspace that contains the binary image to load.
- File: Select the binary image file.
- Object: Choose the object to create from the binary image input.

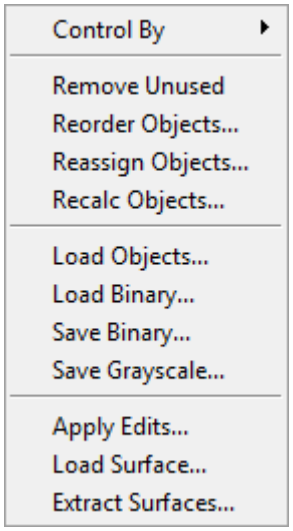


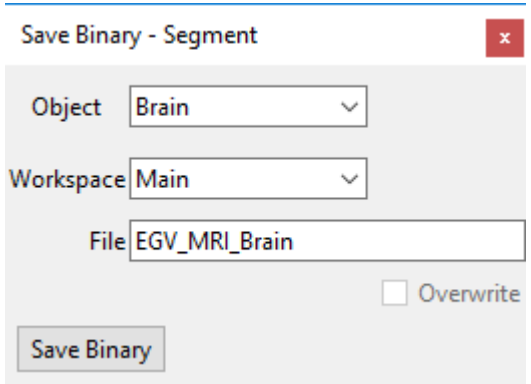
To use, right-click on the object list area and then choose Load Binary from the menu. In the Load Binary window returned use the Workspace menu option to select the workspace that contains the binary image. Next use the File option to select the binary image from the workspace. Finally, use the Object drop-down menu to set the object the binary image will create, by default the option is set to ***New***, however, any object in the object map can be selected. Finally, click Load Binary.

Object Controls Window (continued)

Save Binary: allows users to save any object in the object map out to the selected workspace as a binary image, the voxels part of the object will be saved as 1's while every other voxel will be saved as a zero. The following options are available:

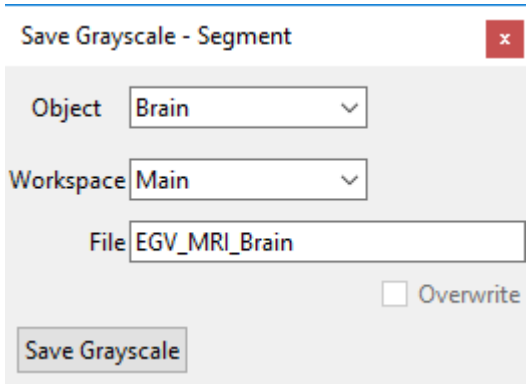
- Object: Chose the object to save.
- Workspace: Select the workspace to save the binary image to.
- File: Name the file.
- Save Binary: Initiates the save process.





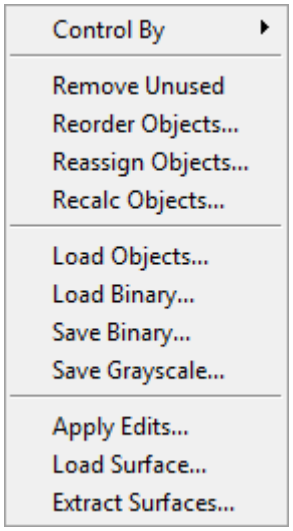
Save Greyscale: allows users to save any object in the object map out to the selected workspace as a grayscale image, with all voxels not part of the object removed from the image (set to the background). The following options are available:

- Object: Chose the object to save.
- Workspace: Select the workspace to save the greyscale image to.
- File: Name the file.
- Save Greyscale: Initiates the save process.

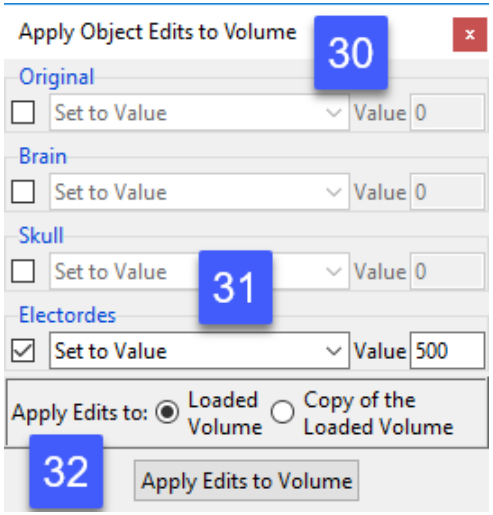


Object Controls Window (continued)

Apply Edits: allows users to change the voxel grayscale values in the image for any object in the object list, including the original object. To use, right-click on the object list area and then choose Apply Edits from the menu. In the Apply Object Edits to Volume window returned [30] select the object(s) to edit [31] and then use the drop-down menu to choose the type of edit to apply. The following options are available:



- Set to Value: Allows users to select a single greyscale value that all voxels represented by the object will be assigned to.
- Intensity Scale Values: Provides users with the ability to the range of the grayscale values by adjusting the minimum and maximum values.
- Random Value: Assigns voxel values to a random value. The Random value maximum and minimum range defaults to volumes maximum and minimum, but these values can be edited by the user.
- Gaussian Value: Assigns voxel values within the object to be assigned to a Gaussian Value. Mu and Sigma values are calculated automatically, but can be updated by the user.



Assign the desired value(s). Choose to Apply the edits to the Loaded Volume or a Copy of the Loaded Volume (recommended) and then click the Apply Edits to Volume button [32] to update the data set.

Load Surface: Allows users to load related .stl or .pogo surface files for the data set.

Extract Surface: The Extract Surface option allows users to generate and save surface files from objects. For instructions on how to use this option please refer to the Generating Surface Files from Objects section of this guide.

Object Controls Window (continued)

The Object Attribute Area Right Mouse Menu

Right click in the object attribute area to access additional object functionality from the right mouse context menu. These options include:

Control By: The Control By option allows users to set the control of object attributes by objects or by attribute. For a full description please see the Control By section in the Object List Right Mouse Menu Options section above.

Neighbors: The Neighbors option allows users to specify which voxels are used to calculate the gradient for image rendering. Changing the neighbors option can help improve the display of rendered objects especially with anisotropic data sets or with objects loaded from related data sets. The following options define the neighbors used:

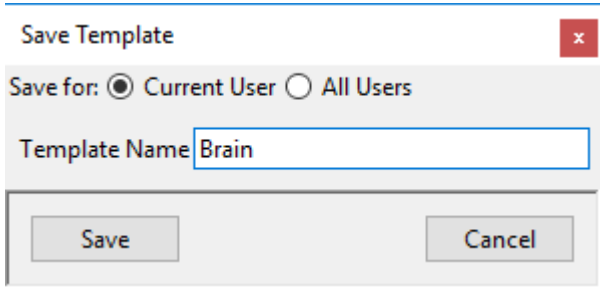
- All: Specifies that all voxels, no matter which object they belong to are used.
- Object w/Gradient: The object with gradient specifies that only the grayscale values of neighboring voxels which belong to the same objects are used.
- Object wo/Gradient: The object without gradient specifies that only neighboring voxels which belong to the same object are used. The grayscale value of the voxels are ignored, with gradient computations applied to the object map itself (binary surface rendering).
- Object Smoothed: This option is similar to object without gradient option, however, instead of using only the neighboring voxels belonging to the same object to calculate the shading, the neighboring voxels within a5x5x5 region around the voxels of interest are used. A weighting factor is applied so that the closest neighbors have twice the contribution as those twice as far away.

Shades: The Shades options allows users to set the number of shades used for the object. Users can choose from; 1, 16, 32, 50, 64, and 256.

Object Controls Window (continued)

The Add Object Area Right Mouse Menu

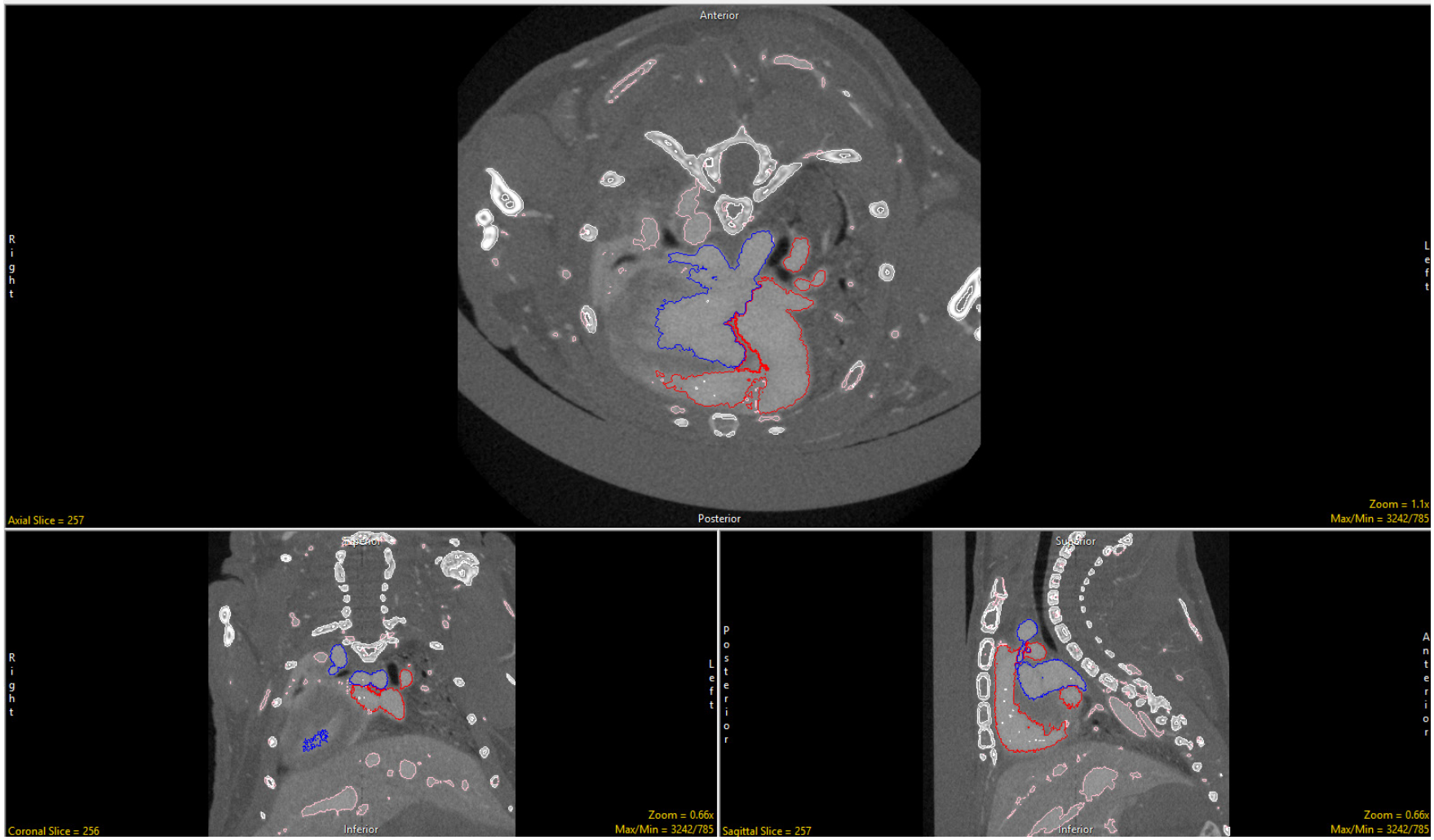
Right click in the Add Object area provides access to the Templates option. The Templates option allows users to create object templates for object maps, this option is especially useful when users create the same object maps containing the same objects for multiple volumes. It is also helpful for object maps that contain may objects. To use this option, create a list of objects specifying object names, colors, and any other attributes and then right-click and choose Templates > Save Templates. Choose to save for the Current User or All Users and then name the template. Click Save.



To load an object template right click in the Add Object area and then select the template. User specific templates (Current User) are shown at the top of the window while system templates (All Users) are shown in the middle. Once the template is selected the objects specified in the template will be loaded to the object list. Note that these are just empty objects, templates will not save any kind of segmented object region.

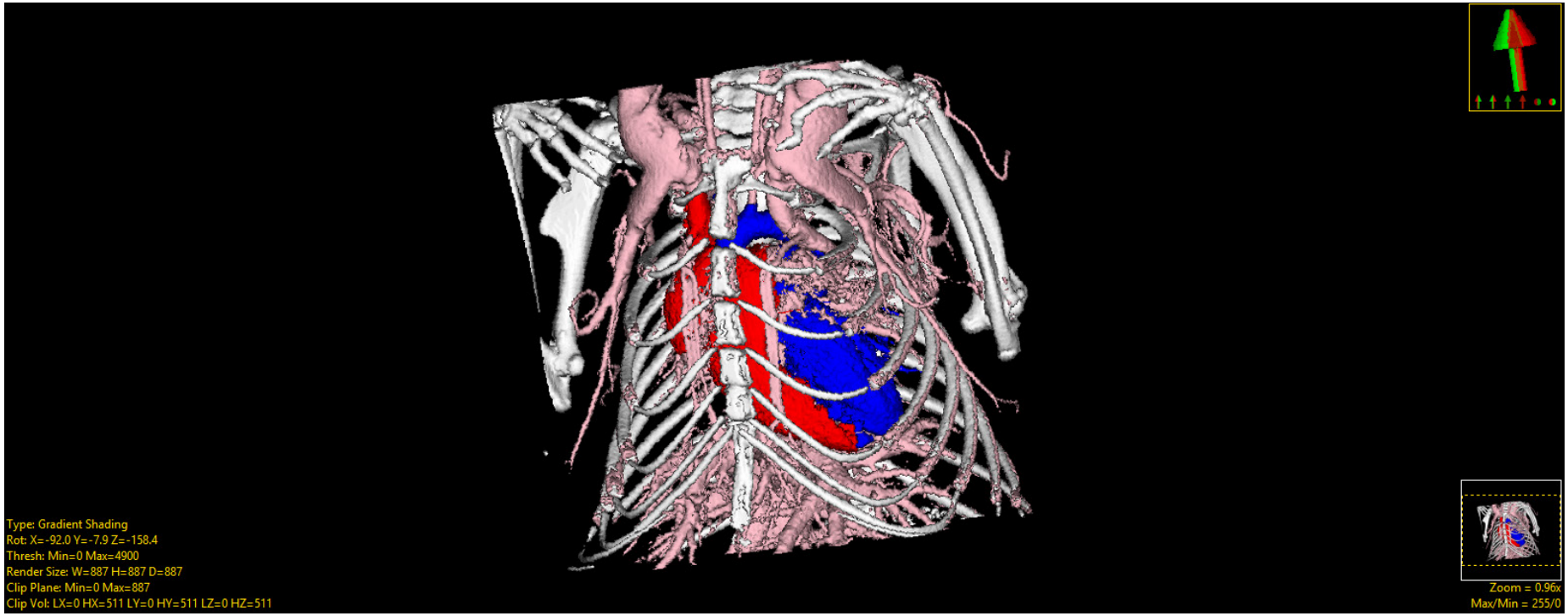
Orthogonal Image Display

The orthogonal slice display windows provide an interactive 2D review tool of the slice data in the axial, coronal and sagittal planes. For more information about the slice display windows, refer to the Display section of The Analyze User's Guide.



Renedering Window

The Rendering Window provides an interactive 3D display of the segmented image data. For more information about the render window, refer to the Display section of The Analyze User's Guide.



Segmentation Tools

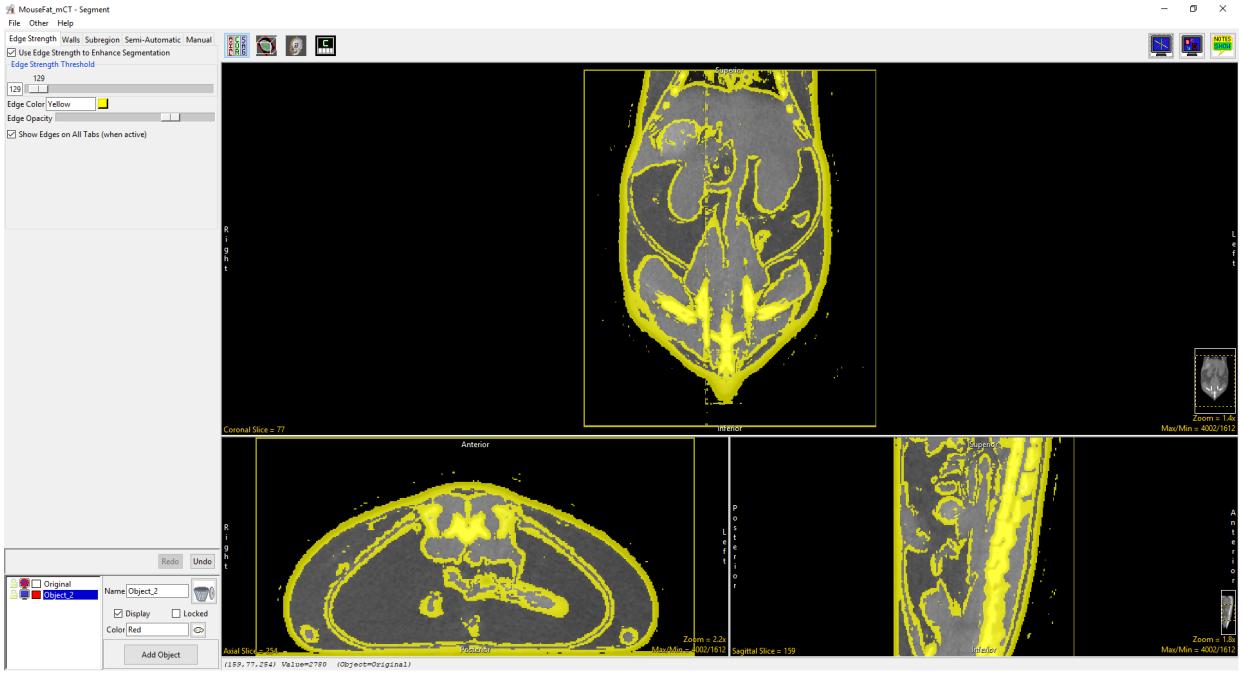
The segmentation options are provided in five tabs:

- Edge Strength
- Walls
- Subregion
- Semi-Automatic
- Manual

These five tabs provide access to all the segmentation tools in Segment. The segmentation tools within each tab will now be described.

Edge Strength

The Edge Strength option allows users to mask the input data with a set of enhanced gradients that act as limits aiding in the segmentation of structures. Edge strength works by applying a 3 X 3 X 3 Sobel filter to the image data, which can be interactively adjusted using the Edge Strength Threshold slider. All voxels with gradient values less than or equal to the selected threshold value are displayed with a definable edge color and form boundaries around structures. The boundaries act as limits, restricting semi-automatic segmentation operations. The following controls are available:



Use Edge Strength to Enhance Segmentation: When this option is checked the Edge Strength option is enabled for the image data, a 3 by 3 by 3 Sobel filter is applied to the volume and the Edge Strength Threshold slider and additional options are enabled.

Edge Strength Threshold: This slicer defines the upper threshold value for the Sobel filtered gradient volume. When the left mouse button is used to drag the slider, all of the voxels with gradient values less than or equal to the threshold value are highlighted. Semi-automated segmentation algorithms are applied to the voxels within the threshold range.

Edge Color and **Edge Opacity:** Allows users to specify the color and adjust the opacity display of the edge overlay on the image data.

Show Edges on All Tabs (when active): maintains the display of the edges on the image data when moving to different segment tabs.

Using Edge Strength

First we will attempt to segment the heart from this CT data set *without* using edge strength.

To follow along, download the data set CT_Heart from analyzedirect.com/data and load into Analyze using Input/Output.

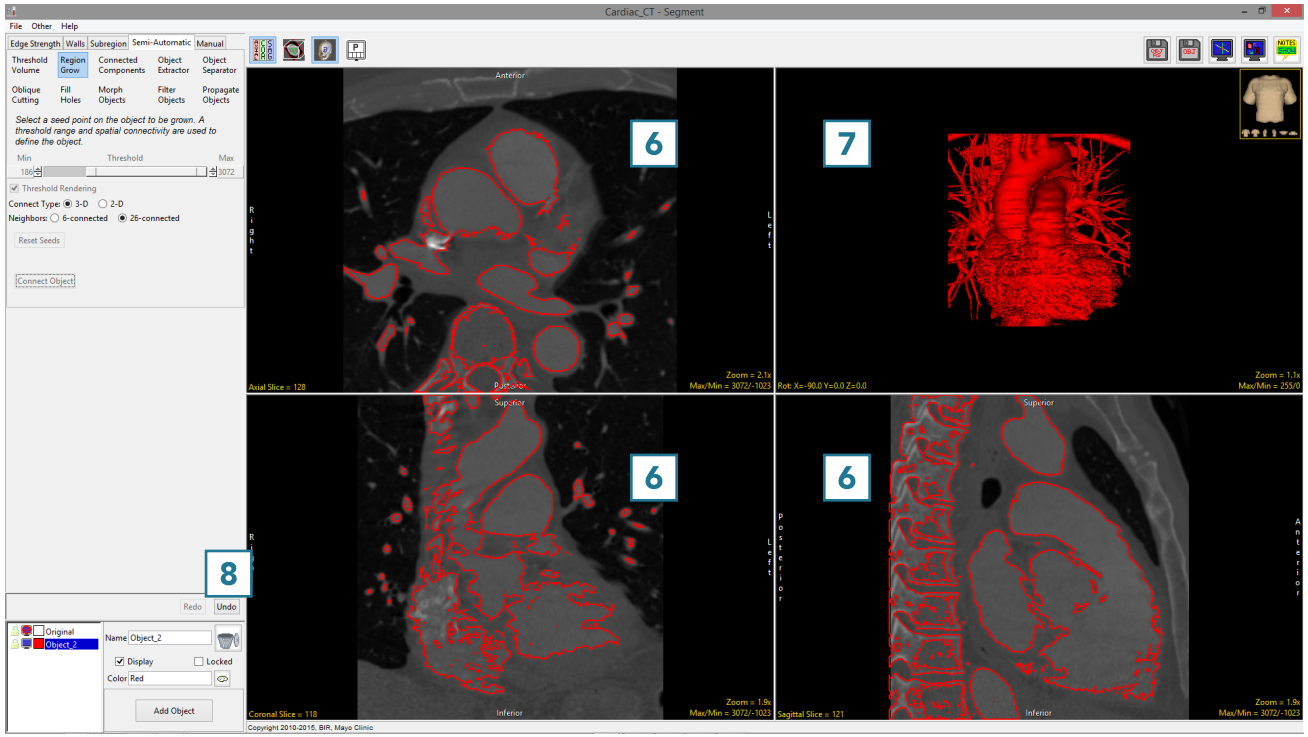
- Select the data set and open Segment.
- Select Semi-Automatic [1], and choose Region Grow [2].
- Click on the image data to set a seed point [3]. The seed point should be in the object you would like to isolate.
- Set the threshold Min/Max values to define the object [4] and click Connect Object [5].

Using Edge Strength (continued)

- The results of the region grow are shown below.
- The segmented object is shown overlaid on the 2D slice data [6] and a 3D representation [7] is displayed.

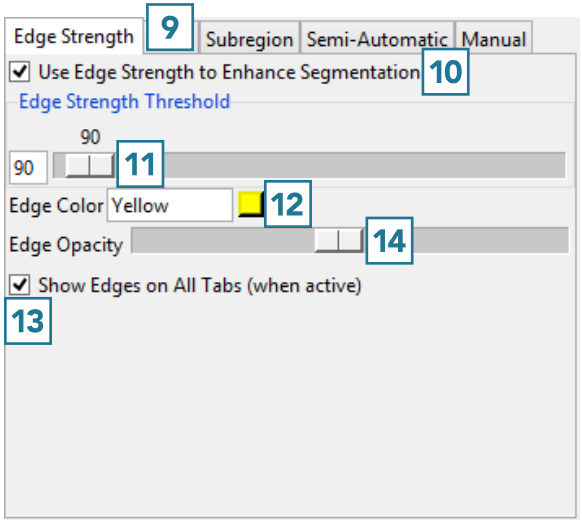
Note that both the heart and the spine have been assigned to Object_2 [8].

- Click Undo.



Using Edge Strength (continued)

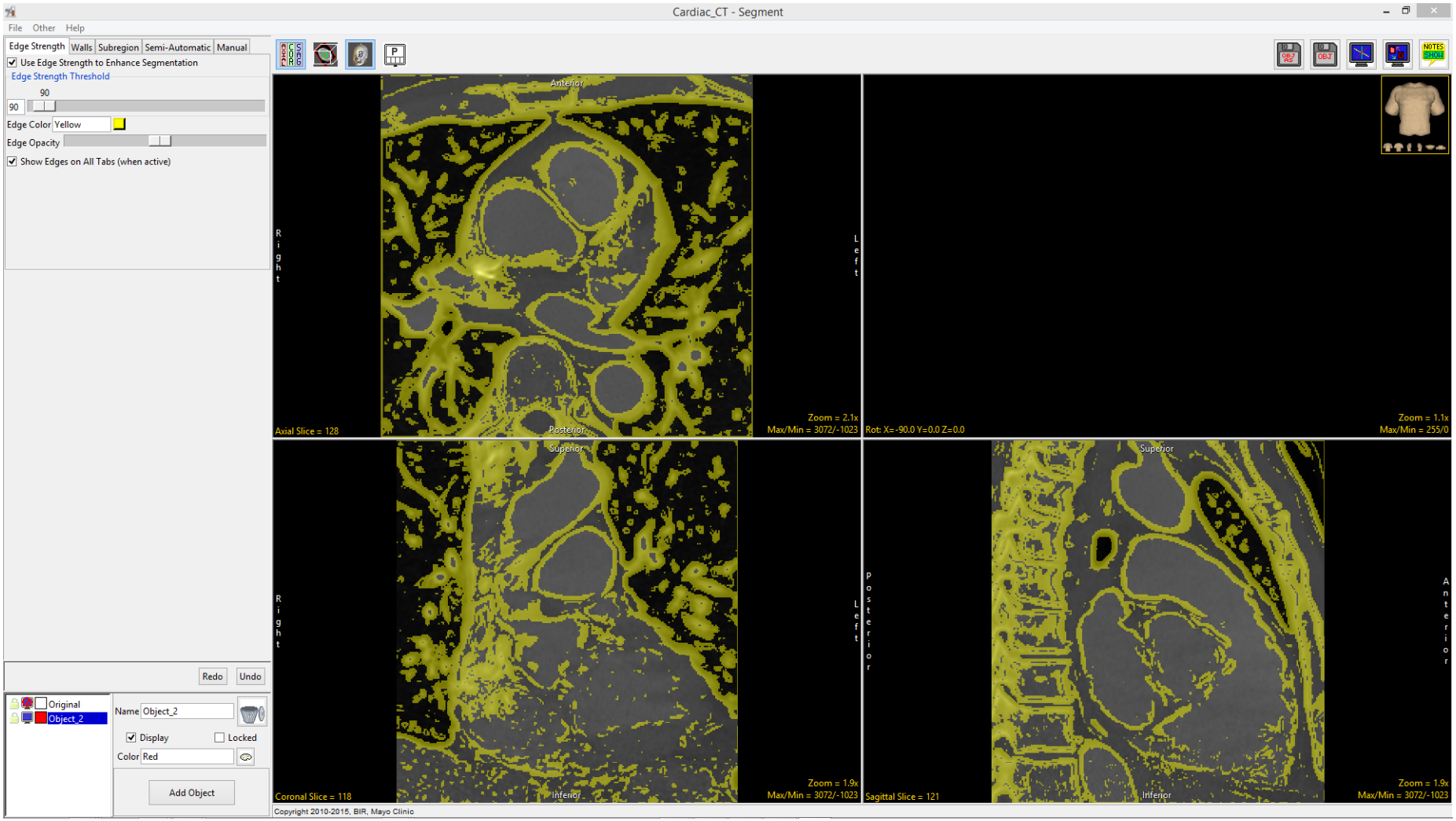
Now we will repeat this segmentation using edge strength to separate the heart from the rest of the data set.



- Select Edge Strength [9] and check Use Edge Strength to Enhance Segmentation [10].
- Set the Edge Strength Threshold to 90. Note that this value will be different for each data set. In general, adjust the edge strength using the slider [11] until you find a suitable value. The edges will interactively update on the data set. Use the edge display to determine the suitable edge strength value.
- Optionally, change the color of the edge by entering the desired color in the text field or by using the color selector [12].
- When performing the segmentation, leave the Show Edges checkbox [13] selected. If required, reduce the Edge Opacity using the slider [14].

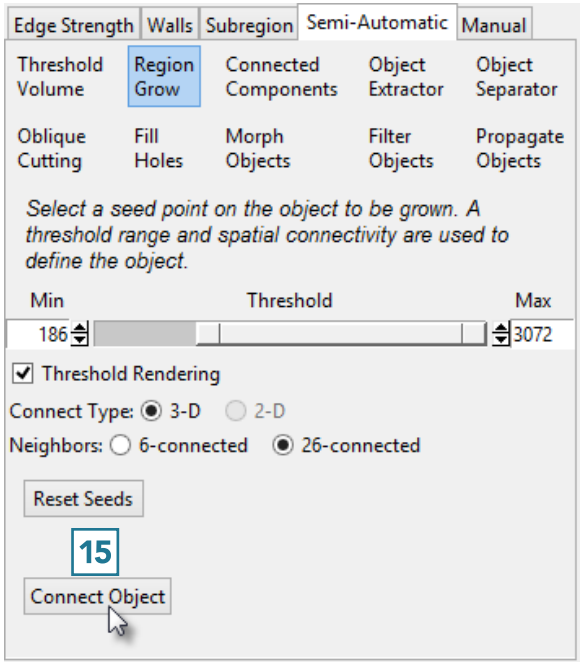
Using Edge Strength (continued)

The edges detected on this data set using the Edge Strength algorithm with an edge strength threshold of 90 are shown overlaid on the data below.



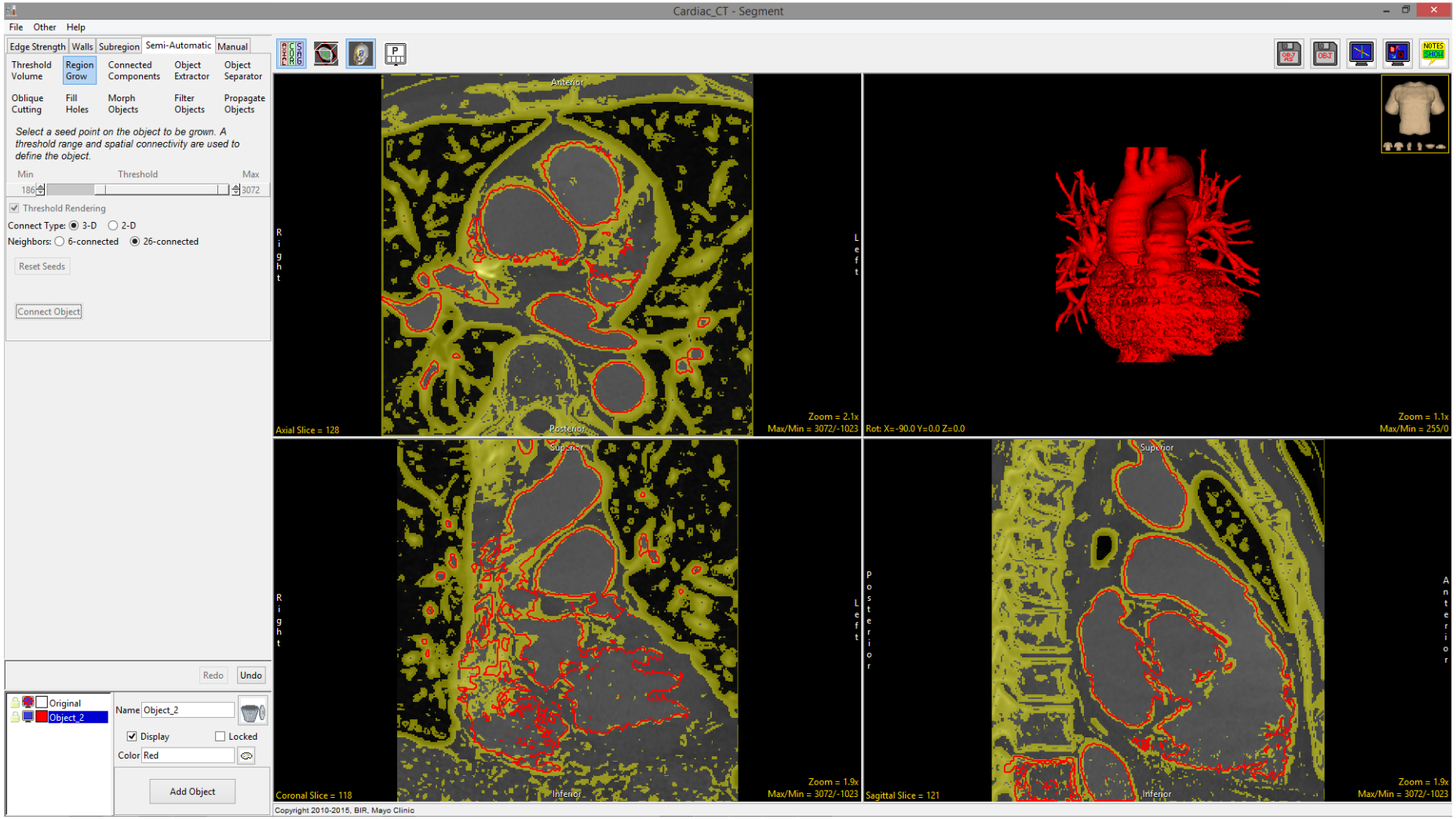
Using Edge Strength (continued)

- Repeat the segmentation. Select Semi-Automatic, then choose Region Grow.
- Click on the image data to set a seed point. The seed point should be in the object you would like to isolate.
- The Threshold Min/Max values should still be set to the previous values. If not, reset them to define the object and then click Connect Object [15].



Using Edge Strength (continued)

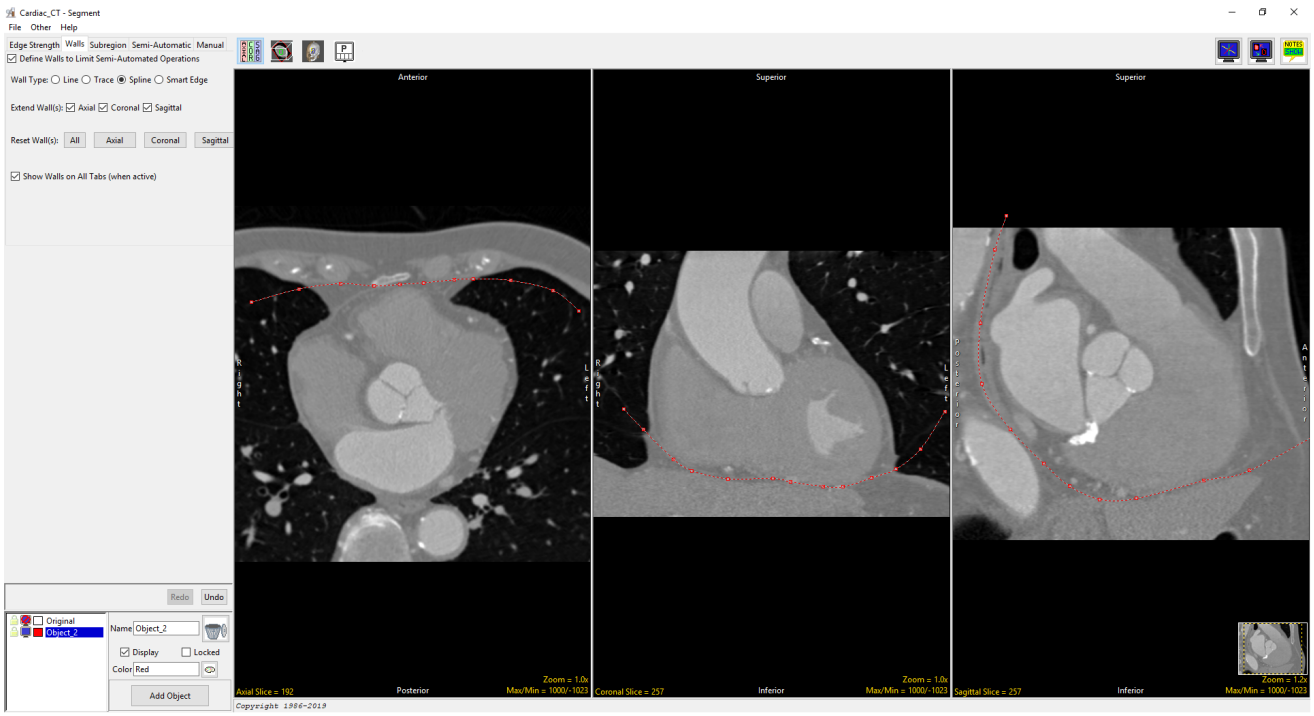
Note that this time, only the heart was segmented. The Edge Strength technique prevented the region grow algorithm from including the spine in the object. Further segmentation can now be achieved with or without Edge Strength enabled. Select File > Save Object Map to save your work.



Walls

Segmenting structures of interest that are connected to surrounding anatomy with similar grayscale values can be challenging. The Walls option provides tools to create adaptable 3D limits to help make this process easier for the user. The Walls tool is useful for many segmentation applications, particularly isolating the cerebellum from the rest of the brain parenchyma or limiting the boundaries of a region grow operation to isolate blood pools from cardiac data.

The Walls option allows users to define traces which are used to limit the extent of an object. Separate walls can be created in each orientation, the wall defined in one orientation is not reflected in the other orientations. Traces defined on slices are linearly interpolated within each orientation reducing user interaction time, so that a trace defined on slice 10 and a trace defined on slice 50 are automatically interpolated between so the user doesn't have to define the wall on each slice between. The interpolated traces are designated by a dashed green line, while the user defined traces appear as a dashed red line.



Walls are used with the Threshold Volume, Region Grow, Connected Components, Object Extractor and Object Separator Semi-Automatic tools. Walls can also be used in conjunction with the Edge Strength and Subregion tools.

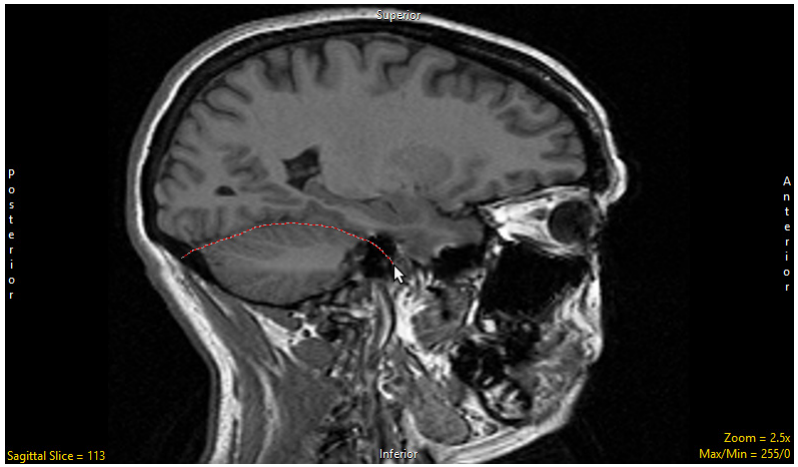
Walls Tab Options

The Walls tab provide the following option:

Define Walls to Limit Semi-Automated Operations: When checked enables wall definition options allowing users to define walls on the image data.

Wall Type: Allows users to select the wall definition mode, the options include:

- Line: The line option allows users to define a straight-line wall on the image data.
- Trace: Allows user to define a freehand wall on the image data
- Spline: The Spline option allows users to define a curved wall. Splines are flexible curve traces with movable control points that are useful for creating smooth walls.



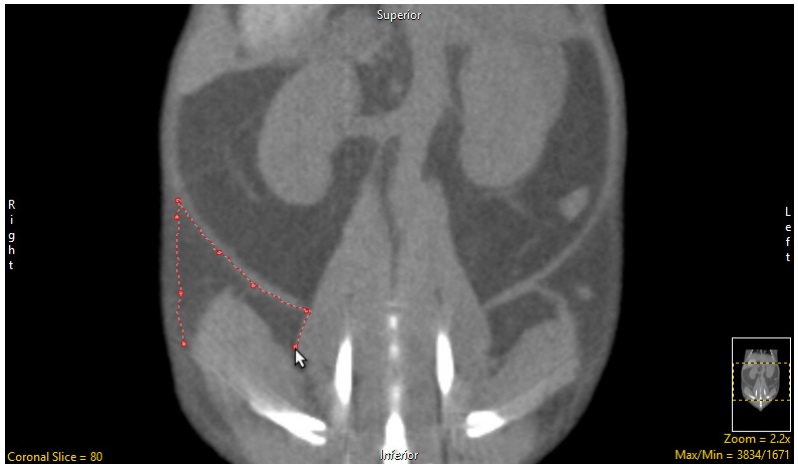
Walls Tab Options (continued)

- Smart Edge: The smart edge option detects regions of high rate of change of voxel intensity (gradient) that represent edges, smart edge snaps to the edges of these regions.

- Sensitivity: The sensitivity of the smart edge can be adjusted using the slider or the mouse scroll wheel. The lower the value the less sensitive the tool is, the higher the value the more sensitive the tool is.

Extend Wall(s): Specifies if the wall is extended beyond the first and last user defined wall in each orientation.

Reset Wall(s): Allows the user to reset the defined walls in any or all orientations.

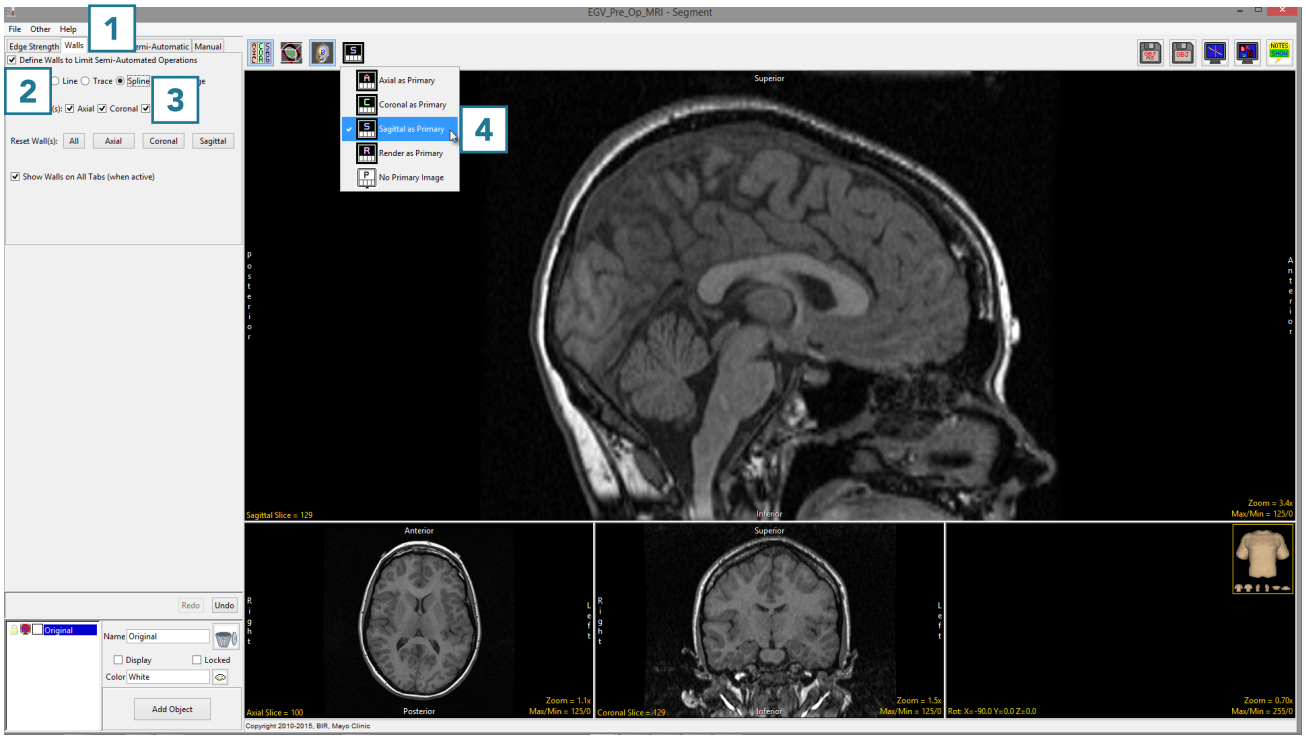


Using Walls

Here we will use the Walls functionality to segment the cerebellum from the rest of the brain parenchyma in a head MRI dataset.

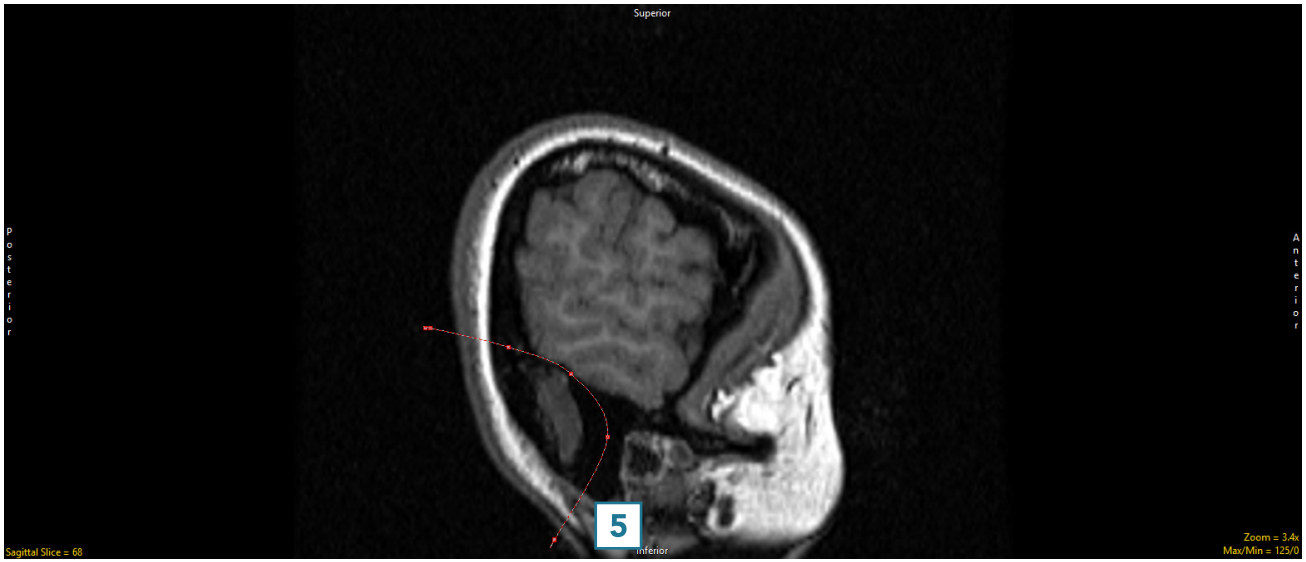
To follow along, download the data set EGV_MRI from analyzedirect.com/data and load into Analyze using Input/Output.

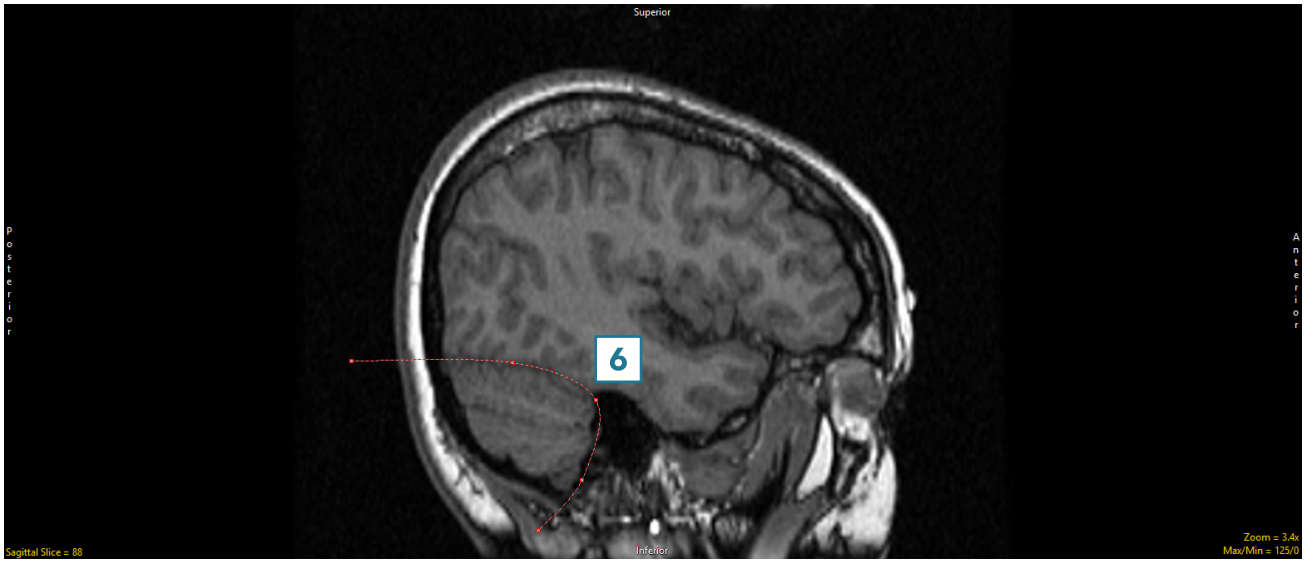
- Select the data set and open Segment.
- Select Walls [1] and check Define Walls to Limit Semi-Automated Operations [2].
- Set the Wall Type to Spline [3].
- Set the primary display to Sagittal [4].



Using Walls (continued)

- Navigate through the sagittal slices to find the first slice that includes tissue belonging to the cerebellum. Draw a wall separating the cerebellum from the cerebrum on this slice.
- To draw a wall using the spline tool, left-click to set spline points which will connect into a smooth line. Double-click when defining the last spline point to set the spline [5].
- The spline points can be adjusted by left-clicking and dragging. Right-clicking on a spline point allows you to delete it or make other changes to the spline such as closing the spline or deleting the entire spline.
- Move forward through the sagittal slices and adjust the wall as required [6].
- The Wall can also be redrawn if necessary.



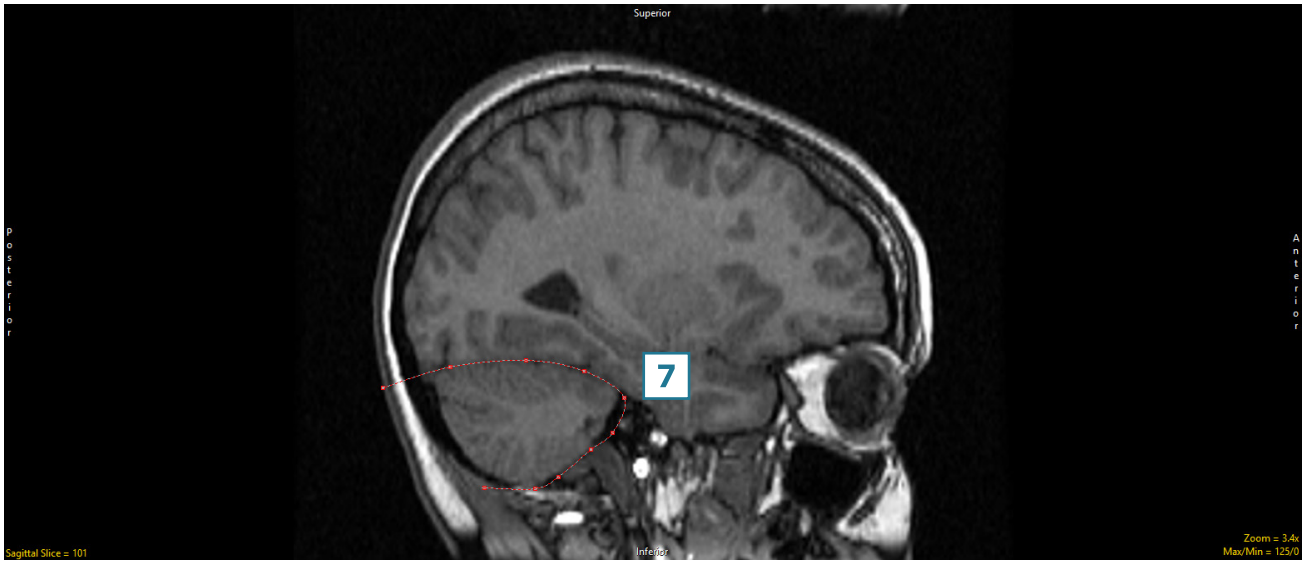


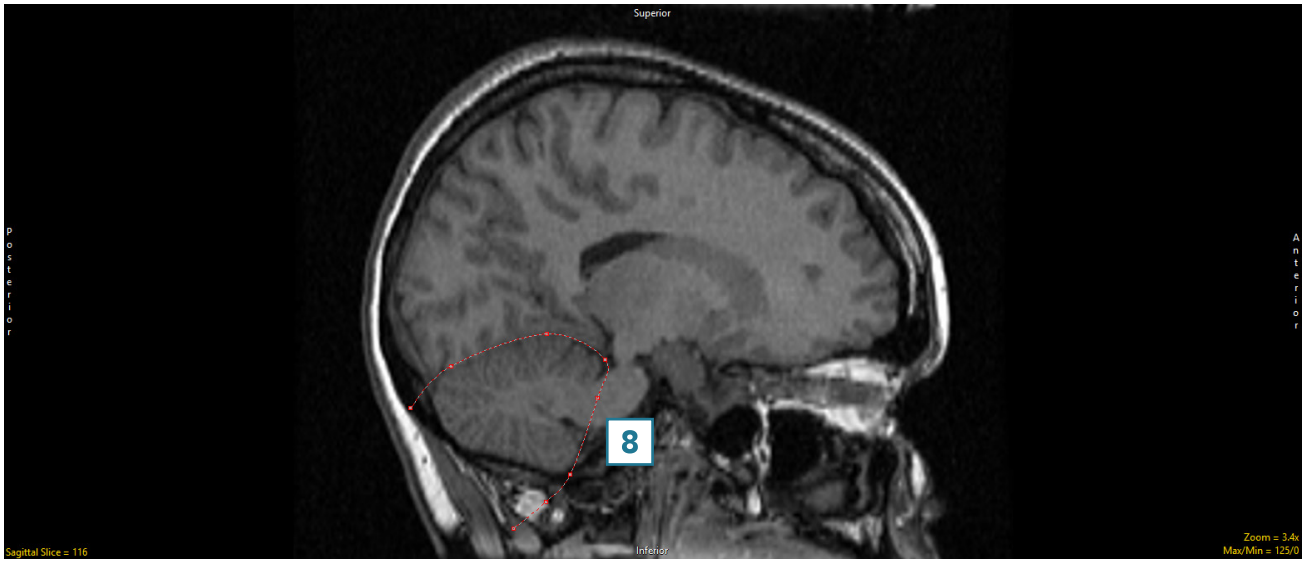
Using Walls (continued)

- Once the cerebellum is no longer well defined by the wall, redefine the wall on that slice. The wall will be interpolated between all slices on which it is defined. When finished, scroll through the slices to ensure that the cerebellum is well defined by the wall.

Note that walls can be set in multiple orientations. This is helpful when trying to isolate structures connected to several surrounding structures in all orientations. For example, it can be used when isolating the heart from the lungs, spine, sternum, etc. It can also be useful to define walls in the sagittal and coronal orientations to better segment the cerebellum.

- Continue to define walls around the cerebellum in the sagittal orientation [7], [8].



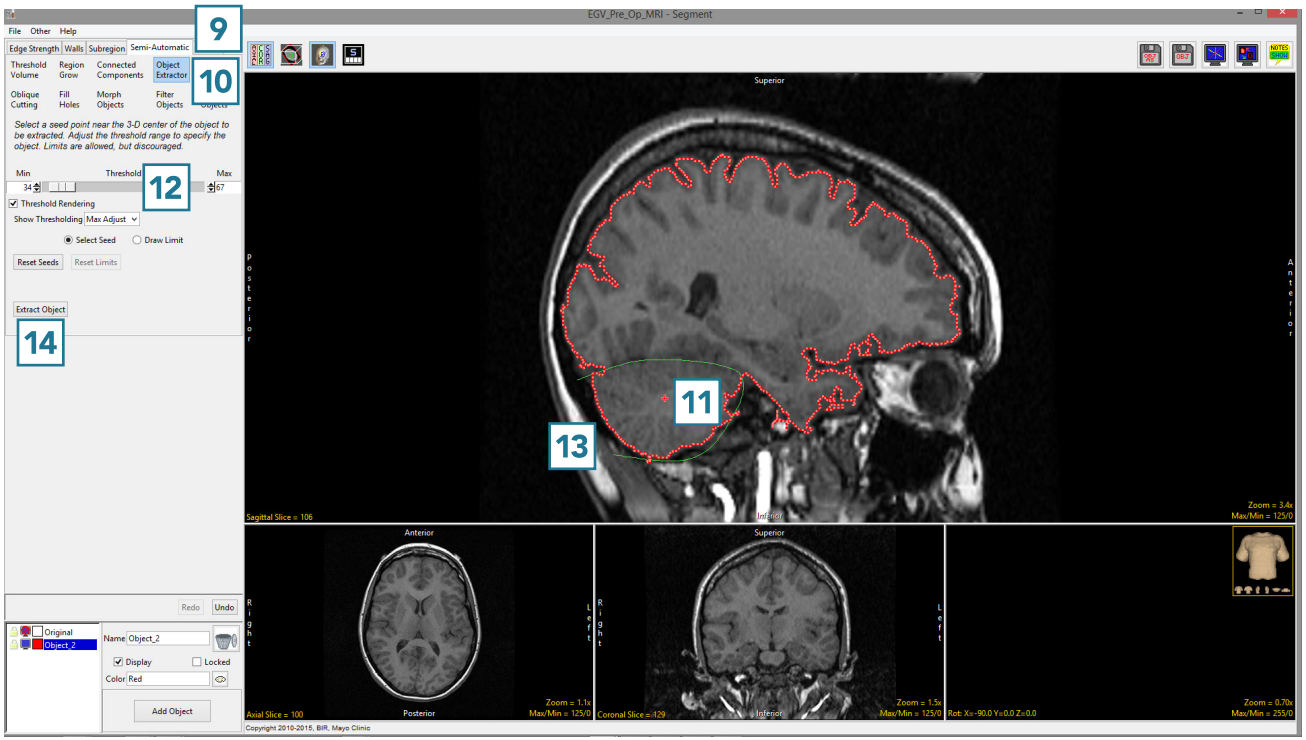


Using Walls (continued)

- Once the cerebellum boundary is defined in three dimensions by the wall, select the Semi-Automatic tab [9] and choose Object Extractor [10].
- Click in the cerebellum on a sagittal slice to set a seed point [11].
- Adjust the maximum and minimum threshold values [12] until the auto trace defines the object [13].

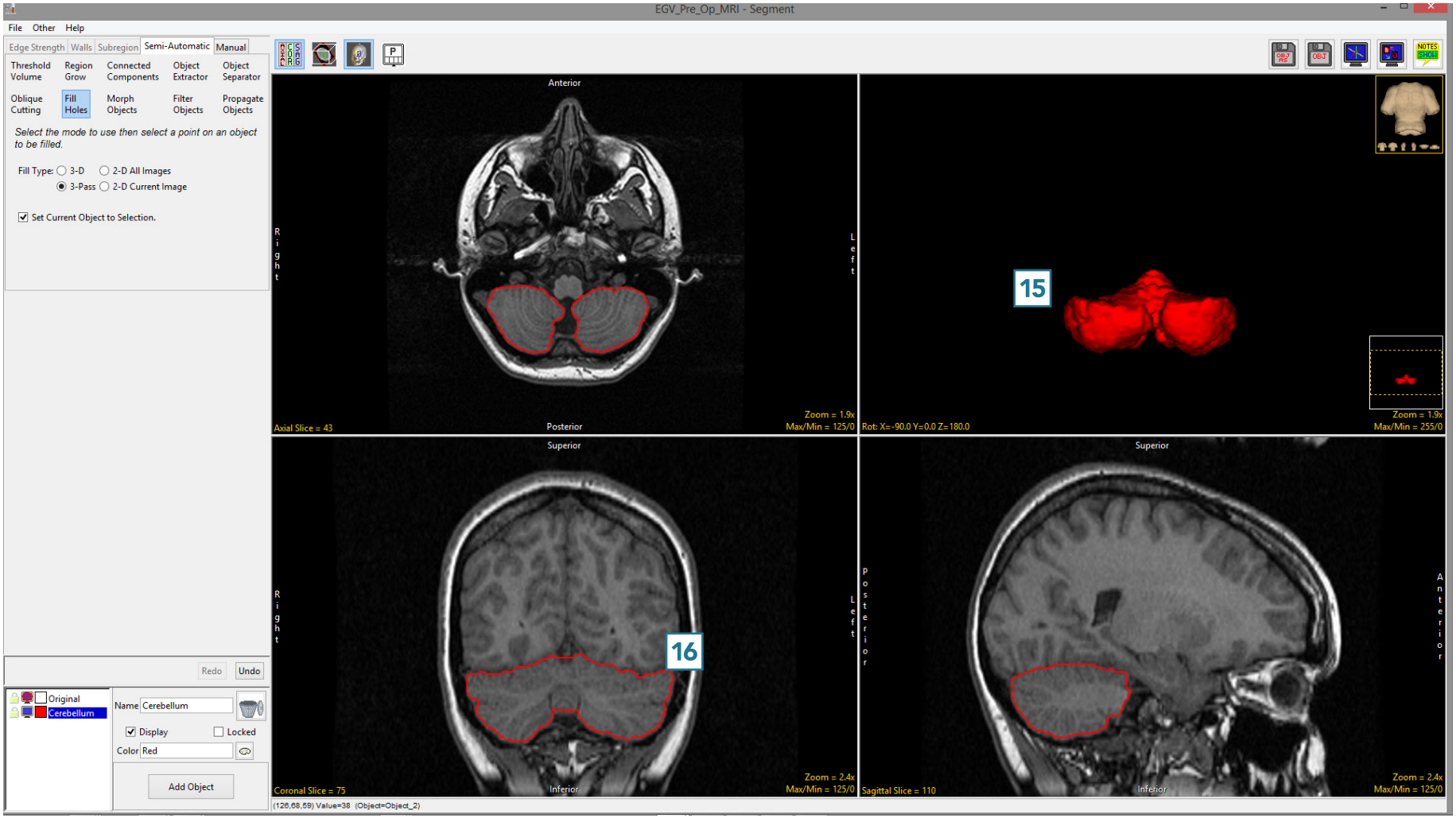
Note that while the entire brain will be defined, the walls will prevent the whole brain from being segmented and will confine the segmentation to the cerebellum.

- Click Extract Object [14].



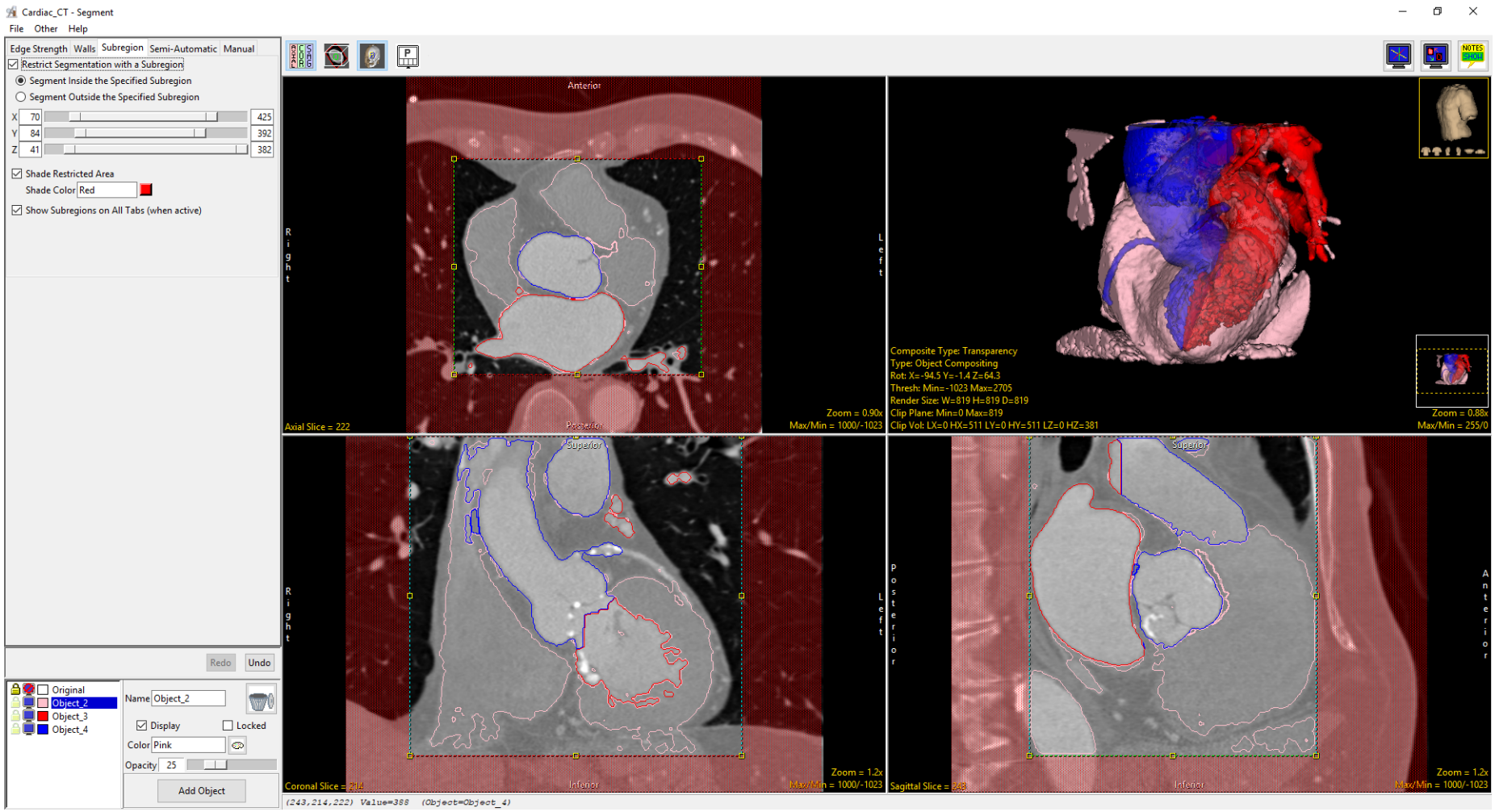
Using Walls (continued)

- The cerebellum will be isolated and displayed in 3D.
- Once segmentation is complete, the structure will be rendered [15] and overlaid on the slice data [16].
- Save your work by selecting File > Save Object Map.



Subregion

Subregion allows users to limit segmentation to a specific user-defined region. This tool is particularly useful when segmenting a structure of interest, such as the hippocampus, without having to crop the original image data.

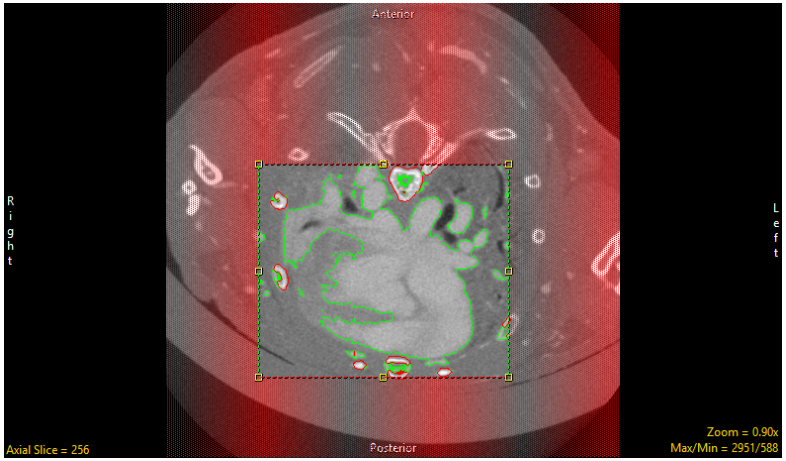


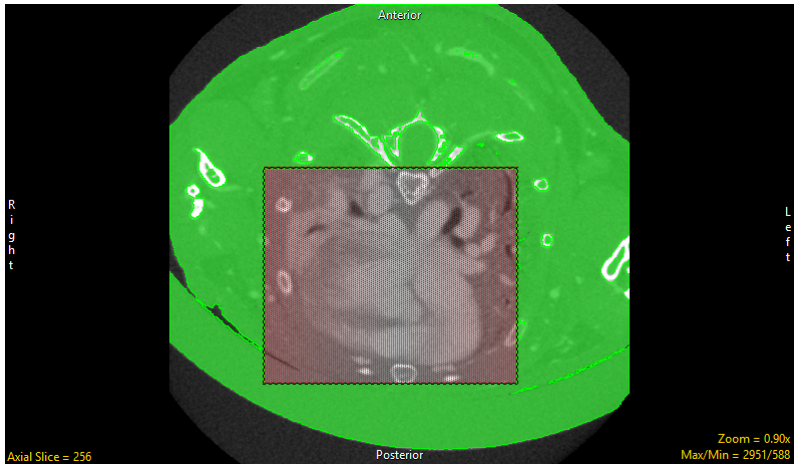
Subregion Options

Subregion can be used with the Threshold Volume, Region Grow, Connected Components, Object Extractor and Object Separator Semi-Automatic tools. Subregion can also be used in conjunction with the Edge Strength and Wall tools.

Restrict Segmentation with a Subregion: When checked enables subregion restriction of semi-automatic and manual segmentation tools. The following options are available:

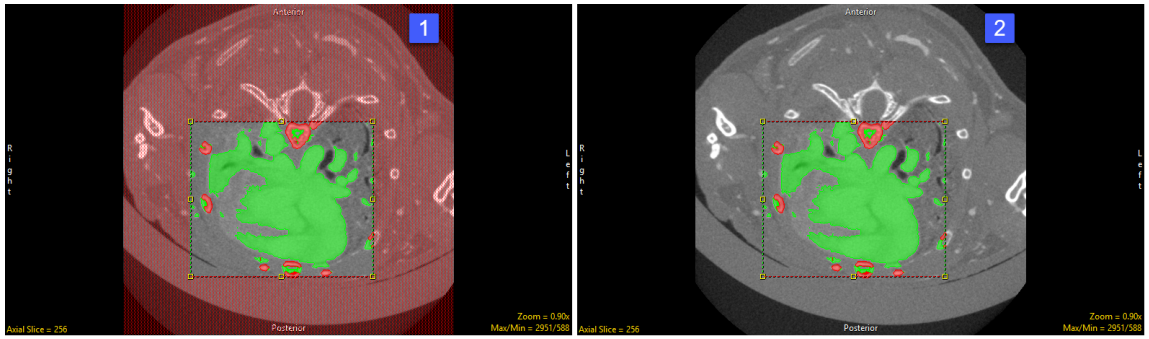
- Segment Inside the Specified Subregion: Allows users to segment within the specified subregion.
- Segment Outside the Specified Subregion: Allows users to segment outside the specified subregion.

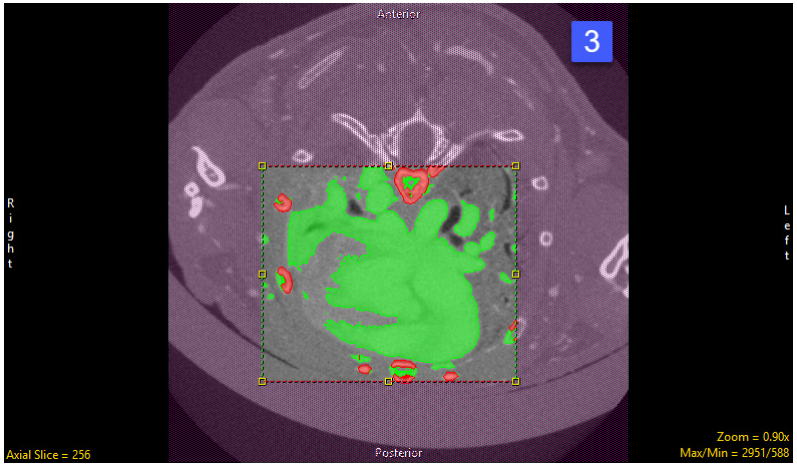




Subregion Options (continued)

- X Slider: Allows users to define the extent of the subregion in the X orientation.
- Y Slider: Allows users to define the extent of the subregion in the Y orientation.
- Z Slider: Allows users to define the extent of the subregion in the Z orientation.
- Shade Restricted Area: Allows users to switch on shading [1] for the restricted area or switch off shading [2] for the restricted area.
- Shade Color: Allows users to change the color of the restricted area [3] by typing a color in the color field area or by selecting a color using the color section option.
- Segment Outside the Specified Subregion: Allows users to segment outside the specified subregion.
- Shade Color: Allows users to change the color of the restricted area [3] by typing a color in the color field area or by selecting a color using the color section option.

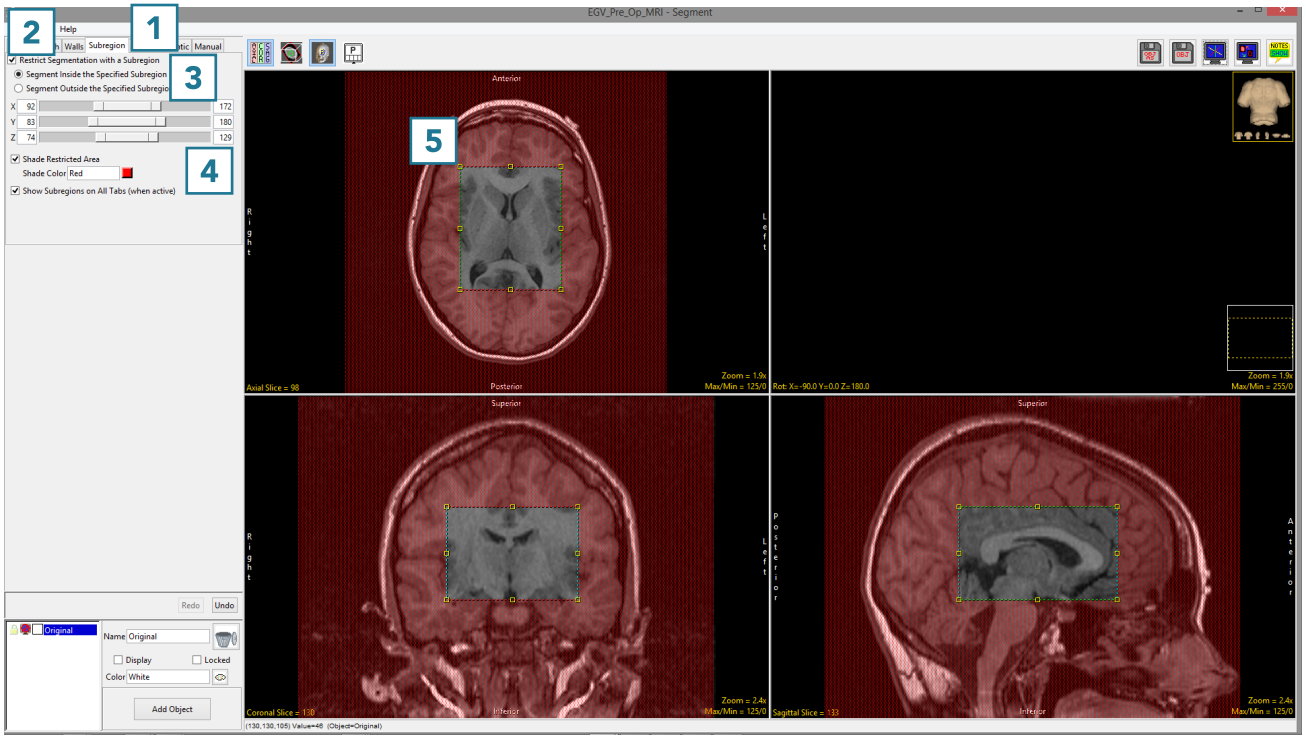




Setting a Subregion

Here we will set a Subregion to protect and limit the region when segmenting with other tools.

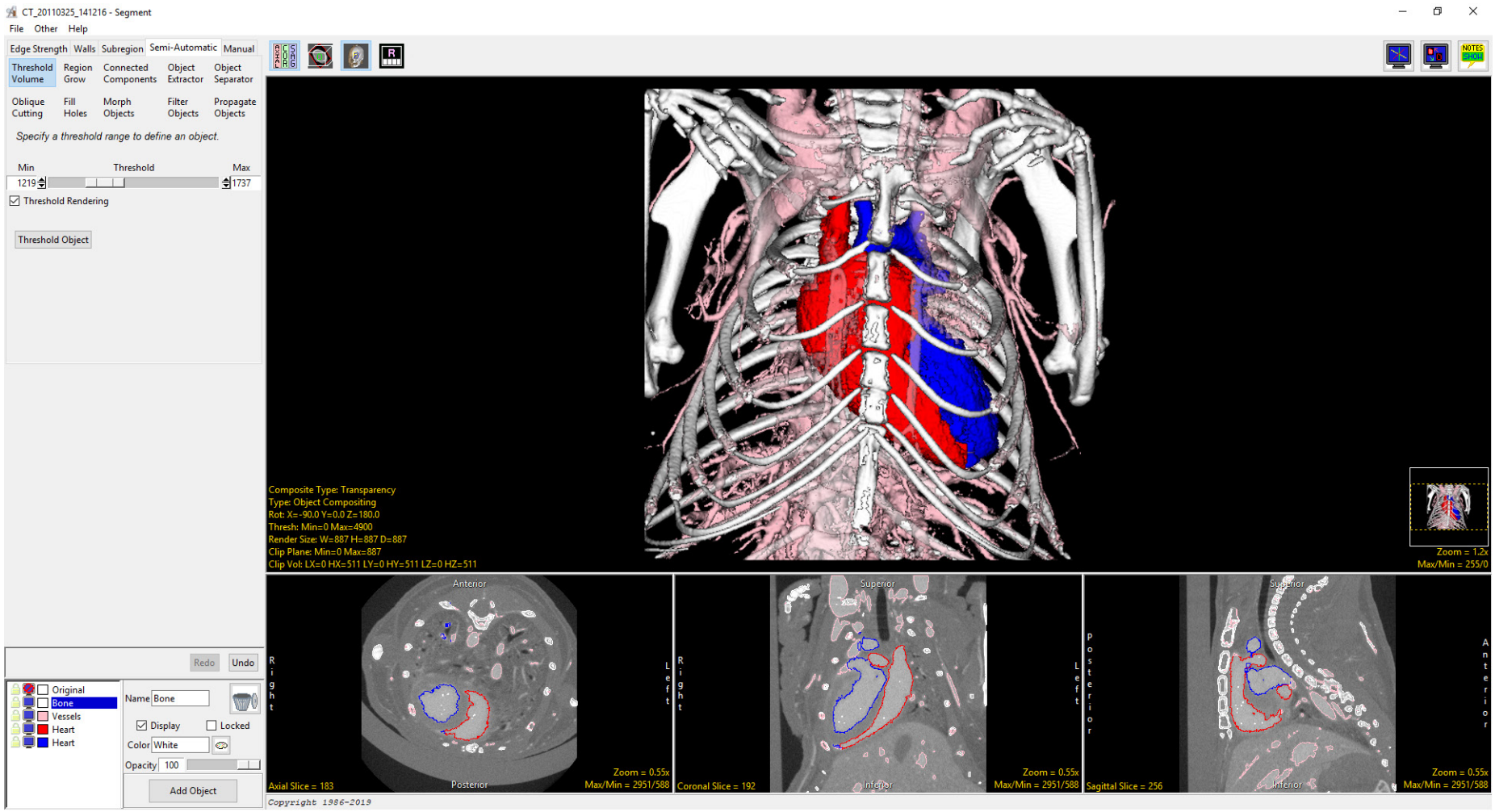
To follow along, download the data set EGV_MRI from analyzedirect.com/data and load into Analyze using Input/Output.



- Select the data set and open Segment.
- Select Subregion [1], and check the Restrict Segmentation with a Subregion checkbox [2].
- Choose to Segment Inside (default) or Outside the Subregion [3]
- Use the X, Y, Z sliders [4] or the yellow control points [5] to specify the Subregion in all orientations.
- The area in red will be protected as you move to the Semi-Automatic or Manual tools to segment regions of interest.

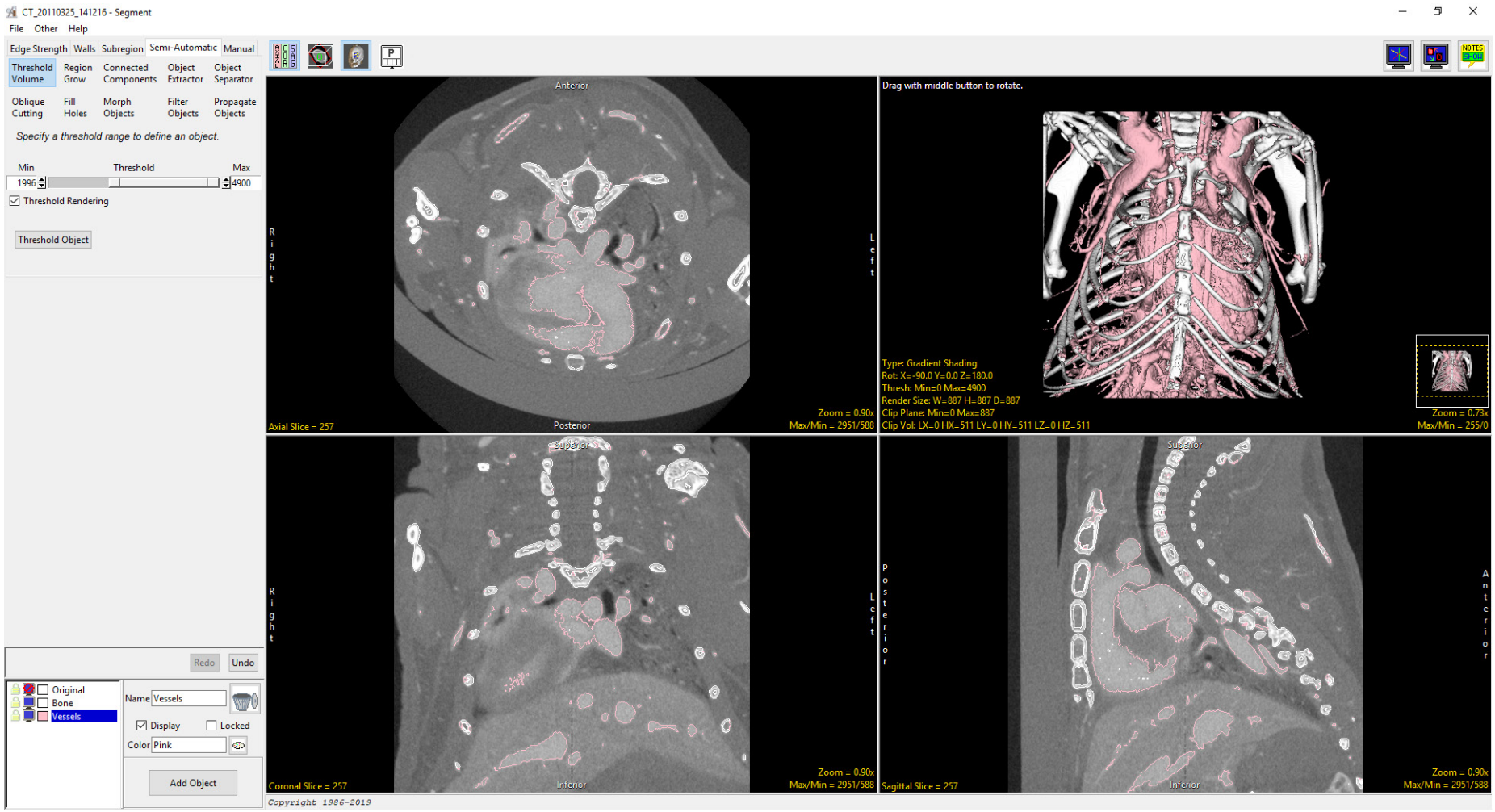
Semi-Automatic Tools

The Semi-Automatic tab provides access to many useful tools for interactive, efficient segmentation of objects. These tools include simple segmentation options, such as threshold, to more advanced, semi-automated techniques like object extraction and object separation. The segmentation tools available also include those that use 3D spatial connectivity and include region growing and connected components.



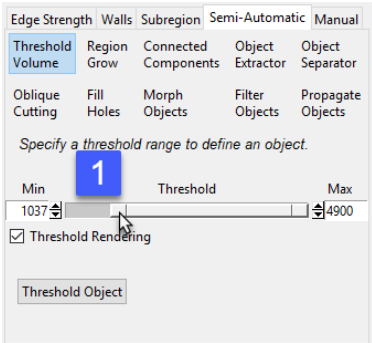
Threshold Volume

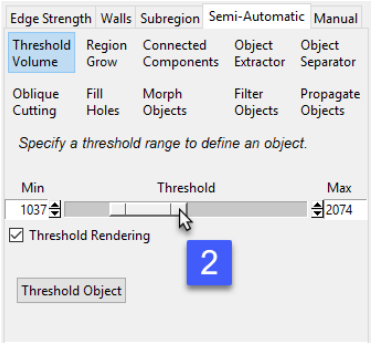
Threshold segmentation allows a range of voxels from the input volume to be assigned to an object. All voxels greater than or equal to the threshold minimum and less than or equal to the threshold maximum are assigned to the object.



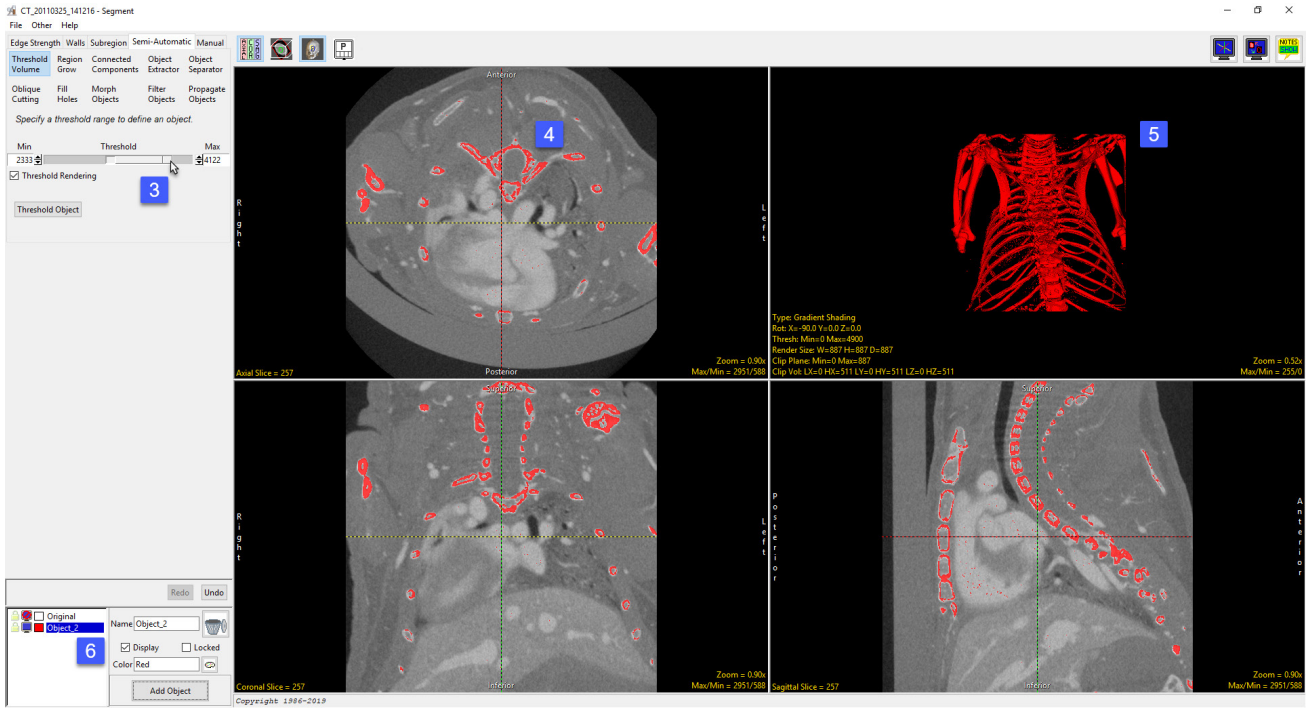
Threshold Volume Options

Threshold Slider: The Threshold double-ended slider bar allows users to specify a range of threshold values using the minimum and maximum ends of the threshold slider. Selecting the minimum end of the slider [1] and moving it to the right will increase the minimum threshold value, moving it to the left will decrease the minimum value. Selecting the maximum side of the slider [2] and moving it to the left will decrease the maximum threshold value, moving the slider to the right will increase the maximum value. Voxel with values outside the range are ignored and not include as part of the current object.



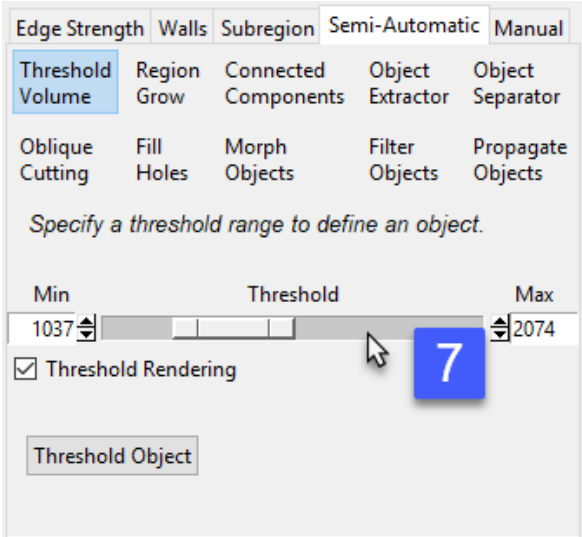


When adjusting the minimum or maximum threshold range [3] an interactive preview showing the range of selected voxels will be displayed overlaid on the grayscale data [4], a 3D display of the voxels will also be displayed in the render window. [5] The color of the previewed voxels will match the color of the object you currently have selected. [6]



Threshold Volume Options (continued)

Holding the Alt key while dragging either the minimum or maximum end of the slider allows for smaller adjustment of the value allowing users to fine tune selections. Clicking in the trough to either side of the minimum or maximum end of the slider [7] will advance the value by 1. Shift-click will decrease the value by 1.



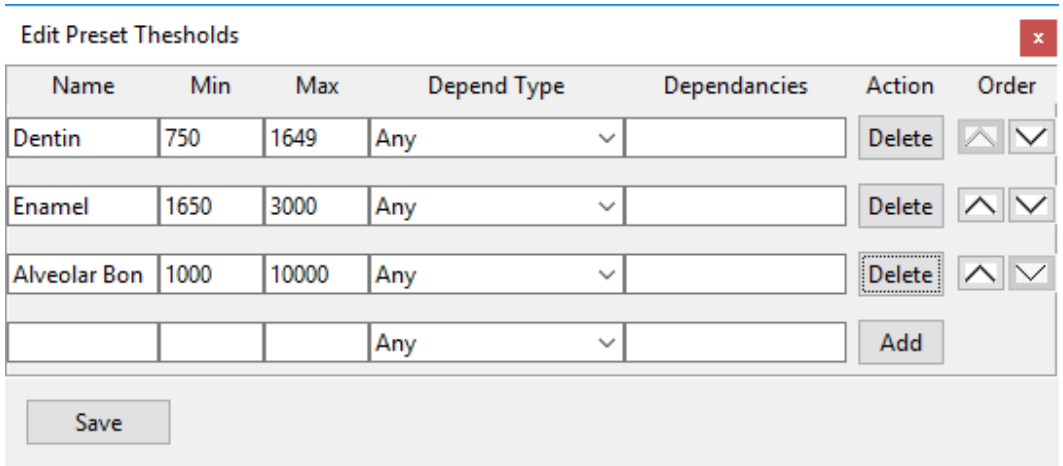
Min and **Max:** The minimum and maximum input field allows users to manually enter the minimum or maximum threshold value. There are also arrow up and down buttons the right of the input field to increase or decrease the currently value by 1.

Threshold Rendering: This option allows users to disable and enable to 3D preview of the selected voxel range. It is recommended to disable this option by unchecking the checkbox when working with large data sets.

Threshold Object: Assigns the voxels in the selected range to the current object.

Right click options: Right clicking on the Threshold slider provides users with access to the following options:

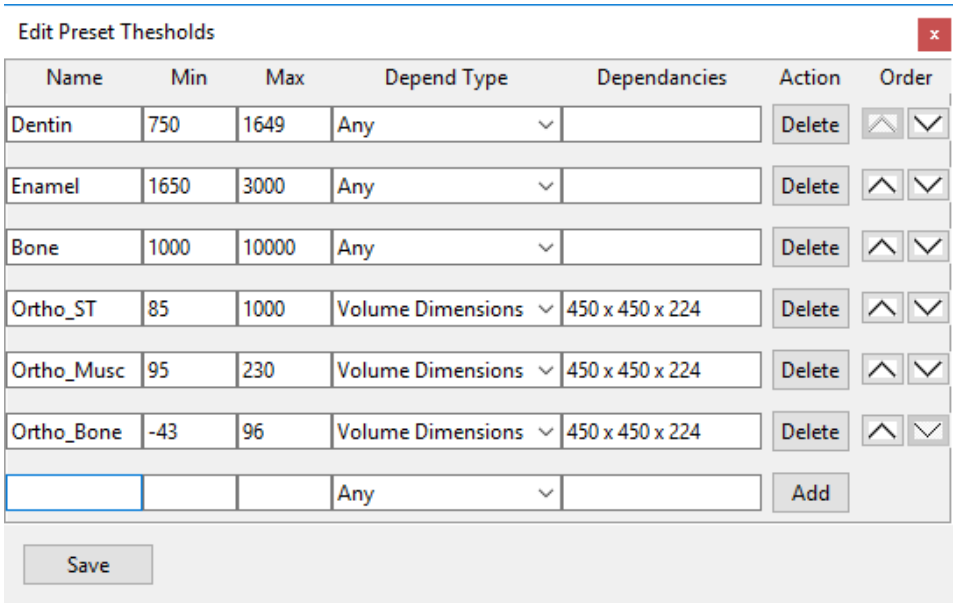
Presets: The Presets option allows users to define threshold values for specific structures or objects of interest. This is particularly useful for those users who routinely segment the same structures from their image data.



Threshold Volume Options (continued)

Right click options (continued)

Presets (continued): When the Edit Presets Thresholds window opens, the following options are available:



Edit Preset Thesholds

Name	Min	Max	Depend Type	Dependancies	Action	Order
Dentin	750	1649	Any		Delete	
Enamel	1650	3000	Any		Delete	
Bone	1000	10000	Any		Delete	
Ortho_ST	85	1000	Volume Dimensions	450 x 450 x 224	Delete	
Ortho_Musc	95	230	Volume Dimensions	450 x 450 x 224	Delete	
Ortho_Bone	-43	96	Volume Dimensions	450 x 450 x 224	Delete	
			Any		Add	

Save

- Name: Allows users to enter the name for preset
- Min: Enter the minimum threshold value for the preset
- Max: Enter the maximum threshold value for the preset
- Depend Type: Allows users to set dependencies for presets. This option allows users to set multiple presets but only the presets that that meet the dependencies requirements are displayed for the current data. In the example screenshot two sets of segmentation presets have been defined. The first three presets are for a dental segmentation application. The second three presets are for a muscle segmentation application. As the first three presets Depend Type is set to Any these presets will be available for any data set loaded into the Segment module. However, the latter three presets have a depend type set to Volume Dimension and the Dependency set to a volume size of 450 by 450 by 224, these presets will only be available for data sets loaded into Segment of this size. The following Depend Types are available:

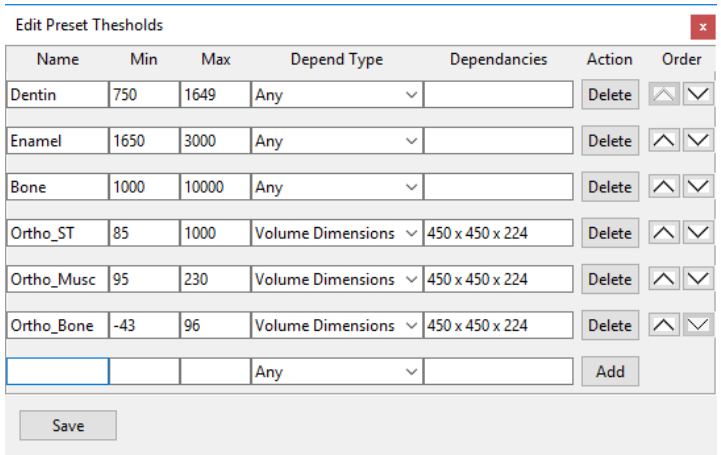
  Module: Defaults can be set for specific modules, for example presents to segment image data can be set to only appear when the data is opened with Segment, presents for rendering set to appear only when data is opened with Display.
  Volume Name: The preset will only display if the volume name meets dependency criteria.
  Volume Data Type: The preset will only display if the volume data type meets the dependency criteria.
  Volume Dimensions: The preset will only display if the volume data type meets the dependency criteria.
  Any: Default option. The preset will be displayed.

Threshold Volume Options (continued)

Right click options (continued)

Presets (continued):

- Dependencies: Allows users to specify the dependency criteria for the selected depend type.
- Action: Allows users to Add or Remove presets.
- Order: Allows users to change the order of hold the presets are listed. As a general rule of thumb presets should be listed in the order they are used for segmentation.

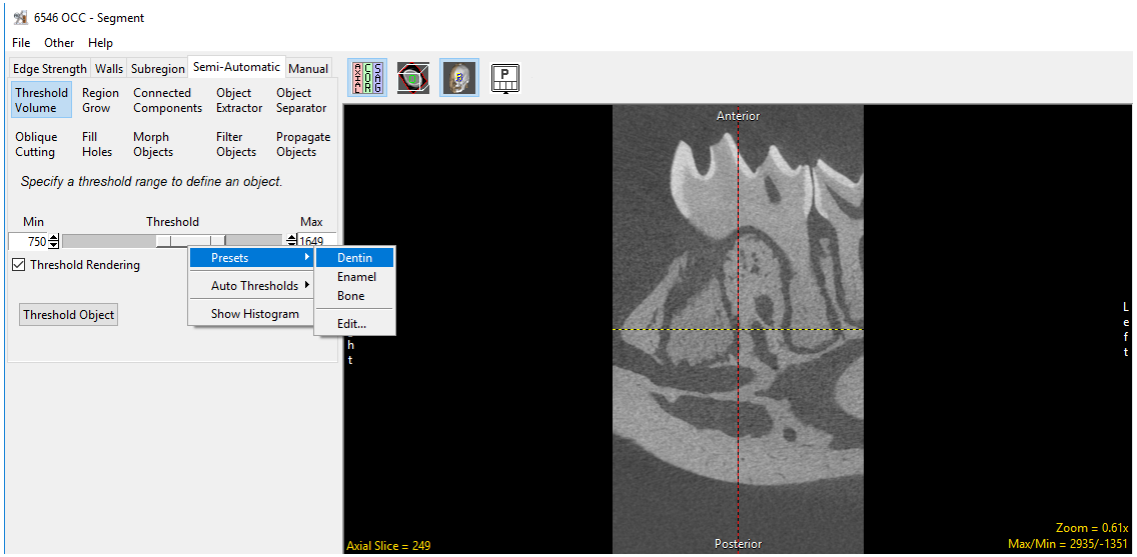


To define a set of presets do the following:

Right-click on the Threshold slider and choose Presets.

In the Presets window set the preset name, next enter the min and max threshold values, finally set a Depend Type and Dependency if desired. Click Add and either enter the next Preset or choose Save.

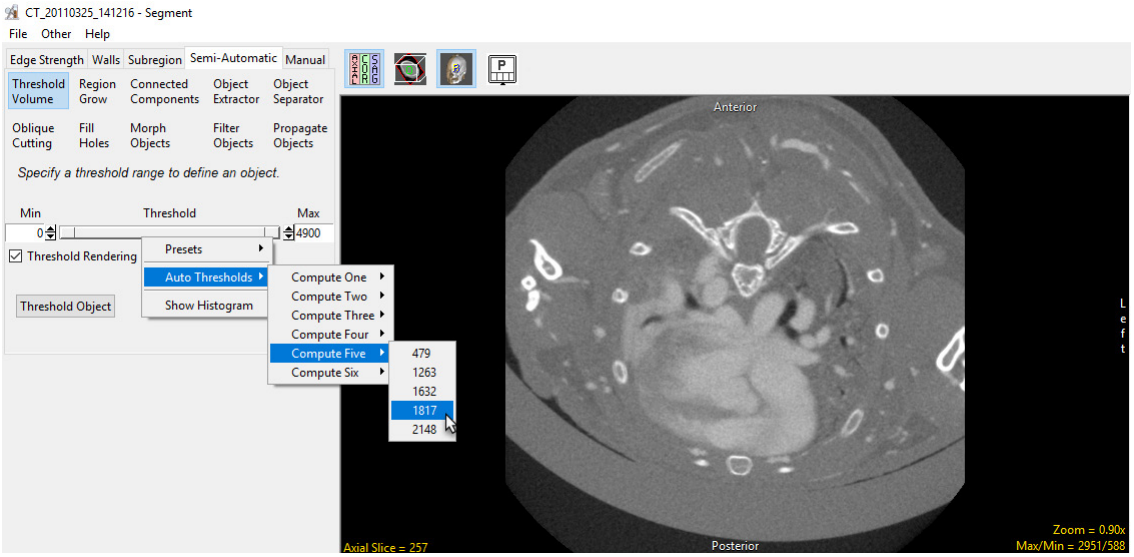
Once Presets are established, they can be accessed by simply right-clicking on the Threshold slider and choosing Presets and then the Present name.



Threshold Volume Options (continued)

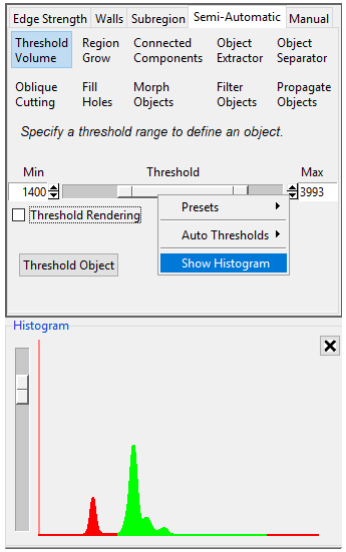
Right click options (continued)

Auto Thresholds: The auto thresholds option allows users to compute up to 6 automatically computed threshold to specify the number of automatic thresholds computed. Selecting a threshold value will set the minimum threshold to that value.

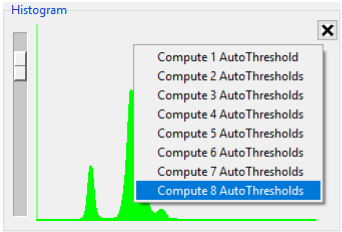


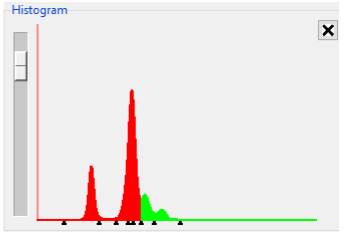
Show/Hide Histogram: When selected, calculates and displays the volume histogram below the Threshold Volume options.

When the threshold minimum and maximum values are adjusted the voxels within the selected range display as green on the histogram while the voxels out of range are displayed in red. Adjusting the scale bar to the left side of the histogram display will increase or decrease the scale the histogram.



Right clicking on the histogram allows users to auto compute up to 8 threshold values for the image data. The thresholds are displayed as triangular buttons at the bottom of the histogram display, selecting a triangle will set the minimum threshold value.



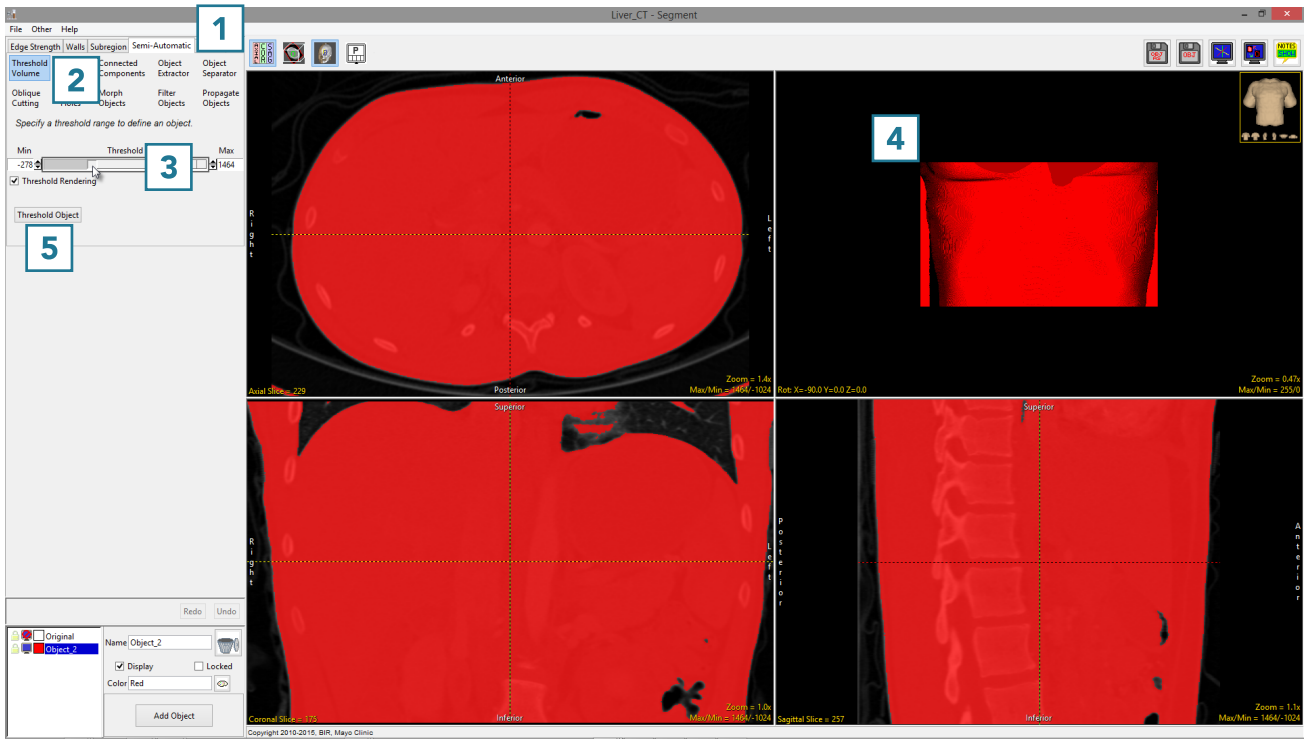


Threshold Volume Segmentation

Here we will use Threshold Volume to create a new object in a dataset.

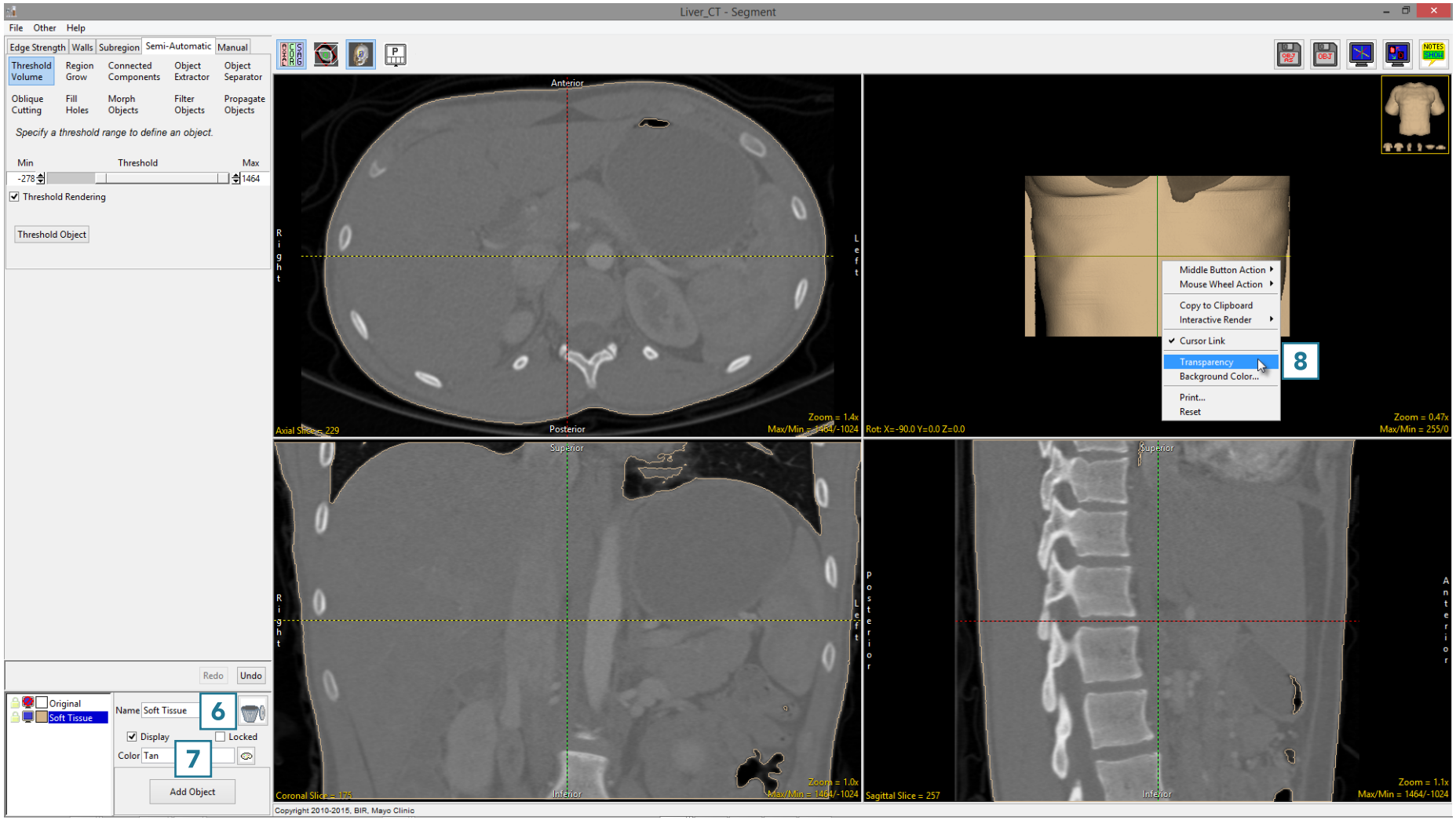
To follow along, download the data set CT_Liver from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the data set and open Segment.
- Select Semi-Automatic [1] and choose Threshold Volume. [2].
- Use the Threshold slider [3] to adjust the voxel intensity range, so that the soft tissue is displayed in the binary mask preview. This data set is scaled to Hounsfield Units (HU), so the grayscale intensities represent HU. This may be used to isolate tissue with a known HU range [4].
- Click Threshold Object [5] to assign all selected voxels to the current object.



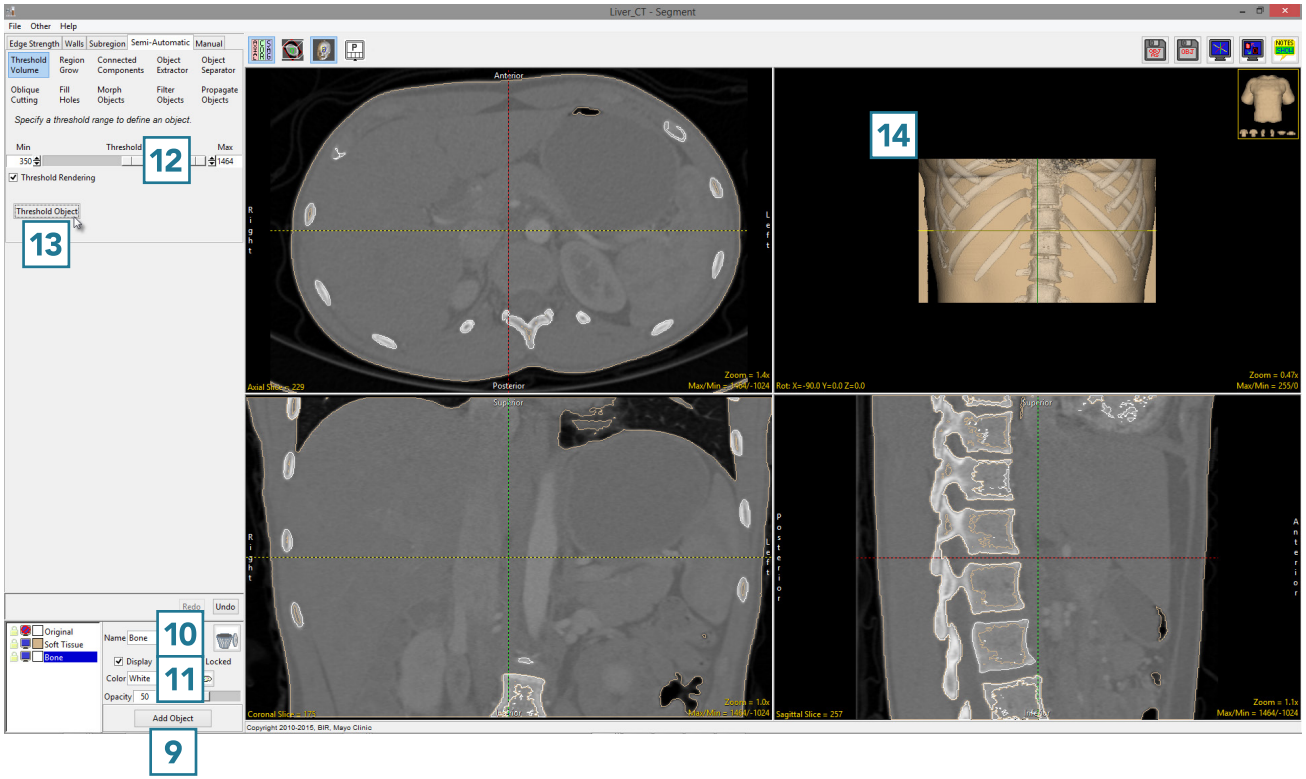
Threshold Volume Segmentation (continued)

- Rename the object, [6] then change the color [7].
- Right-click on the rendering and select Transparency [8].



Threshold Volume Segmentation (continued)

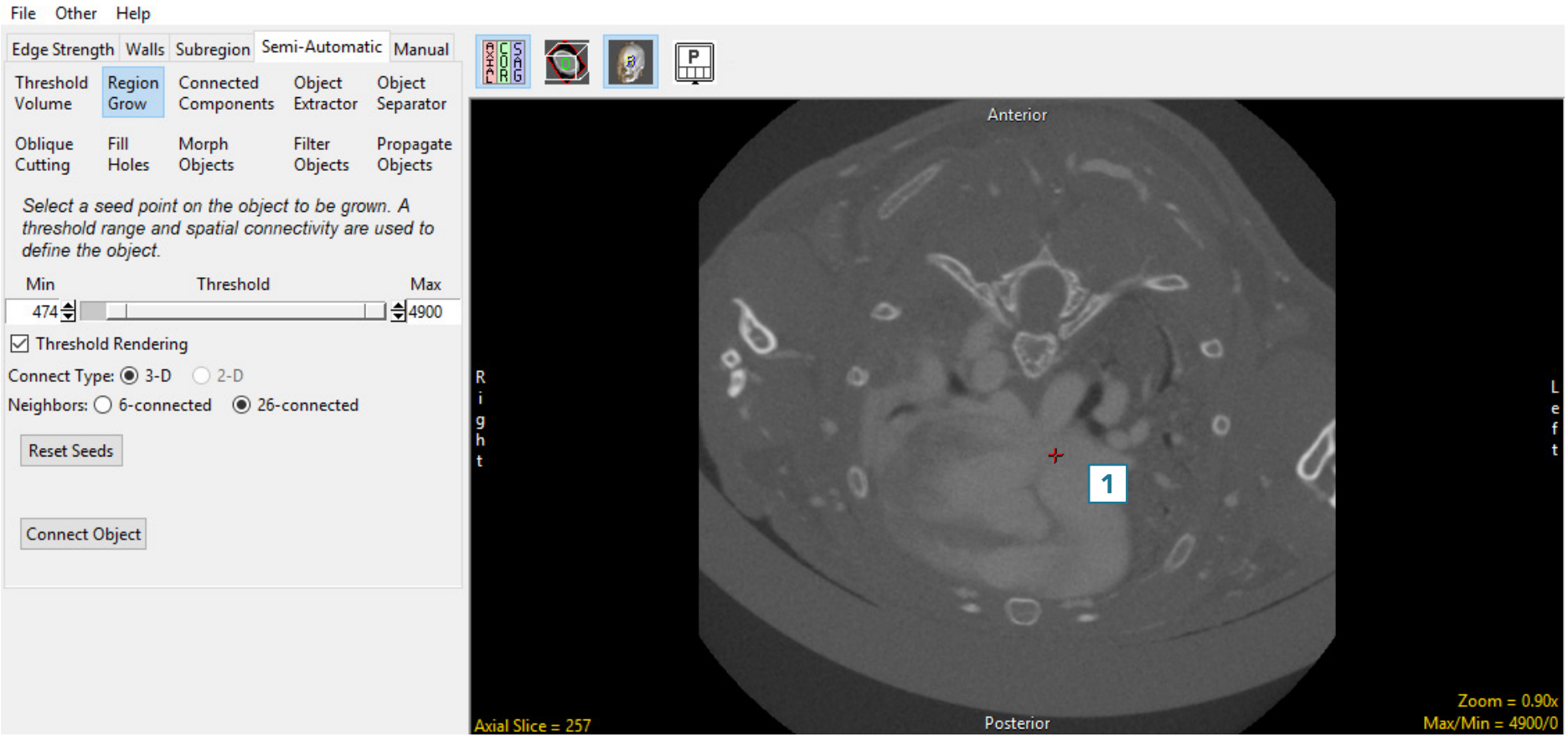
- Add a new object [9].
- Update the name [10] and color [11].
- Adjust the threshold range [12] so that the bone is displayed in the binary preview, then click Threshold Object [13].
- Note that the rendering [14] will update to display both objects. The bone is now fixed to visible, as the rendering transparency is enabled [8].
- Select File > Save Object Map to save your work.



Region Grow

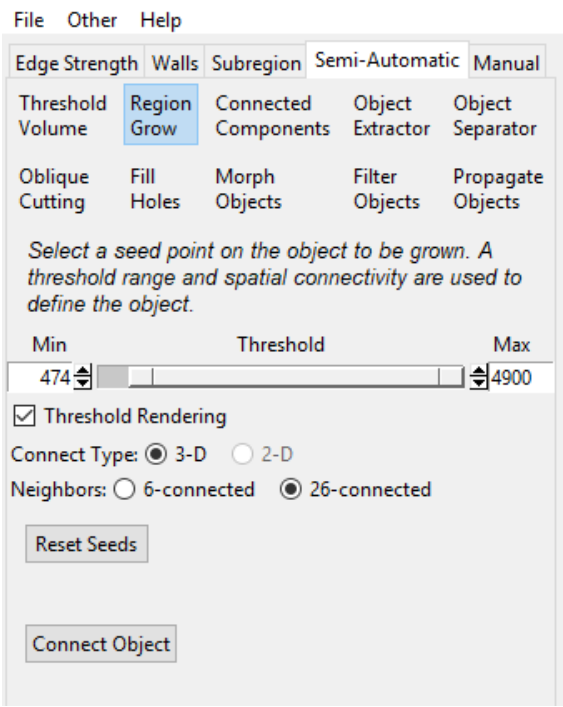
Whereas threshold-based segmentation applies globally to all voxels in the volume, region growing can be used to limit the segmentation to voxels that are connected to a user-defined seed point which fall within a specified threshold range.

To enable the Region Grow options, first a seed point must be set on the structure you wish to isolate [1]. Note, multiple seeds can be selected to facilitate the simultaneous segmentation of multiple objects as long as the objects have the same threshold properties, for example multiple disconnected bones.



Region Grow Options

When the seed is set the following options become available:



Threshold slider: The Threshold double-ended slider bar allows users to specify a range of threshold values using the minimum and maximum ends of the threshold slider. For a full description of the threshold slider please refer to the Threshold Volume section.

Min and **Max:** The minimum and maximum input field allows users to manually enter the minimum or maximum threshold value. There are also arrow up and down buttons the right of the input fields to increase or decrease the currently value by 1.

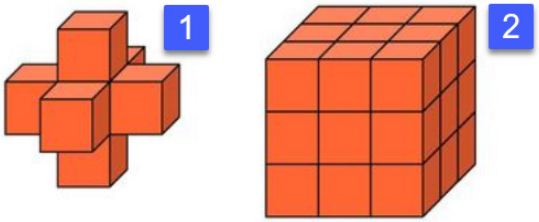
Threshold Rendering: Allows users to disable and enable to 3D preview of the selected voxel range. Disable this option by unchecking the checkbox when working with large data sets.

Connect Type: Determines if the connection type will be 3D or 2D.

3-D: Region grow will be applied to the (3D) volume.

2-D: Region grow will be limited to the current (2D) slice.

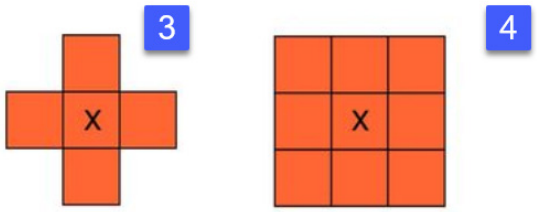
Neighbors: Allows users to select the number of neighboring voxels during the connection process. The options available depend on the connect type. For 3D, users can choose 6-connected or 26-connected. For 2D, 4-connected or 8-connected can be selected.



- **3D Neighbor options:**
  6-connected: Specifies that only 3-D neighbors are checked for connectivity during the region growing process. [1]
  26-connected: Specifies that the entire 26-voxel neighborhood is checked for connectivity during the region growing process. [2]

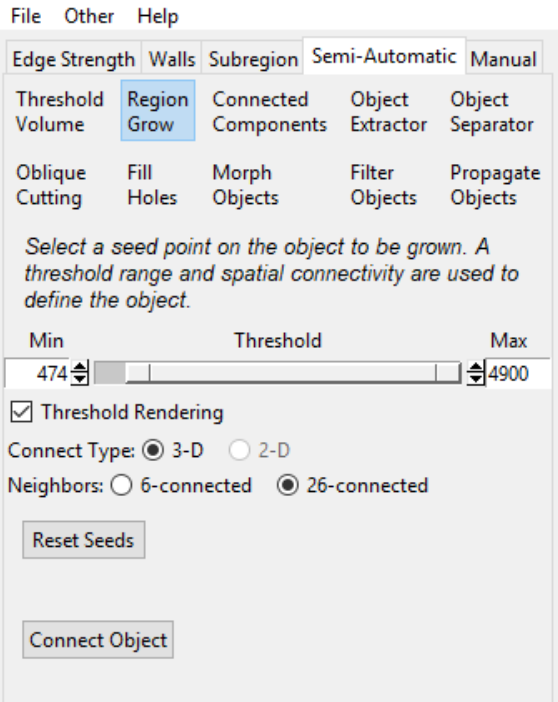
Region Grow Options (continued)

- **2D Neighbor options:**
  4-connected: Specifies that only 2-D neighbors are checked for connectivity during the region growing process. [3]
  8-connected: Specifies that the entire 8-voxel neighborhood is checked for connectivity during the region growing process. [4]



Reset Seeds: Resets the user defined seed(s). Seeds can also be deleted by right clicking on the seed and then selecting delete.

Connect Object: Initiates the connection process.



Threshold Slider right click options: Right clicking on the Threshold slider provides users with access to the following additional options; Presets, Auto Threshold, Show/Hide Histogram. For more information please refer to the Threshold Slider right click options in the Threshold Volume section.

Seed point right click options: Right clicking on a seed point provides the following options:

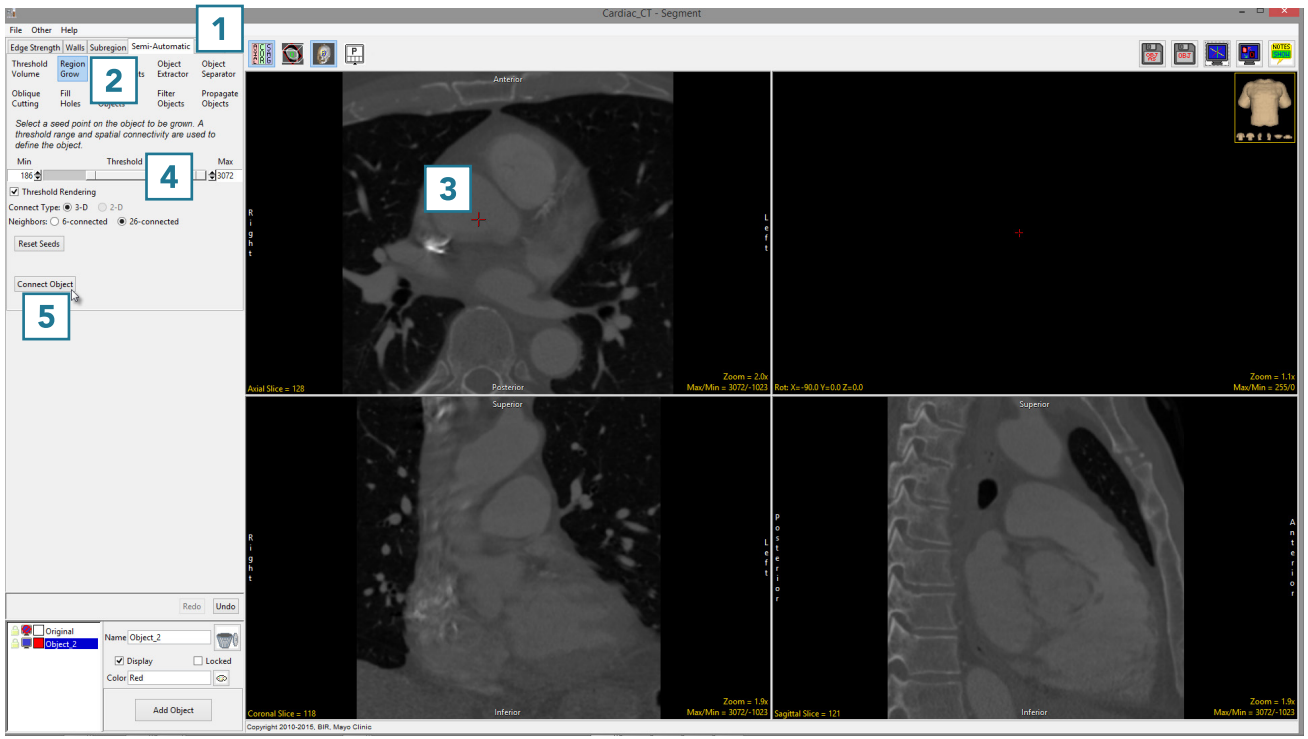
- **Style:** The style options allows users to change the of the seed point. Select from Dot, Crosshair (default), Arrow, and Diamond.
- **Label:** The label options allows user to enable and disable labels for seed points. Select from None (default), Number (useful when setting multiple seeds), and Tag.
- **Shadow:** Allows users to enable (default) or disable the shadow effect for the seed.
- **Delete:** Deletes selected seed point.

3D Segmentation with Region Grow

Here we will use Region Grow to segment a new object in a dataset.

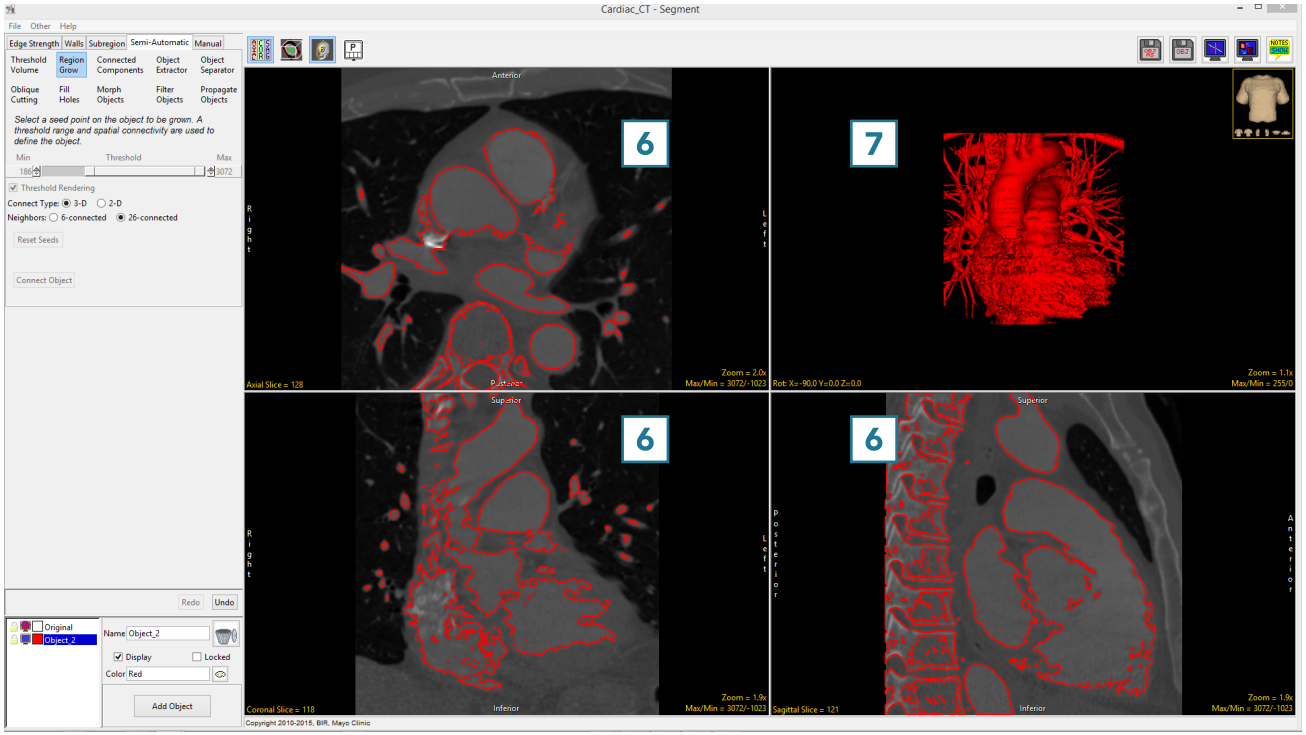
To follow along, download the data set CT_Heart from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the data set and open Segment.
- Select Semi-Automatic [1] and choose Region Grow [2].
- Click on the image data to set a seed point in the object you would like to isolate [3]
- Set the Threshold Min/Max values to define the object [4]
- Click Connect Object [5].



3D Segmentation with Region Grow (continued)

- The voxels fulfilling the seed point and threshold criteria for the region grow will be assigned to a new object.
- The segmented object is shown overlaid on the 2D slice data [6] and a 3D rendering [7] is displayed.

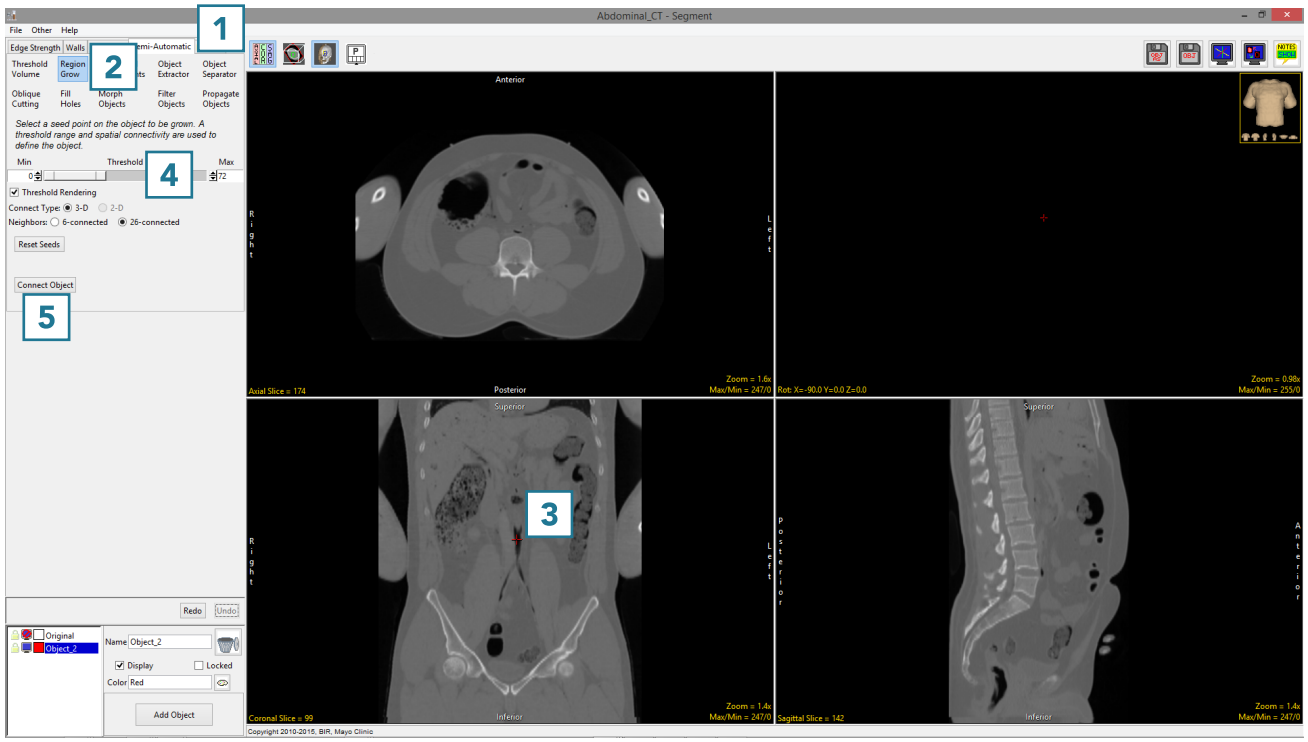


3D Segmentation with Region Grow (continued)

It may be necessary to adjust the number of neighbors used in order to limit the region grow. This will help prevent unwanted objects from being segmented with the target object.

To follow along, download the data set VH_Abdomen from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the data set and open Segment.
- Select Semi-Automatic [1] and choose Region Grow [2].
- Click on the image data to set a seed point in the structure you would like to isolate [3].
- Set the Threshold Min/Max values to define the object [4] and click Connect Object [5].

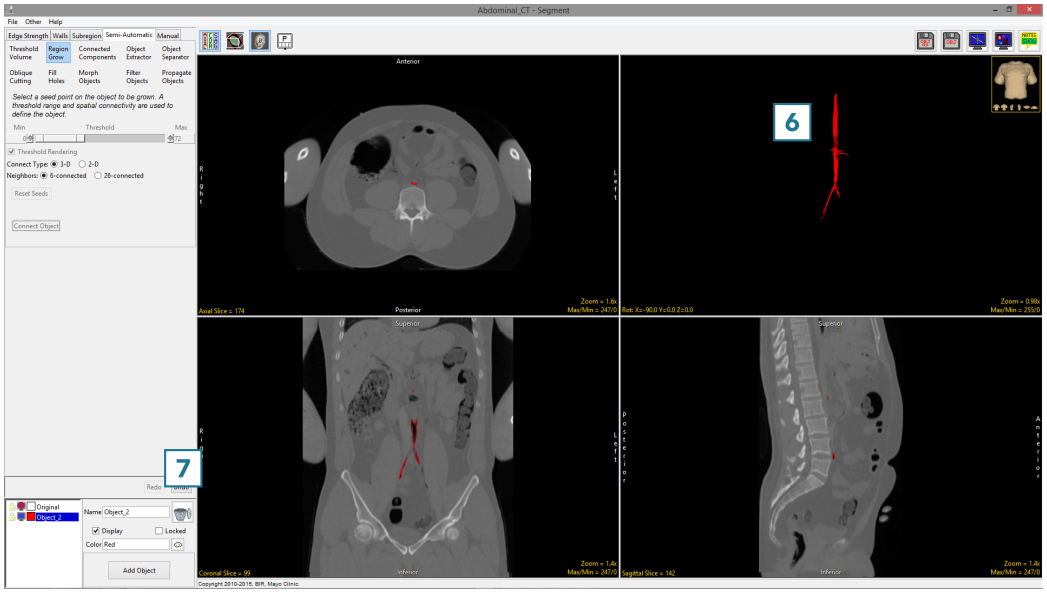


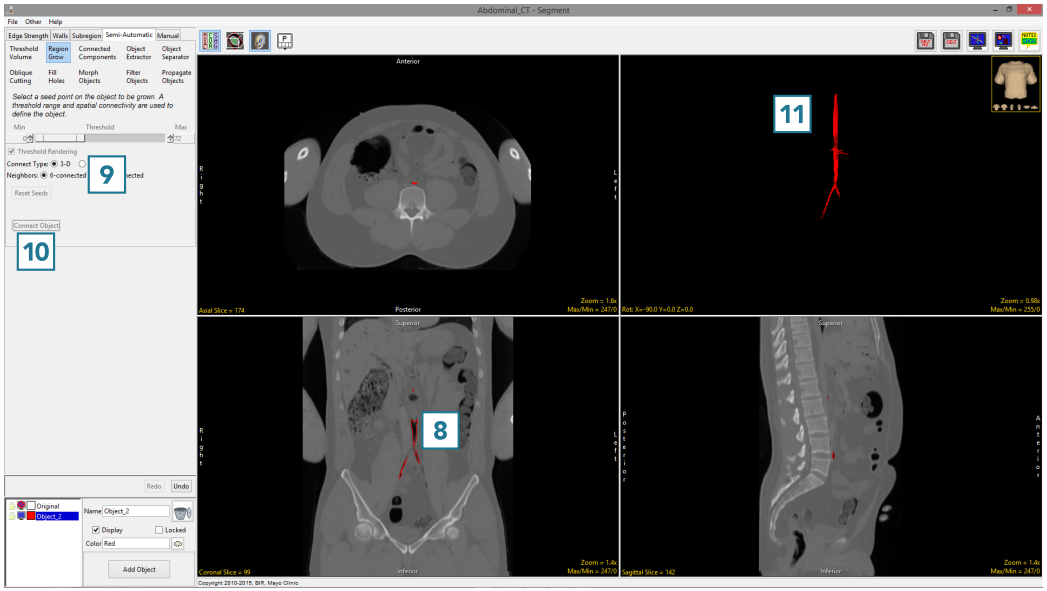
3D Segmentation with Region Grow (continued)

Note that the segmentation of the abdominal aorta in the example, using the default 26-connected neighbors, also assigns part of the left lung into the object [6].

- Click Undo [7]
- Set the seed point, [8] set Neighbors to 6-connected, [9] and click Connect Object [10].

Note the segmentation result for the abdominal aorta [11] no longer contains part of the left lung.



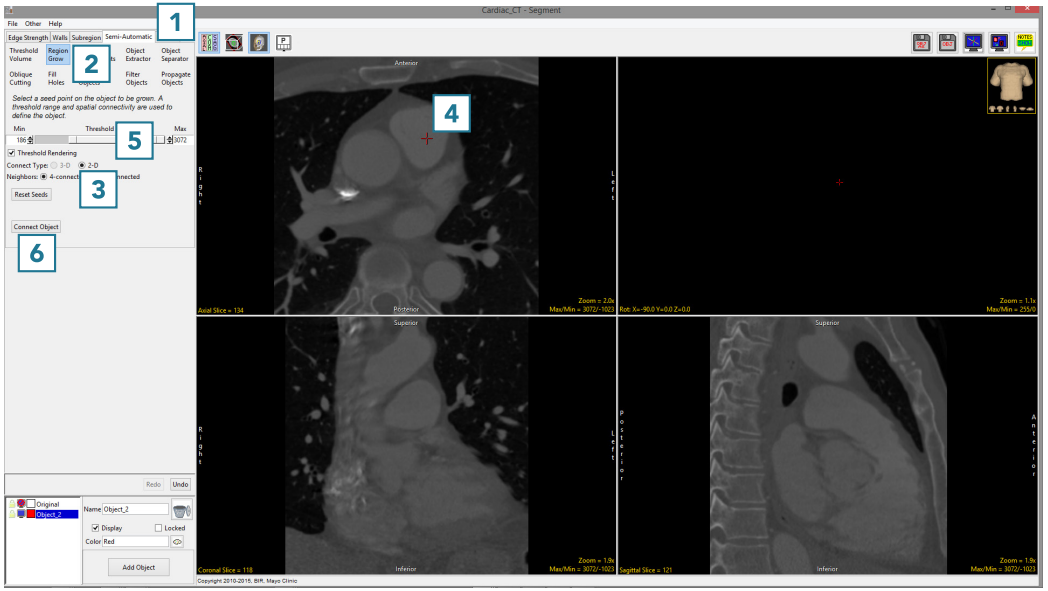


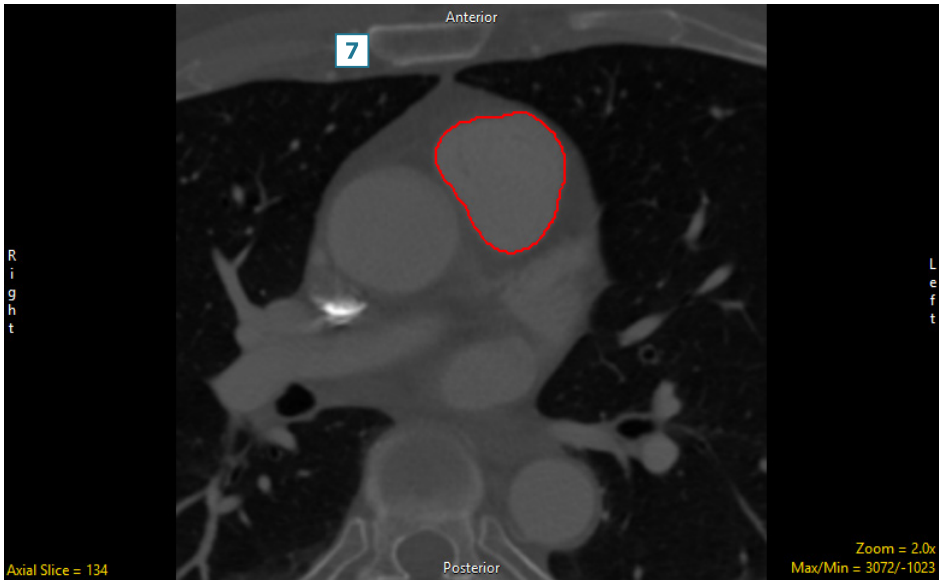
2D Segmentation with Region Grow

Region grow also provides the ability to limit the region to a single slice via the 2D Connect Type option.

To follow along, download the data set CT_Heart from analyzedirect.com/data and load into Analyze using Input/Output.

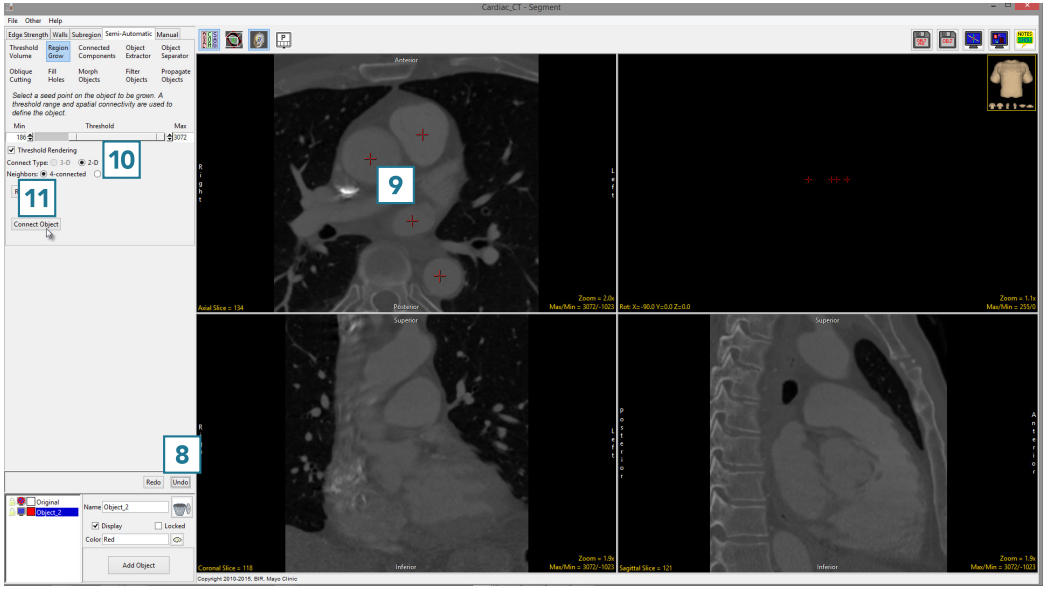
- Select a data set and open Segment.
- Select Semi-Automatic, [1] choose Region Grow [2 and set the Connect Type to 2D. [3].
- Click on the image data to set a seed point. [4] The seed point should be in the 2D structure you would like to isolate.
- Set the Threshold Min/Max values to define the object [5] and click Connect Object. [6].
- The region will be isolated on the single slice [7].



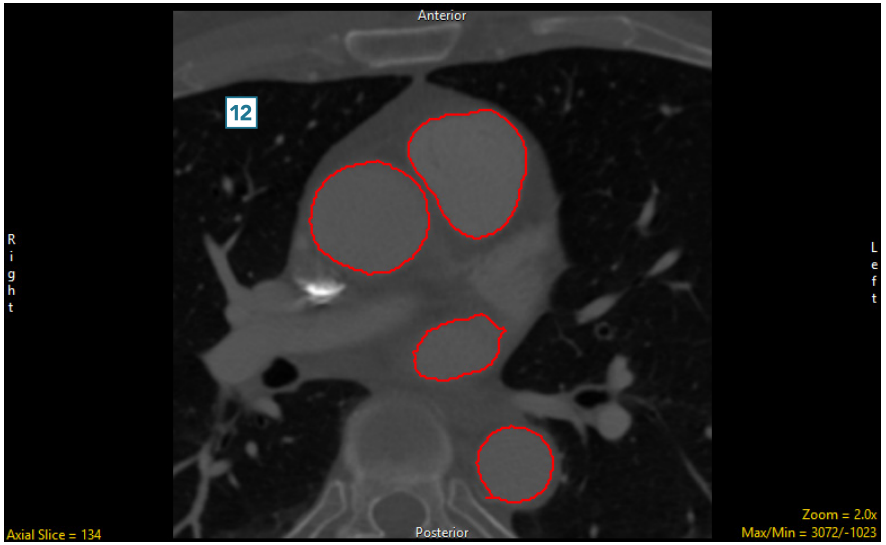


2D Segmentation with Region Grow (continued)

- To segment multiple 2D regions, click Undo [8].
- Click on the image data to set multiple seed points on the regions you want to segment [9].
- Set the Threshold Min/Max values to define the object [10] and click Connect Object [11].



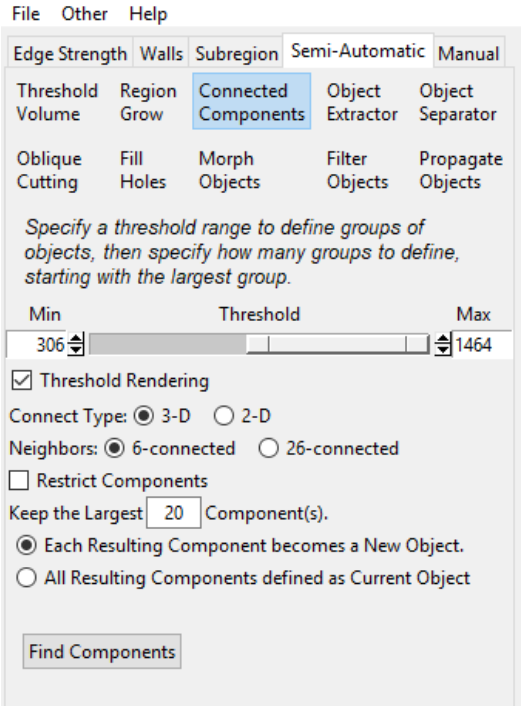
- All of the regions falling within the threshold criteria will be isolated in 2D [12].



Connected Components

The connected components tool allows users to identify groups of objects based on spatial connectivity and intensity range. This segmentation method finds groups of voxels within a user-specified intensity range and assigns spatially disconnected groups to independent objects. The number of objects identified is specified by the user, and objects are created in order of largest to smallest based on the number of connected voxels in each object.

Connected Components Options



The following Connected Components options are available:

Threshold slider: The Threshold double-ended slider bar allows users to specify a range of threshold values using the minimum and maximum ends of the threshold slider. For a full description of the threshold slider please refer to the Threshold Volume section.

Min and **Max:** The minimum and maximum input field allows users to manually enter the minimum or maximum threshold value. There are also arrow up and down buttons the right of the input fields to increase or decrease the currently value by 1.

Threshold Rendering: Allows users to disable and enable to 3D preview of the selected voxel range. Disable this option by unchecking the checkbox when working with large data sets.

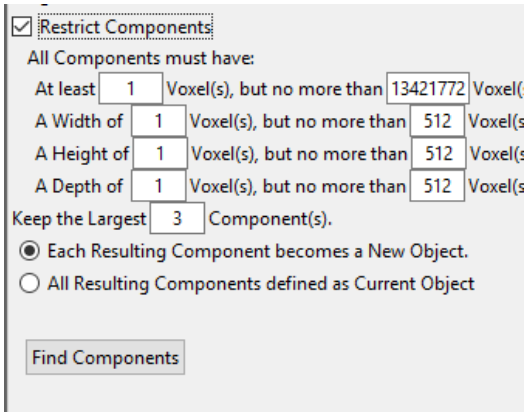
Connect Type: Determines if the connection type will be 3D or 2D.

3-D: Region grow will be applied to the (3D) volume.

2-D: Region grow will be limited to the current (2D) slice.

Neighbors: Allows users to select the number of neighboring voxels during the connection process. The options available depend on the connect type. For 3D, users can choose 6-connected or 26-connected. For 2D, 4-connected or 8-connected can be selected. For a full description of the neighbor options refer to the Region Grow section.

Connected Components Options (continued)



Restrict Components: When enabled displays a set of criteria that can be used to restrict the object segmentation resulting from the connected component analysis. Components with less than or more that the values entered in the x and y parameters will be ignored in the connected components analysis. These options specify that All Components must have:

- At least 'x' voxel(s), but no more than 'y' Voxels(s): Segmented components must have at least the minimum number of voxels in its structure as specified by 'x' and no more than the maximum number of voxels in its structure as specified by 'y'.
- A Width of 'x' voxel(s), but no more than 'y' Voxels(s): Segmented components must have a width of at least the minimum number of voxels as specified by 'x' and no more than the number of voxels as specified by 'y'.
- At Height of 'x' voxel(s), but no more than 'y' Voxels(s): Segmented components must have a height of at least the minimum number of voxels as specified by 'x' and no more than the number of voxels as specified by 'y'.
- At Depth of 'x' voxel(s), but no more than 'y' Voxels(s): Segmented components must have a depth of at least the minimum number of voxels as specified by 'x' and no more than the number of voxels as specified by 'y'.

Keep Largest X Component(s): Allows users to set the maximum number of objects to be kept in the connected component process.

Each Resulting Component becomes a New Object: When selected determines that each segmented component is assigned to its own object in the object map.

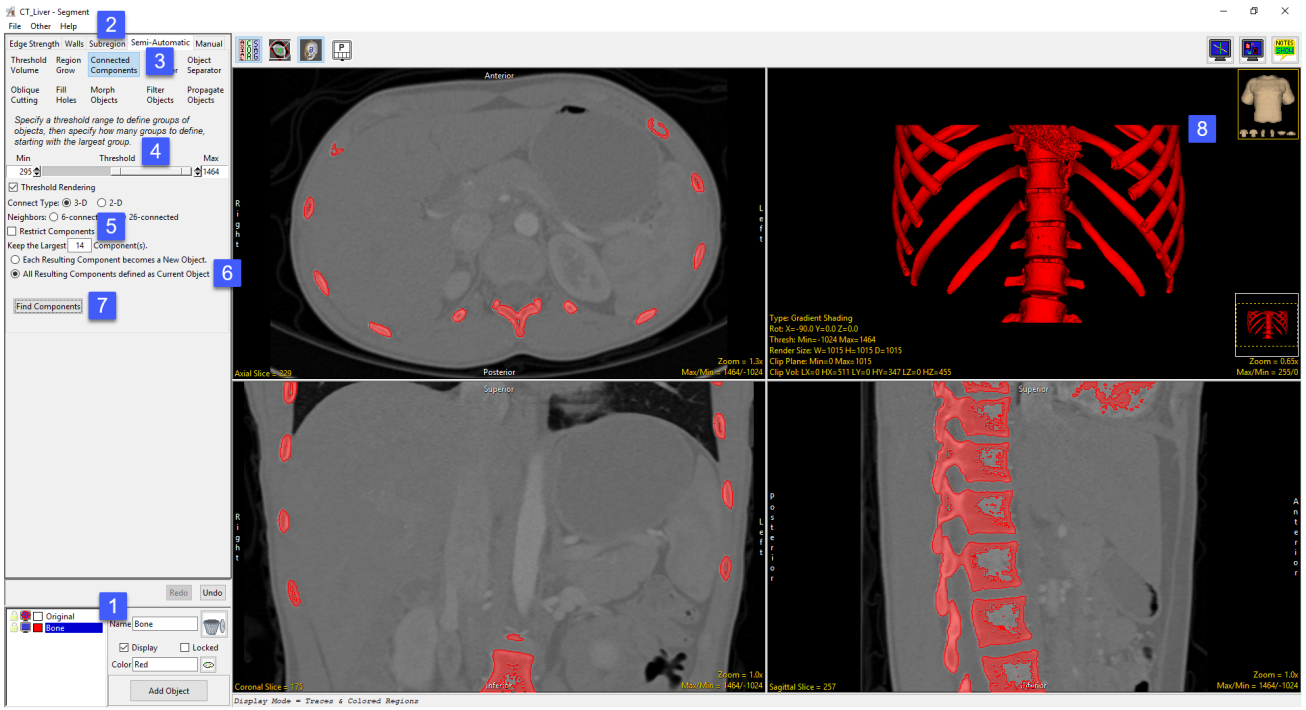
Each Resulting Component defined as Current Object: When selected determines that each segmented component is assigned to the current object selected in the object map.

Find Components: Initiates the connected components segmentation.

Segmenting Multiple Objects Using Connected Components

Here we will use Connected Components to segment several objects in a dataset.

To follow along, download the data set CT_Liver from analyzedirect.com/data and load into Analyze using Input/Output.



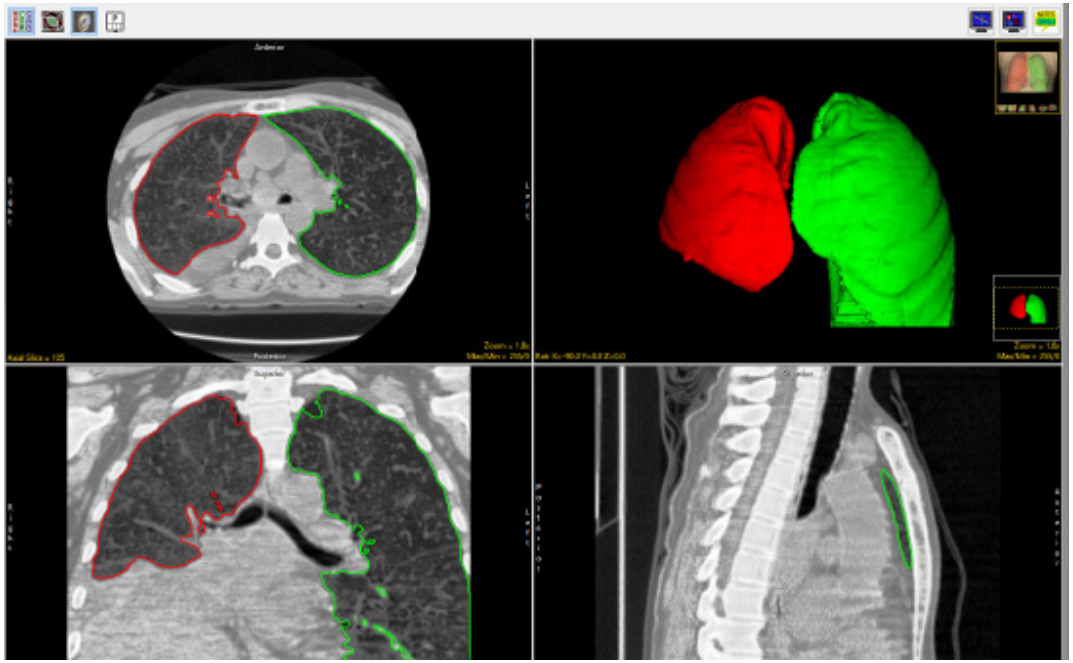
- Select the data set and open Segment.
- In the Object Control window click Add Object, name the object Bone and then make sure the object is selected [1].
- Select Semi-Automatic [2] and choose Connected Components [3].
- Set the threshold range [4] to isolate the spine and ribs. A minimum threshold value of 295 and a maximum of 1464 works well for this dataset.
- Set the number of components to keep to 14 [5]
- This time select the *Each Resulting Component defined as Current Object* option [6]. Now all 14 isolated components will be set to a single object.
- Click Find Components [7].
- The data will be thresholded and the largest groups of voxels specified will be identified and rendered as a single object [8].

Object Extractor

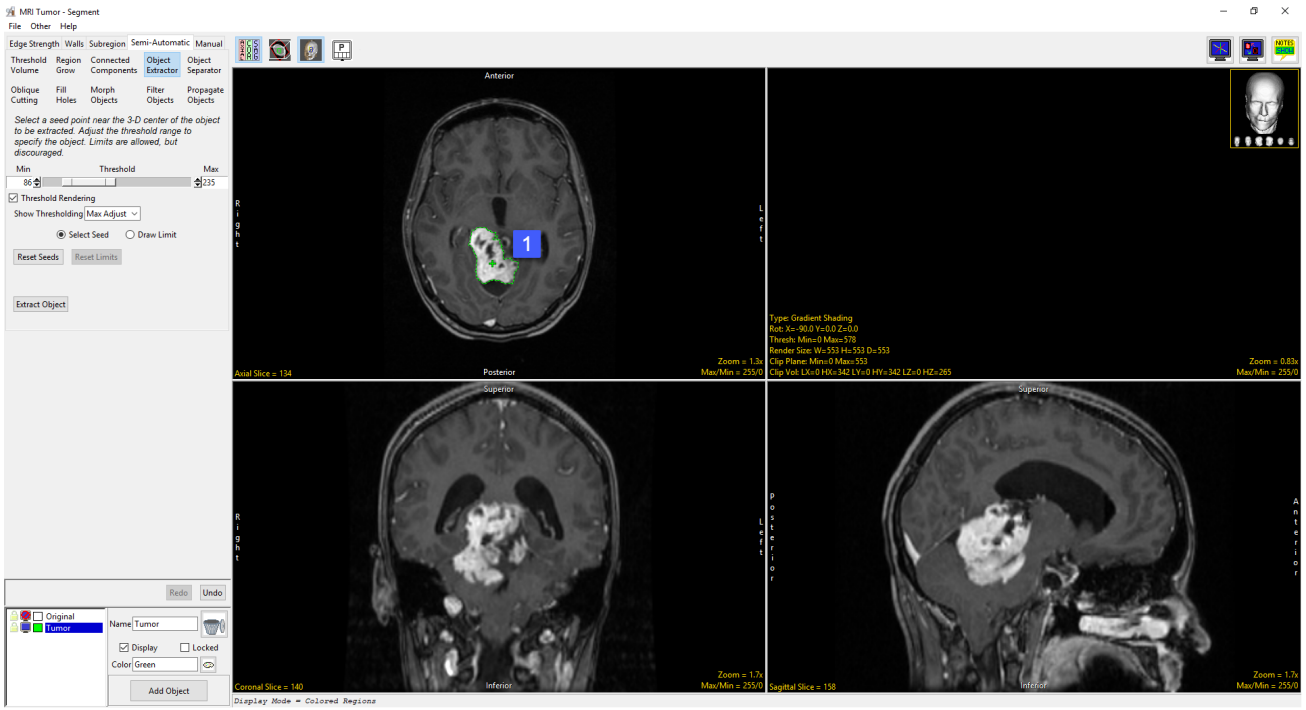
The Object Extractor tool enables the user to define and extract objects from image data using a combination of thresholding, region growing and morphological operations.

First, a seed point is manually set on a structure of interest. Next, a threshold range is established by the user to define the structure. The region defined by a given threshold range is shown on the 2D slice containing the seed point using a 2D auto trace mechanism. This region updates interactively as the threshold range is adjusted, allowing the user to determine the threshold range that properly defines the region of interest. The Object Extractor segmentation routine is ready to be started once the seed point and threshold range define the structure on the initial slice.

The algorithm first applies a global threshold to the data set, using the minimum and maximum values specified by the user. Next a 3D binary erosion is performed on the binary result of the global threshold. The erosion attempts to break connections between the target structure and neighboring regions which have similar intensity values. The erosion is followed by a 3D 6-neighbor region grow, which uses the initial seed point. The processed target slice on which the initial seed point was set is compared to the initial auto trace from the user-defined seed point and threshold range. The erosion and region growing steps are repeated until the set of voxels on the processed target slice are a subset of the initial auto trace. Next, the processed data is conditionally dilated until 99% of the voxels in the auto traced region on the processed target slice are recovered. Once the extraction process is complete, the resulting object is rendered and displayed over the 2D slice data.



Object Extractor Options



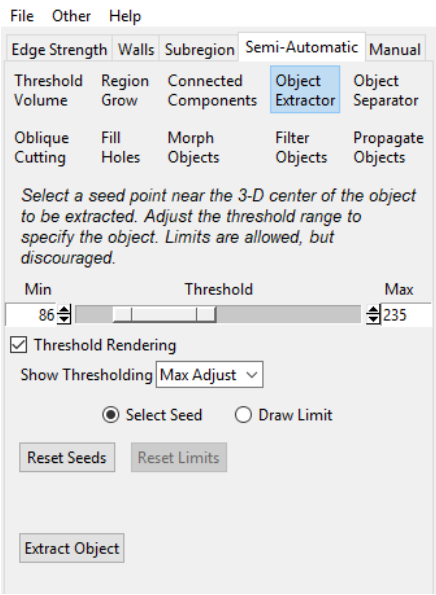
As with the Region Grow tool, a seed point must be set on the structure you wish to segment [1] before the Object Extractor options are enabled. Note, multiple seeds can be selected for the simultaneous segmentation of multiple structures with the same threshold parameters, for example the segmentation of both the left and right lungs. When the seed is set the following options become available:

Threshold slider: The Threshold double-ended slider bar allows users to specify a range of threshold values using the minimum and maximum ends of the threshold slider. For a full description of the threshold slider including right click options, please refer to the Threshold Volume section.

Min and **Max:** The minimum and maximum input field allows users to manually enter the minimum or maximum threshold value. There are also arrow up and down buttons the right of the input fields to increase or decrease the currently value by 1.

Threshold Rendering: This option allows users to disable and enable to 3D preview of the selected voxel range. It is recommended to disable this option by unchecking the checkbox when working with large data sets.

Object Extractor Options (continued)



Show Thresholding: When the minimum and maximum threshold values are selected the adjustment is previewed on the 2D slice data. By default, the Show Thresholding option is set to Max Adjust. Adjusting the minimum threshold value will display as a update of the outer boundaries of the object only {x} while adjusting the maximum will display as a filled preview. To enable the filled preview the following options are available.

Max Adjust: Only adjusting the maximum threshold level will preview with the filled region.

Min Adjust: Selecting Min Adjust will reverse the default preview display so that adjusting the minimum threshold value will show a filled region while adjusting the maximum threshold values will display the outer boundaries of the object only.

Any Adjust: Will set the filled preview display when adjusting either the minimum or maximum threshold value.

Never: Disables the filled preview display. Both minimum and maximum threshold adjustment will display the outer boundaries of the object only.

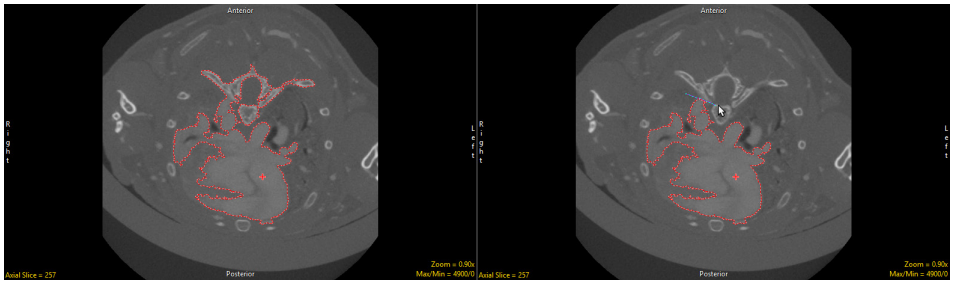
Select Seed: Switches to seed selection mode.

Draw Limit: Switches to limit definition mode. Allowing users to define limits on the image data to prevent the defined region from leaking into surrounding structures.

Reset Seeds: Resets the user defined seed(s). Note, you can delete a seed point by right-click on the seed and choosing Delete. Seeds can also by moved by left-clicking on the seed and then dragging to a new location.

Reset Limit: Resets all user defined limits.

Extract Object: Initiates the Object Extraction segmentation process.

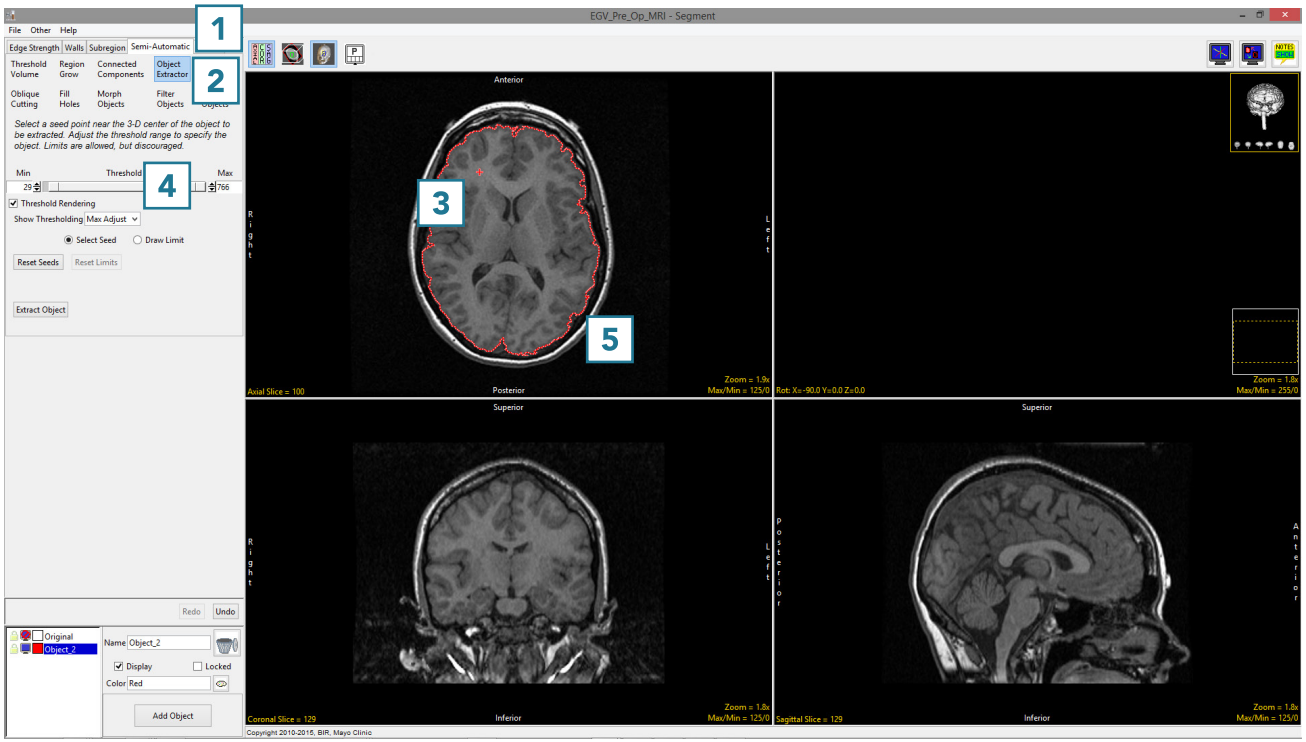


Segmentation of a Single Object Using Object Extractor

Here we will use Object Extrator to segment a single object in a dataset.

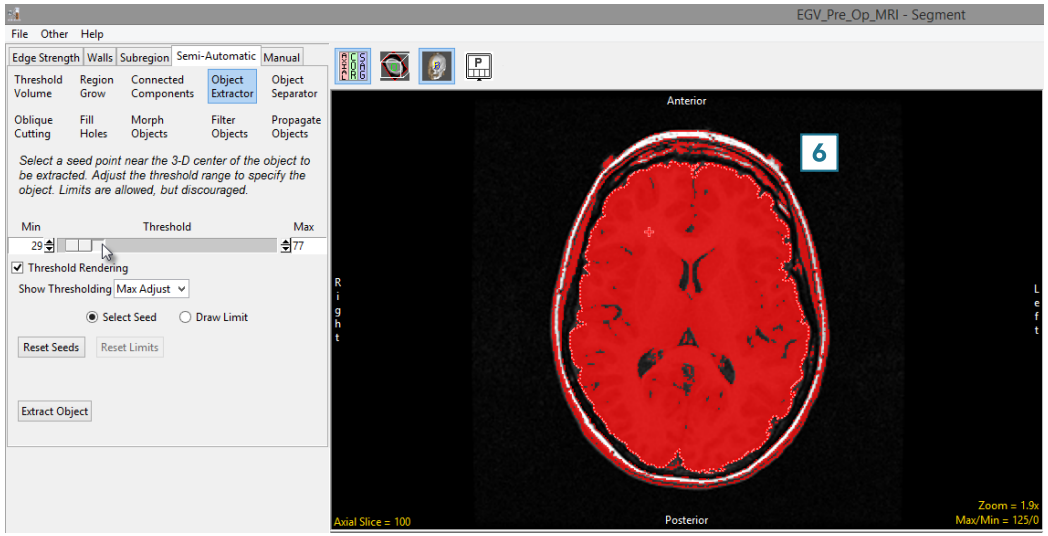
To follow along, download the data set EGV_MRI from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the data set and open Segment.
- Select Semi-Automatic [1] and choose Object Extractor [2].
- Click on the image data to set a seed point in the object you would like to isolate [3].
- Adjust the minimum threshold value [4] until the auto trace defines the object [5].

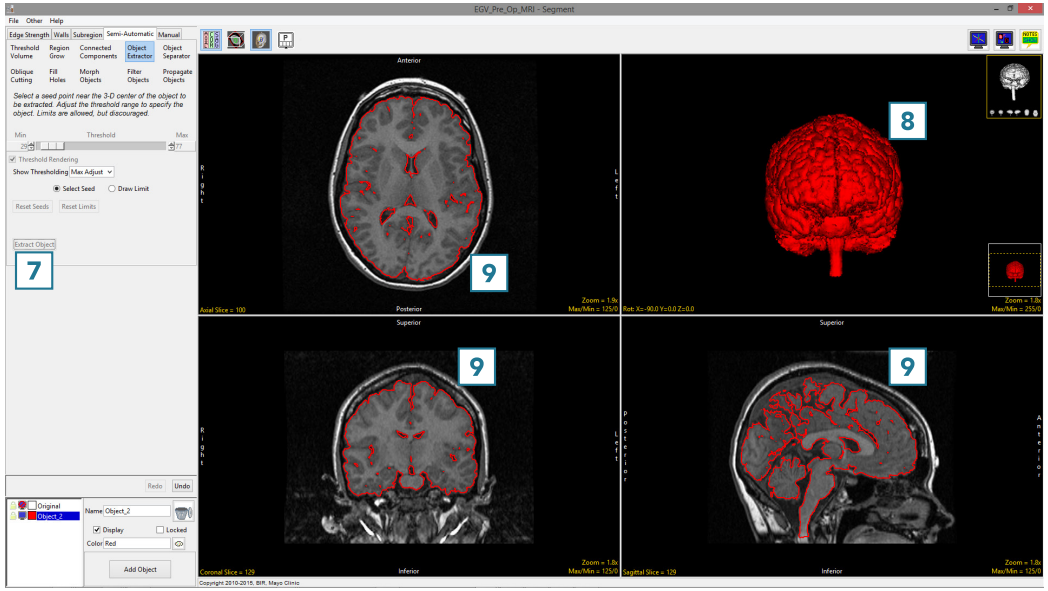


Segmentation of a Single Object Using Object Extractor (continued)

- Adjust the maximum threshold level and note that the red binary mask will interactively update.
- Lower the maximum threshold value until holes start to appear in the red binary mask in the structures surrounding the brain, but not in the brain [6].



- Click Extract Object [7].
- Once segmentation is complete, the object map will be rendered [8] and overlaid on the slice data [9].
- Save your work by selecting File > Save Object Map.

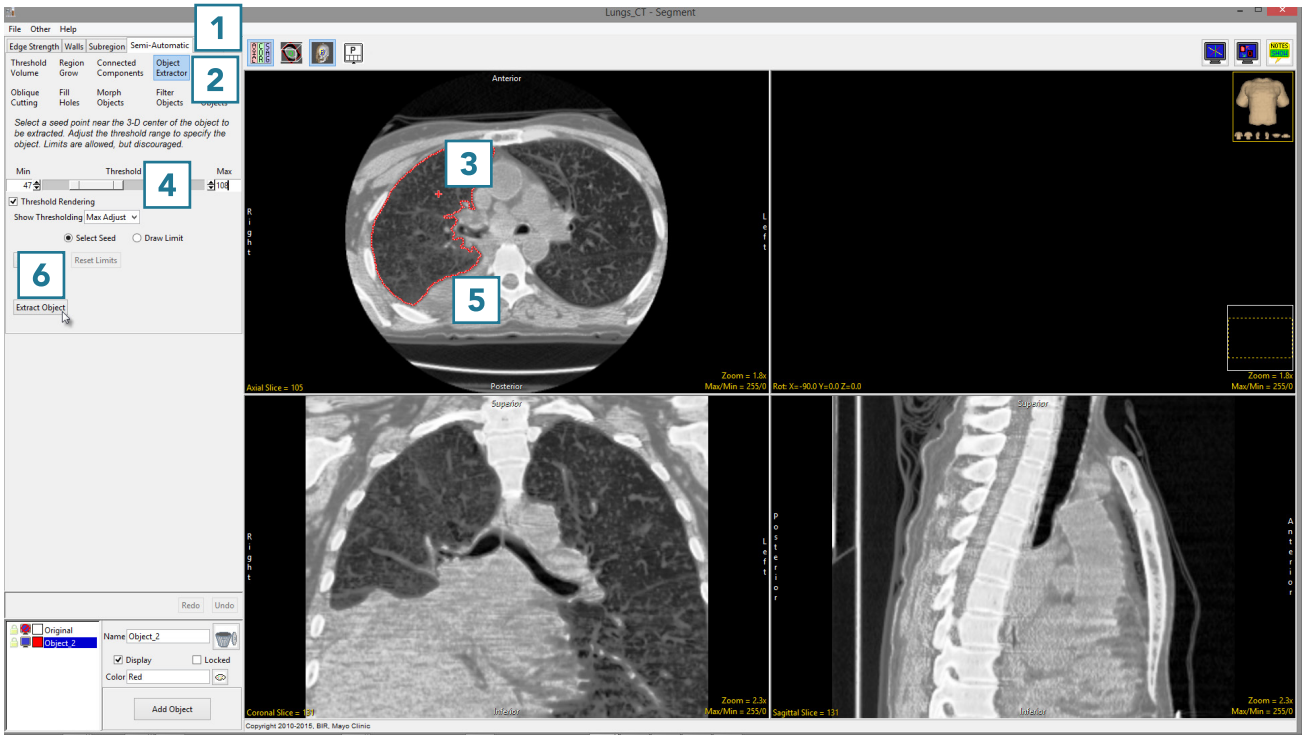


Segmentation of Multiple Objects Using Object Extractor

Here we will use Object Extrator to segment multiple objects in a dataset.

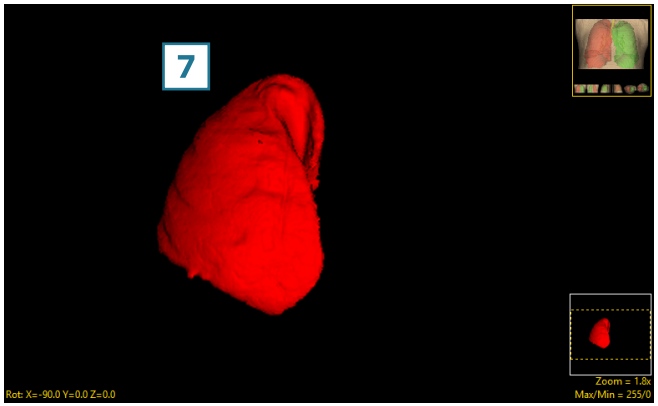
To follow along, download the data set CT_Lungs from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the data set and open Segment.
- Select Semi-Automatic [1] and choose Object Extractor [2}.
- Click on the image data to set a seed point in the object you would like to isolate. [3].
- Adjust the minimum and maximum threshold values [4 until the auto trace defines the object. [5].
- Select Extract Object. [6]

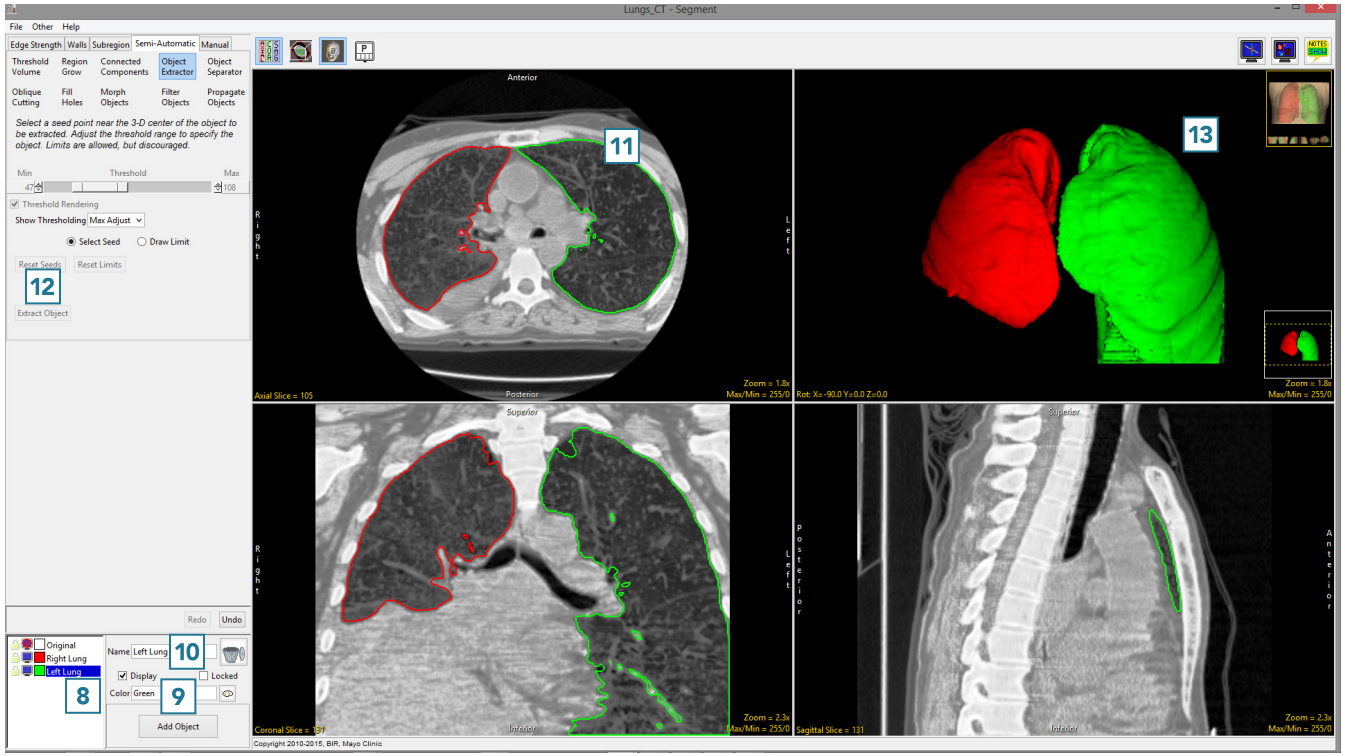


Segmentation of Multiple Objects Using Object Extractor (continued)

- Once the segmentation process is complete, the object will be rendered [7].

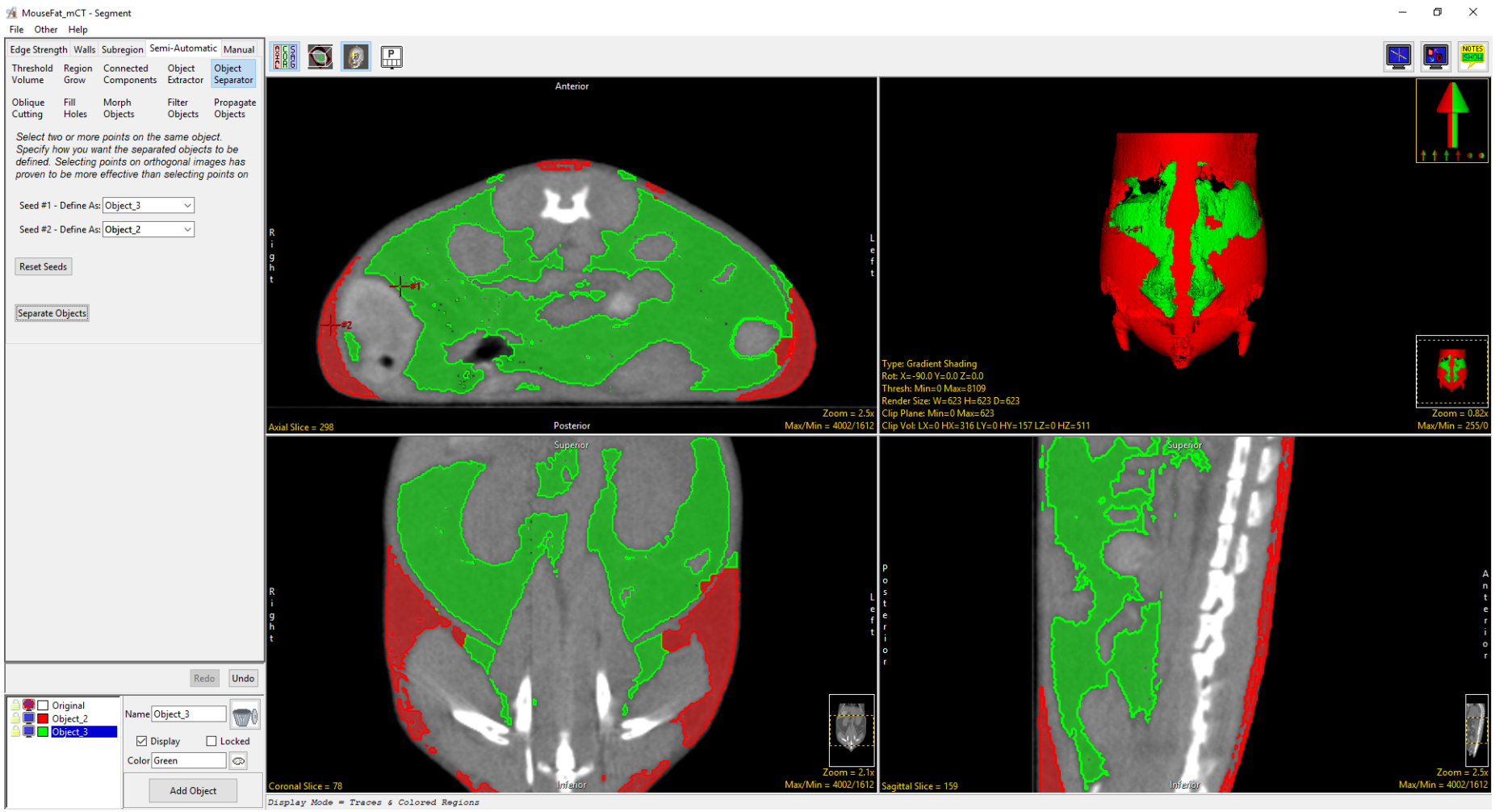


- Rename the object [8]. Add a new object [9] and rename [10].
- Set a seed point in the next object [11] and select Extract Object [12].
- Once the segmentation process is complete, the object will be rendered [13].
- Save your work by selecting File > Save Object Map.

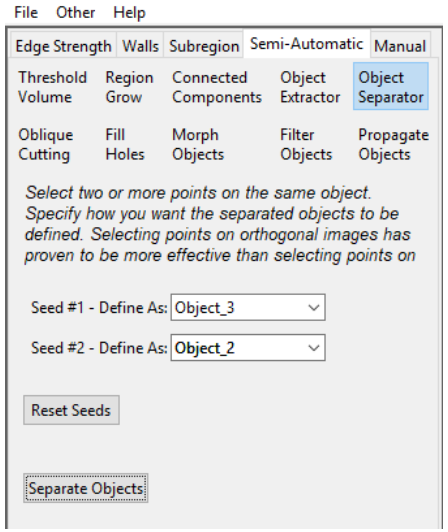


Object Separator

The Object Separator tool uses morphologic erosion to break connections between objects based on user-defined seed points to specify objects to separate. The purpose of the tool is to break objects into two or more objects. The tool requires a minimum of two seed points to be set.



Object Separator Options



The following Object Separator Options are available:

Seed #1 – Define As: This option is enabled when the first seed point location is set. By default this option is set to Current Object, that is the object currently selected in the object control window. Selecting the drop-down menu allows users to choose from; Current Object, Not Changed (the object that the seed voxel is already assigned to), New, and then any objects in the object list.

Seed #2 – Define As: This option is enabled when the second seed point location is set. By default this option is set to Not Changes, that is the object the seed point voxel is currently assigned to. Selecting the drop-down menu allows users to choose from; Current Object, Not Changed, New, and then any objects in the object list.

Reset Seeds: Deletes all defined seed points.

Separate Objects: Begins the Object Separator process.

Seed point right click options: Right clicking on a seed point provides the following options:

Style: The style options allows users to change the of the seed point. Select from Dot, Crosshair (default), Arrow, and Diamond.

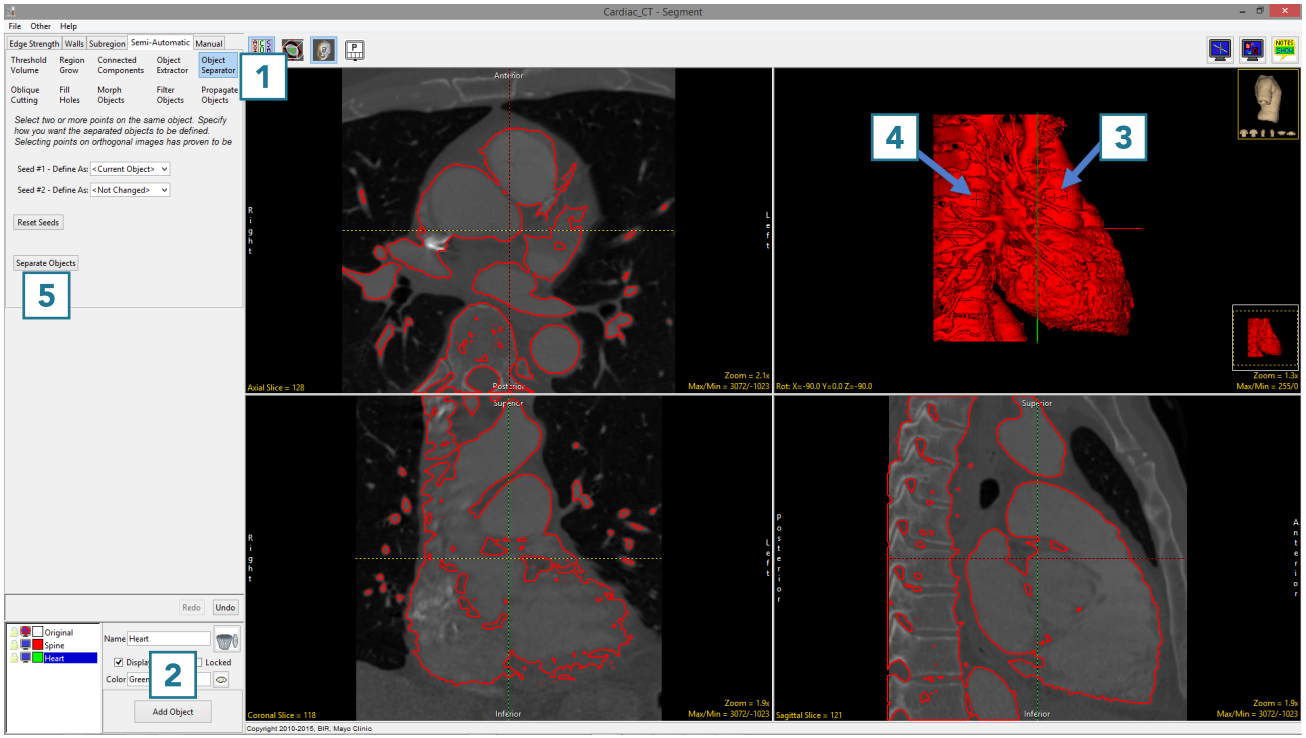
- Label: The label options allows user to enable and disable labels for seed points. Select from None (default), Number (extremely useful when setting multiple seeds), and Tag.
- Shadow: Allows users to enable (default) or disable the shadow effect for the seed.

Delete: Deletes selected seed point.

Separating Objects

Here we will use Object Separator to disconnect objects in a dataset.

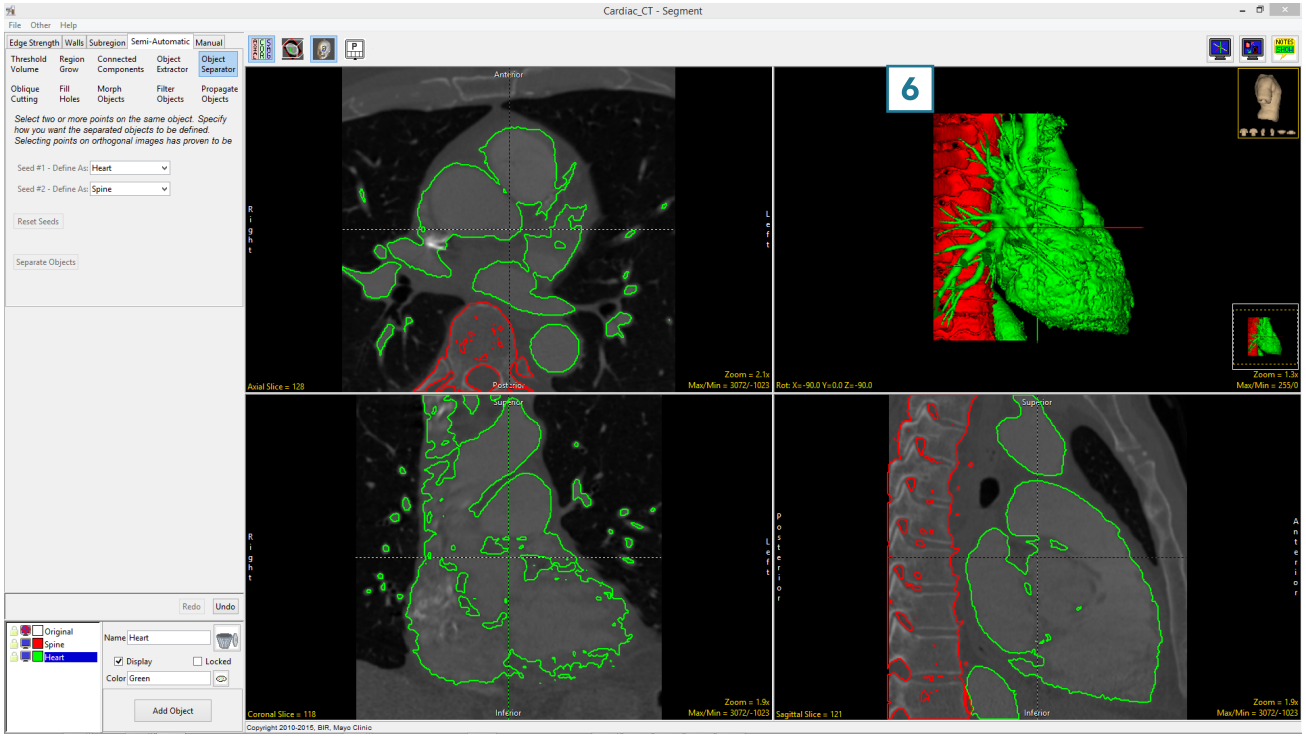
To follow along, download the data set CT_Heart from analyzedirect.com/data and load into Analyze using Input/Output.



- Select the data set and open Segment.
- Select Semi-Automatic and choose Region Grow.
- Click on the image data to set a seed point. The seed point should be in the object you would like to isolate.
- Set the Threshold Min/Max values to define the object and then click Connect Object.
- The structure will be isolated.
- Rotate the rendering to view the objects to disconnect.
- Select Object Separator [1] and click Add Object [2].
- Set a seed point on the first structure [3] and add a seed point to the second structure [4]. Object separator usually works best when the seed points are set in the orthogonal images.
- Click Separate Objects [5].

Separating Objects (continued)

- The structures will be disconnected and assigned to different objects [6].
- Save your work by selecting File > Save Object Map.



Oblique Cutting

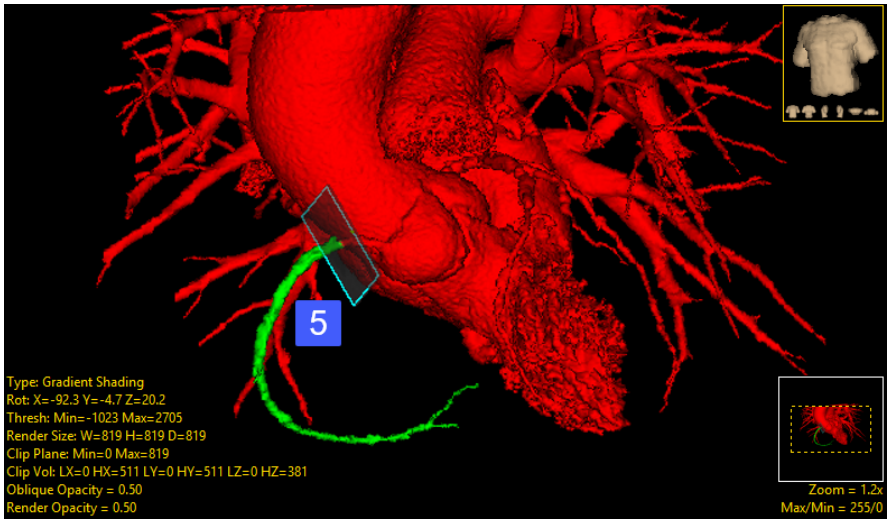
The Oblique Cutting tool enables the specification and display of an oblique cut plane in the volume image. The selected object can be split at the cut plane, with the smaller region after the split assigned to a different object as specified in the object control window. This tool is particular useful for splitting and reassigning vessels to new objects.

When the Oblique Cutting tool is selected the user must click on the image in the approximate location were the cut is to be placed, this can be done by clicking on the rendering or any of the orthogonal views. Once selected the Obliques window will open [1] and the oblique cut plane will be displayed on the rendering [2] and as a blue dashed line on the orthogonal displays. [3] The following Oblique Cutting options [4] will be made available:

Oblique Cutting Options

The following Oblique Cutting Options are available:

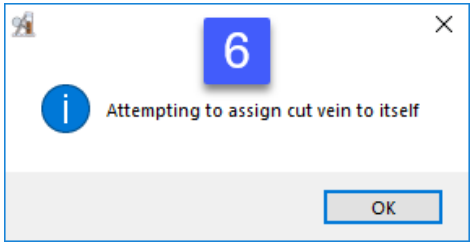
Cut: When the Cut option is clicked the selected object is split at the location of the oblique cut plane, the smaller object after the split is assigned to the object currently selected in the object window [5]. If the same object is selected a message will be returned stating 'Attempting to assign cut vein to itself'. [6] Click OK to dismiss the warning and then select or add a new object in the object control window.



Cancel: Selecting cancels will cancel the Oblique Cut, the Oblique Cut options will no longer be available and then Oblique Cut Plane will be removed from the orthogonal slice displays.

Find Best: The Find Best option searches for the oblique image which contains the most circular representation of the selected object.

Recenter: Recenters the oblique plane. The center of the selected object on the oblique plane is computed. The oblique plane is then adjusted so that this computed center is displayed as the center in the oblique window.



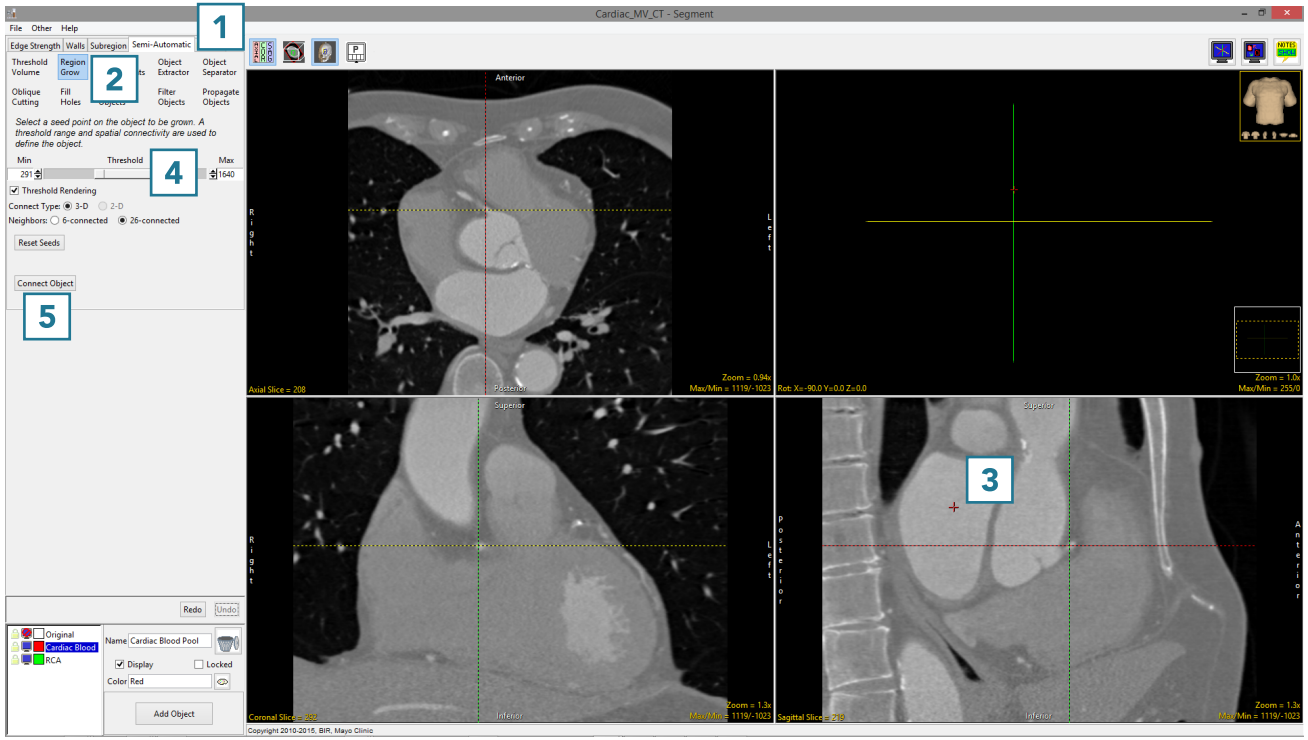
Additional Options: The oblique cut plane can be adjusted by dragging an edge of the plane on the rendered image or by dragging the endpoints or center of the cut plane lines displayed on the orthogonal images.

Oblique Cutting of Objects

Here we will use Oblique Cutting to specify and display an oblique cut plane in a dataset.

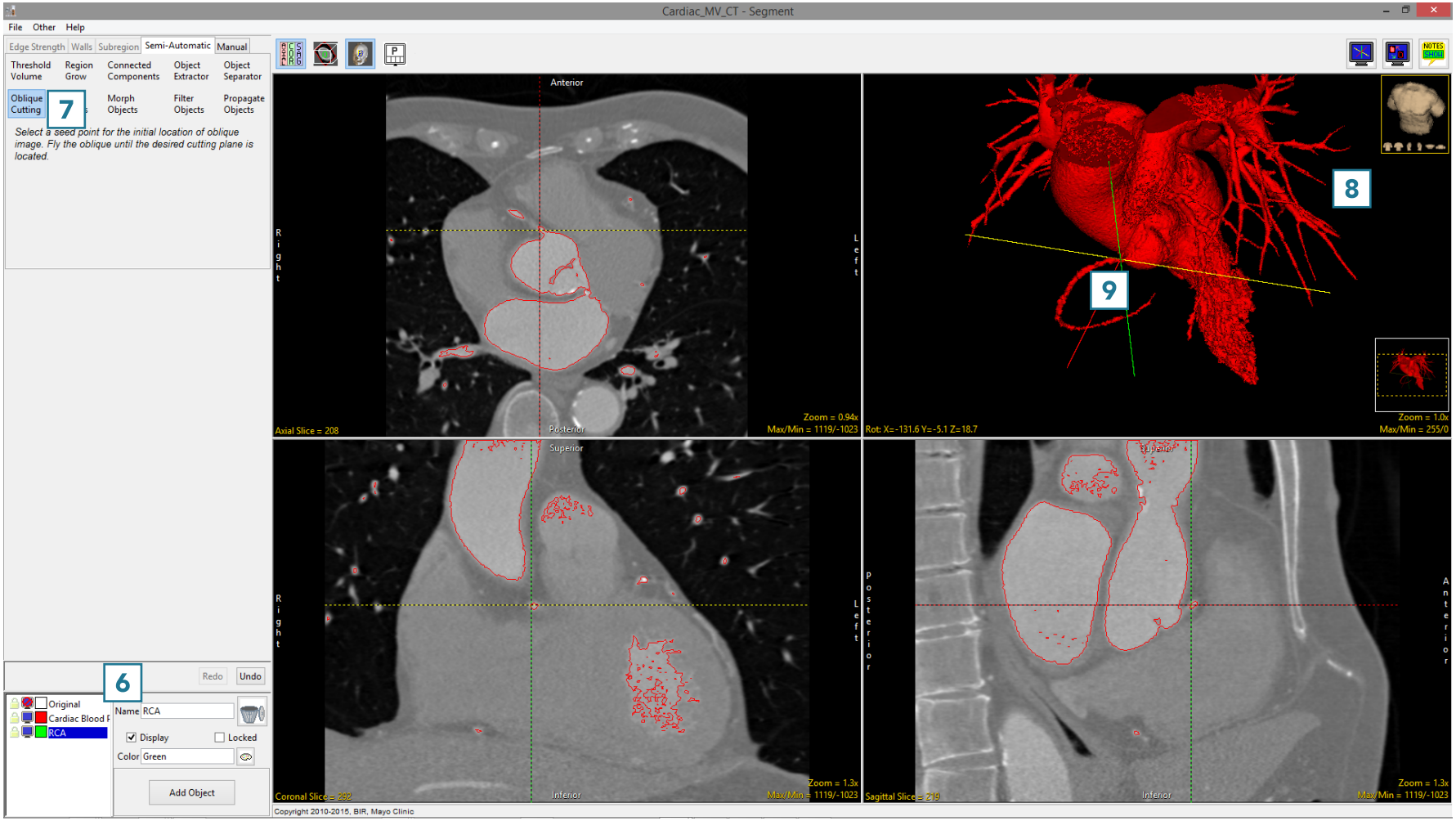
To follow along, download the data set Cardiac_CT from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the data set and open Segment.
- Select Semi-Automatic [1] and choose Region Grow [2].
- Set a seed point in the middle of the left atrium [3].
- Define a threshold range to describe the blood pool [4] and click Connect Object [5].



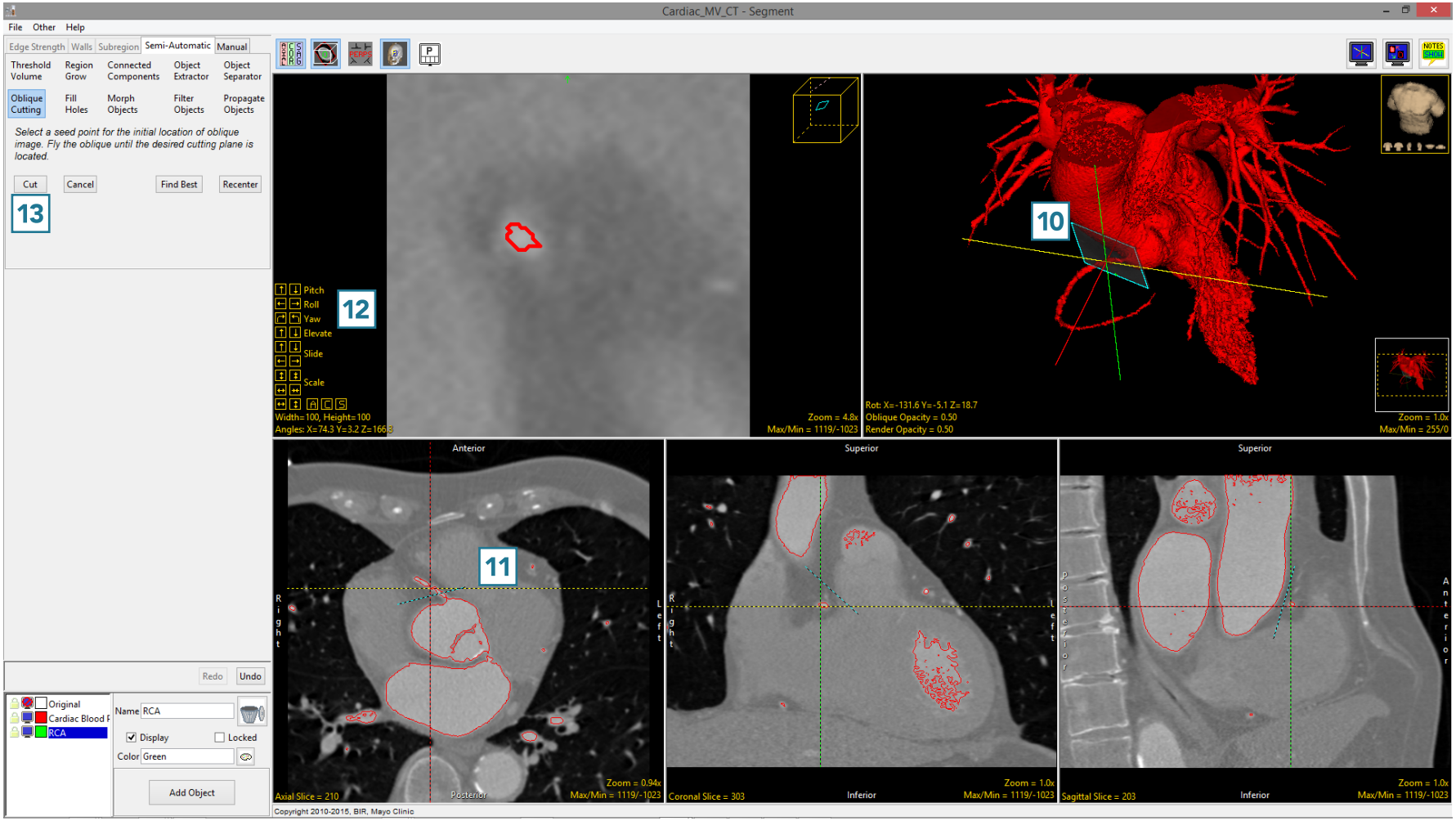
Oblique Cutting of Objects (continued)

- Add a new object and name it RCA (right coronary artery) [6].
- Select Oblique Cutting [7].
- Rotate the rendering of the heart so the RCA is visible [8].
- Move your cursor to the base of the RCA and click to set a seed point on the RCA [9].



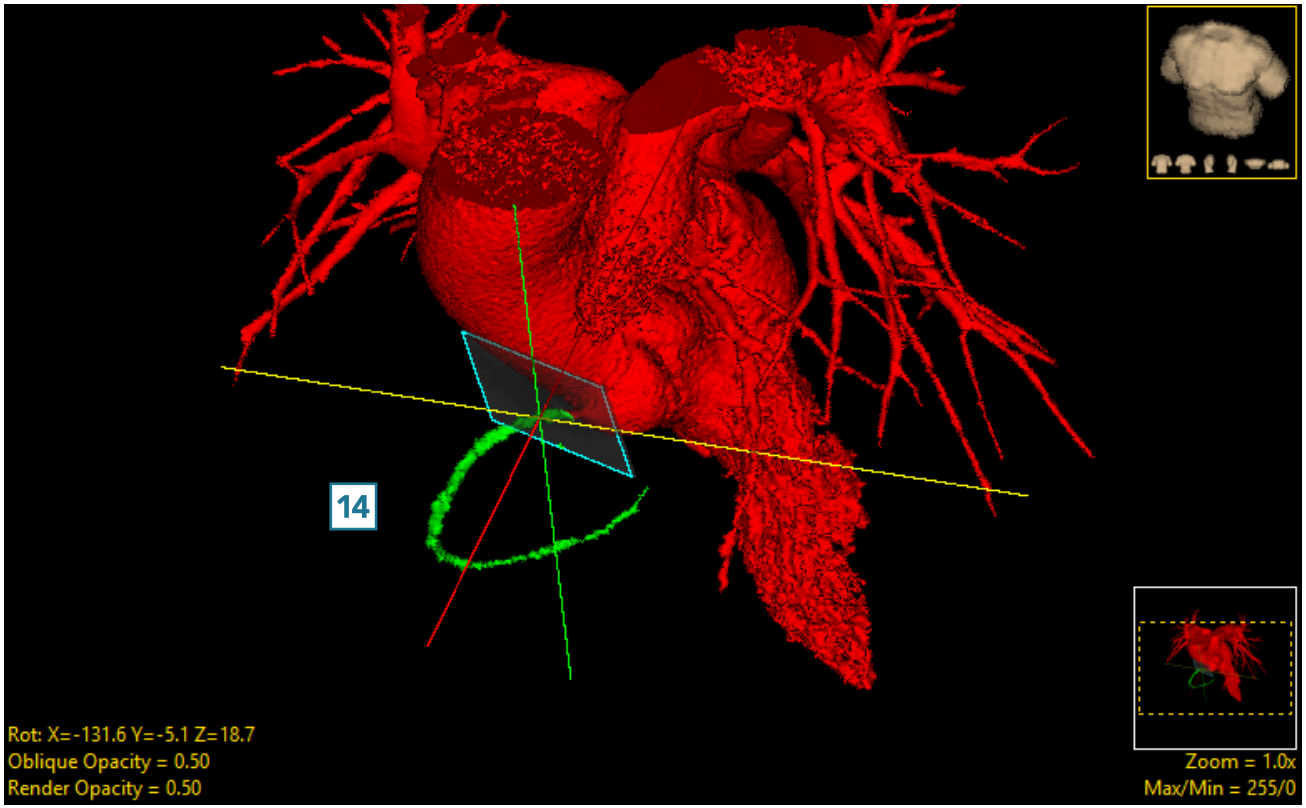
Oblique Cutting of Objects (continued)

- The Segment interface will update while the Oblique Cutting algorithm finds the best plane to cut the RCA from the main heart object.
- If the computed cut plane is not ideal you can adjust the plane interactively on the rendering [10] or on any of the slice displays [11].
- The navigation tools can also be used on the oblique image [12].
- Select Cut [13] to cut the data.

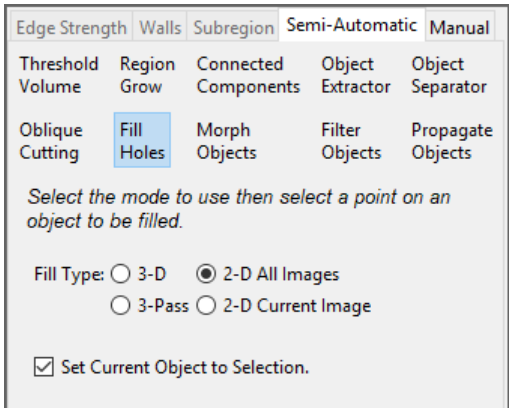


Oblique Cutting of Objects (continued)

- The RCA will be separated from the main object and assigned to the RCA object [14].
- To return to the regular display, click on the Toggle Obliques button to switch off the display of the oblique image.
- Select File > Save Object Map to save your work.



Fill Holes

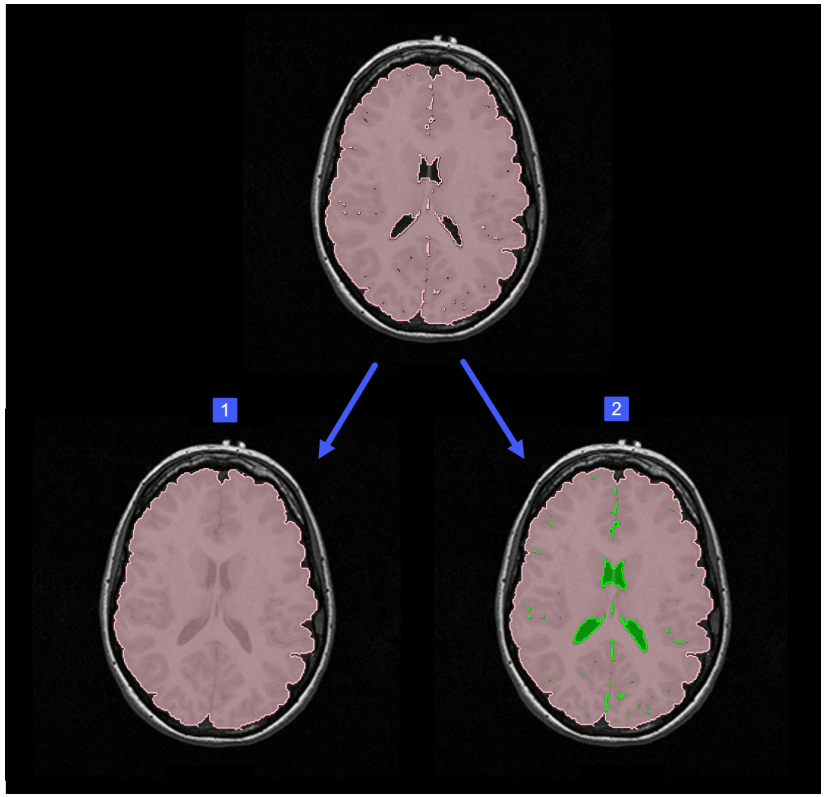


The Fill Holes function performs a flood-fill operation on the selected object. The operation reassigns voxels belonging to other objects to the selected object. The fill operation stops when it reaches the boundary of the object.

Fill Type: The fill type option allows users to select from the following fill type operations:

- 3-D: Fills three dimensional holes in the volume. This option is useful for filling small holes in the image data.
- 3-Pass: This option fills holes by process the volume, image by image in all three orthogonal directions.
- 2-D All Images: Conducts a 2D region fill on all 2D slices in the selected orientation.
- 2-D Current Image: Conducts a 2D region fill on the current 2D slice.

Set Current Object to Selection: Allows users to enable (default) or disable setting the filled region to the same object as being filled. Keep this option enabled if you wish to fill holes in an object and have them assigned to the same object [1], uncheck and disable this option if you wish to have the voxels that fill the holes in the object assigned to a different object, an object that is selected from the object list [2].



Filling Holes in Objects

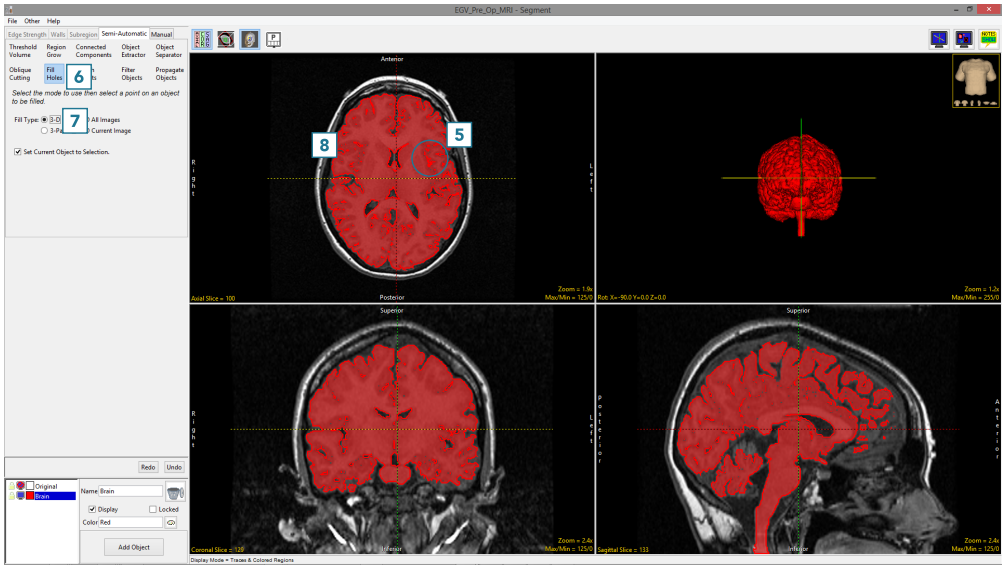
After the initial segmentation, an object may contain holes, which are voxels belonging to the Original object. To obtain an accurate volume measurement and to ensure the object is whole, it may be necessary to apply a fill holes operation on the object.

To follow along, download the data set EGV_MRI from analyzedirect.com/data and load into Analyze using Input/Output.

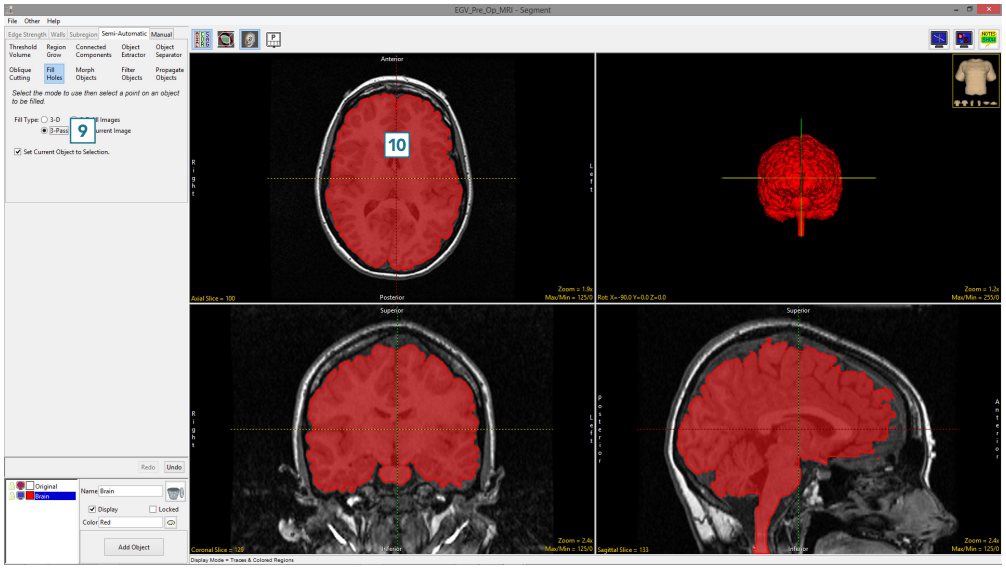
- Select the data set and open Segment.
- Select Semi-Automatic [1] and choose Object Extractor [2].
- Click on the image data to set a seed point.
- Adjust the minimum and maximum threshold values [3] to define the structure and select Extract Object [4].

Filling Holes in Objects (continued)

- To remove small holes in the object [5] which are a result of the segmentation parameters, select Fill Holes [6].
- With the Fill Type set to 3D, [7] click on the object to fill smaller holes in the object [8]



- To fill larger holes, such as the ventricular CSF, use the 3-Pass Fill Type [9] and click on the brain [10]. All larger holes will be filled and assigned to the object.
- Select File > Save Object Map to save your work.

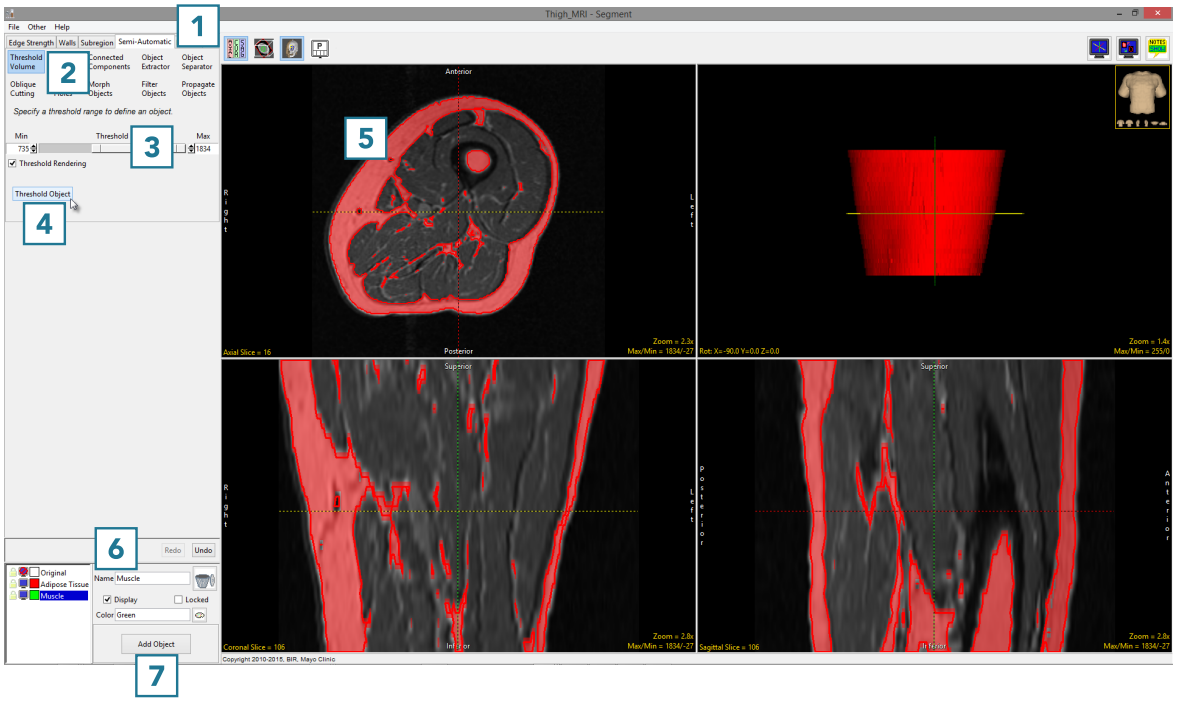


Using Fill Holes for Segmentation

The fill holes option can also be used as a strategy to segment multiple objects. In this example we isolate the adipose tissue via threshold-based segmentation from a water-suppressed MRI data set. We will then use fill holes to create the muscle object and the intramuscular adipose tissue object.

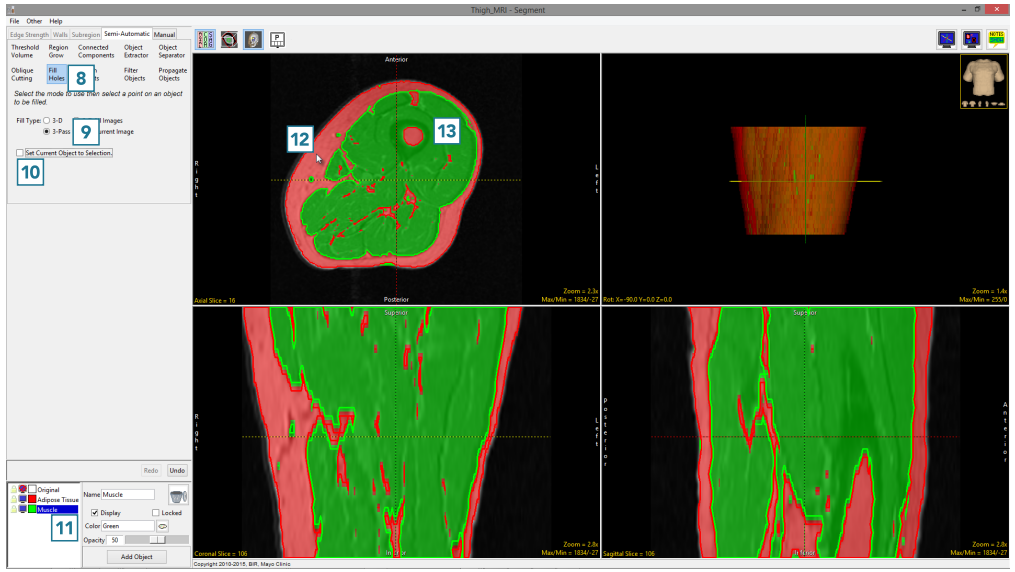
To follow along, download the data set Thigh_MRI from analyzedirect.com/data and load into Analyze using Input/Output.

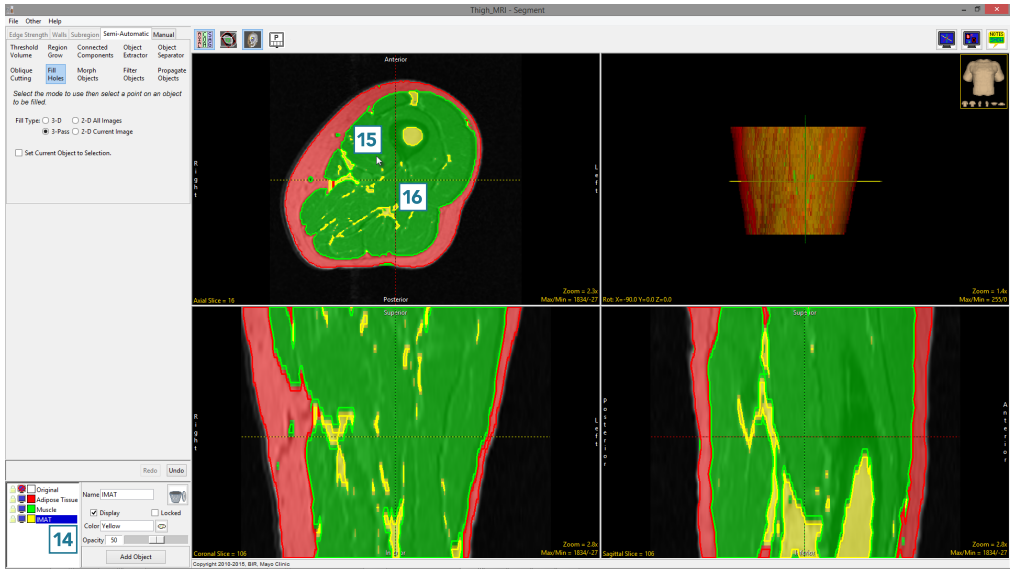
- Select the data set and open Segment.
- Select Semi-Automatic [1] and choose Threshold Volume [2].
- Set a threshold range [3] to globally segment the adipose tissue and click Threshold Object [4].
- The adipose tissue will be segmented [5].
- Rename the object [6], add a new object [7] and name it Muscle.



Using Fill Holes for Segmentation (continued)

- Select Fill Holes [8] and set the Fill Type to 3-Pass [9].
- Uncheck the Set Current Object to Selection [10] checkbox.
- Ensure that the Muscle object is selected [11] and click on the Adipose Tissue object [12]. The voxels inside the Adipose Tissue object currently assigned to the Original object will be reassigned to the Muscle object [13].
- To assign the voxels labeled as Adipose Tissue within the Muscle object to Intramuscular Adipose Tissue (IMAT).
- Add a new object [14] and name it IMAT.
- Click on the Muscle object to fill it [15]. The voxels inside the Muscle object currently assigned to the Adipose Tissue object will be filled and assigned to the IMAT object [16].
- Select File > Save Object Map to save your work.



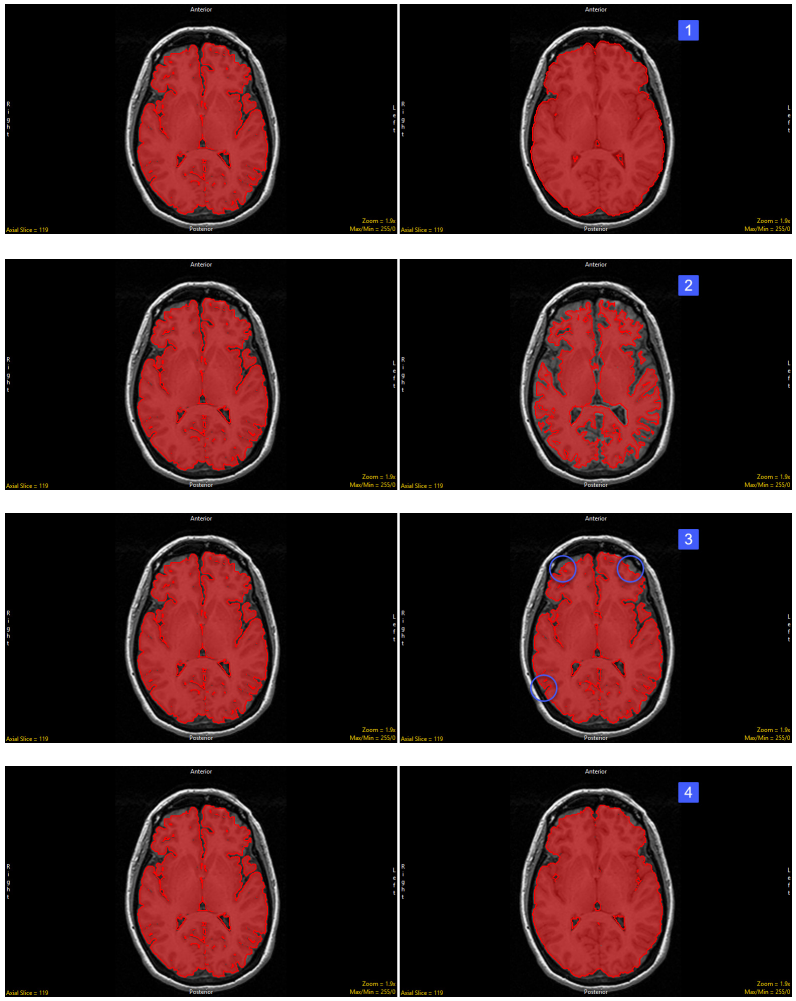


Morph Objects

The Morph Objects option allows users to apply rudimentary morphological operations to objects. The operations available are dilate, erode, open and close. Additional morphological operations are accessible from the Morphology tool in Process. The following Morph Objects options are available:

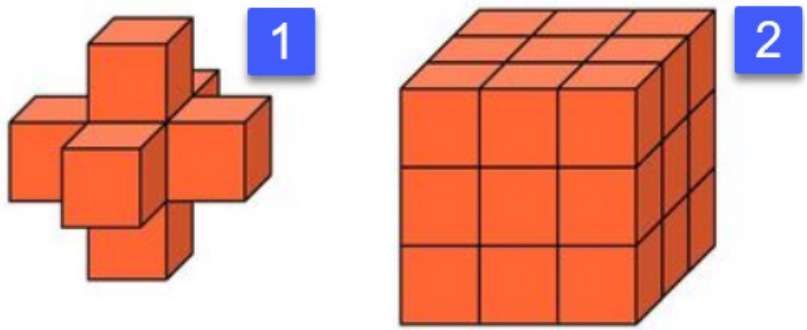
Operation: The operation drop-down menu allows users to select the morphological operation to perform. Choose from:

- Dilate: Adds a layer of voxels to an object, increasing the size of the object by increasing the objects boundaries while reducing the size of holes in the object [1].
- Erode: Removes a layer of voxels from an object, decreasing the size of the object by eroding the objects boundaries and increasing the size of holes in the object [2].
- Open: Performs an erode followed by a dilate [3]. In general, an open is less destructive than an erosion. The effect of the operation is to preserve voxels that have a similar shape to the structuring element, while removing other regions from the object. The effect on the image can be subtle as indicated in the image below.
- Close: Performs an dilate followed by a erode [4]. The close operation is similar to the dilate operation in that it tends to increase the object boundaries and shrink holes within the object. However, the close operation is less destructive of the original object boundary.



Morph Objects (continued)

Element Shape: Allows users to choose between a jack [1] or box [2] shaped element.



- Jack: A jack-shaped structuring element includes only the orthogonal elements to the center voxel of the structuring element. In a 3x3x3 jack-shaped structuring element, there are 7 voxels - one center voxel surrounded by the 6 orthogonal neighbors. The diagonal voxels are not part of this structuring element [1].
- Box: A rectilinear structuring element is a solid rectangle (or cube) of the given size in X, Y, and Z. For example, a 3x3x3 rectilinear structuring element is a 27-voxel cube - one center voxel surrounded by 26 orthogonal and diagonal voxels [2].

Element Size: The element size, sometimes referred to as kernel size, allows users to set the X, Y, and Z dimensions of the selected element shape that will be used in the chosen morphological operation.

- X: The X option allows users to specify the width of the structuring element. Select 1, 3, 5, 7, 9, or enter an odd numbered value into the text entry field.
- Y: The Y option allows users to specify the height of the structuring element. Select 1, 3, 5, 7, 9, or enter an odd numbered value into the text entry field.
- Z: The Z option allows users to specify the depth of the structuring element. Select 1, 3, 5, 7, 9, or enter an odd numbered value into the text entry field.

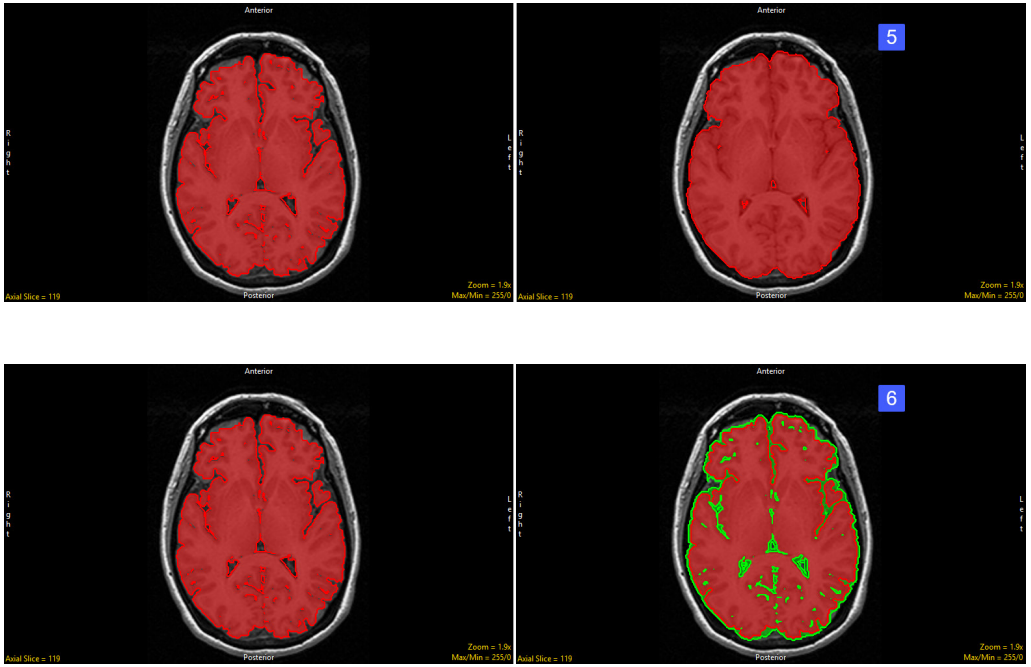
Note, to specify a 2D element set any of the dimensions to 1. A 3x3x3 jack-shaped structuring element will erode away or dilate (add) a single layer of voxels on the structure, a 5x5x5 structuring element will generally take away or add two voxels, etc.

Morph Objects (continued)

Use Conditional Volume: The use conditional volume option is only available for the dilate operation. When selected the option allows a user to limit the dilation of the current object, conditioning the results with a volume selected from the workspace. The voxels that exist in the conditional volume define a 'mask' for voxels to be processed in the current volume. When selected the following options are available to choose the conditioning volume:

- Workspace: Allows the user to select the workspace that contains the conditional volume.
- Name: Allows user to select the volume to use as the conditional volume. Note volumes can be binary or grayscale.
- Drag and drop here: Allows users to select the conditional volume via drag-and-drop from the workspace.

Set Current Object to Selection: The Set Current Object to Selection option is only available for the dilate and close operations. The option allows users to enable (default) or disable setting the current object as the selected object for the output of the morphological operation, that is the voxels that will be added to the object once the dilate or close operation is complete. Keep this option enabled if you wish to assign the additional voxels to the same object [5], uncheck and disable this option if you wish to have assign the additional voxels to a different object, an object selected from the object list. [6]

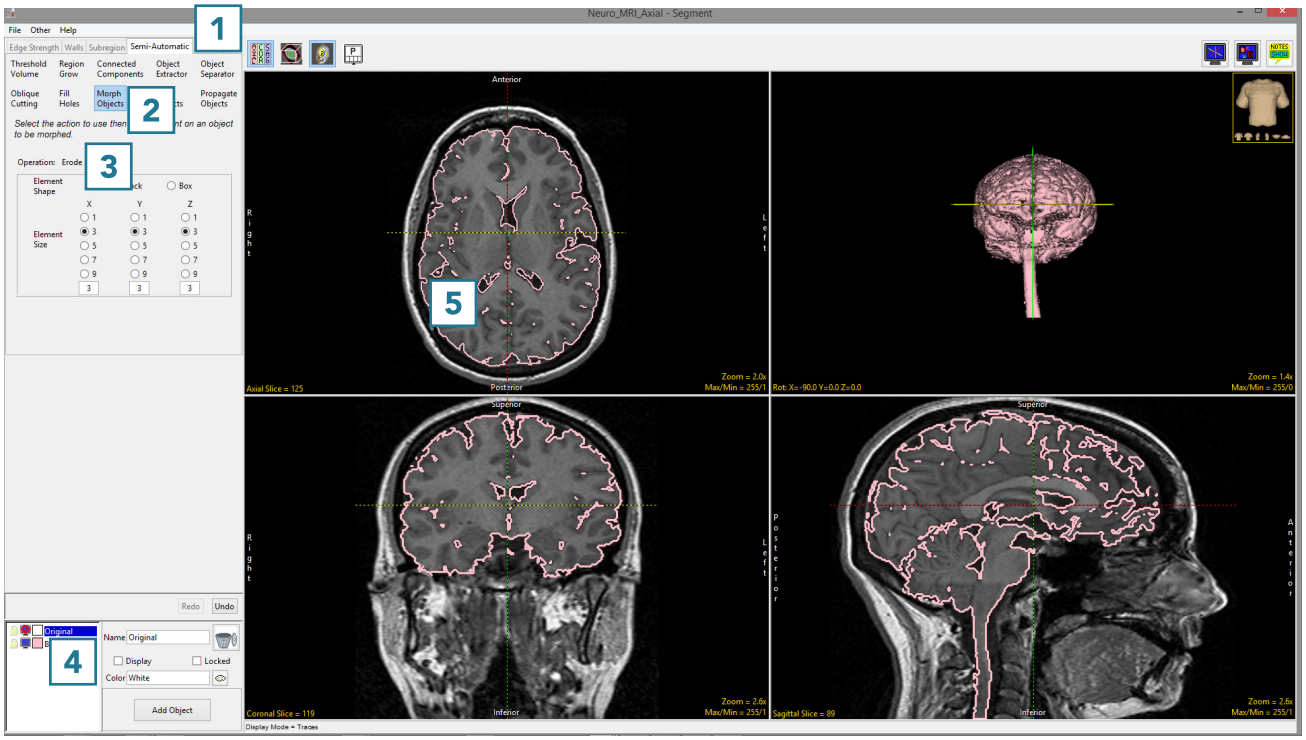


Using Morph Objects to Improve Segmentation

Here we will improve the segmentation of an object by applying rudimentary morphological operations to the object.

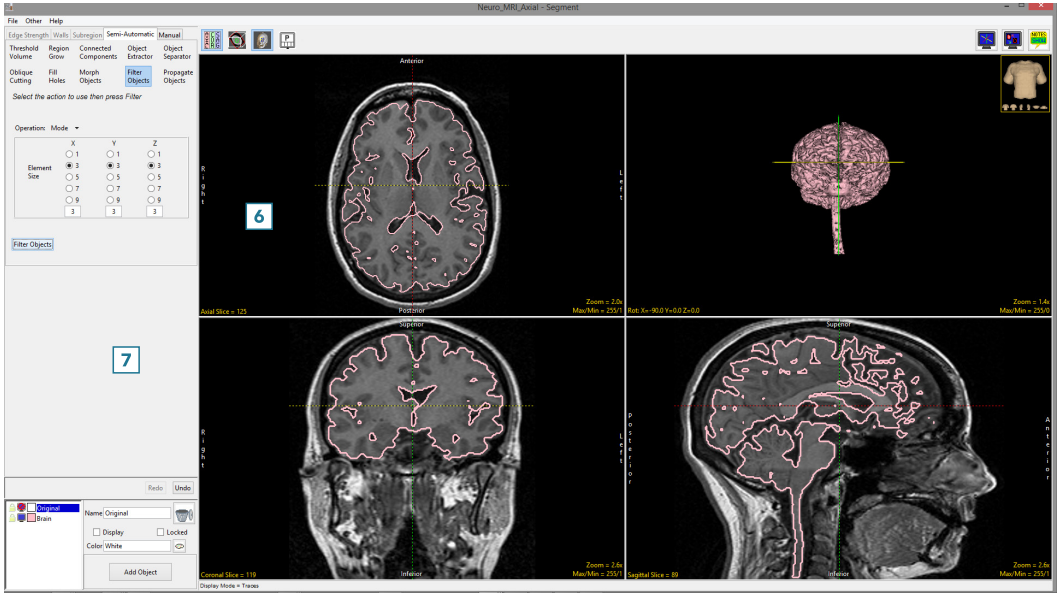
To follow along, download the data set MRI_3D_Head from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the data set and open Segment.
- Select Semi-Automatic [1] and choose Object Extractor.
- Click on the image data to set a seed point.
- Adjust the minimum and maximum threshold values to define the structure and select Extract Object.
- Once the object is segmented, rename and update the color.
- Choose Morph Object [2] and set Operation to Erode [3].
- Leave the element size set to 3 X 3 X 3.
- Set the target object to Original [4]. This will specify that any eroded voxels will be reassigned to the Original object.
- Now click on the brain [5] to initiate the erosion.

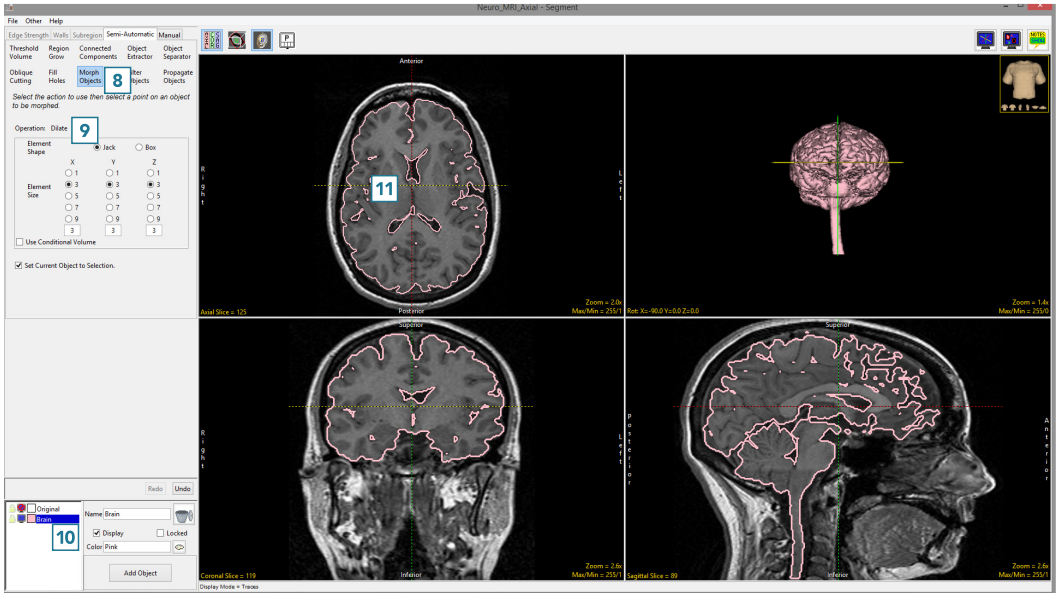


Using Morph Objects to Improve Segmentation (continued)

- Select Filter Objects [6] and apply a 3 X 3 X 3 Mode filter to the brain by clicking Filter Objects [7].

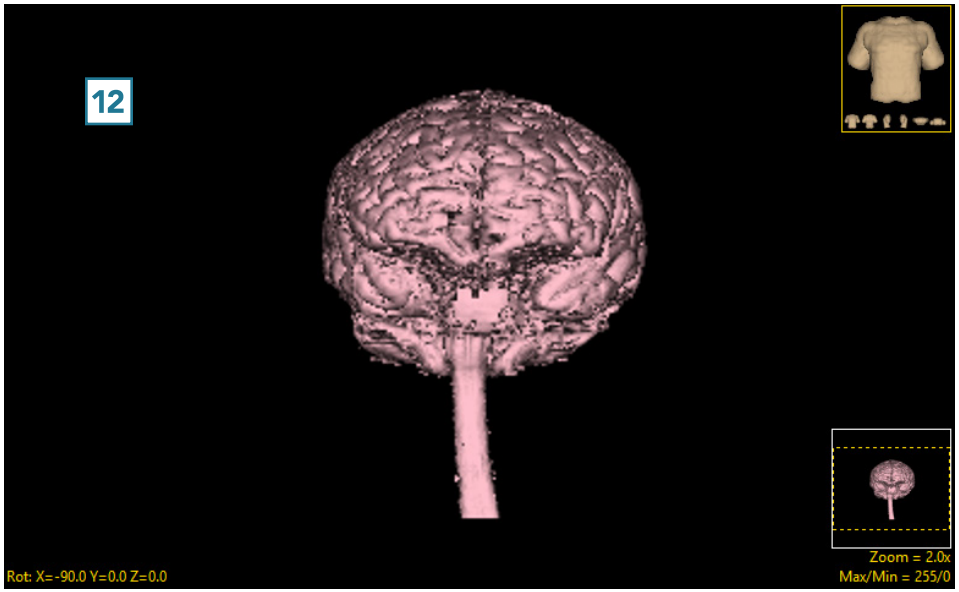


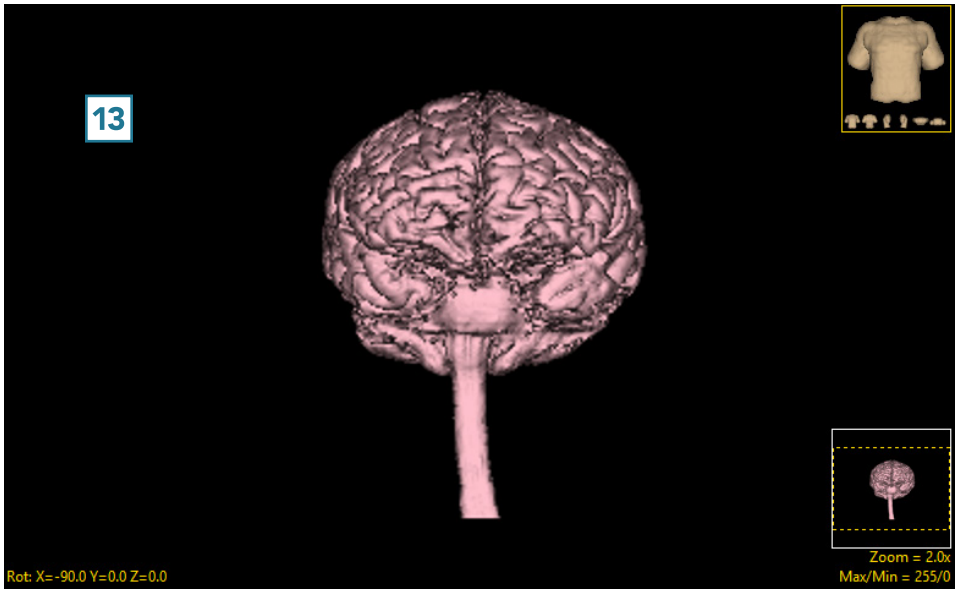
- Select Morph Objects [8] and set the Operation to Dilate [9].
- Select the Brain object [10] and click on the brain [11].



Using Morph Objects to Improve Segmentation (continued)

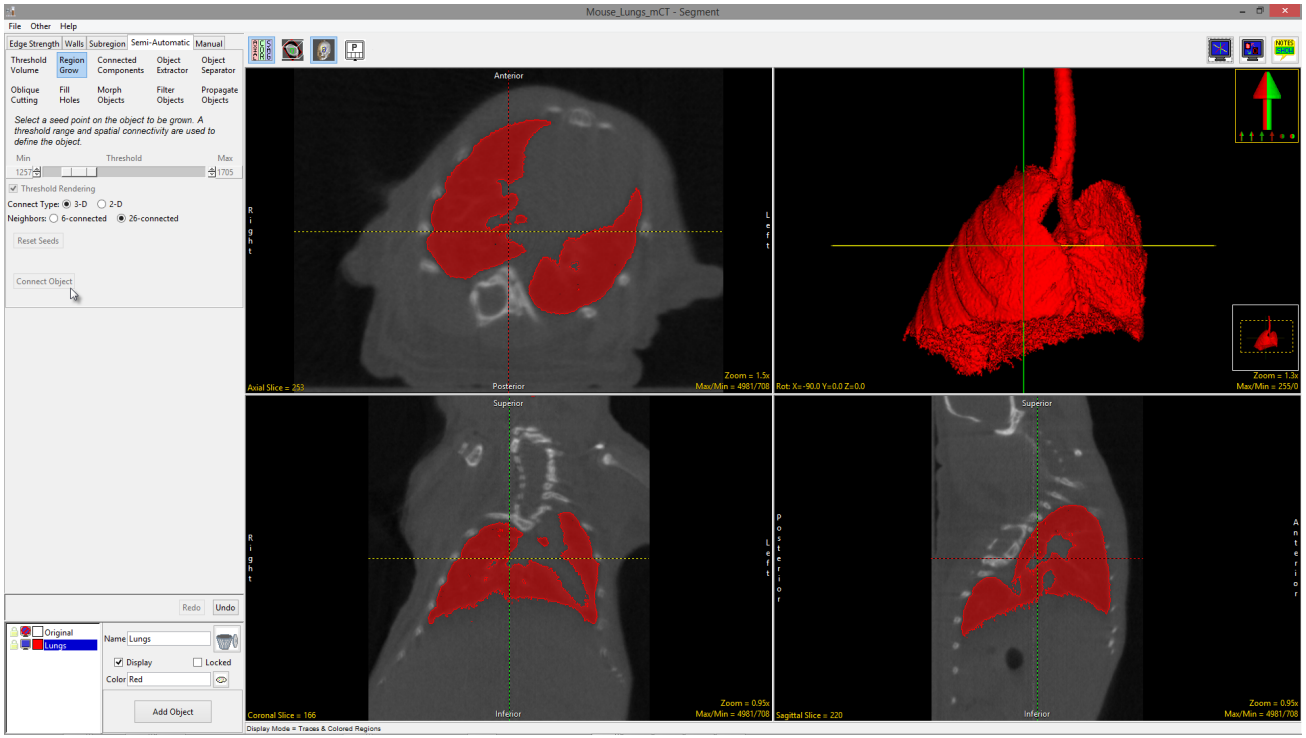
Note the difference between the pre [12] and post [13] processed brain objects.





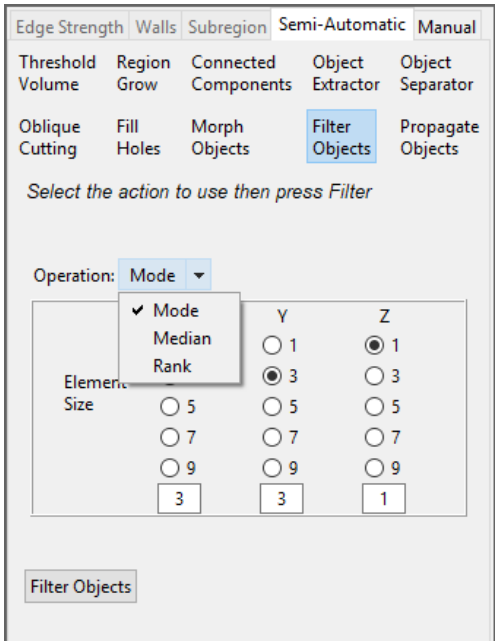
Filter Objects

Filtering objects is a simple and intuitive way to reduce noise, fill small holes, and smooth object edges. Filtering objects reduces the amount of variation between the pixels (2D) or voxels (3D) that make up the object. The filtering process simply replaces each pixel or voxel with a function of itself and its neighbors, defined by the element size selected.



The filter is only applied to segmented objects and does not change the original data. If after attempting to segment a structure from a data set you decide that filtering the grayscale image data would improve the segmentation result refer to the Process module > Spatial Filters processing type to access all of the software's filtering options.

Filter Objects Options



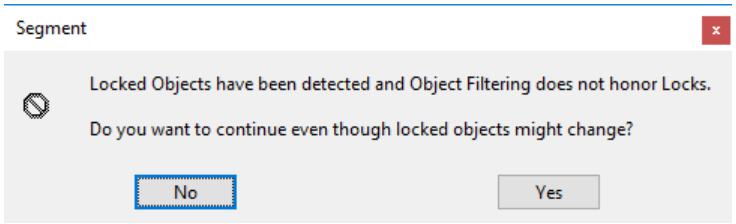
Operation: Three filtering operations are available:

- Mode: The mode filter replaces the target voxel with the mode of the neighborhood of voxels specified by the element size. The value repeated most often is the mode.
- Median: Like the mode filter the median filter considers each voxel in the neighborhood specified by the element size to replace the target, however, instead of simply replacing the voxel with the mode of the neighboring voxel values, it replaces is with the median of those values. The median is calculated by first sorting all the voxel values into numerical order and then replacing the target voxel with the middle voxel value.
- Rank: Like the median filter the rank filter first sorts the values with in the neighborhood specified by the element size, numerically. However, the value used to replace the target voxel is dependent upon the rank value selected by the user using the Rank Slider.
  - Rank Slider: The slider allows users to specify of rank value used. The range of rank values is dependent on the neighborhood of voxels used for the filter, which is controlled by the element size. For example, in a 3x3x1 region the minimum rank value would be 1 while the maximum rank value would be 9. If the rank value was set to 6, the corresponding voxel value for that ranked voxel would by used to replace the target voxel.

Element Size: Allows users to set the X, Y, and Z dimensions of the rectilinear element to be used in the selected filtering operation.

- X: allows users to specify the width of the element. Select 1, 3, 5, 7, 9, or enter an odd numbered value into the text entry field.
- Y: allows users to specify the height of the element. Select 1, 3, 5, 7, 9, or enter an odd numbered value into the text entry field.
- Z: allows users to specify the depth of the element. Select 1, 3, 5, 7, 9, or enter an odd numbered value into the text entry field.

Filter Objects: Initiates object filtering. Note that object filtering does not honor object locking, and locked objects will be filtered. If any objects in the object list are locked a message will be returned stating that locked objects have been detected and object filtering does not honor locks. The option to cancel (No) or to continue (Yes) with the filtering operation will be given.

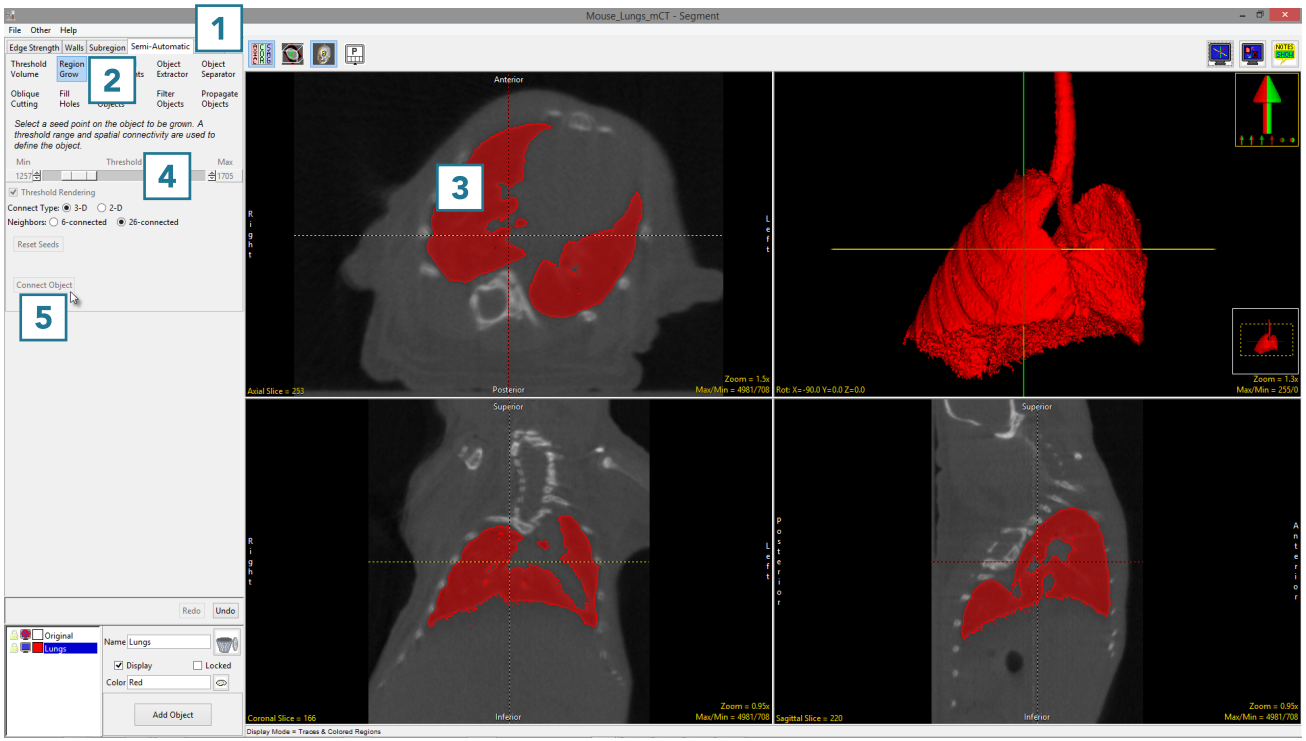


Using Filter Objects to Improve Segmentation

Here we will improve the segmentation of an object by using Filter Objects.

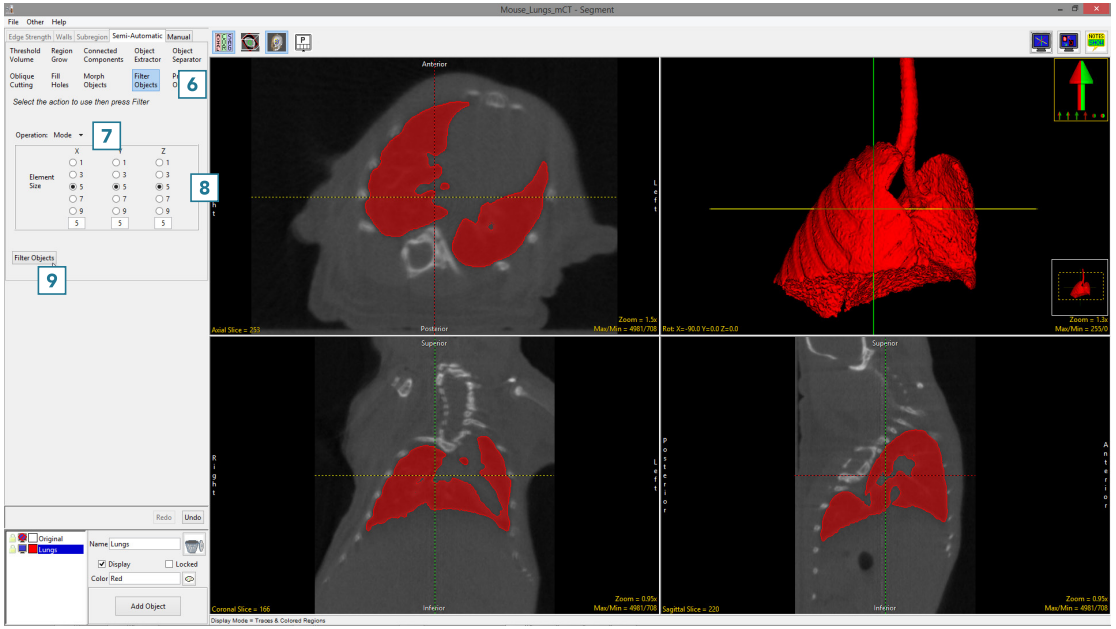
To follow along, download the data set Mouse_Lungs from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the data set and open Segment.
- Select Semi-Automatic [1] and choose Region Grow [2].
- Set a seed point on the object you want to isolate [3] and set a threshold range [4] that describes the object.
- Click Connect Object [5].

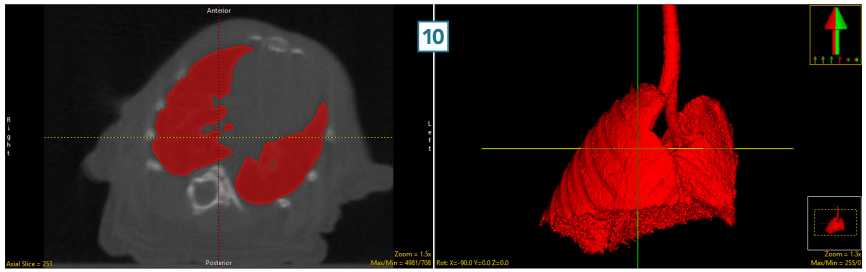


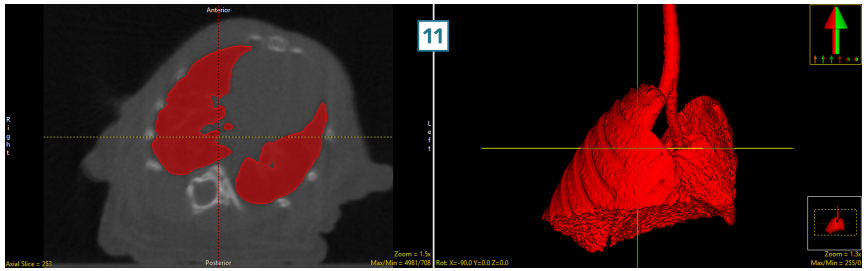
Using Filter Objects to Improve Segmentation (continued)

- Select Filter Objects. [6].
- Set the Operation to Mode. [7]
- Set the Element Size to 5 X 5 X 5 [8] and select Filter Objects [9].



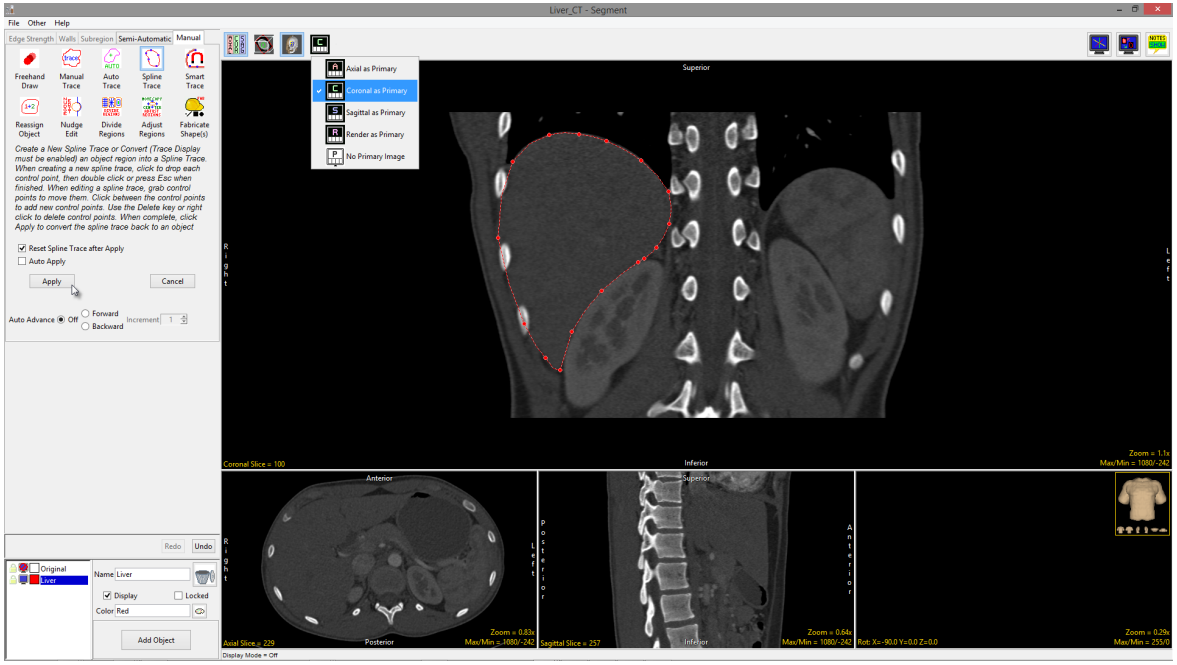
Note the difference in the 2D and 3D regions between the unfiltered [10] and filtered [11] segmentation results. Filtering has filled small holes, removed noise around the surface of the lung parenchyma and smoothed the contours of the segmentation.





Propagate Objects

The Propagate Objects tool uses shape-based interpolation to extend the definition of a region to slices of the volume on which it was not defined. For example, if the user defines a region on every fifth slice, this tool could be used to fill in the region on the skipped slices. The user must specify the direction in which objects are propagated by choosing the orthogonal orientation in which they were defined. A smoothing option is available which filters the objects to produce a smoother segmentation result.



The following options are available:

Propagation Type: choose between propagating the current object (default) selected from the object list or all objects in the object list.

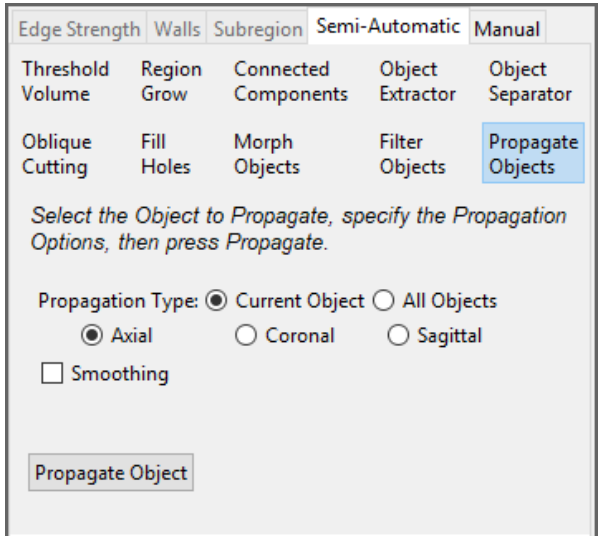
Axial: Select axial if the regions to propagate were defined in this orientation.

Coronal: Select coronal if the regions to propagate were defined in this orientation.

Sagittal: Select sagittal if the regions to propagate were defined in this orientation.

Smoothing: Enables a smoothing operation to be applied to the object(s) after propagation is completed.

Propagate Object: Initiates the region propagation process.

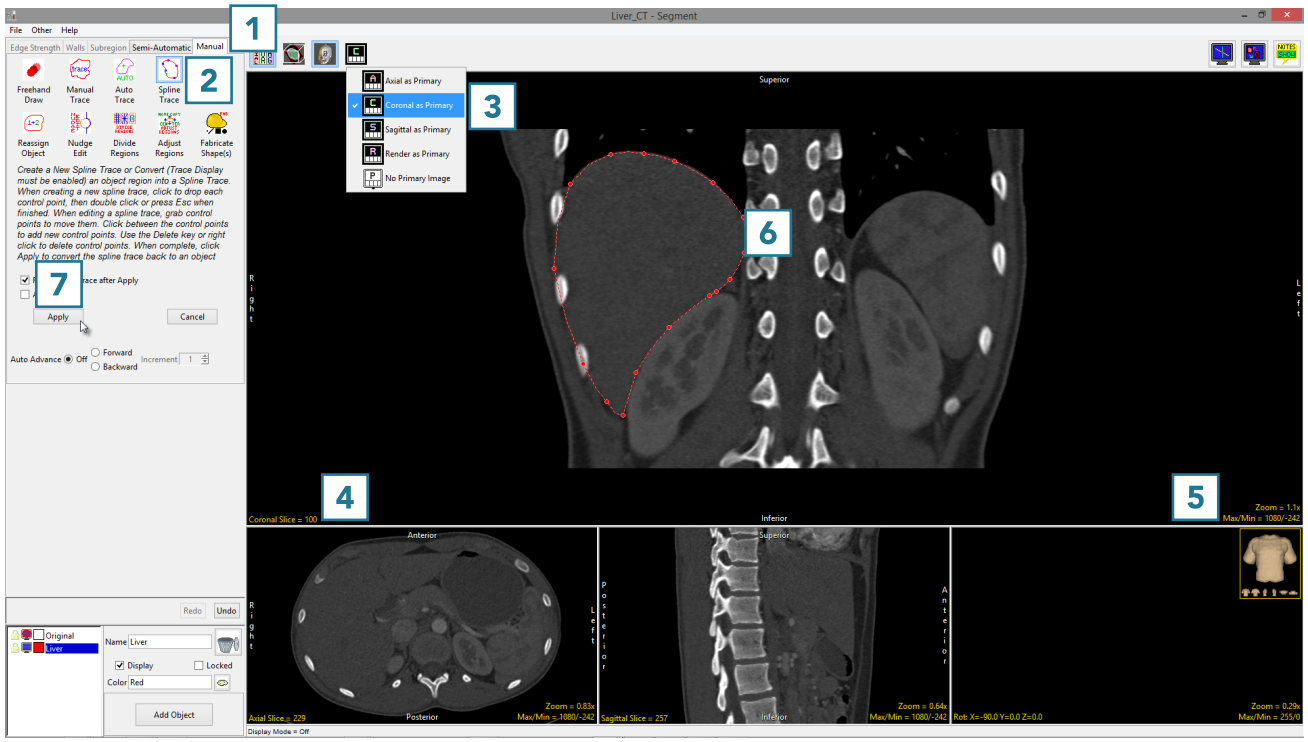


Using Propagate Objects

Here we will extend the definition of a region using Propagate Objects.

To follow along, download the data set CT_Liver from analyzedirect.com/data and load into Analyze using Input/Output.

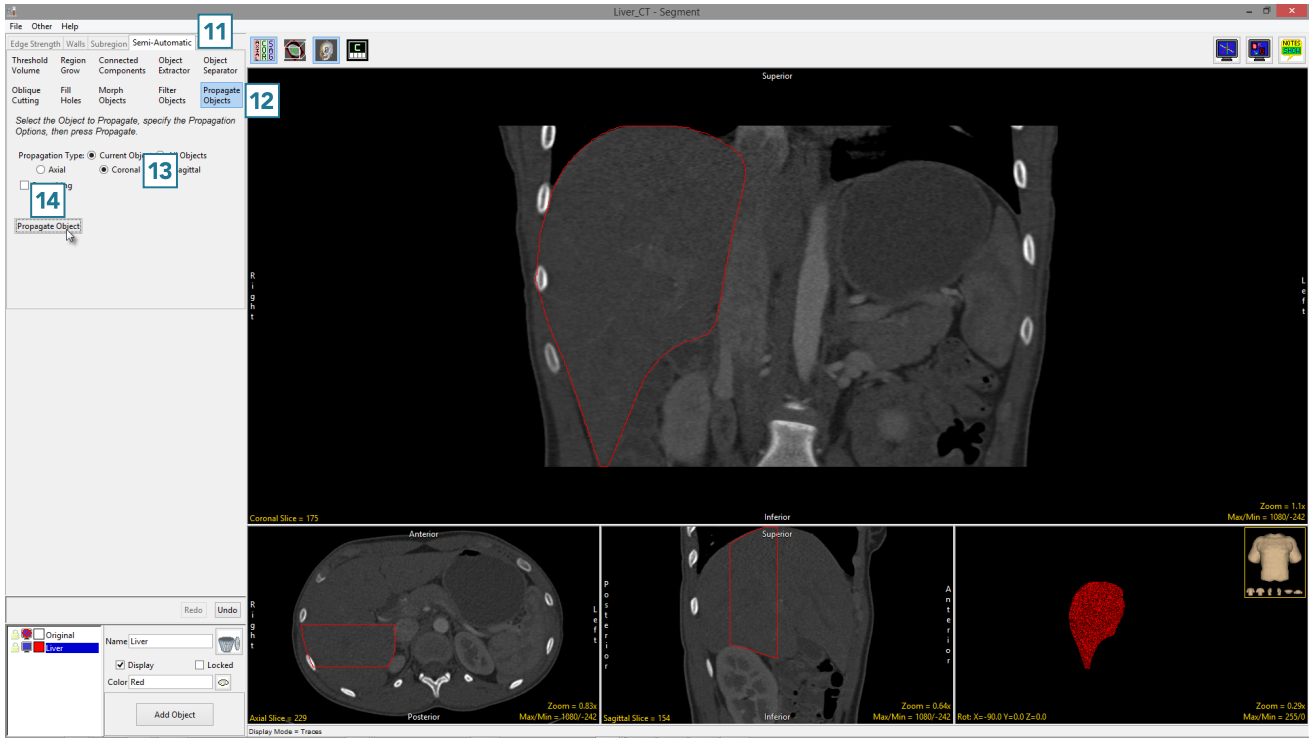
- Select the data set and open Segment.
- Select Manual [1] and choose Spline [2].
- Set the primary display to Coronal [3] and double-click on Slice [4] to move to coronal slice 100.
- Adjust the display intensity, [5] if desired.
- Trace a spline around the liver [6] and select Apply [7].



Using Propagate Objects (continued)

- Move to coronal slice 125 and trace the liver [8].
- Repeat on coronal slices 150 [9] and 175 [10].

- Select Semi-Automatic [11] and Propagate Objects [12].
- Set the propagation orientation to Coronal [13] and click Propagate Object [14].
- After the object propagation process is complete, the liver object will be defined from slice 100 to slice 175. The object can be reviewed in each orientation and the 3D rendering.



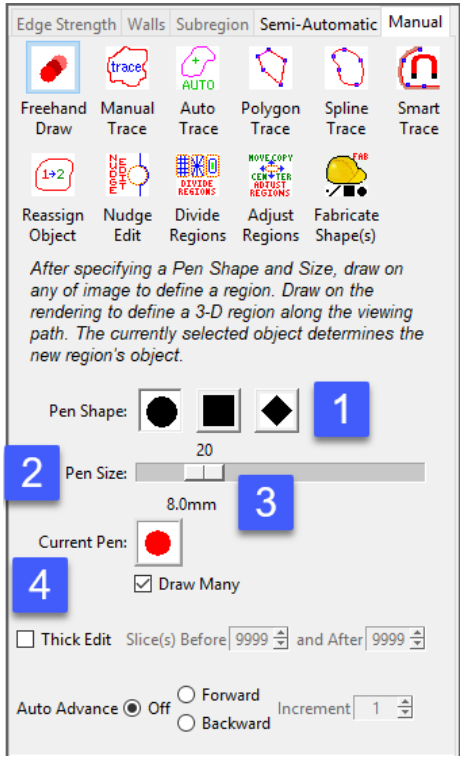
Manual Tools

The Manual tab provides users with access to interactive segmentation tools for manual 2D slice-based segmentation. These tools allow users to define regions with precision while reducing the time required to perform manual segmentation.

The Manual Tools that will described in this section include the following:

- Freehand Draw
- Manual Trace
- Auto Trace
- Polygon Trace
- Spline Trace
- Smart Trace
- Reassign Object
- Nudge Edit
- Divide Regions
- Adjust Regions
- Fabricate Shape(s)

Freehand Draw



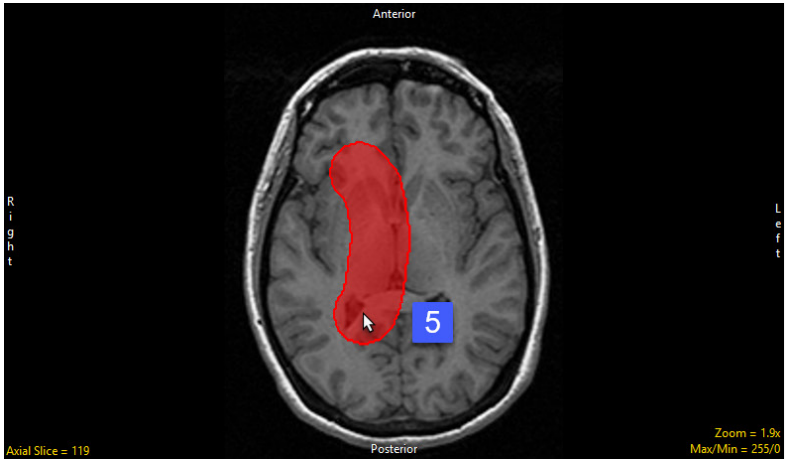
The Freehand Draw tool lets the user draw regions of interest directly onto the image data. The following options are available.

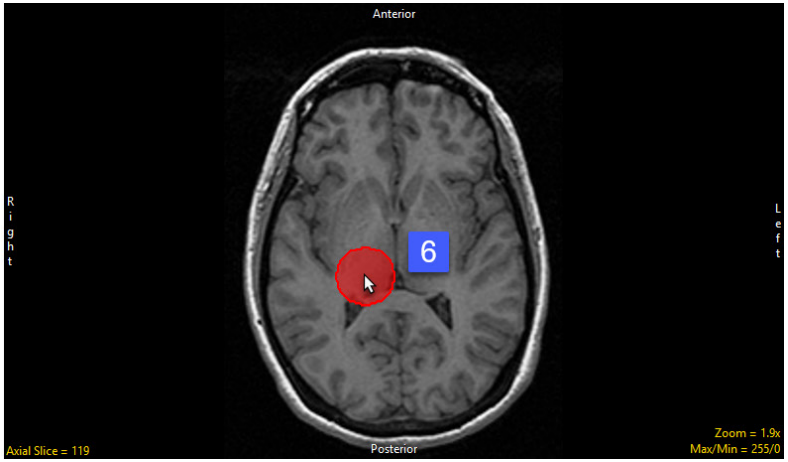
Pen Shape: The pen shape option [1] allows users to specify the shape of the pen for region definition, choose from Round, Square, or Diamond.

Pen Size: The pen size slider [2] provides users with the ability to adjust the size of the pen used for region definition. The pen size ranges from 1 to 100 pixels. Note that the real-world size of the pen is reported below the pen size slider [3].

Current Pen: The current pen icon [4] is a quick reference tool for users, displaying the selected pen shape, pen size, and object color of the selected object from the object list.

Draw Many: The draw many option allows users to enable (default) or disable the draw many option. Enable this option is you wish to draw a continuous region, [5] disable the option is you wish to draw a single region as defined by the pen shape, pen size, and selected object [6].





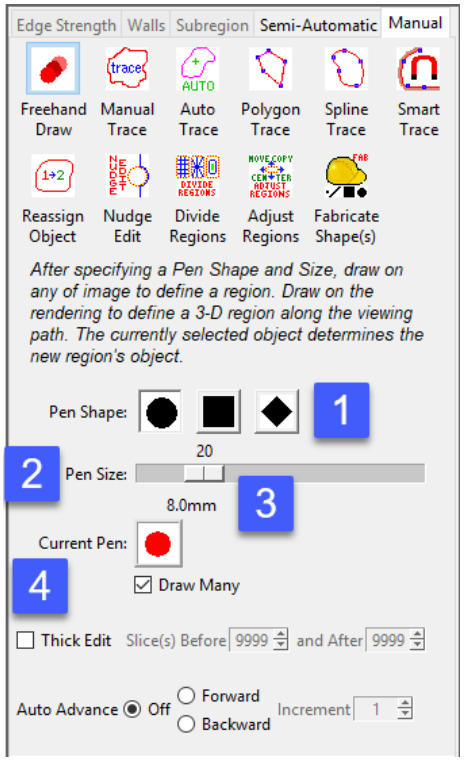
Freehand Draw (continued)

Thick Edit: The thick edit option allows users to apply edits (region definitions) defined on the current slice to other slices in the volume. When thick is enabled the following options are available:

- Slices(s) Before: Specifies the number of slices before the current slice in which to apply the edits.
- And After: Specifies the number of slices after the current slice in which to apply the edits.

Auto Advance: The auto advance option automatically moves users to a new slice, as defined by the auto advance options, once the current edit is defined. Note the auto advance will occur after the user releases the left mouse button and the edit is applied to the current slice. The auto advance option is a productivity tool allowing users to move through the image data without having to move the cursor from the current orientation window that regions are being defined on. The following options are available.

- Off: Off is the default option for auto advance. When off is selected auto advance is disabled.
- Forward: Specifies that auto advance will move forward through the image data (slice number increases).
- Backwards: Specifies that auto advance will move backwards through the image data (slice number decreases).
- Increment: Specifies the number of slices the auto advance will move forward or backwards.

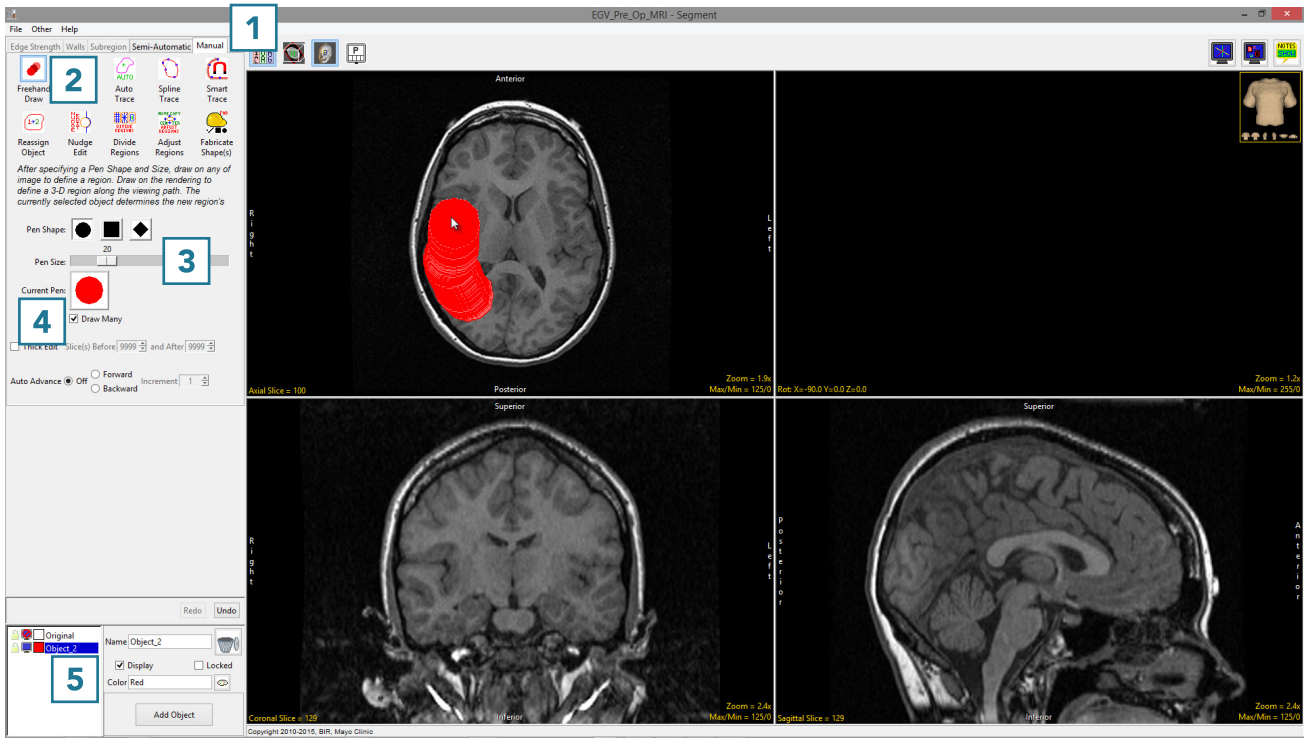


Using Freehand Draw to Define a 2D Region

Freehand Draw allows easy definition of 2D regions.

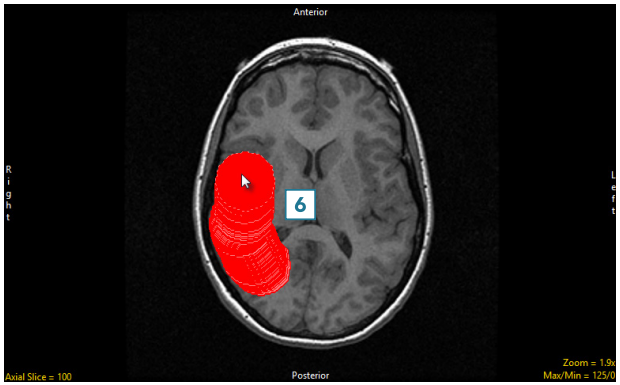
To follow along, download the data set EGV_MRI from analyzedirect.com/data and load into Analyze using Input/Output.

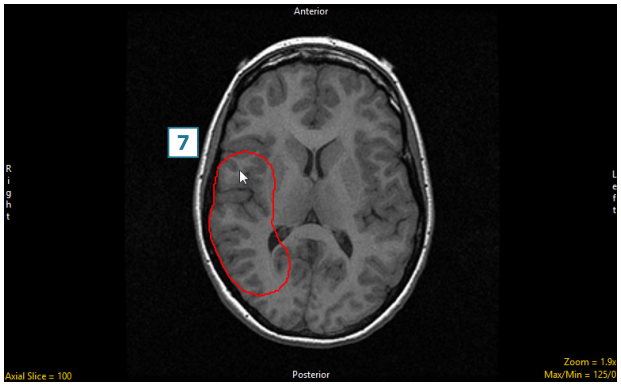
- Select the data set and open Segment.
- Select Manual [1] and choose Freehand Draw [2].
- Use the Pen Size slider to change the Pen Size to 20 [3].
- The Current Pen [4] will update to the color of the currently selected object [5].



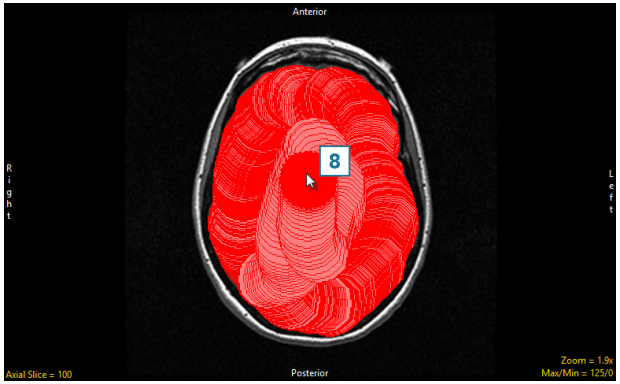
Using Freehand Draw to Define a 2D Region (continued)

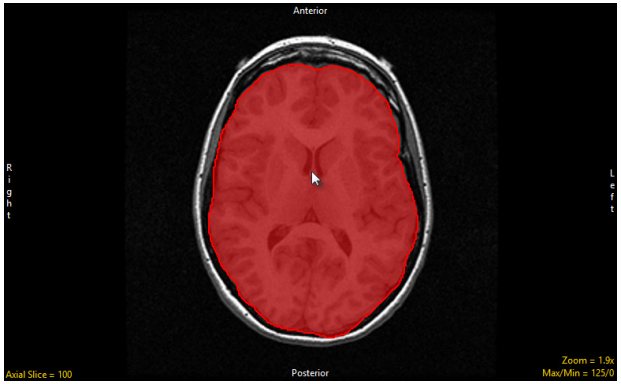
- Left-click on the image and drag the cursor to trace a region [6].
- Releasing the left mouse button will end the trace [7].





- Continue to define the brain using the pen tool [8].



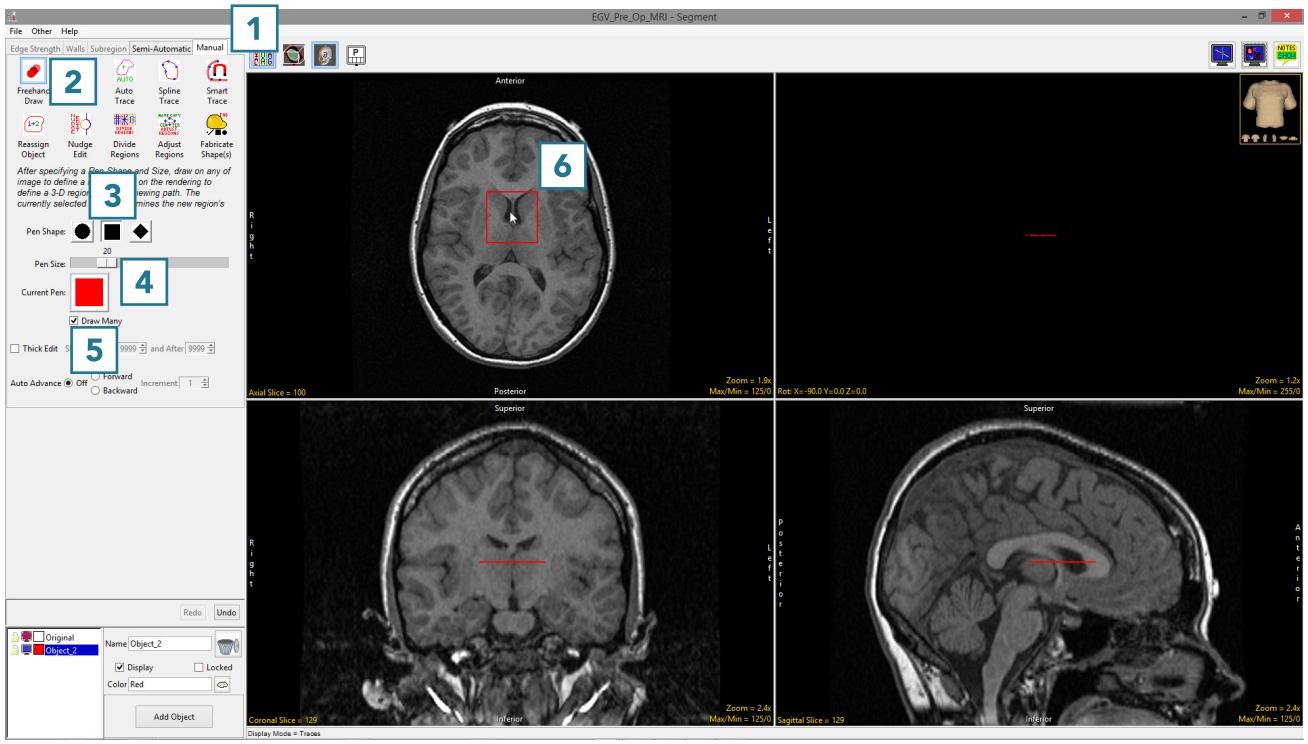


Using Freehand Draw to Define a Single Shape on a 2D Slice

The Freehand Draw tool allows users to define a single circle, square, or diamond.

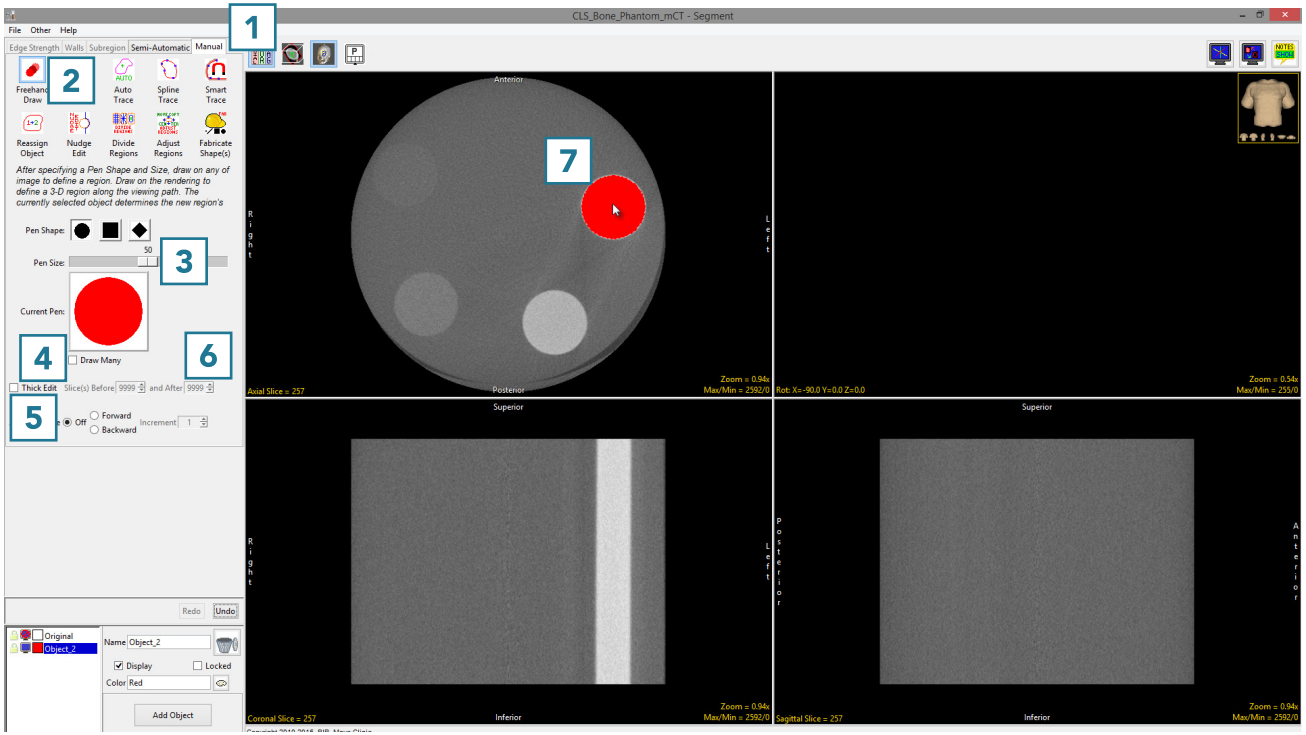
To follow along, download the data set EGV_MRI from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the data set and open Segment.
- Select Manual [1] and choose Freehand Draw [2].
- Set the Pen Shape to Square [3] and change the Pen Size to 25 [4].
- Uncheck the Draw Many option [5].
- Click on the image to define a square. [6]
- Additional squares can be defined by clicking on the slice again.



Using Freehand Draw to Define a Single Shape in 3D

The Freehand Draw tool allows users to define a single shape (circle, square, or diamond) over many slices. This can be helpful when defining regions that are constant through the 3D volume.

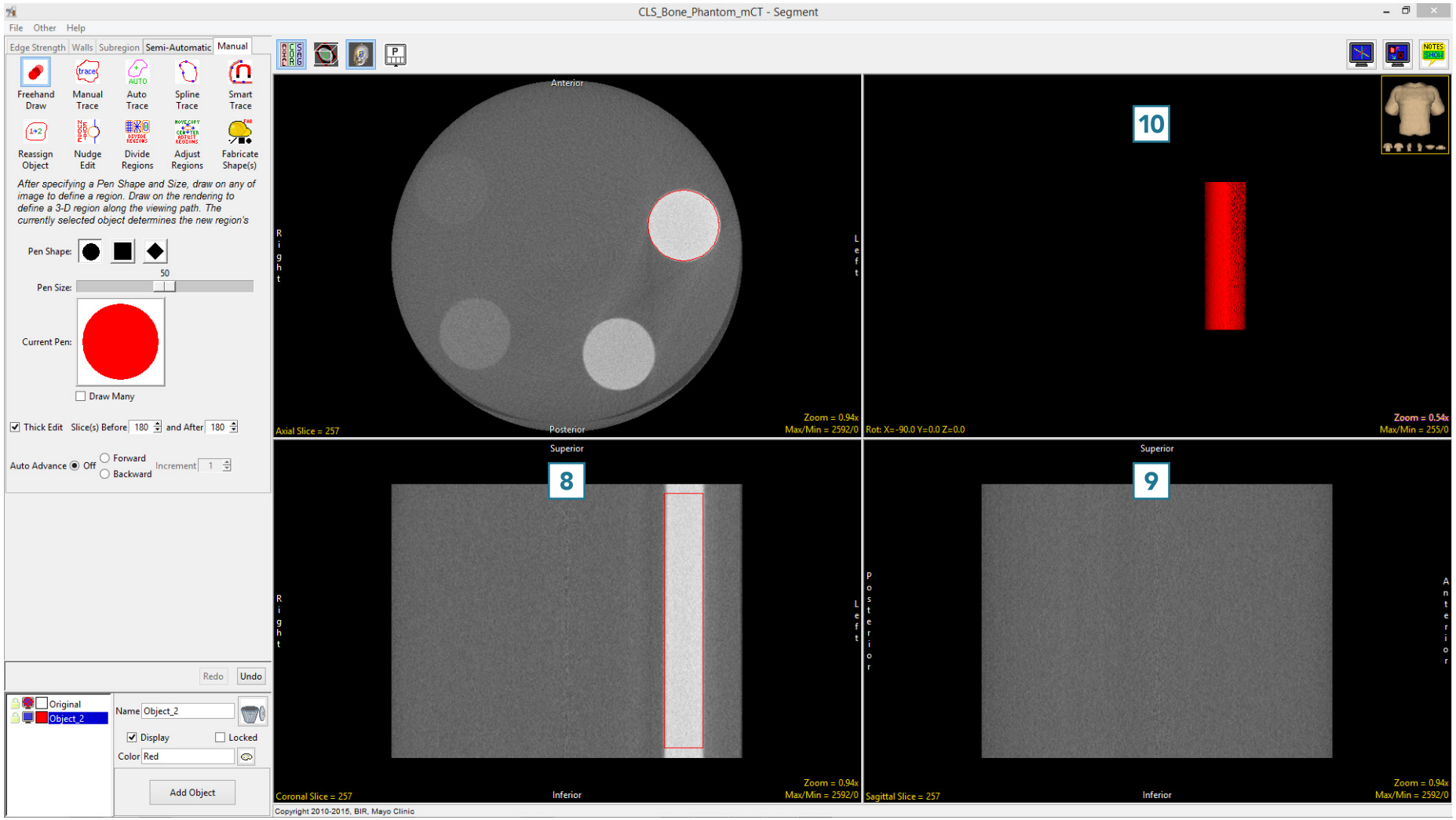


To follow along, download the data set CLS_Bone_Phantom from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the data set and open Segment.
- Select Manual [1] and choose Freehand Draw. [2]
- Change the Pen Size to 50 [3] and uncheck the Draw Many option [4].
- Check the Thick Edit option [5].
- To define the phantom insert on multiple slices, use the Slice(s) Before and After options [6] to specify the extent of propagation of the 2D region through the data set. In this example, set both parameters to 180.
- Click on an insert [7] to define a region, and note that you can move the 2D region around. The region will not be defined until the left mouse button is released.

Using Freehand Draw to Define a Single Shape in 3D (continued)

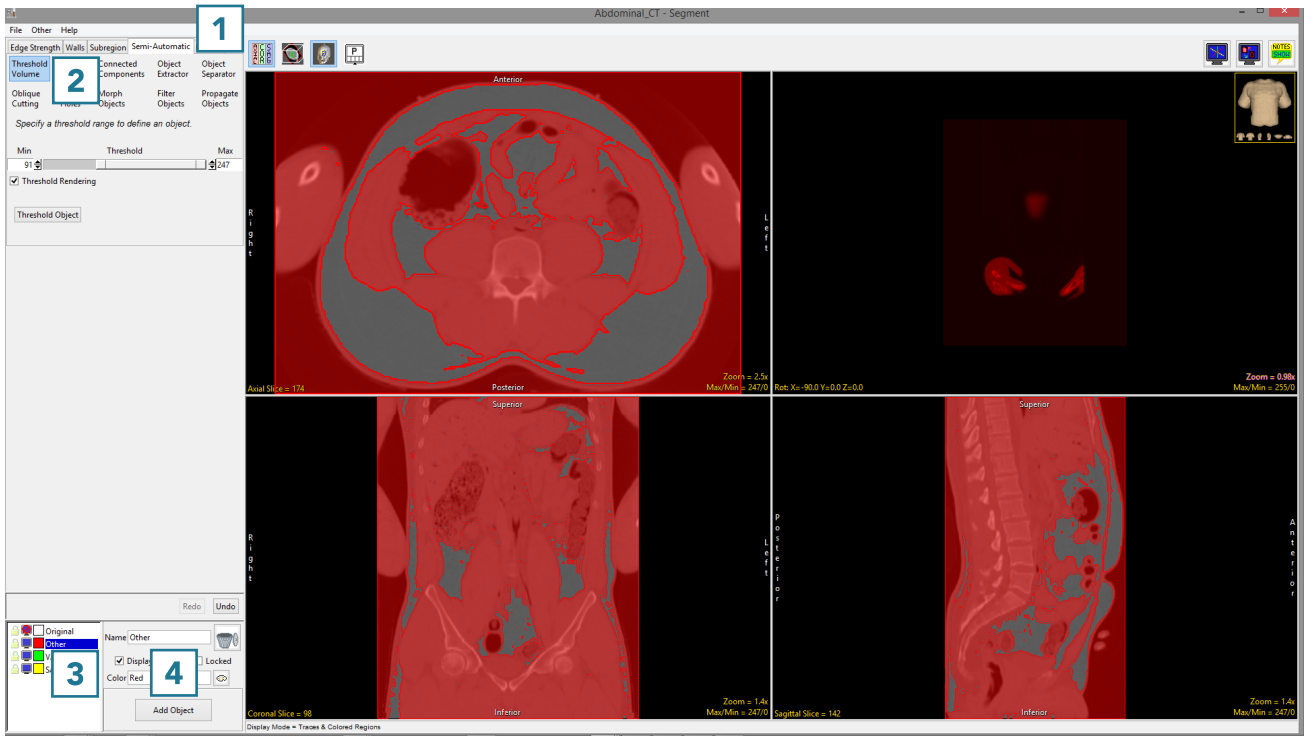
Once the left mouse button is released the regions will be applied to the specified slices. Note the update in the coronal [8] and Sagittal [9] orientations and the 3D rendering [10].



Using Freehand Draw to Paint Regions of Interest

The Freehand Draw tool is particularly useful for manually defining or filling regions between locked objects, specifically when the region of interest is not easily segmentable but the surrounding tissue is.

To follow along, download the data set VH_Abdomen from analyzedirect.com/data and load into Analyze using Input/Output.

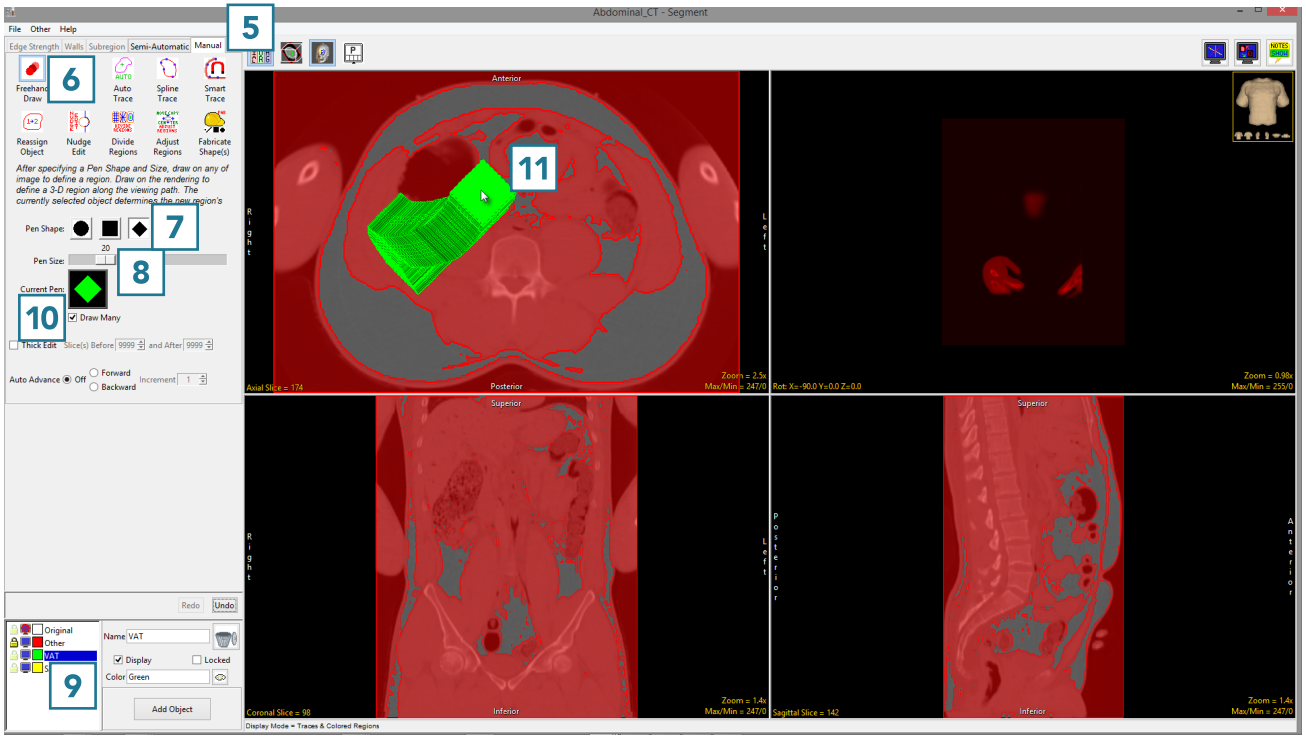


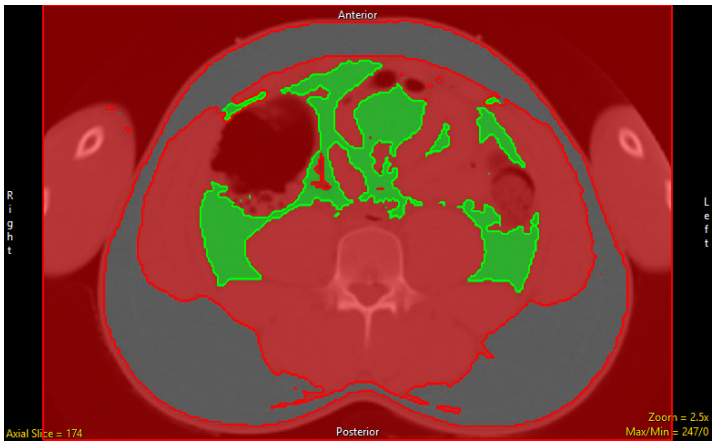
- Select the data set and open Segment.
- Select Semi-Automatic [1] and choose Threshold Volume [2].
- Change the name of the current object to Other, then add two new objects: VAT (visceral adipose tissue) and SAT (subcutaneous adipose tissue) [3].Select the Other object and use global thresholding to assign voxels having intensity values of 0 to 81 and 91 to 247 to the Other object. This will assign all of the non-adipose tissue voxels to the Other object.
- Lock the Other object [4].

For more information on threshold-based segmentation, refer to Threshold Volume.

Using Freehand Draw to Paint Regions of Interest (continued)

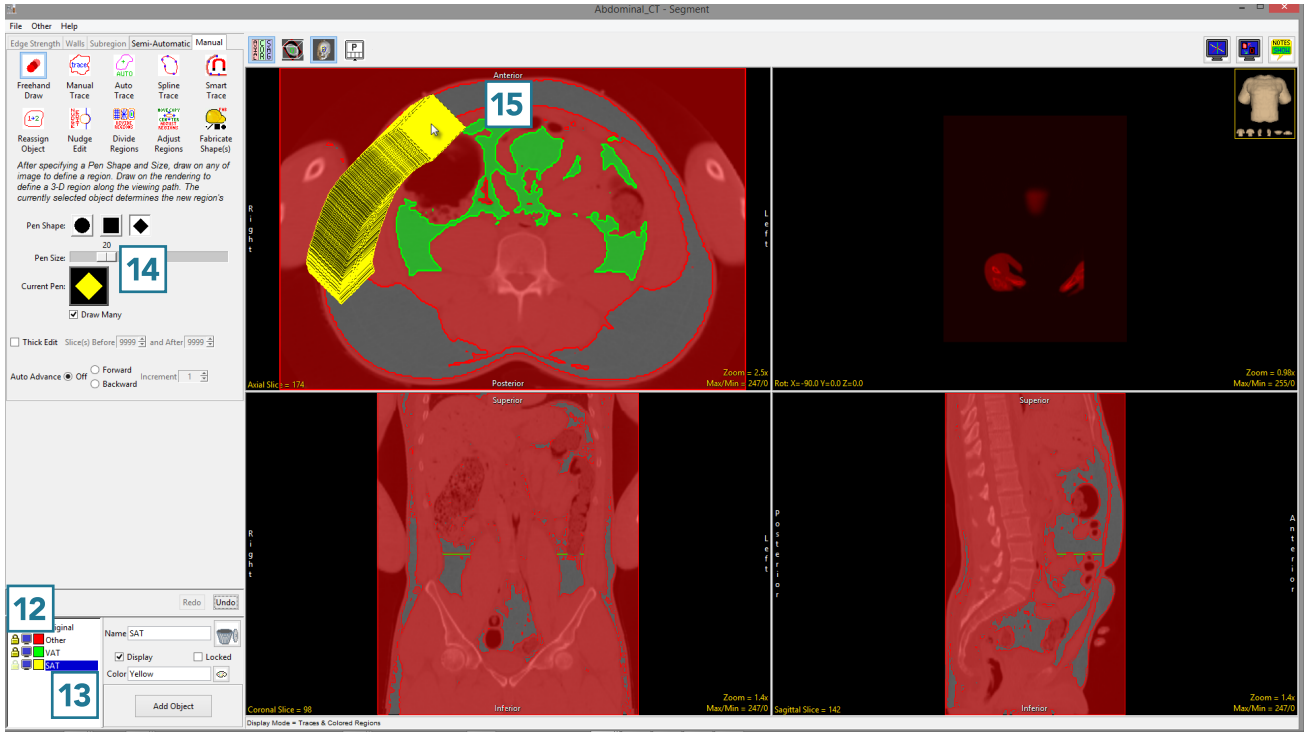
- Select Manual [5] and choose Freehand Draw [6].
- Set the Pen Shape to Diamond [7] and change the Pen Size to 20 [8].
- Select the VAT object [9] and note that the Current Pen [10] will update to the color of the VAT object.
- Use the pen tool to draw over the VAT regions [11].



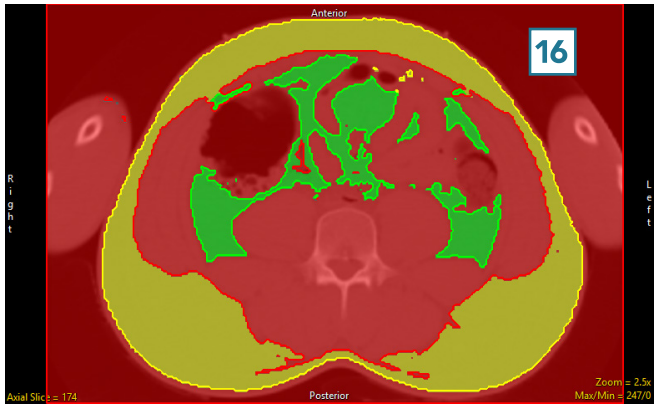


Using Freehand Draw to Paint Regions of Interest (continued)

- Once the VAT region is defined, lock the VAT object 12 and select the SAT object. 13
- Increase the Pen Size to 30 14 and draw over the SAT regions [15].

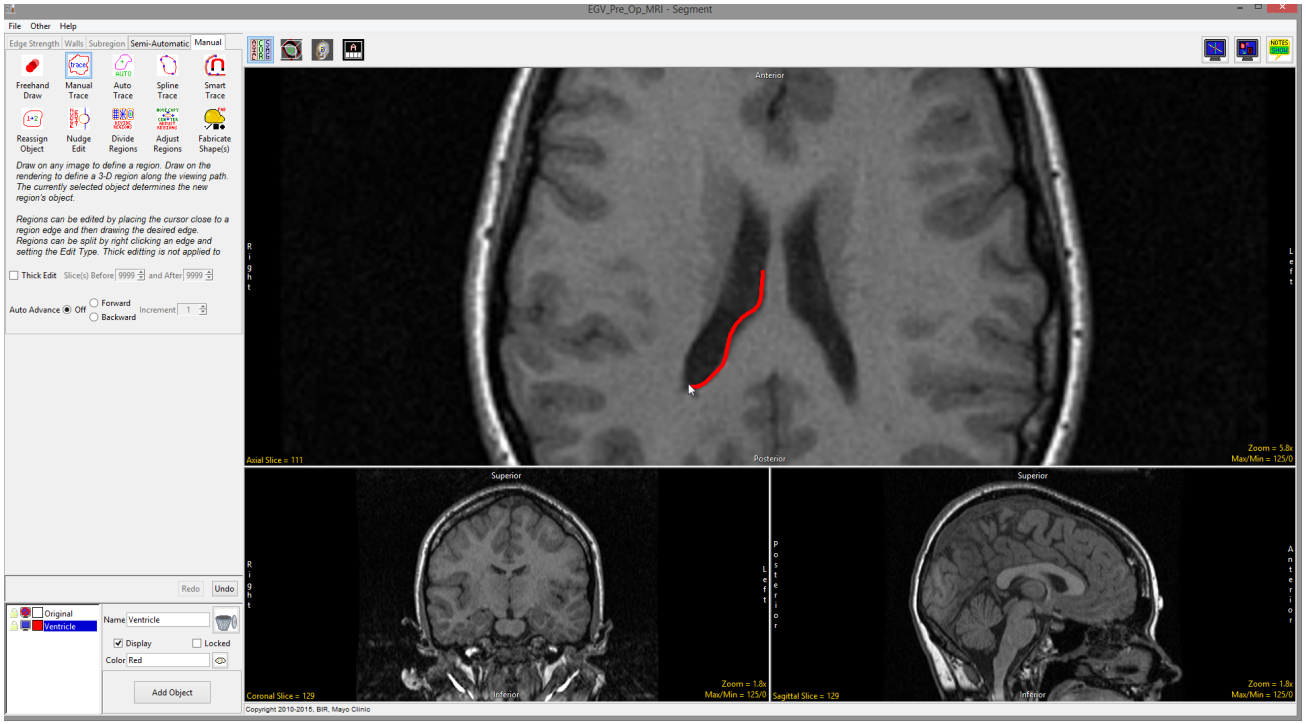


- When finished, [16] use File > Save Object Map to save your work.



Manual Trace

Like the Freehand Draw tool, the Manual Trace tool allows the user to draw regions of interest directly onto the image data. Manual tracing allows contours to be drawn around the edges of a region of interest.



When the Manual Trace tool is selected the following options are available:

Thick Edit: The thick edit option allows users to apply edits (region definitions) defined on the current slice to other slices in the volume. When thick is enabled the following options are available:

- Slices(s) Before: Specifies the number of slices before the current slice in which to apply the edits.
- And After: Specifies the number of slices after the current slice in which to apply the edits.

Auto Advance: The auto advance option automatically moves users to a new slice, as defined by the auto advance options, once the current edit is defined. Note the auto advance will occur after the user releases the left mouse button and the edit is applied to the current slice. The auto advance option is a productivity tool allowing users to move through the image data without having to move the cursor from the current orientation window that regions are being defined on. The following options are available.

- Off: Off is the default option for auto advance. When off is selected auto advance is disabled.

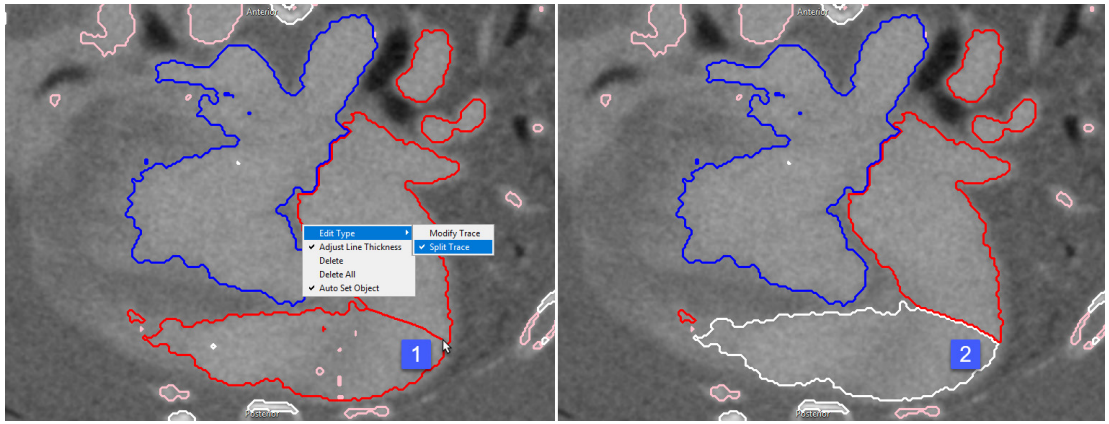
Manual Trace Options (continued)

Auto Advance (continued):

- Forward: Specifies that auto advance will move forward through the image data (slice number increases).
- Backwards: Specifies that auto advance will move backwards through the image data (slice number decreases).
- Increment: Specifies the number of slices the auto advance will move forward or backwards.

Right click options: Right clicking on a trace when Auto Trace is selected will provide access to the following additional editing options:

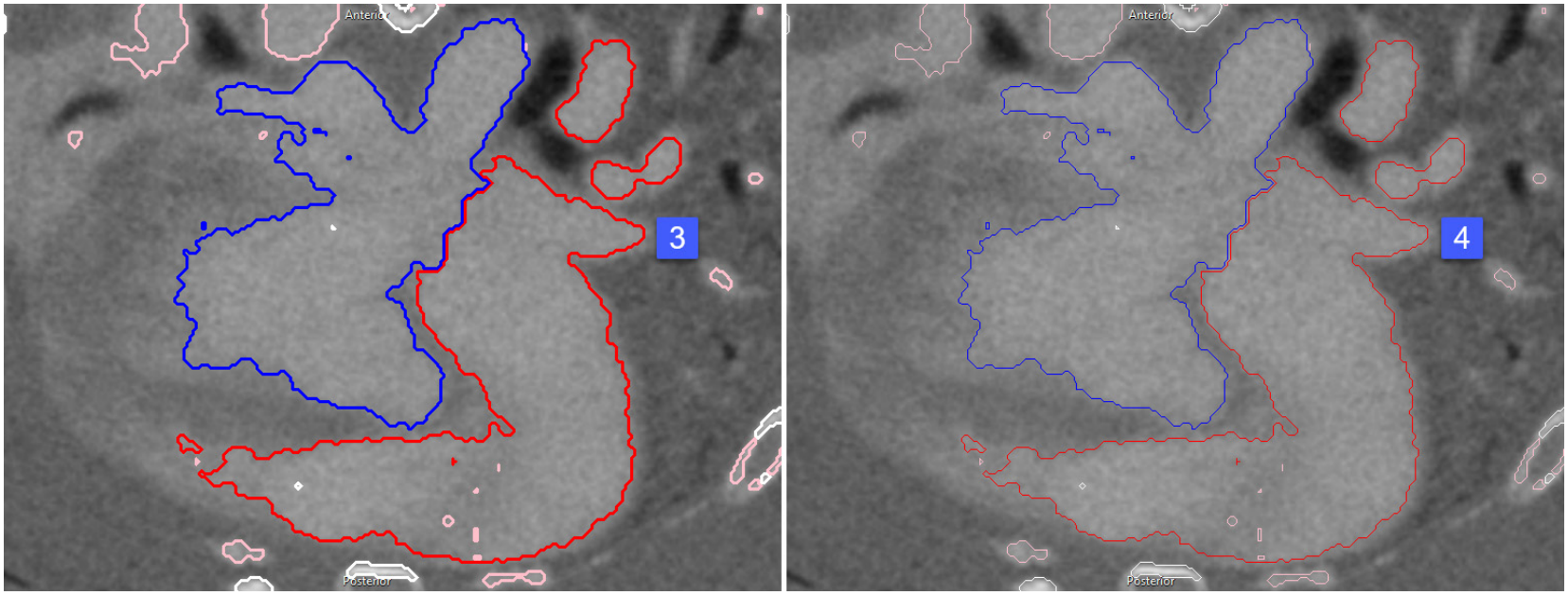
- Edit Type: Allows users to switch between the modify trace and split trace edit modes.
  - Modify Trace: The modify trace option is the default mode for manual trace editing. If the cursor is held over the boundary of an object when tracing begins the edit will apply to that object whose boundary is being modified, regardless of the object selected from the object list. If you wish to have edits applied to the object selected in the object list uncheck the Auto Set Object option. For more information on how to edit a trace refer to Manual Contour Tracing and Editing.
  - Split Trace: Split trace mode allows the current object to be edited [1] and split into two objects with the smaller section of the trace being assigned to the object selected in the object list. If the object selected is the same as the object being split the smaller section will be automatically assigned to a new object [2].



Manual Trace Options (continued)

Right click options (continued):

- Adjust Line Thickness: The adjust line thickness options allows users to switch the thickness display of the traced boundaries of objects. When enabled (default) traces appear thicker, [3] when disabled traces appear thinner. [4]



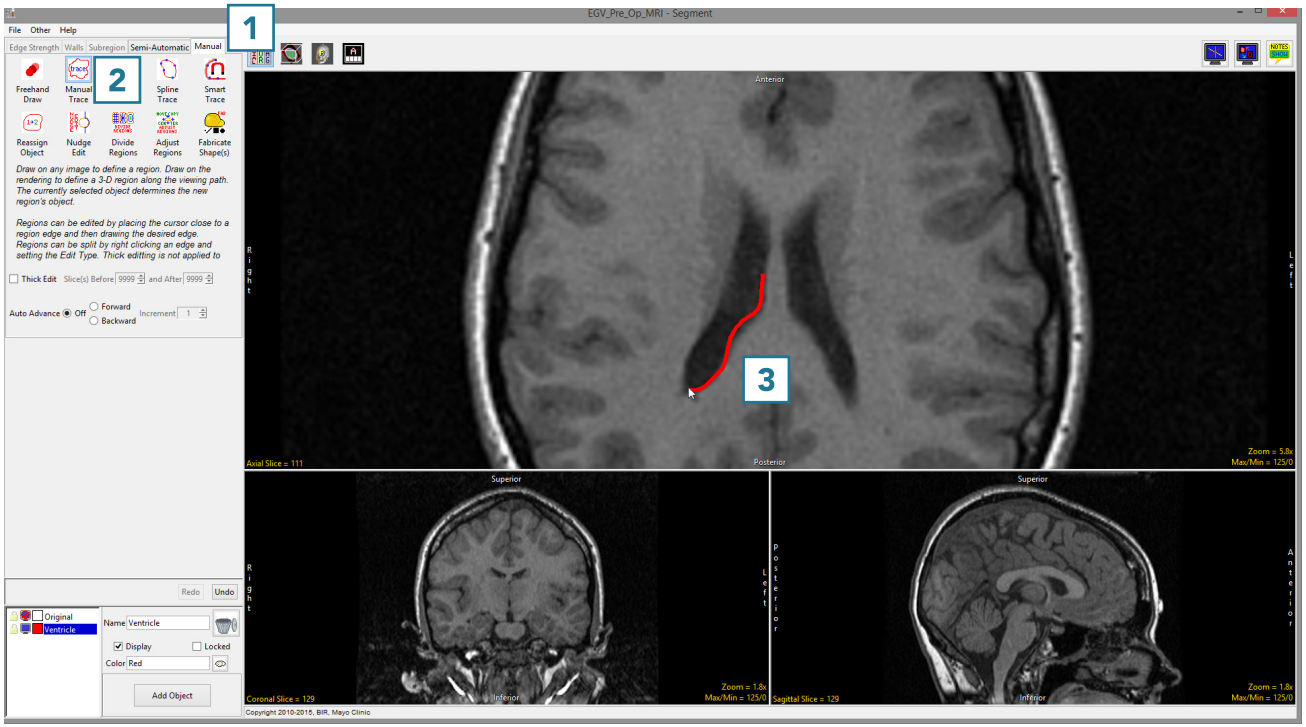
- Delete: Deletes selected region.
- Delete All: Deletes all regions on the slice.
- Auto Set Object: When enabled (default) edits made to object boundaries in Modify Trace mode are assigned to the object being edited. Unchecking the option will ensure boundary edits are assigned to the object selected in the object list.

Manual Contour Tracing and Editing

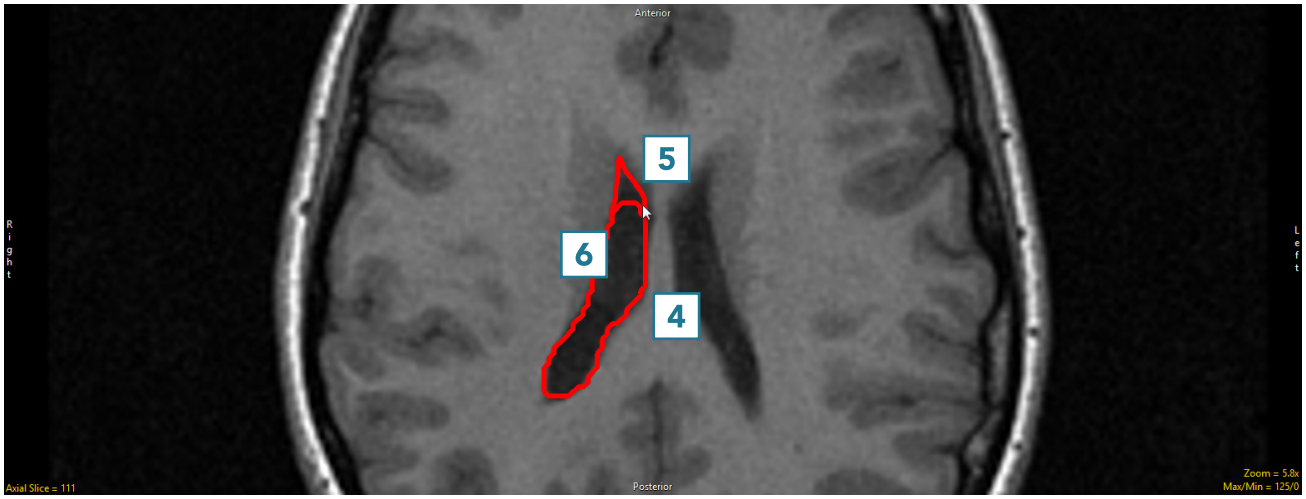
To perform contour tracing and editing using Manual Trace, use the following steps.

To follow along, download the data set MRI_3D_Head from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the data set and open Segment.
- Select Manual [1] and choose Manual Trace [2].
- Left-click on a slice to begin tracing and move the cursor around the region you want to define [3].

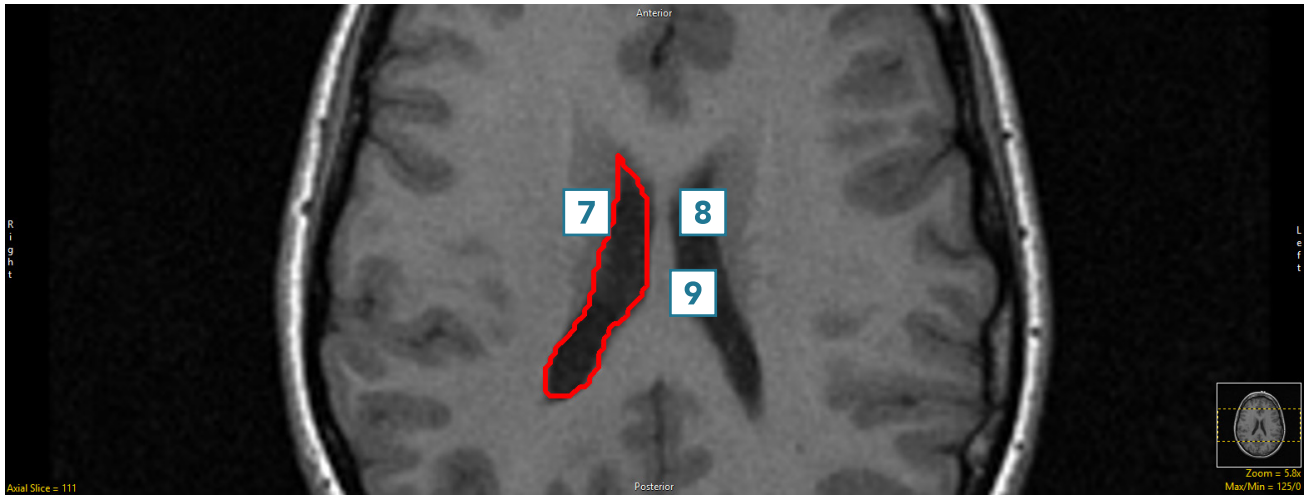


- Release the left mouse button to complete the trace [4].
- To edit the trace and add pixels that may be missing [5], click on the trace [6].

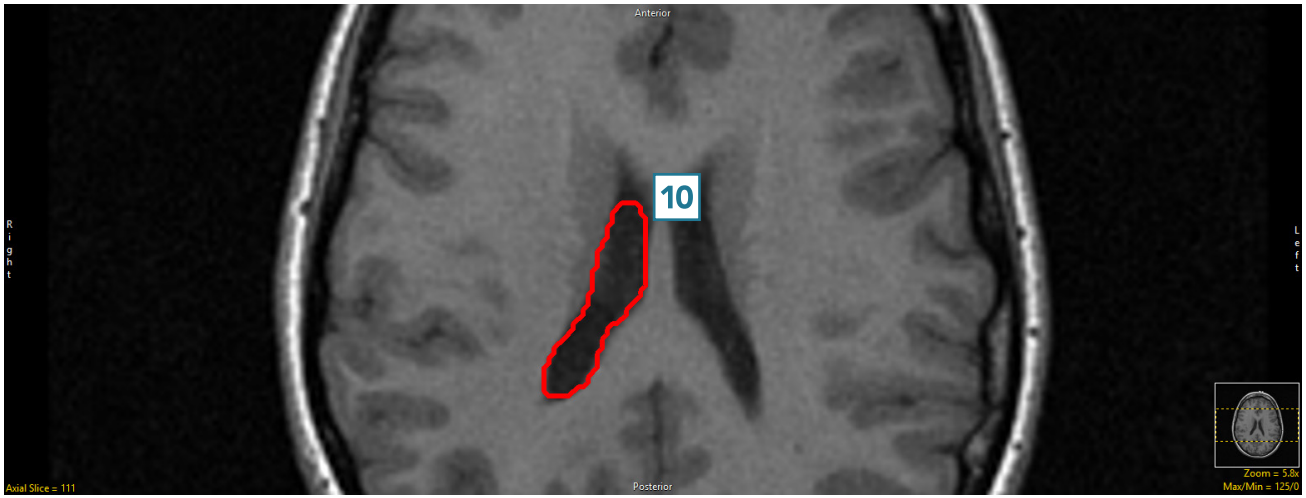


Manual Contour Tracing and Editing (continued)

- After clicking on the trace, draw in the missing region [7].
- To edit the trace and remove additional pixels [8], hover near the edge of the contour until the cursor changes to a + sign, then drag the cursor into the trace [9].



- Adjust the trace to remove the undesired pixels [10].

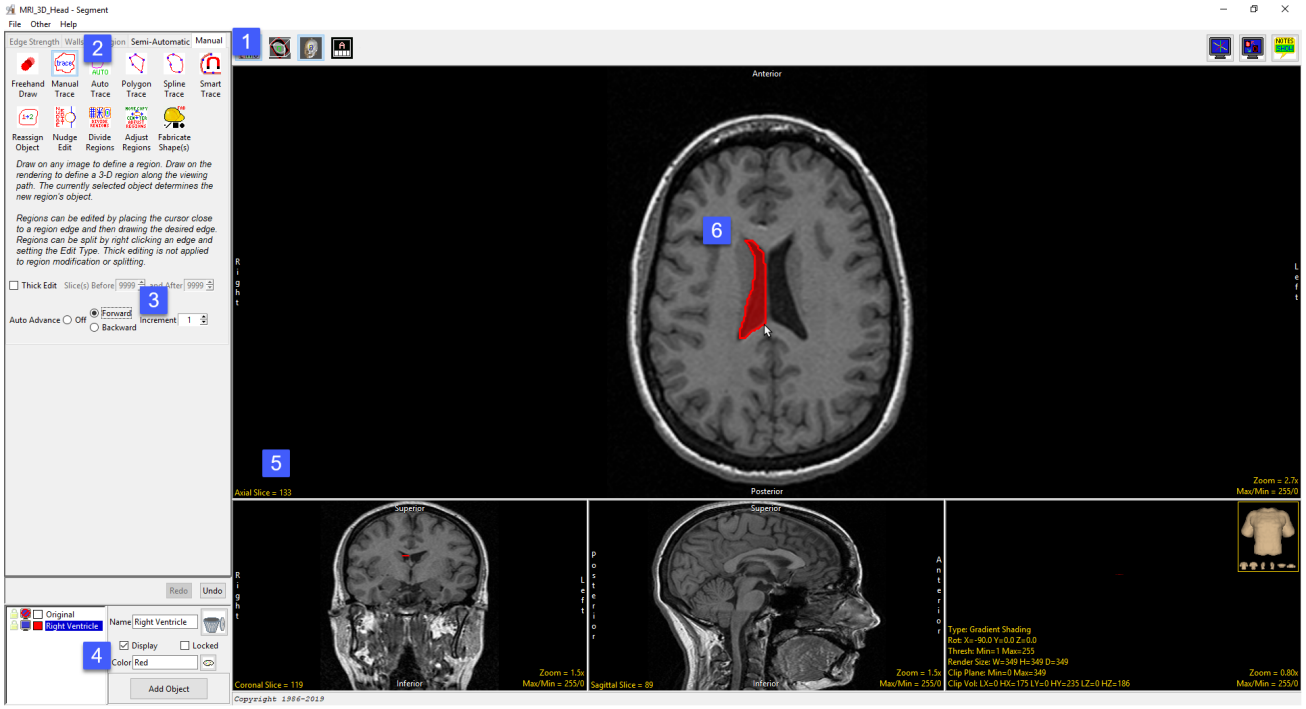


Manual Trace and Auto Advance

Here we will use the Auto Advance function of Manual Trace to automatically move forwards and backwards through image data as the region of interest is defined.

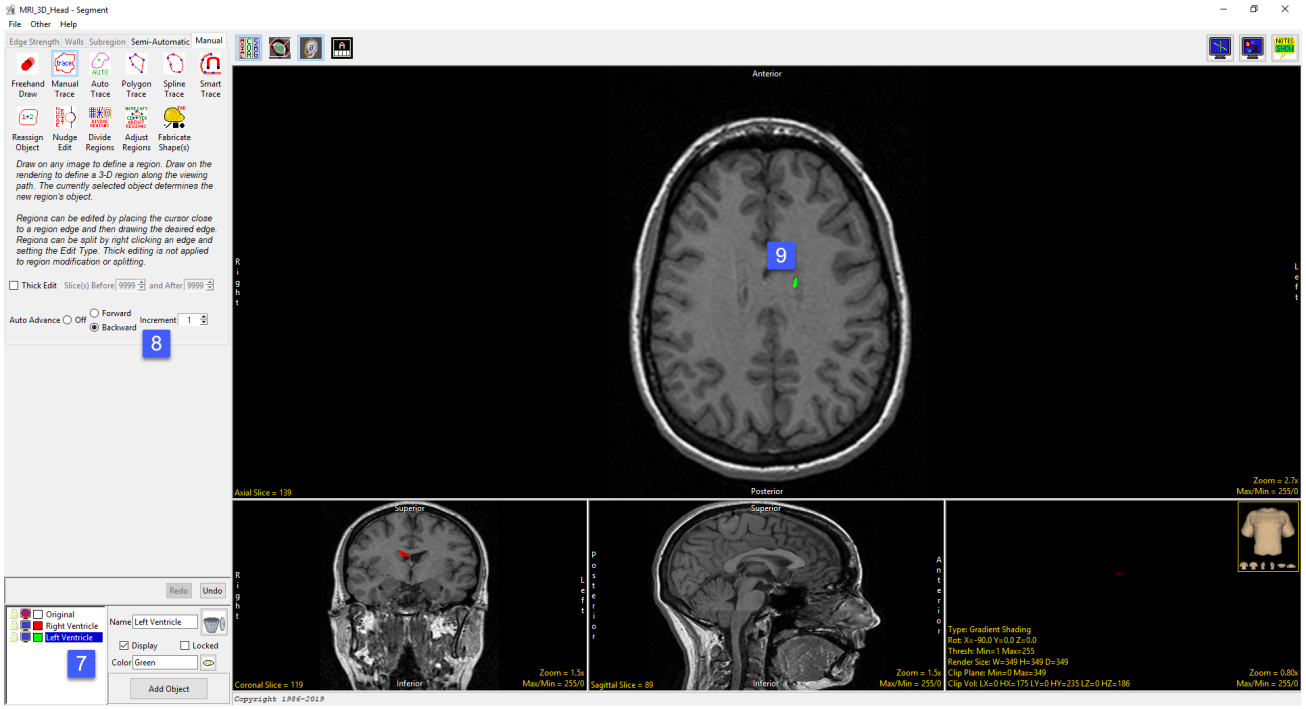
To follow along, download the data set MRI_3D_Head from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the data set and open Segment.
- Select Manual [1] and choose Manual Trace [2].
- Set Auto Advance to Forward [3].
- Add an object and name it Right Ventricle [4].
- Move to Axial slice 133 [5].
- Left click on the border of the right ventricle and trace the structure [6]. When complete release the left mouse button. The trace will be applied to this slice, and the next slice forward, slice 134, will appear.

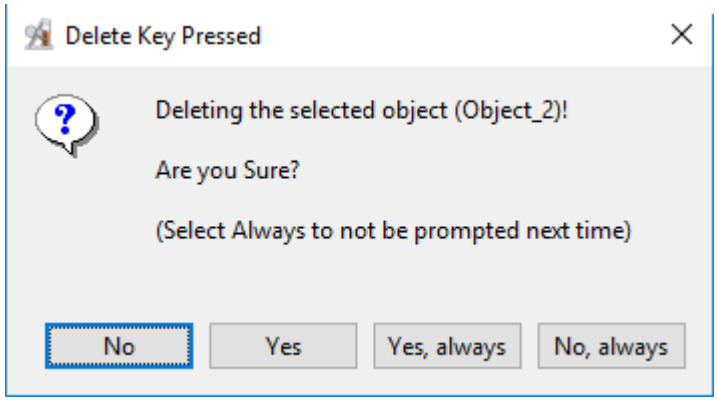


Manual Trace and Auto Advance (continued)

- Continue tracing the right ventricle in this manner until slice 139 is reached.
- At slice 139 add a new object and name it Left Ventricle [7]. Make sure the new object is selected.
- Change the Auto Advance option to Backward [8]
- Left click on the border of the left ventricle and trace the structure [9]. When complete release the left mouse button. The trace will be applied to slice 139 and slice 138 will appear. Continue tracing the left ventricle until slice 133 is reached.



Tip: Object regions can be deleted by holding the cursor over the object and then pressing the delete key on your keyboard. Note that the first time you delete an object in this way for the current segmentation session you will be prompted on which action to take; don't delete (No), delete (Yes), delete and don't prompt this message in the future (Yes, always), don't delete and don't prompt this message in the future.



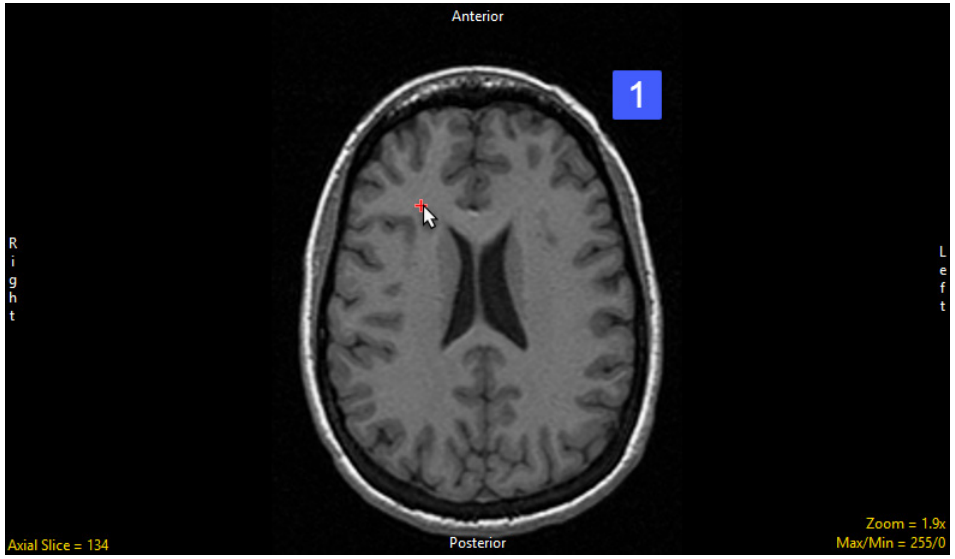
Auto Trace

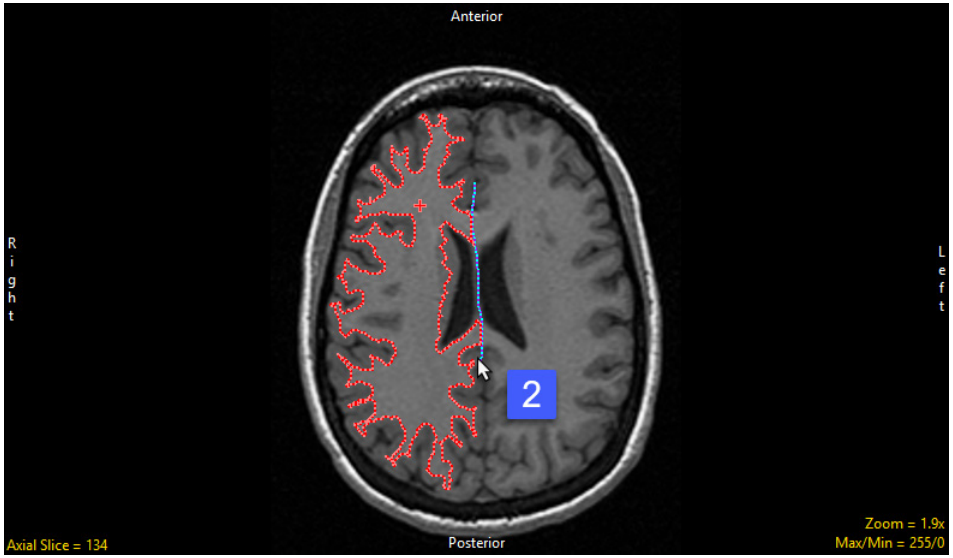
The Auto Trace tool enables the user to define and extract regions of interest from the image data using 2D seeded region growing. Region definition begins with a seed pixel, manually set by the user, on a structure of interest. Next, a threshold range is established by the user to define the boundary of the structure. The 2D region is defined by all the pixels in the threshold range that are connected to the seed pixel.

The following options are available:

Select Seed: The select seed mode is the default mode the Auto Trace tool will open in. Select seed allows users to set a seed point on the image data [1] to enable the Auto Trace tool options.

Draw Limit: The draw limit mode allows users to manually define limits on the image data to limit the auto trace region [2].



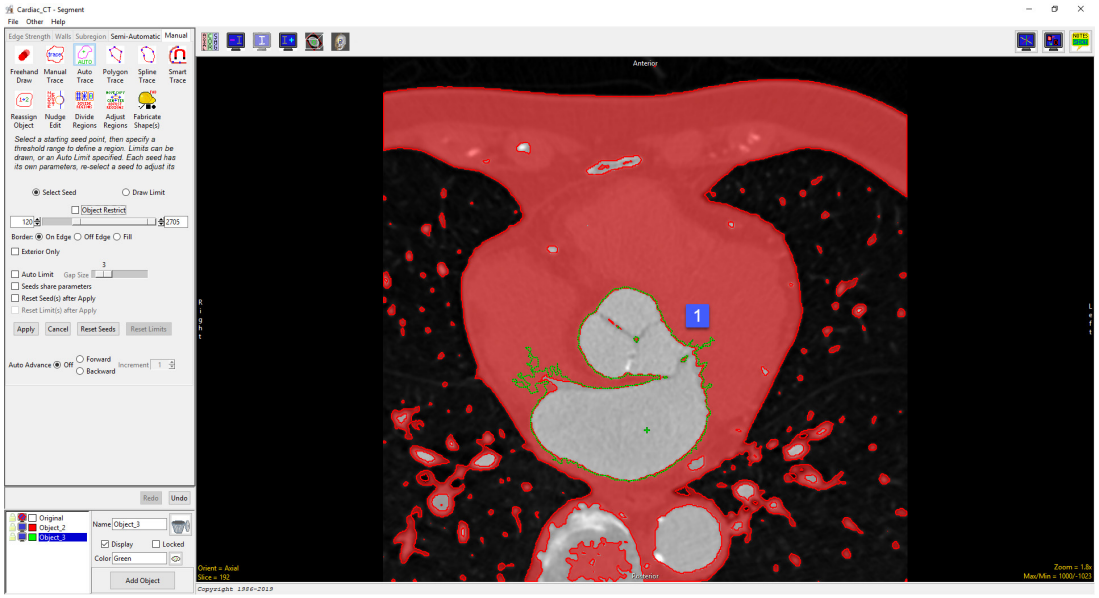


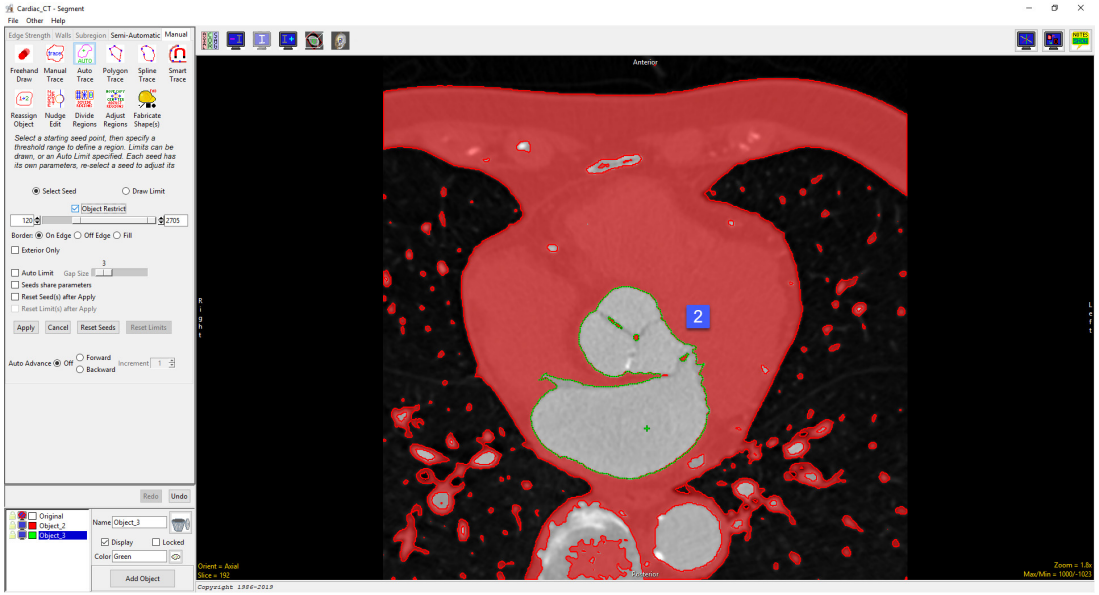
Auto Trace Options (continued)

Object Restrict: The Object Restrict options allows users to restricts the definition of the current object with the boundaries of any established objects. When disabled traces are not limited by object boundaries [1]. However, when the option is enabled traces are restricted [2].

Threshold slider: The Threshold double-ended slider bar allows users to specify a range of threshold values using the minimum and maximum ends of the threshold slider. Minimum and Maximum values can be entered in the text entry fields while the arrow up and down keys to the right of the minimum and left of the maximum text entry fields can be used to increase or decrease values 1 point at a time. Click left and right of the text entry boxes

Tip: Clicking in the trough to either side of the minimum or maximum end of the slider will advance the value by 1. Shift-click will decrease the value by 1.



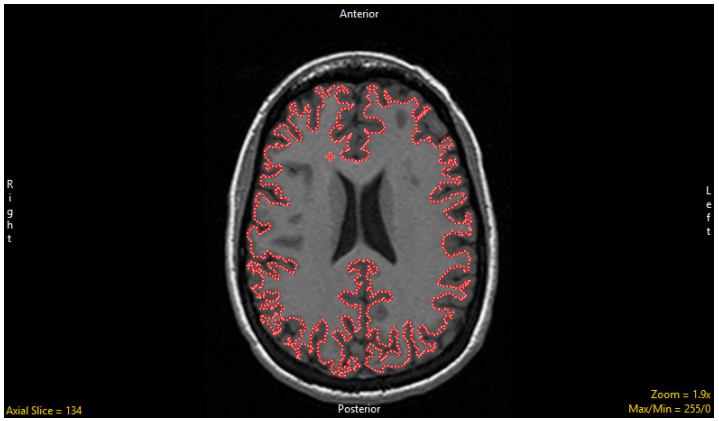


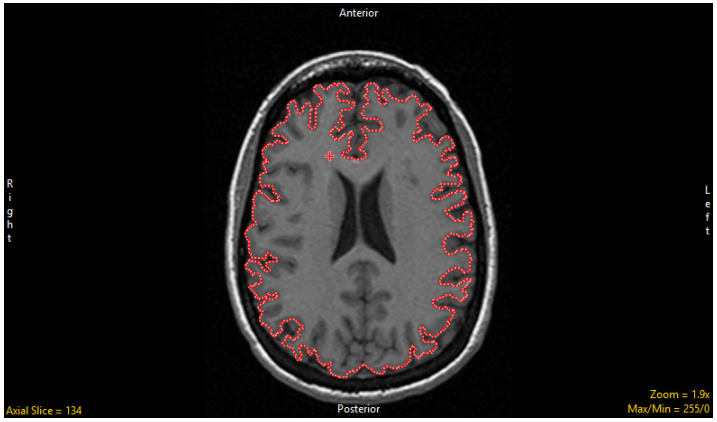
Auto Trace Options (continued)

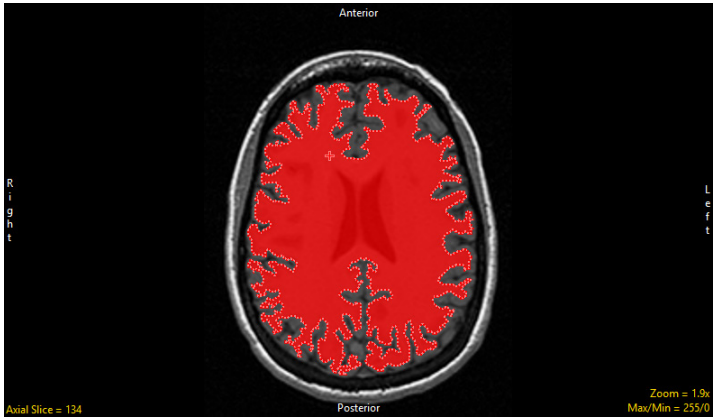
Right clicking options: Right clicking on the threshold slider will provide access to threshold presents. The Presets option allows users to select predefined thresholds or define new threshold values for specific areas of interest. For more information on Presets, including how to configure presents refer to the Threshold Volume.

Border: The Border options allows users to specify how the border of the trace will be displayed on the image, choose from:

- On Edge: The auto trace will be positioned exactly on the edge of the thresholded region (top image).
- Off Edge: The auto trace will be positioned one pixel off the edge of the thresholded region (middle image).
- Fill: The auto trace will display On Edge with a filled interior (bottom image).



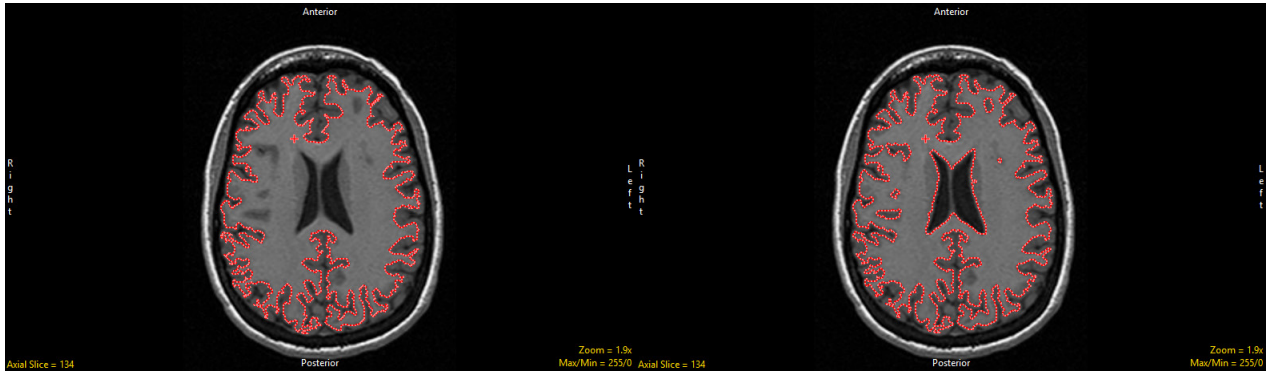


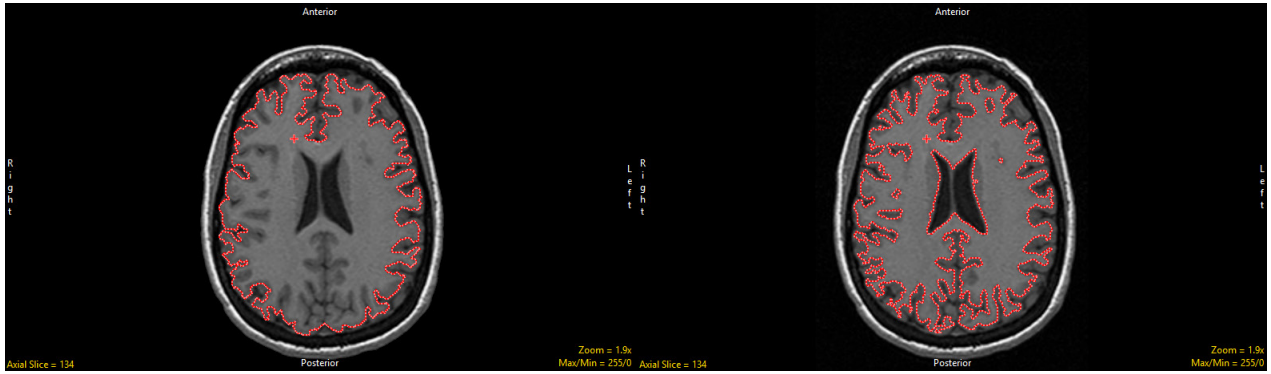


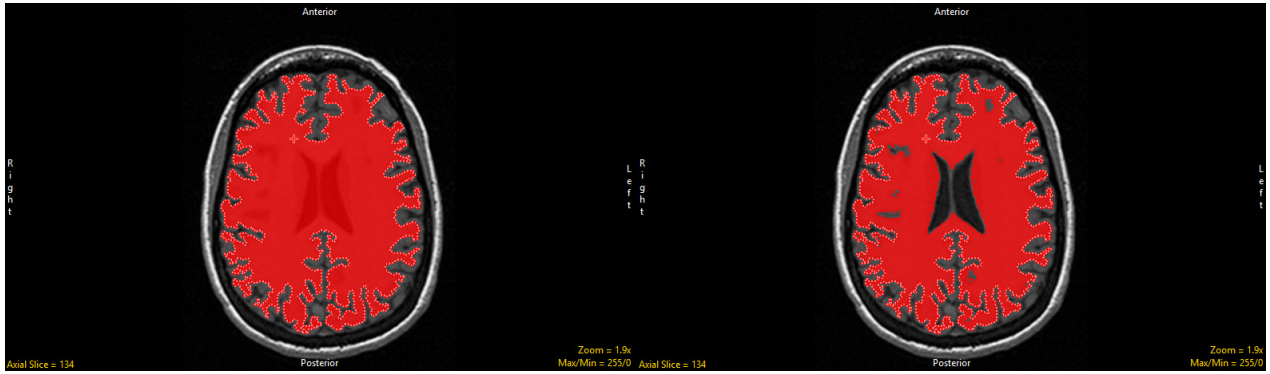
Auto Trace Options (continued)

Exterior Only: The Exterior Only option allows users to enable (default) or disable the display of the exterior border only. Enable the option if you only wish to see the exterior borders of the trace, uncheck and disable the option if you wish to view the exterior and interior borders. The option is compatible for all Border displays.

- Top image: Exterior Only disabled with On Edge selected
- Middle Image: Exterior Only disabled with Off Edge selected
- Bottom image: Exterior Only disabled with On Fill selected



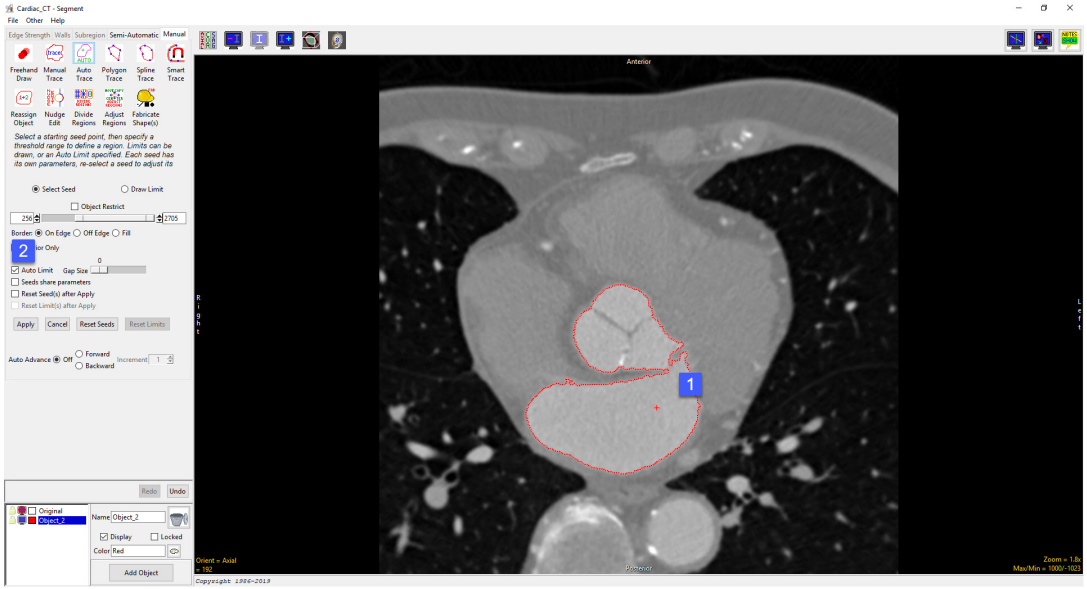


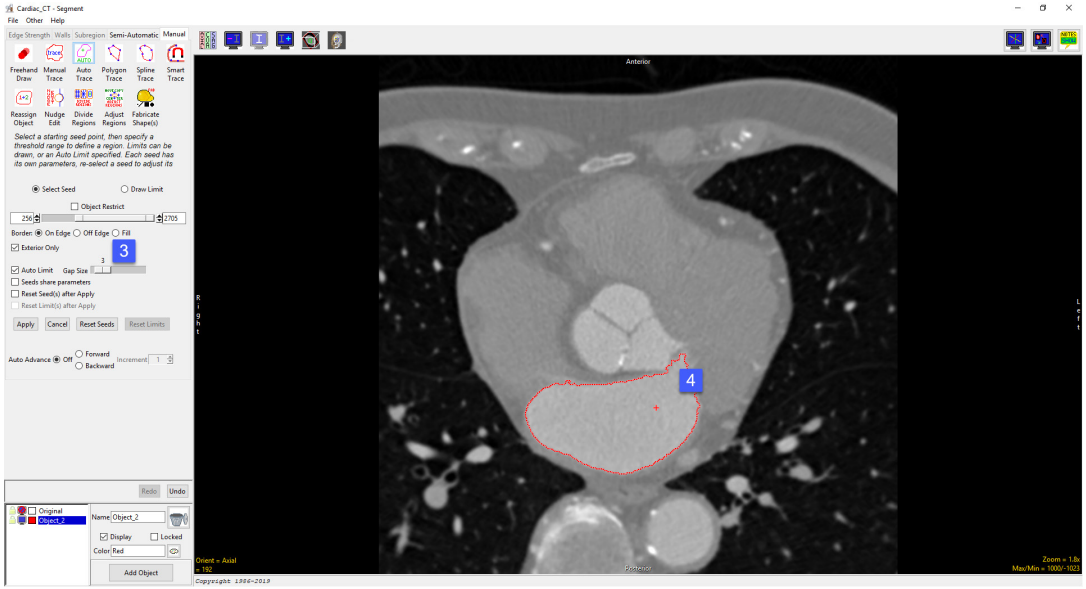


Auto Trace Options (continued)

Auto Limit: The Auto Limit option applies a post processing step to the auto trace to eliminate thin portions of the auto trace. This option performs a morphologic open using the Gap Size value, defined by the user, to define the number of layers to be removed from the trace and then added back.

To use the option, after setting a seed point and appropriate threshold criteria to define a region [1], click the Auto Limit check box [2], then set the Gap Size using the slider, [3] review the impact on the defined region. [4] Note that the Gap Size of 0 is the same as having no Auto Limit set. This option helps eliminate the need for manually defining limits in some situations.





Auto Trace Options (continued)

Seeds share parameters: The Seeds share parameters option allows users to enable or disable (default) seeds from sharing the same auto trace options including threshold range, border settings, auto limit, and object information. Enable this option if you wish to define multiple separate regions with the same parameters, keep this option disabled if you wish to define multiple separate regions with different parameters.

Reset Seed(s) after Apply: After applying the trace all seeds will be reset (deleted).

Reset Limit(s) after Apply: After applying the trace all limits will be reset (deleted).

Apply: Applies the trace to the slice.

Cancel: Cancels the Auto Trace, resets all defined seed points and limits.

Reset Seeds: Resets all seeds.

Reset Limits: Resets all limits.

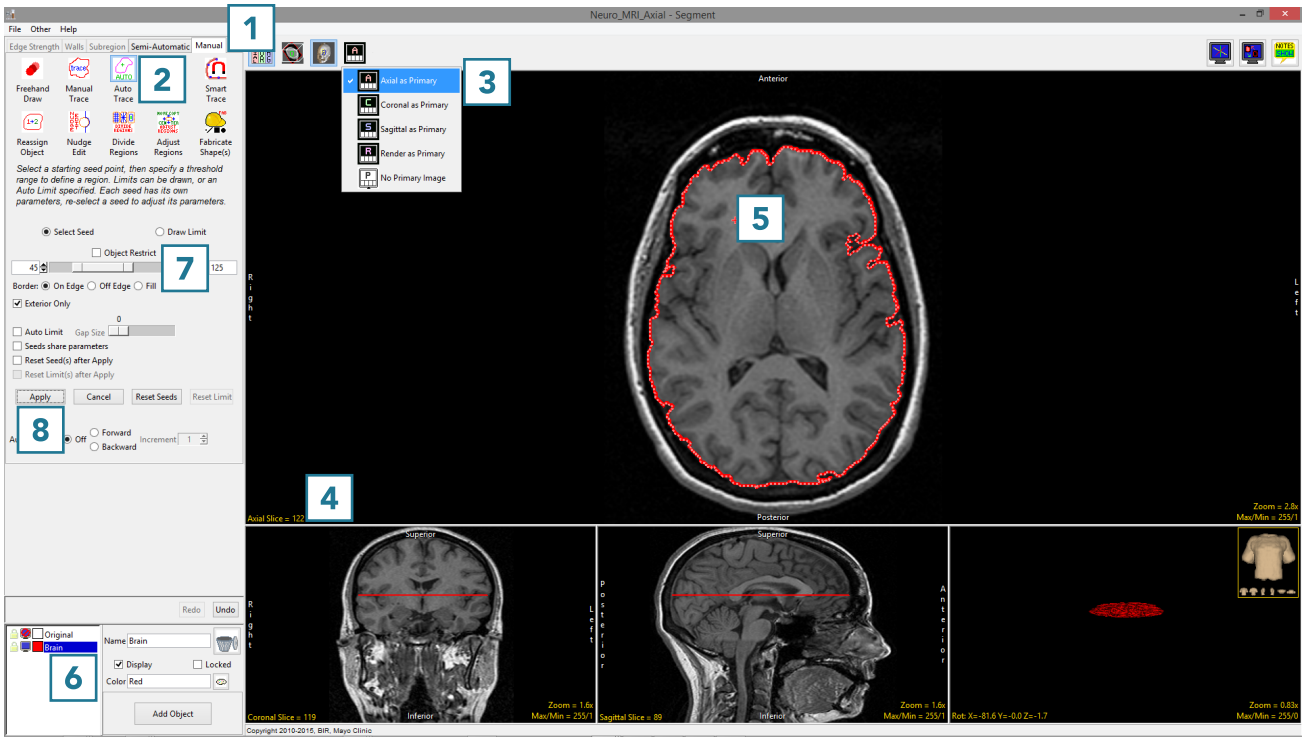
Auto Advance: The auto advance option automatically moves users to a new slice, as defined by the auto advance options, once the current edit is defined. Note the auto advance will occur after the user releases the left mouse button and the edit is applied to the current slice. The auto advance option is a productivity tool allowing users to move through the image data without having to move the cursor from the current orientation window that regions are being defined on. The following options are available.

- Off: Off is the default option for auto advance. When off is selected auto advance is disabled.
- Forward: Specifies that auto advance will move forward through the image data (slice number increases).
- Backwards: Specifies that auto advance will move backwards through the image data (slice number decreases).
- Increment: Specifies the number of slices the auto advance will move forward or backwards.

Using Auto Trace to Define a 2D Region of Interest

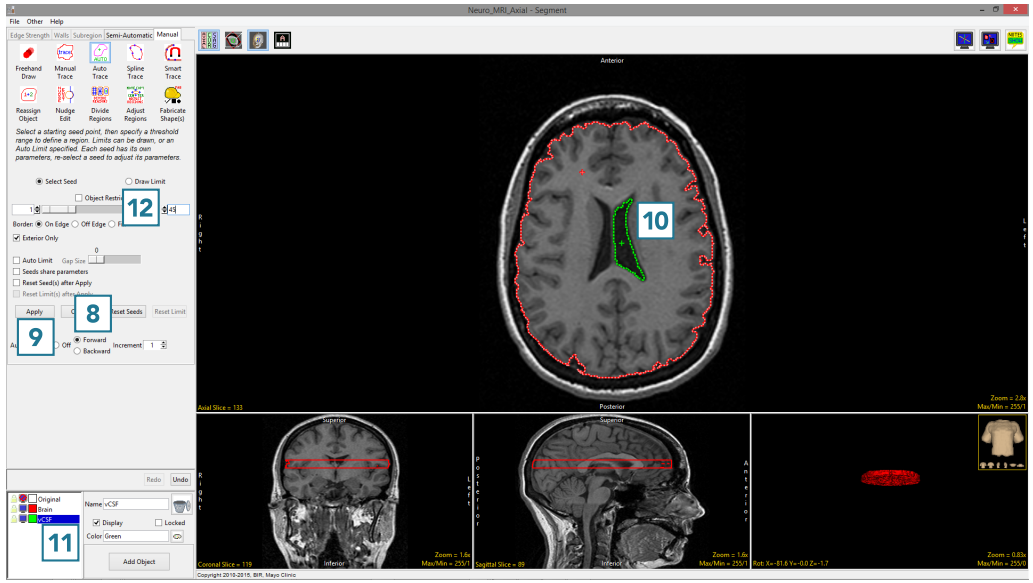
To follow along, download the data set MRI_3D_Head from analyzedirect.com/data and load into Analyze using Input/Output.

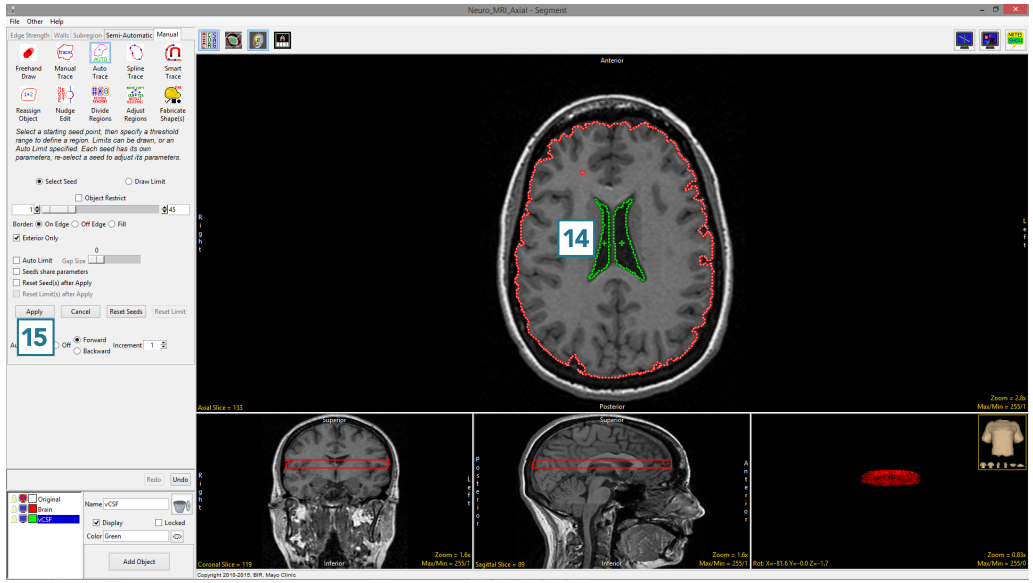
- Select the data set and open Segment.
- Select Manual [1] and choose Auto Trace [2].
- Set the primary display to Axial [3] and double-click Slice [4] to move to axial slice 122.
- Set a seed pixel in the white matter [5].
- Rename Object_2 to Brain [6] and then adjust the minimum and maximum threshold values [7] to define the brain.
- Click Apply [8] to trace the brain on this slice.
- Scroll forward to slice 123. The + key can also be used instead if your mouse has no scroll wheel.
- As the seed point and threshold range are carried forward, the brain will be redefined on this slice.



Using Auto Trace to Define a 2D Region of Interest (continued)

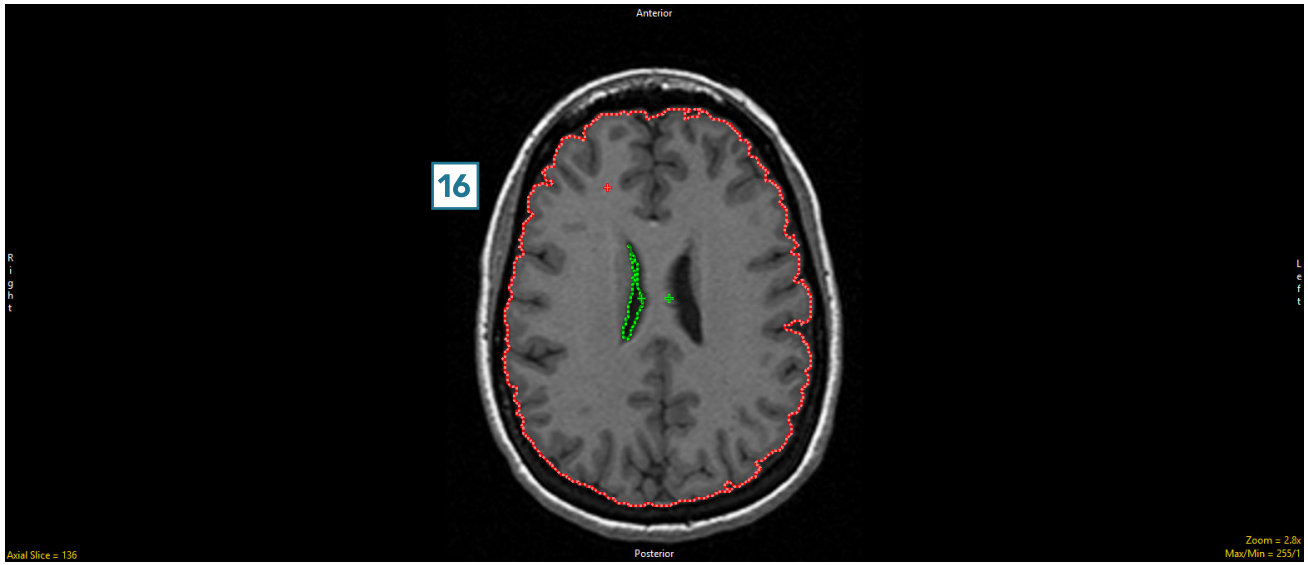
- Set the Auto Advance option to Forward [8] and click Apply [9]. The brain will be traced on this slice and the display will automatically move forward to slice 124.
- Continue to apply the auto trace to the brain up to slice 133. If the initial seed point is copied to a slice where it does not fall within the brain, reset the seed point and threshold range and click Apply to set a new auto trace on that slice.
- Click in the ventricular CSF to set a seed point [10].
- Add a new Object and rename it vCSF [11]. Note that the second seed point will change color to match the color of the new object. Adjust the threshold range to define the vCSF object [12].
- Set a second seed point to define the remaining vCSF [14] and click Apply [15].

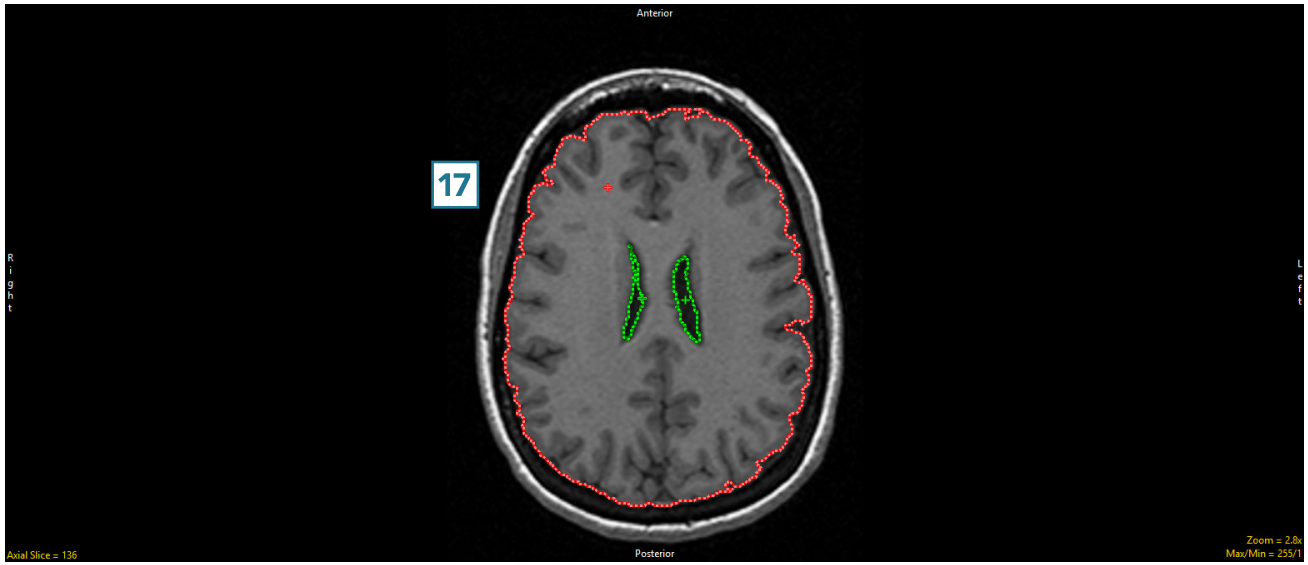




Using Auto Trace to Define a 2D Region of Interest (continued)

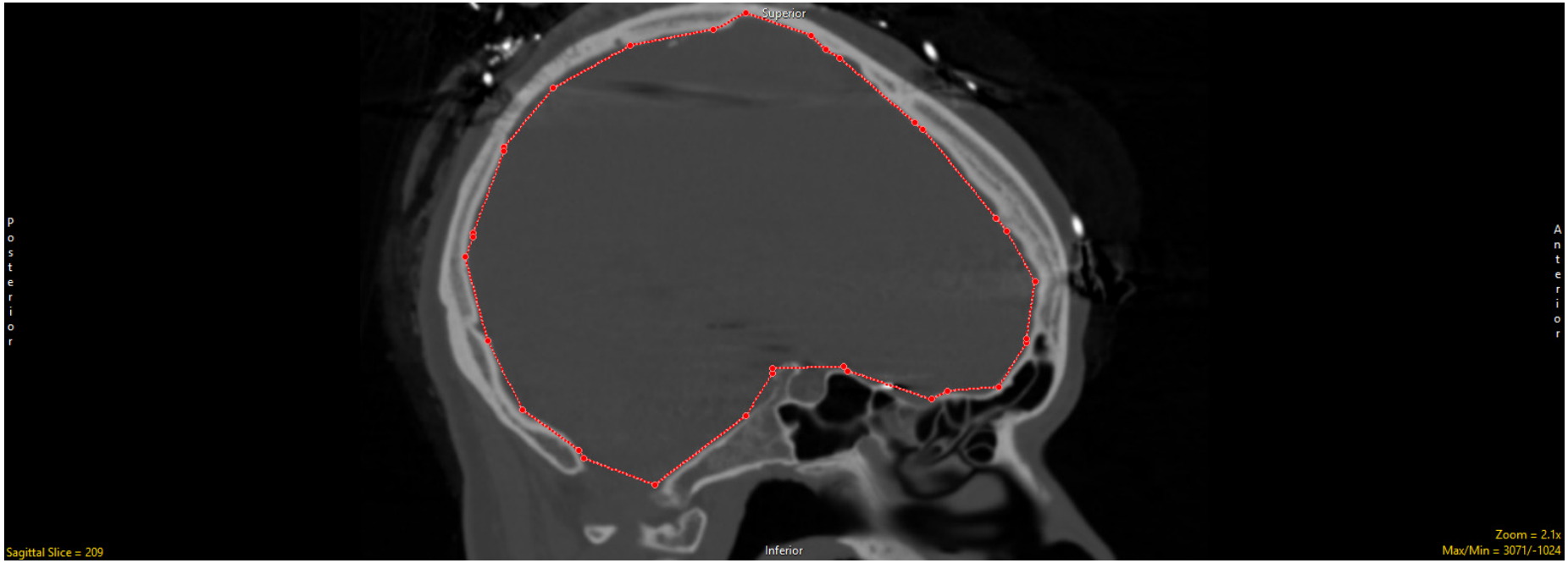
- Continue clicking Apply to trace the Brain and vCSF objects. If a seed point is copied to a location where it is no longer on the target object [16], move the seed point back onto the object [17] and continue to apply the auto trace.
- Stop defining objects at slice 137.
- Select File > Save Object Map to save your work.





Polygon Trace

The Polygon Trace tool enables the definition of a closed polygon region.



The following options are available:

Reset Polygon Trace after Apply: Resets (deletes) the polygon trace after the region is defined. Polygon traced regions are defined after the user double-clicks or presses the escape (Esc) key to close the trace ending the tracing process, the trace is applied when the Apply button is clicked, the 'A' key on your keyboard is pressed, the user right-clicks on the spline trace and selects Apply from the menu or the Auto Apply option is enabled.

Auto Apply: When selected the polygon trace is automatically applied once the user double-clicks or presses the escape key to close the trace.

Polygon Trace Options

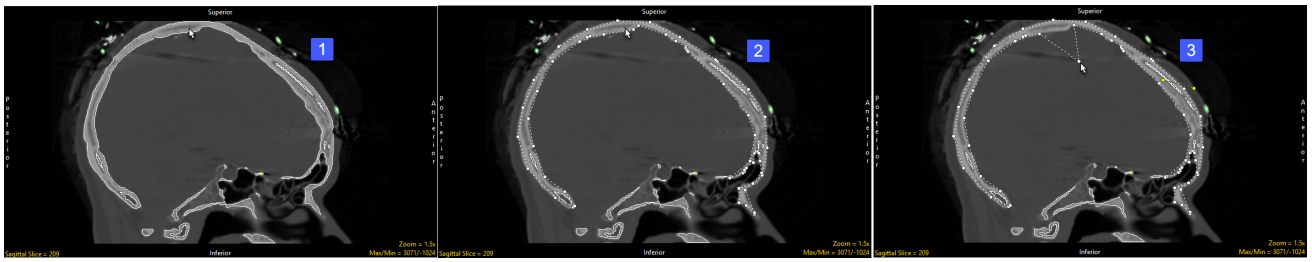
Auto Advance: The auto advance option automatically moves users to a new slice, as defined by the auto advance options, once the current edit is defined. Note the auto advance will occur after the user releases the left mouse button and the edit is applied to the current slice. The auto advance option is a productivity tool allowing users to move through the image data without having to move the cursor from the current orientation window that regions are being defined on. The following options are available.

- Off: Off is the default option for auto advance. When off is selected auto advance is disabled.
- Forward: Specifies that auto advance will move forward through the image data (slice number increases).
- Backwards: Specifies that auto advance will move backwards through the image data (slice number decreases).
- Increment: Specifies the number of slices the auto advance will move forward or backwards.

Right click options: Right clicking on the Polygon trace provides users with the following options:

- Apply: Applies the trace.
- Cancel: Cancels the trace, deleting the trace and controls points.
- Auto Apply on Control Point Adjust: This option is only available when Auto Apply is enabled and when editing a Polygon trace or trace converted to a Polygon. When selected any edits made to the Polygon will be automatically applied when a control point is moved.
- Delete Control Point: Deletes the control point the cursor if currently over.
- Delete Spline: Deletes the trace and controls points.

Note: Clicking on an object border [1] when the Polygon Trace is selected will convert the object region into a polygon [2] with adaptable control points [3].

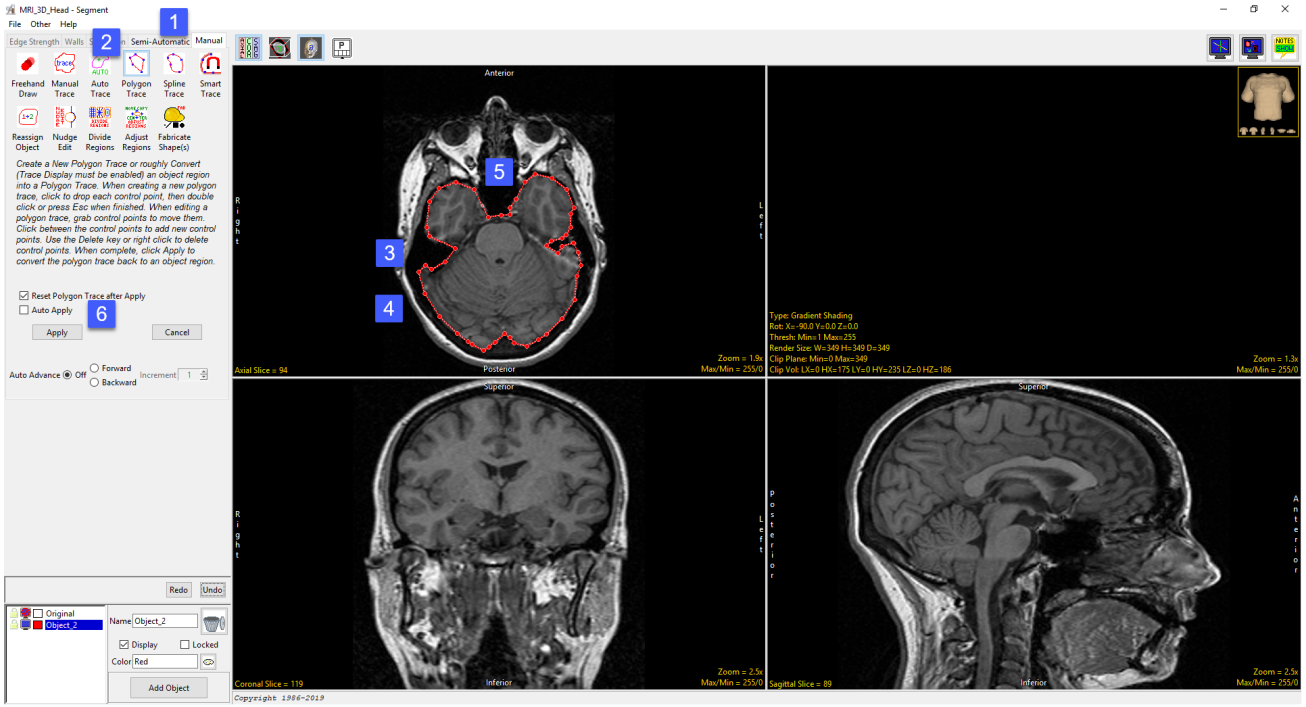


Region Definition and Region Modification with Polygon Trace

Here we will use the Polygon Trace tool to define a region of interest and then how to divide a region into subregions.

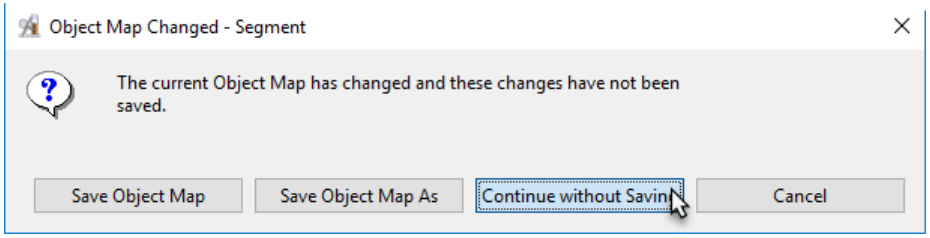
To follow along, download the data set MRI_3D_Head from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the data set and open Segment.
- Select Manual [1] and choose Polygon Trace [2].
- To define a Polygon trace around the brain in the axial image, left click on the image to set the first control point [3] and then move the cursor and left click again to set a second control point [4].
- Continue in defining the border or the brain in this manner until complete [5]. Double-click or press the Esc key to end tracing and then process Apply [6] to define the region.

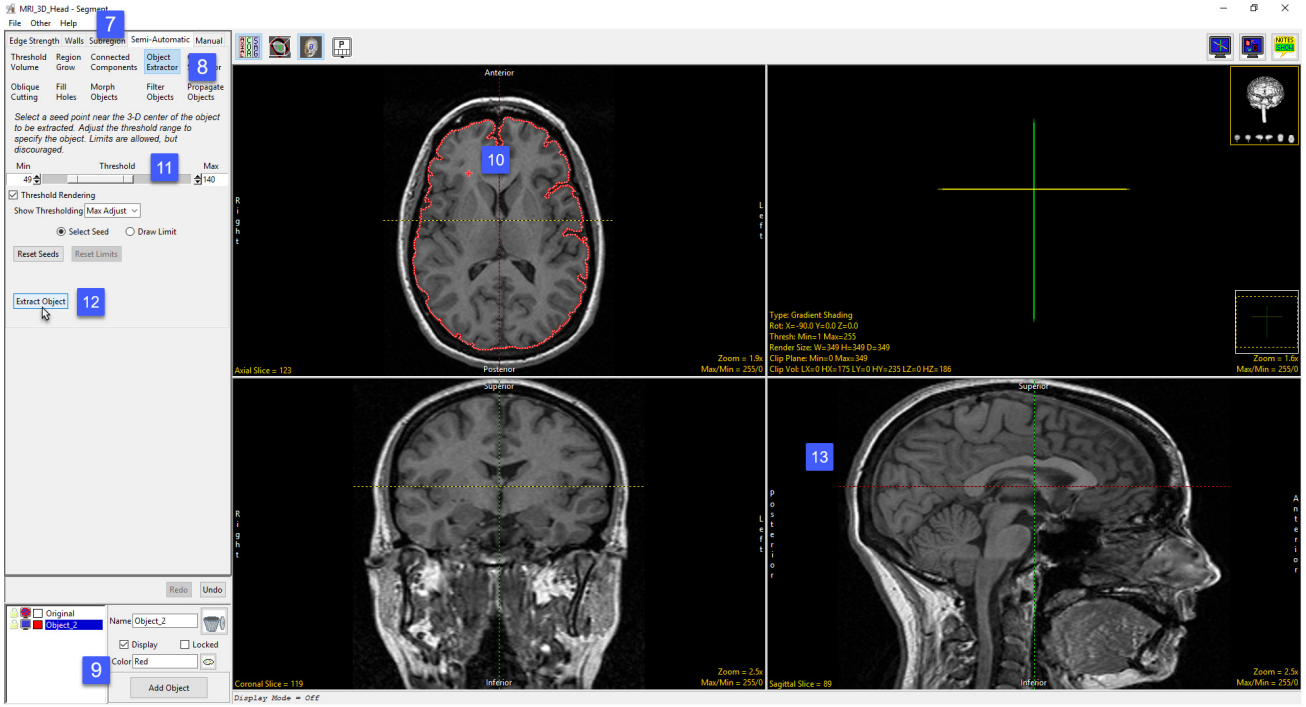


Region Definition and Region Modification with Polygon Trace (continued)

- Select File > Reset Object Map to delete the trace, select 'Continue without Saving' when prompted.

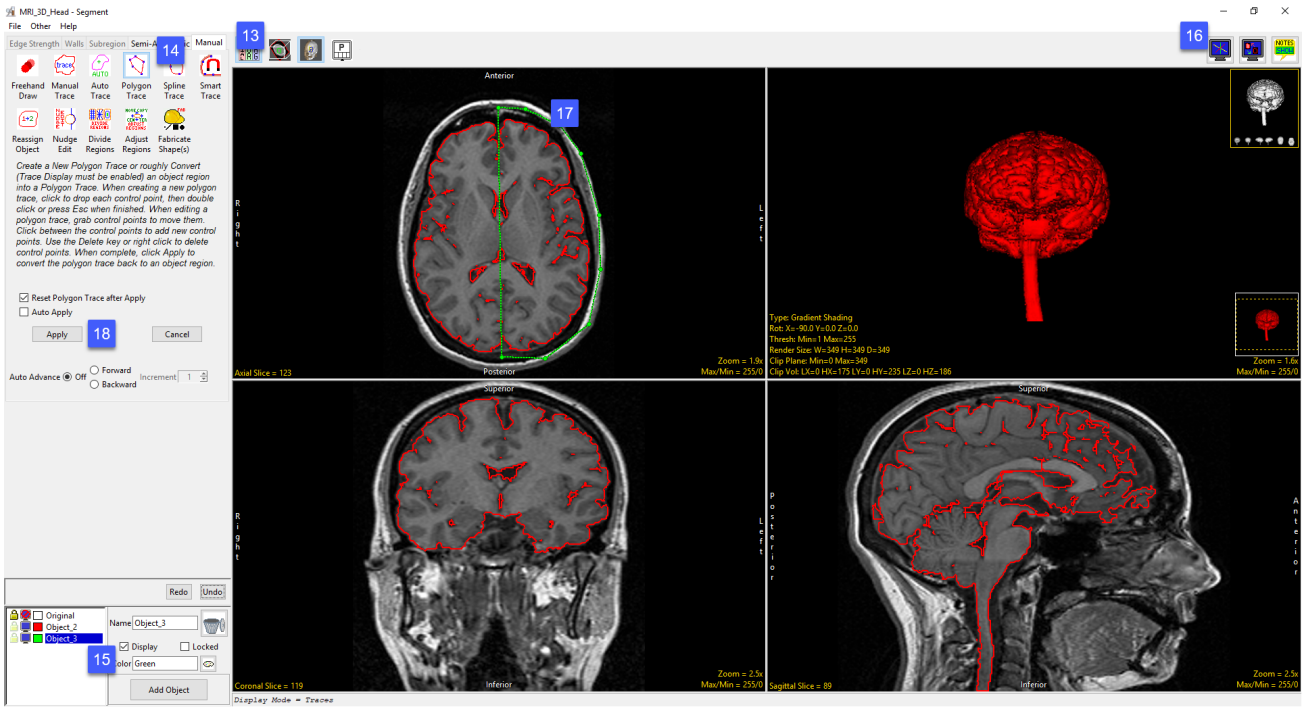


- Next, segment the brain in 3D using the Object Extractor. Select the Semi-Automatic tab [7] and then choose Object Extractor [8].
- Click Add Object [9] to add an object to the object list and then click in the white matter on axial slice 123 to set a seed point [10].
- In the Threshold option set the minimum threshold value to 49 and the maximum to 140 [11] and then click Extract Object [12].



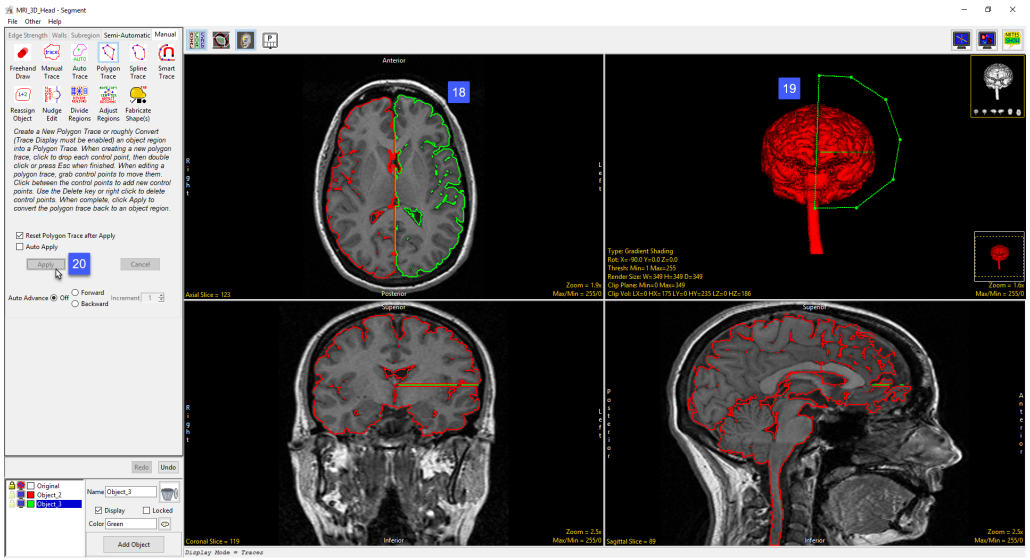
Region Definition and Region Modification with Polygon Trace (continued)

- To subsegment a 2D region do the following. Select the Manual tab [13] and then choose the Polygon tool [14]. Lock the Original object and then add a new object to the object list [15].
- Switch off the Linked Cursor [16] and then use the Polygon tool to define the left hemisphere of the brain on axial slice 123, [17] and then click Apply [18].

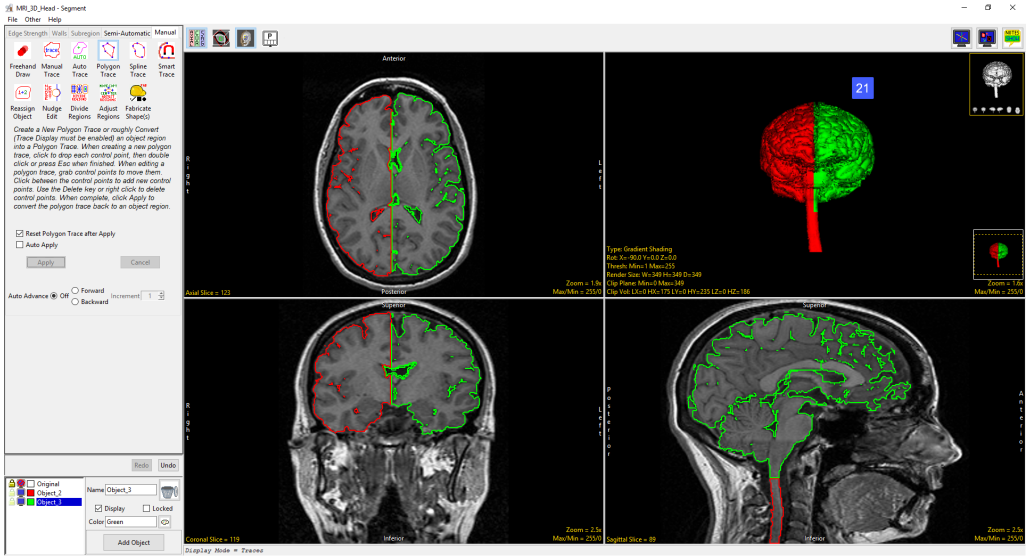


Region Definition and Region Modification with Polygon Trace (continued)

- The brain on slice 123 has been split into two objects representing the left and right hemisphere [18].
- The Polygon trace tool can also be used to edit 3D objects. To subsegment a 3D region define a Polygon trace over the left hemisphere of the brain in the Rendering window [19] and then click Apply [20].



- All voxels not assigned to a locked object within the trace (and all voxels along the ray path) have be assigned to the selected object [21].



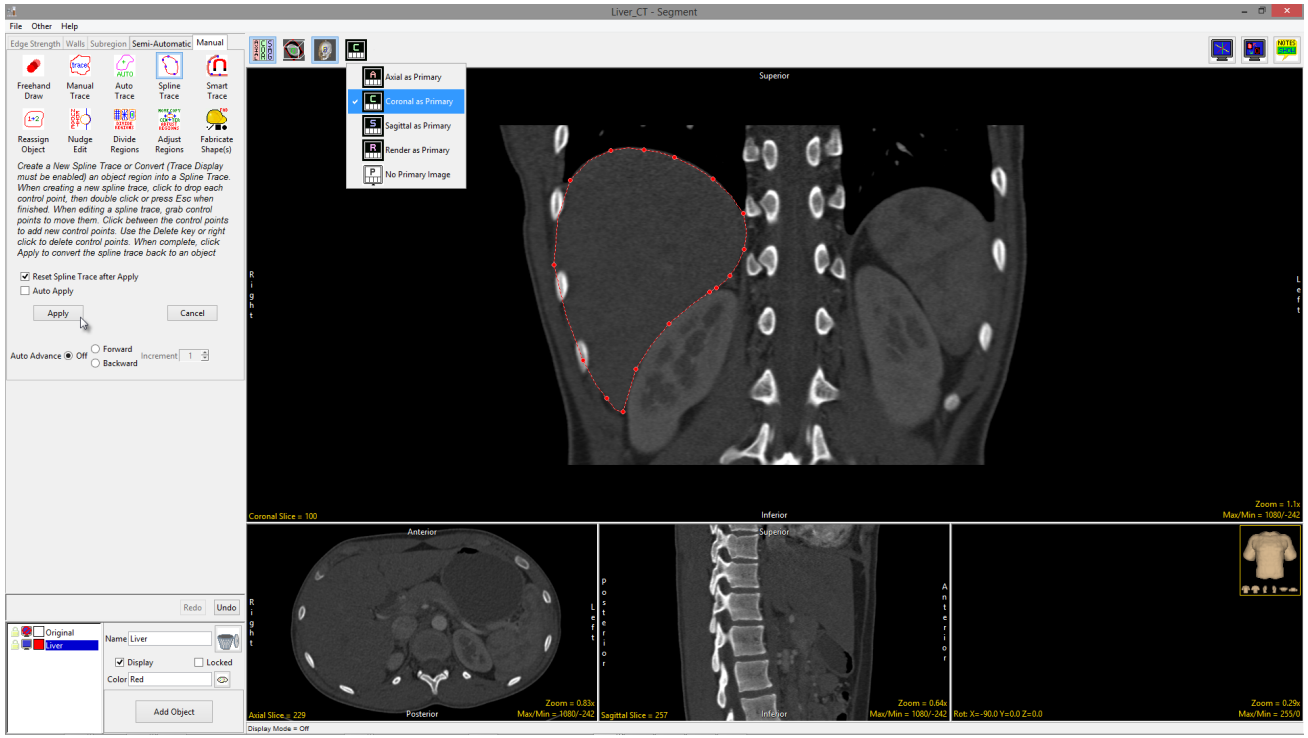
Spline Trace

The Spline Trace tool allows users to define curved regions of interest. Splines are flexible curve traces with movable control points that are useful for creating smooth edge traces.

The available options are as follows:

Reset Spline Trace after Apply: Resets (deletes) the spline trace after the region is defined. Spline traced regions are defined after the user double-clicks or presses the escape (Esc) key to close the trace ending the tracing process, the trace is applied when the Apply button is clicked, the 'A' key on your keyboard is pressed, the user right-clicks on the spline trace and selects Apply from the menu or the Auto Apply option is enabled.

Auto Apply: When selected the spline trace is automatically applied once the user double-clicks or presses the escape key to close the trace.



Spline Trace Options

Auto Advance: The auto advance option automatically moves users to a new slice, as defined by the auto advance options, once the current edit is defined. Note the auto advance will occur after the user releases the left mouse button and the edit is applied to the current slice. The auto advance option is a productivity tool allowing users to move through the image data without having to move the cursor from the current orientation window that regions are being defined on. The following options are available.

- Off: Off is the default option for auto advance. When off is selected auto advance is disabled.
- Forward: Specifies that auto advance will move forward through the image data (slice number increases).
- Backwards: Specifies that auto advance will move backwards through the image data (slice number decreases).
- Increment: Specifies the number of slices the auto advance will move forward or backwards.

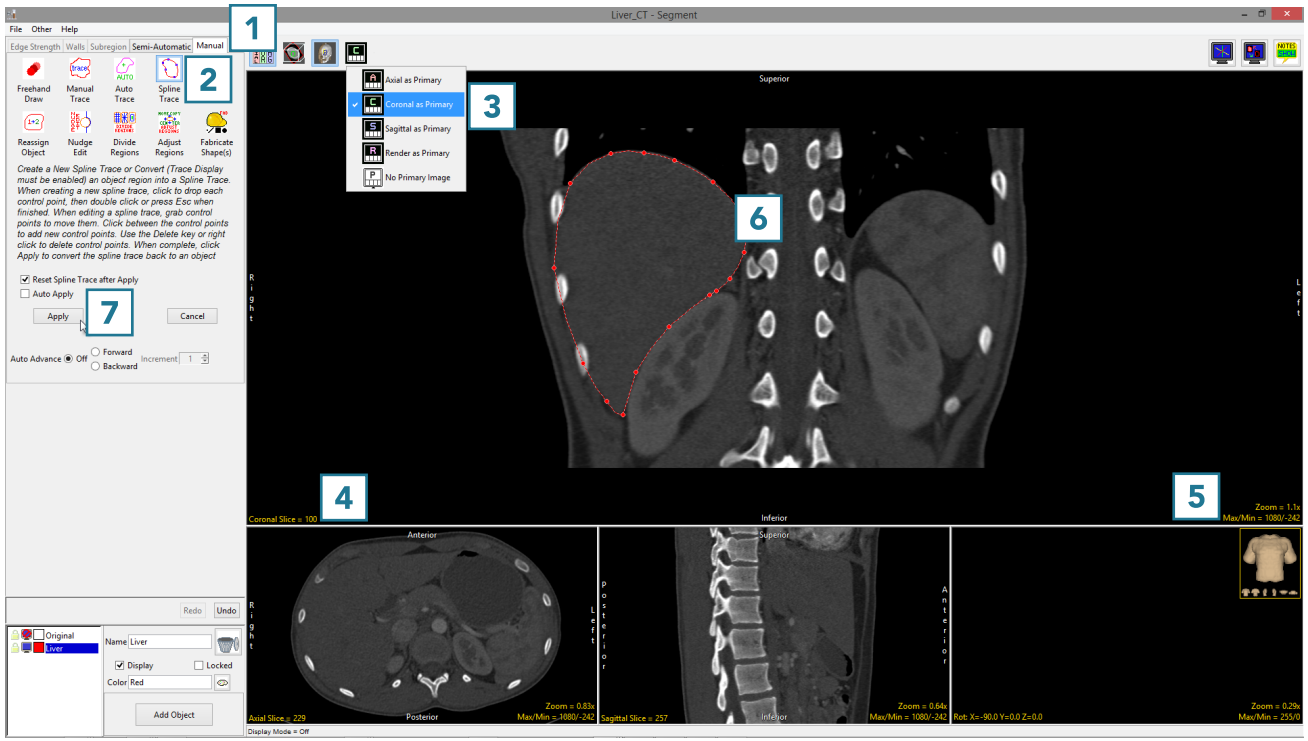
Right click options: Right clicking on the Spline trace provides users with the following options:

- Apply: Applies the trace.
- Cancel: Cancels the trace, deleting the trace and controls points.
- Auto Apply on Control Point Adjust: This option is only available when Auto Apply is enabled and when editing a Spline Trace or trace converted to a Spline Trace. When selected any edits made to the trace will be automatically applied when a control point is moved.
- Delete Control Point: Deletes the control point the cursor if currently over.
- Delete Spline: Deletes the trace and controls points.

Note: Clicking on an object border when the Spline Trace is selected will convert the object region into a spline with adaptable control points.

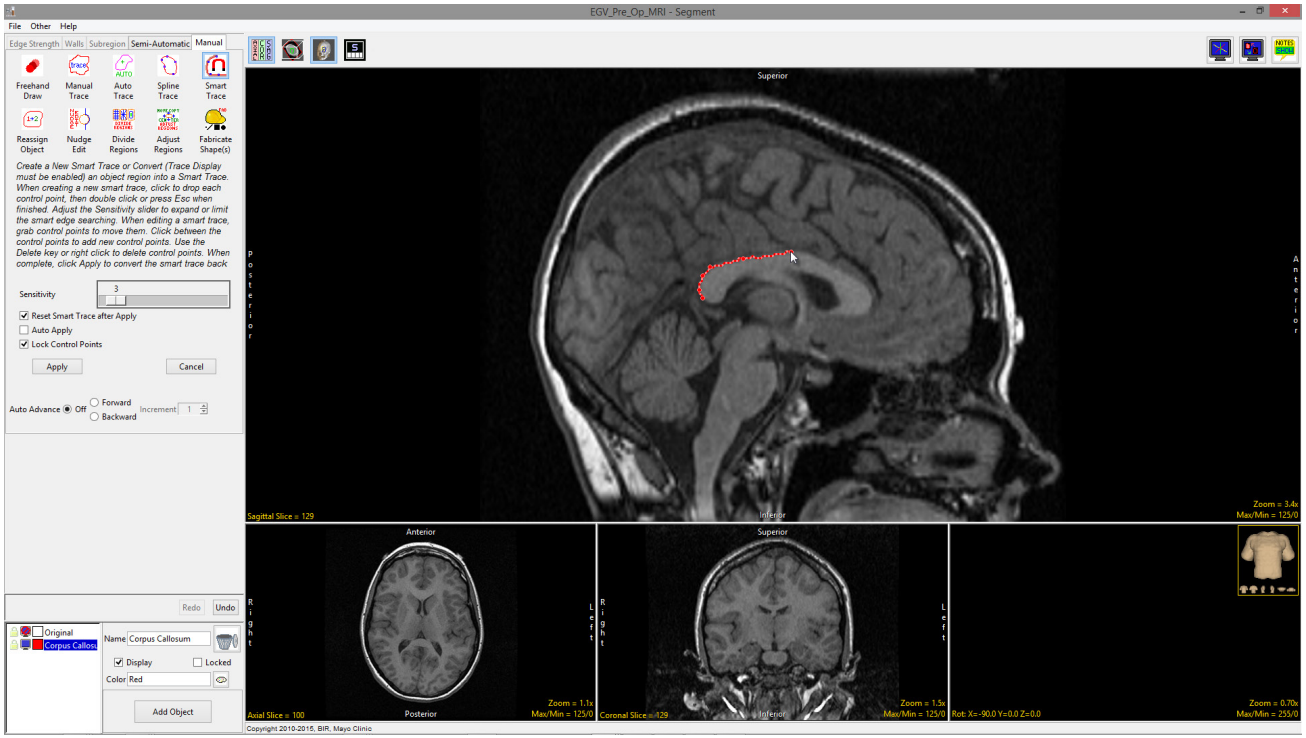
Using Spline Trace to Define a Region of Interest

- Select a data set and open Segment.
- Select Manual [1] and choose Spline Trace. [2]
- Set the primary display to Coronal [3] and double-click Slice [4] to move to coronal slice 100.
- To begin drawing a spline, position the cursor on the image and left-click [5]. Reposition the cursor and left-click to continue drawing the spline around the object of interest [6.]
- Double-click to end and close the spline.
- Note that control points can be moved. Click a control point, drag to a new location and the Spline will update.
- Select Apply [7] to apply the spline trace.
- Use File > Save Object Map to save your work.



Smart Trace

The Smart Trace tool detects regions of high rate of change of voxel intensity (gradient) representing edges. The tool snaps to the edges of these regions. The sensitivity of the smart edge can be adjusted using the slider or the mouse scroll wheel.



The following options are available:

Sensitivity: The sensitivity of the smart edge can be adjusted using the slider or the mouse scroll wheel. The lower the value the less sensitive the tool is, the higher the value the more sensitive the tool is.

Reset Smart Trace after Apply: Resets (deletes) the smart trace after the region is defined. Smart trace regions are defined after the user double-clicks to close and end the tracing process and then pressing the Apply button, selecting the 'A' key on your keyboard, or having the Auto Apply option selected.

Smart Trace Options

Auto Apply: When selected automatically applies the Smart Trace region.

Lock Control Points: Allows users to lock or unlock (default) the smart trace controls points. Unlocking the control points allows users to move the control points.

Auto Advance: The auto advance option automatically moves users to a new slice, as defined by the auto advance options, once the current edit is defined. Note the auto advance will occur after the user releases the left mouse button and the edit is applied to the current slice. The auto advance option is a productivity tool allowing users to move through the image data without having to move the cursor from the current orientation window that regions are being defined on. The following options are available.

- Off: Off is the default option for auto advance. When off is selected auto advance is disabled.
- Forward: Specifies that auto advance will move forward through the image data (slice number increases).
- Backwards: Specifies that auto advance will move backwards through the image data (slice number decreases).
- Increment: Specifies the number of slices the auto advance will move forward or backwards.

Right click options: Right clicking on the Smart Trace provides users with the following options:

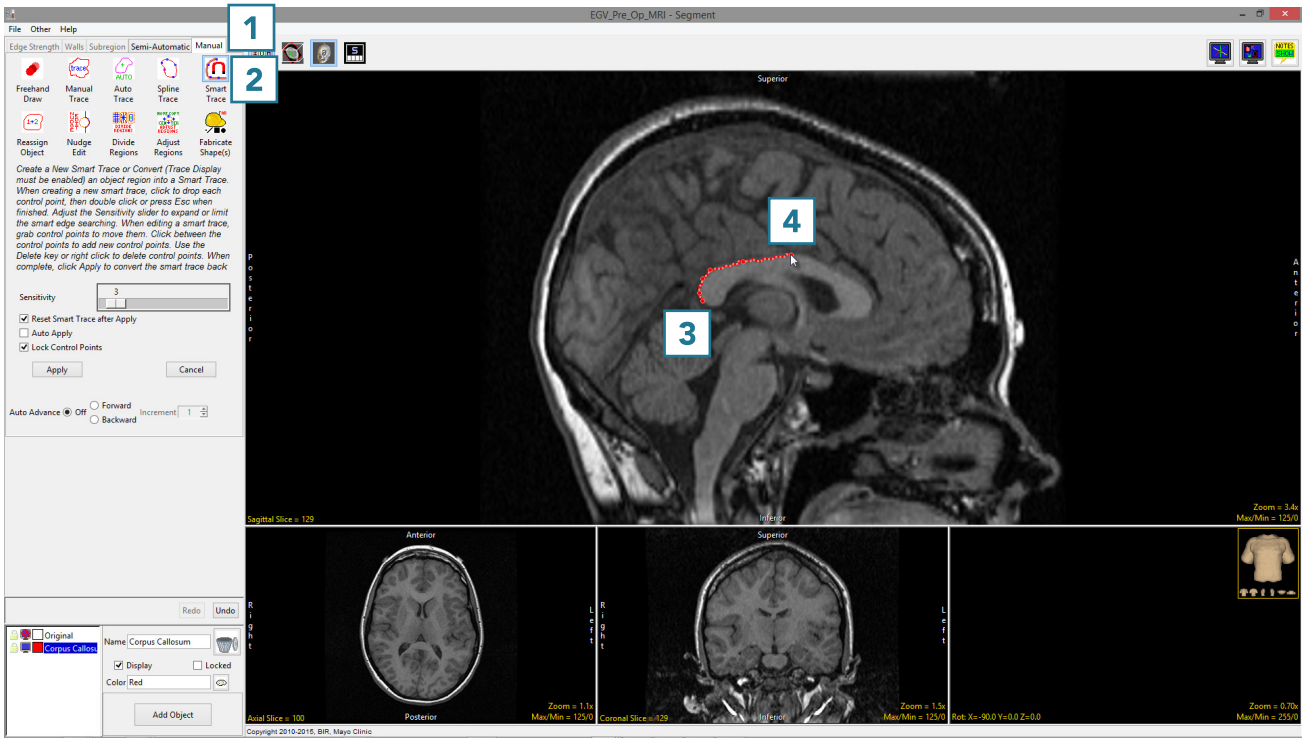
- Apply: Applies the trace.
- Cancel: Cancels the trace, deleting the trace and controls points.
- Auto Apply on Control Point Adjust: This option is only available when Auto Apply is enabled and when editing a Smart Trace or trace converted to a Smart Trace. When selected any edits made to the Smart Trace will be automatically applied when a control point is moved.
- Delete Control Point: Deletes the control point the cursor if currently over.
- Delete Spline: Deletes the trace and controls points.

Note: Clicking on an object border when the Smart Trace is selected will convert the object region into a Smart trace with adaptable control points.

Smart Trace Region Definition

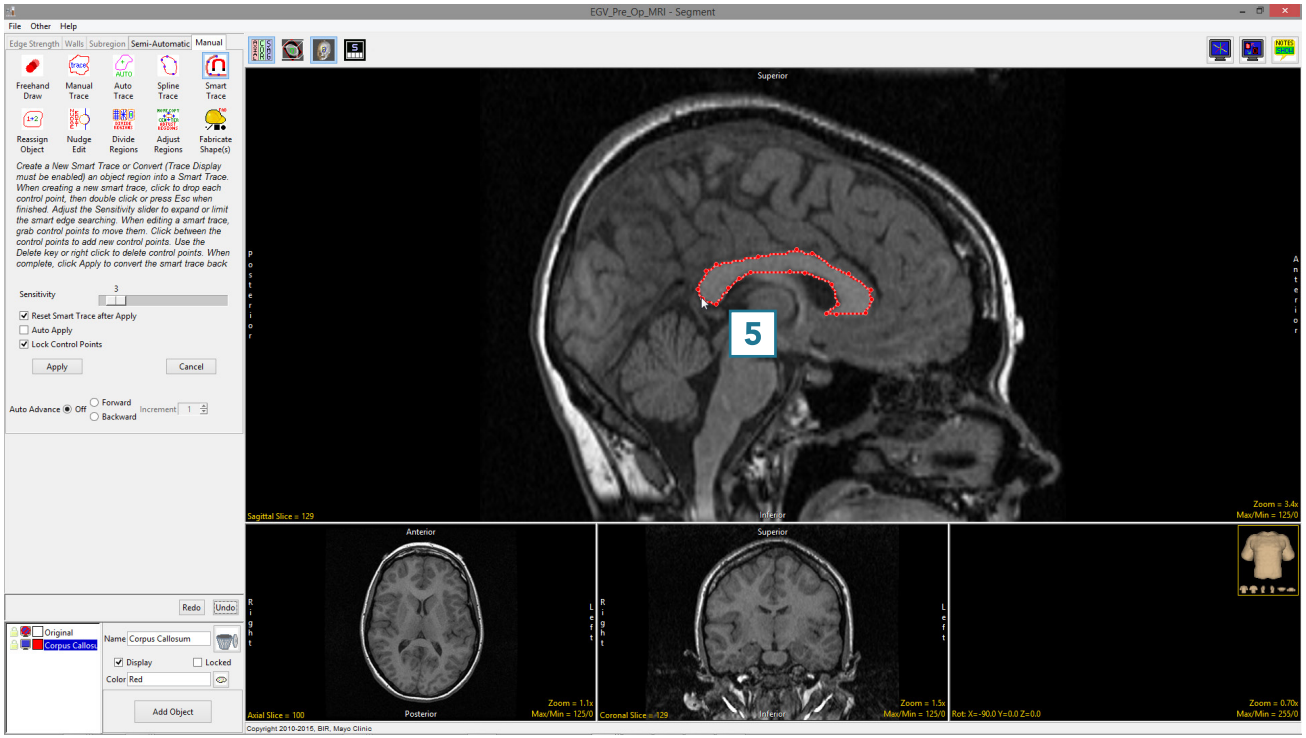
To follow along, download the data set MRI_3D_Head from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the data set and open Segment.
- Select Manual [1] and choose Smart Trace. [2].
- Left-click in the image to set the first control point [3].
- Move the cursor along the edge of the object and click to set additional control points [4]. To adjust the sensitivity of the smart edge, use the mouse scroll wheel. Scrolling up will increase the sensitivity and scrolling down will decrease sensitivity.



Smart Trace Region Definition (continued)

- When the trace is complete, double-click to close the spline [5].
- If needed, control points can be moved. Uncheck the Lock Control Points option, click on a control point and drag it to a new location. The Smart Trace will update.
- Control points can be deleted. Select a control point, right-click and select Delete Control Point.
- Select Apply or use the A key to apply the trace.
- Use File > Save Object Map to save your work.



Reassign Object

The Reassign Object tool allows users to interactively reassign the voxels of one object to another object. First, select the object to which the voxels will be reassigned from the object control window. Then, select a reassignment type. Finally, to establish a seed pixel, click on the object to be reassigned. Object reassignment occurs immediately. Reassignment options are described in the table below:

Reassignment Types

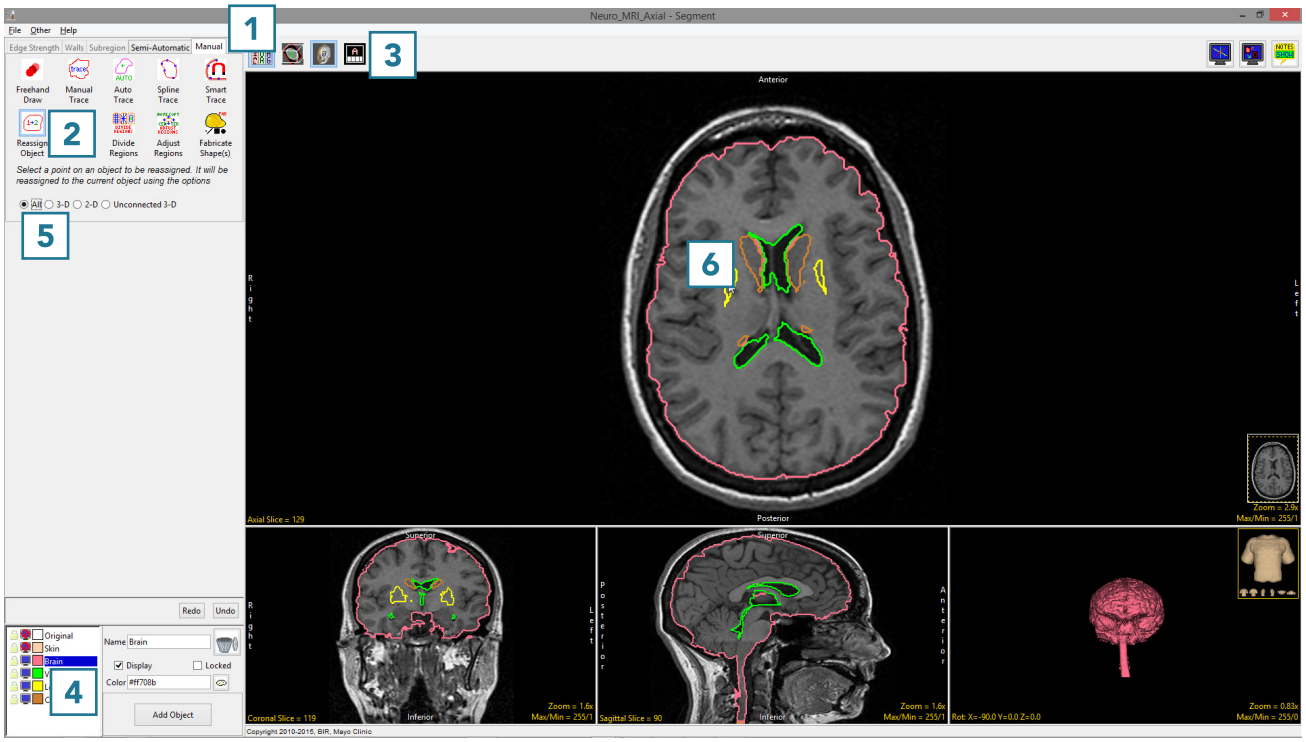
Reassignment Type	Action
All	All voxels in the selected object are reassigned to the current object
3D	All voxels in the selected object that are connected in 3D to the seed pixel are reassigned to the current object
2D	All voxels in the selected object that are connected in 2D to the seed pixel are reassigned to the current object
Unconnected 3D	All voxels in the selected object that are not connected in 3D to the seed pixel are reassigned to the current object

Reassigning Objects

Here we will reassign the voxels of one object to another object.

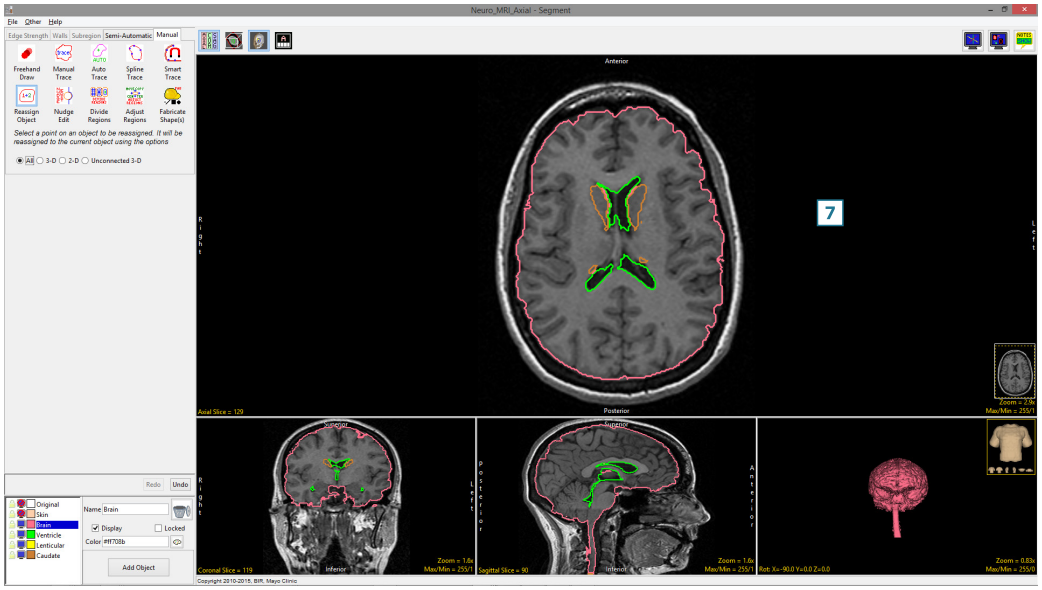
To follow along, download the data set MRI_3D_Head from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the data set and open Segment.
- Use File > Load Object Map to load the corresponding object map.
- Select Manual [1] and choose Reassign Object [2].
- Set the primary display to axial [3] and move to axial slice 130.
- Switch the display of the Skin object off and switch on the display of the Lenticular and Caudate objects. Select the Brain object and change the Opacity level of the Brain to 2 [4].
- Set the reassignment type to All [5] and click on the yellow Lenticular object [6].

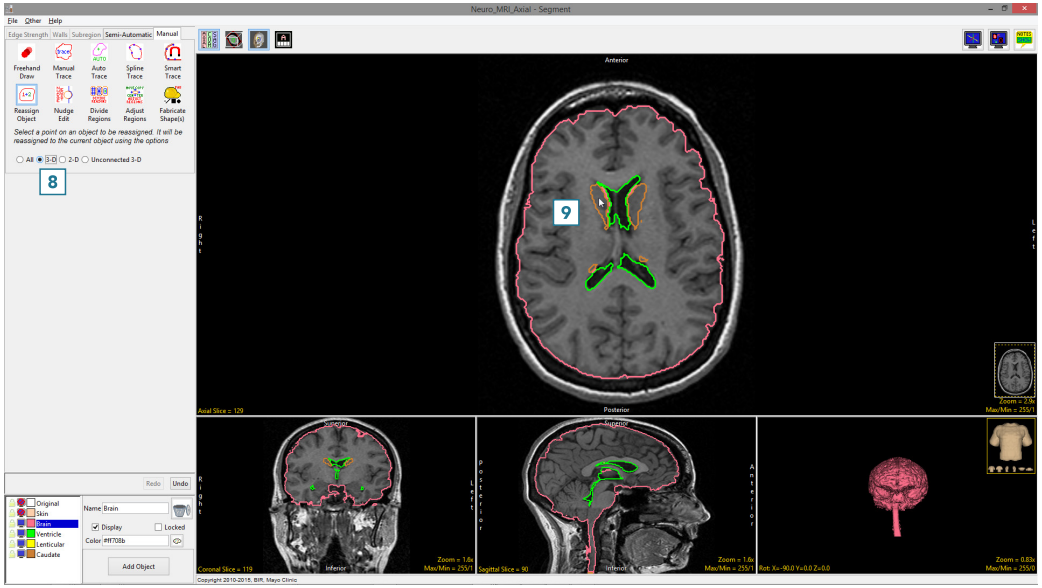


Reassigning Objects (continued)

- Note that all the voxels of the Lenticular object have been reassigned to the Brain object [7].

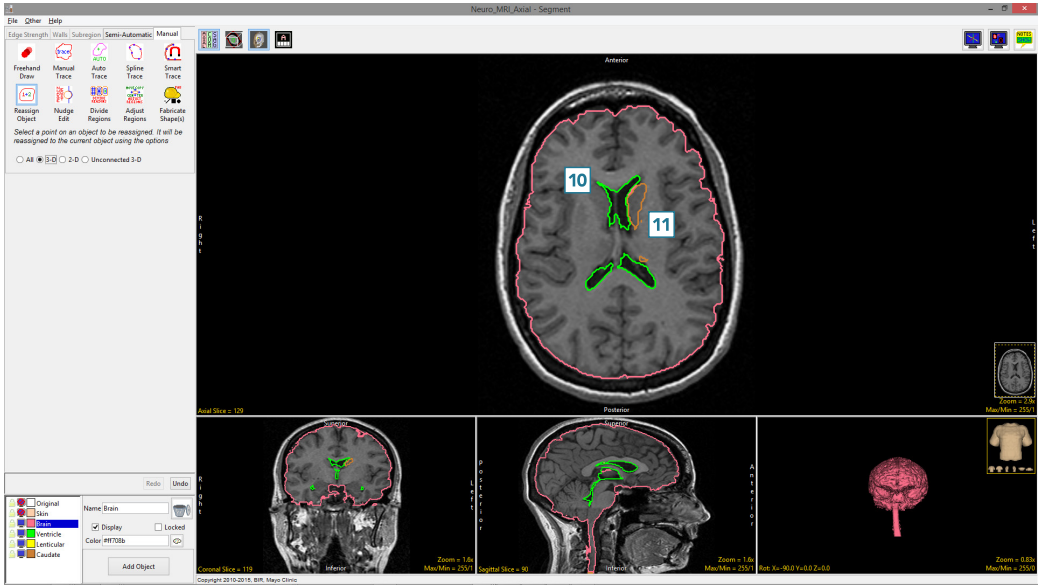


- Set the reassignment type to 3D [8] and click on the brown Caudate object on the right side of the brain [9].

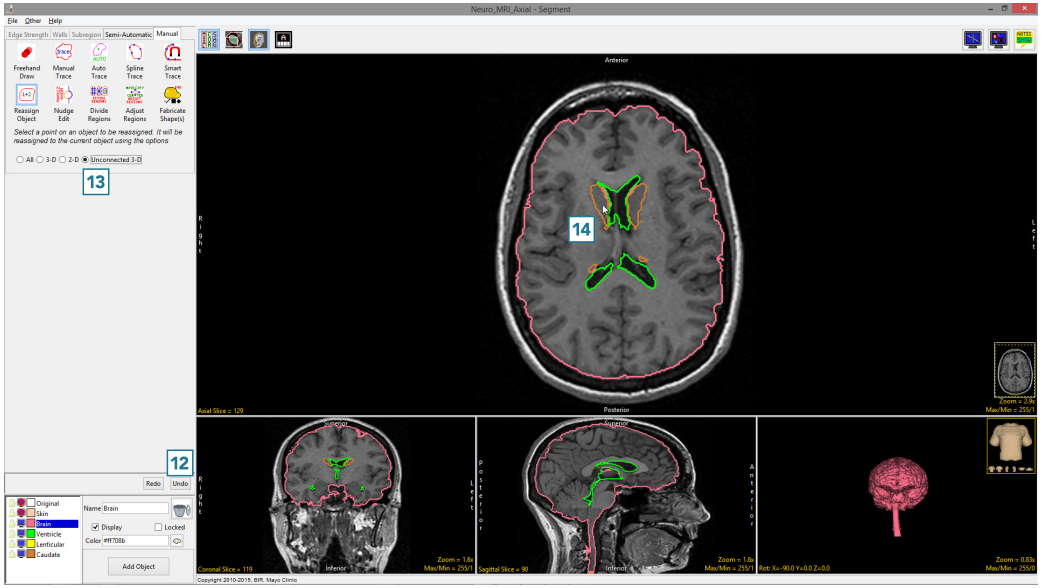


Reassigning Objects (continued)

- Note that the all the voxels of the Caudate object connected to the seed pixel have been reassigned to the Brain object [10]. As the left caudate nucleus is not connected to the right caudate nucleus, that part of the object remains [11].

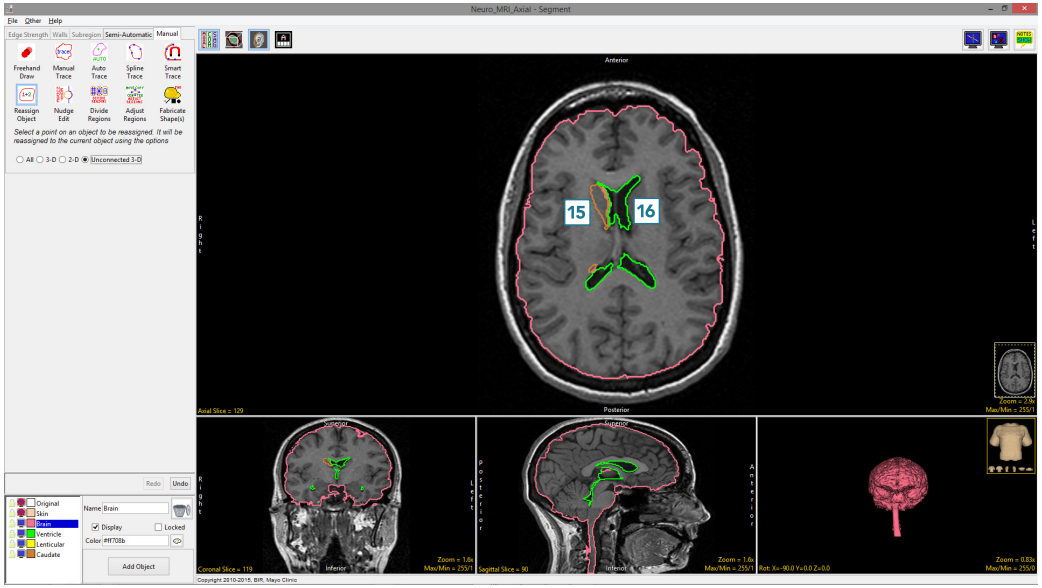


- Click Undo [12] and set the reassignment type to Unconnected 3D [13].
- Click on the brown Caudate object on the right side of the brain [14].

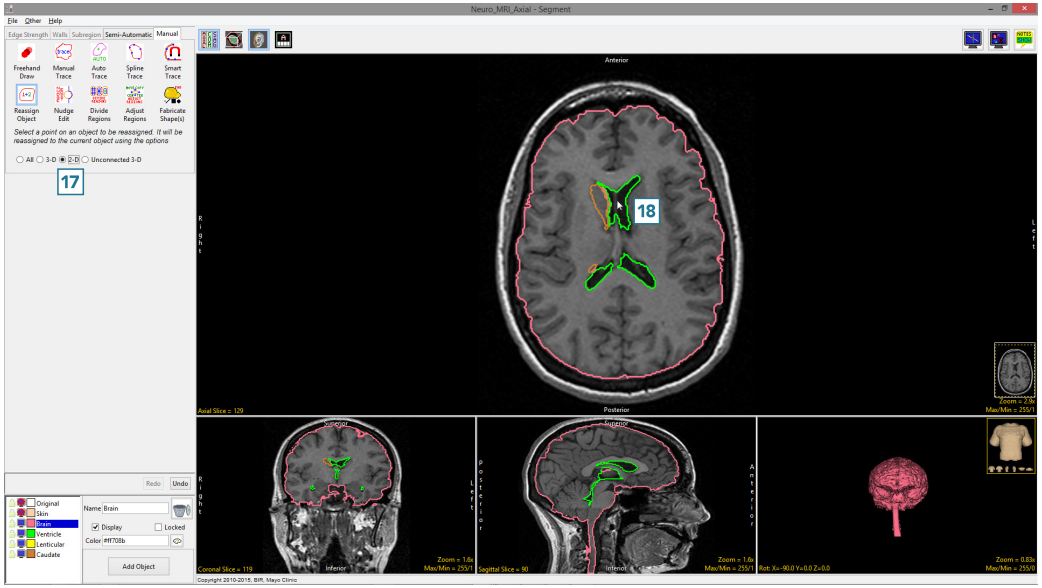


Reassigning Objects (continued)

- Note that this time, all the voxels assigned to the Caudate object connected to the seed pixel have been kept [15] while those unconnected voxels representing the left caudate nucleus have been reassigned to the Brain object [16].

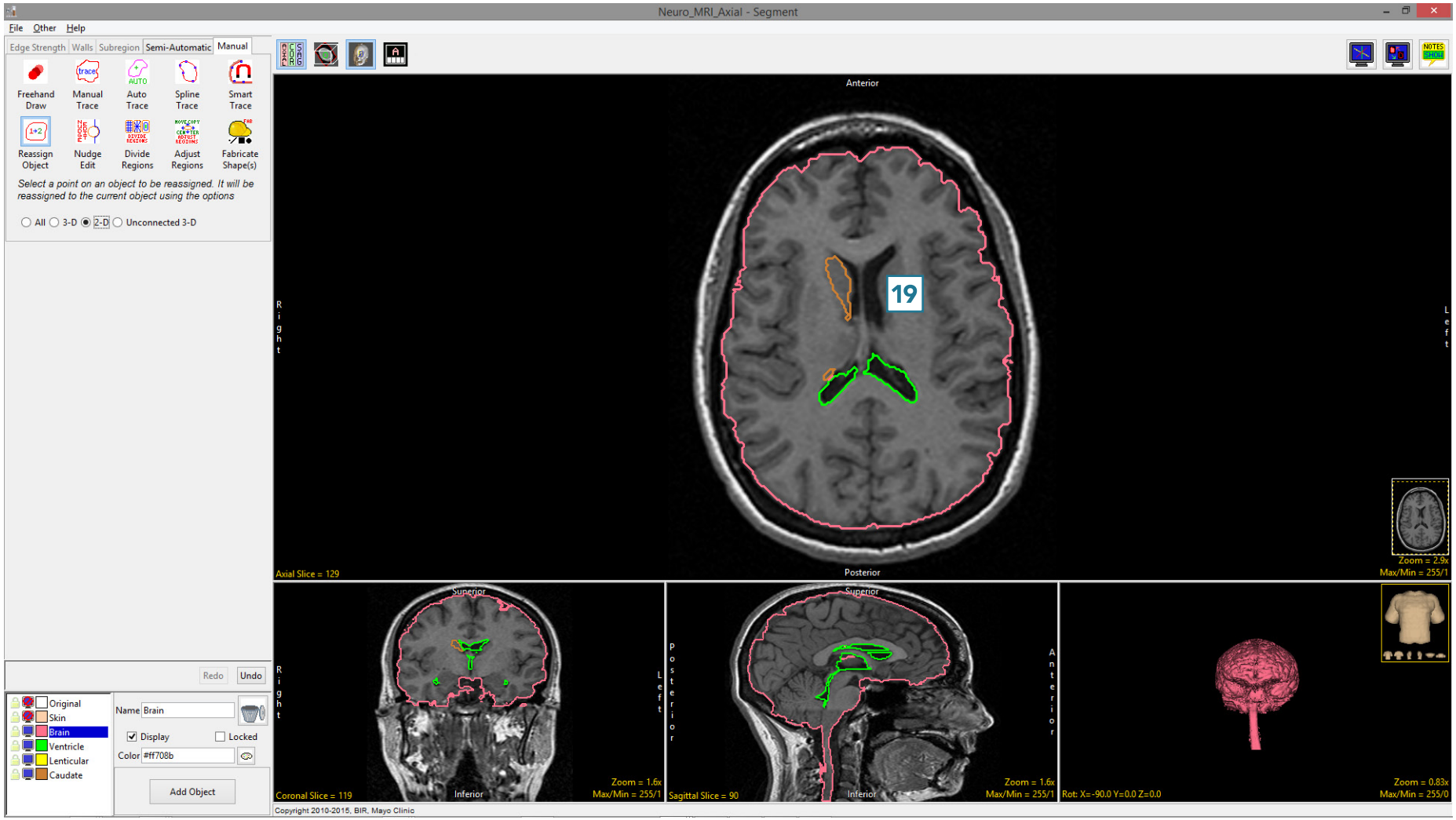


- Note that for the All, 3D and Unconnected 3D reassignment types, seed points can be set on the 3D rendering.
  - Set the reassignment type to 2D [17] and click on the anterior section of the green Ventricle object [18].

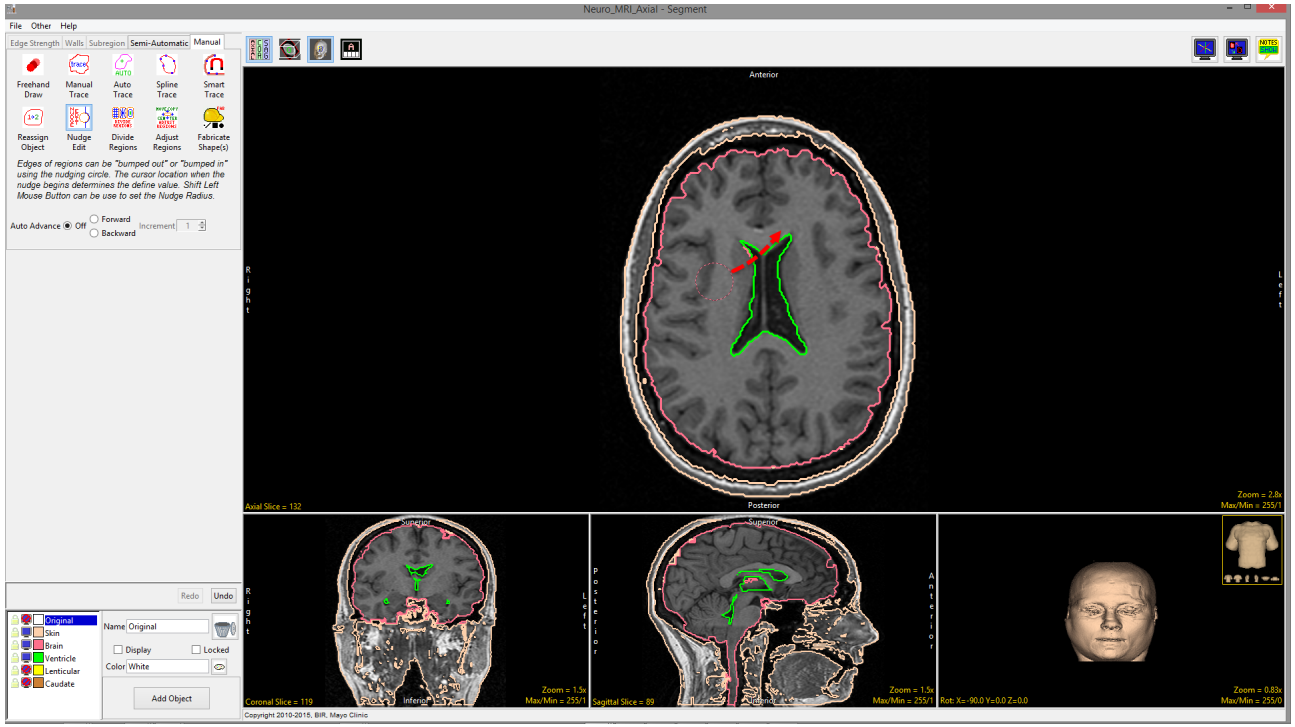


Reassigning Objects (continued)

The voxels assigned to the Ventricle object, which are connected to the seed pixel only on this 2D slice have been reassigned to the Brain object [19].



Nudge Edit



Nudge Edit enables users to manually edit borders of defined regions. The tool allows object borders to be pushed inwards or outwards using an adjustable circular cursor. The size of the cursor can be adjusted using the middle mouse button. When Nudge Edit is selected the cursor mode will update to the Nudge Edit tool when an image is clicked on. Available options include:

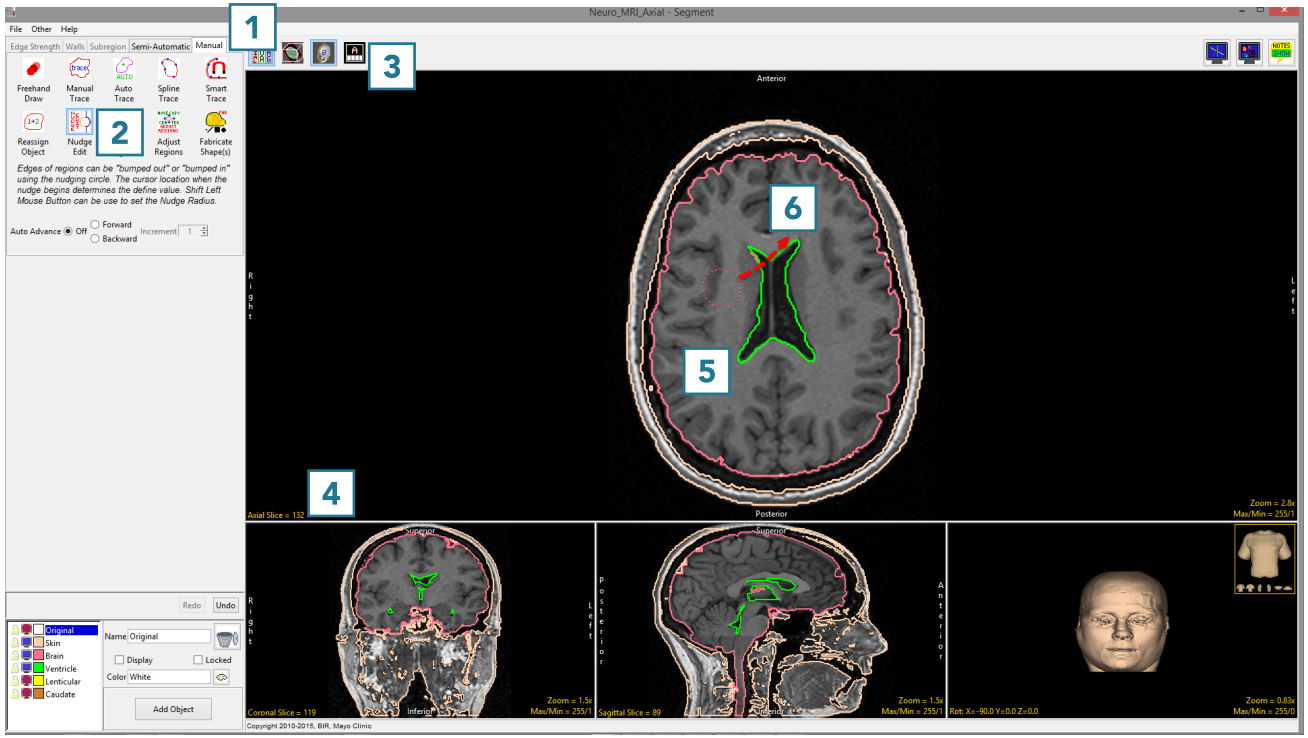
Auto Advance: This option automatically moves users to a new slice as defined by the auto advance options, once the current edit is defined. Note the auto advance will occur after the user releases the left mouse button and the edit is applied to the current slice. The auto advance option is a productivity tool allowing users to move through the image data without having to move the cursor from the current orientation window that regions are being defined on. The following options are available.

- Off: Off is the default option for auto advance. When off is selected auto advance is disabled.
- Forward: Specifies that auto advance will move forward through the image data (slice number increases).
- Backwards: Specifies that auto advance will move backwards through the image data (slice number decreases).
- Increment: Specifies the number of slices the auto advance will move forward or backwards.

Editing Object Borders using Nudge Edit

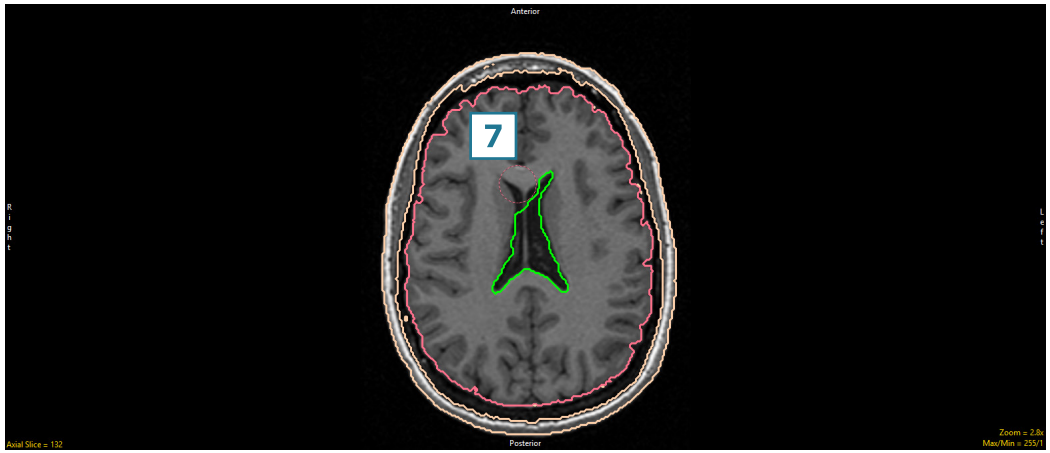
To follow along, download the data set MRI_3D_Head from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the data set and open Segment.
- Select File > Load Object Maps and load MRI_3D_Head.obj.
- Select Manual, [1] then choose Nudge Edit [2].
- Set the primary display to Axial [3] and move to Axial slice 132 [4].
- To edit the border of the Brain and Ventricle objects click in the brain. The circular nudge tool cursor will appear [5].



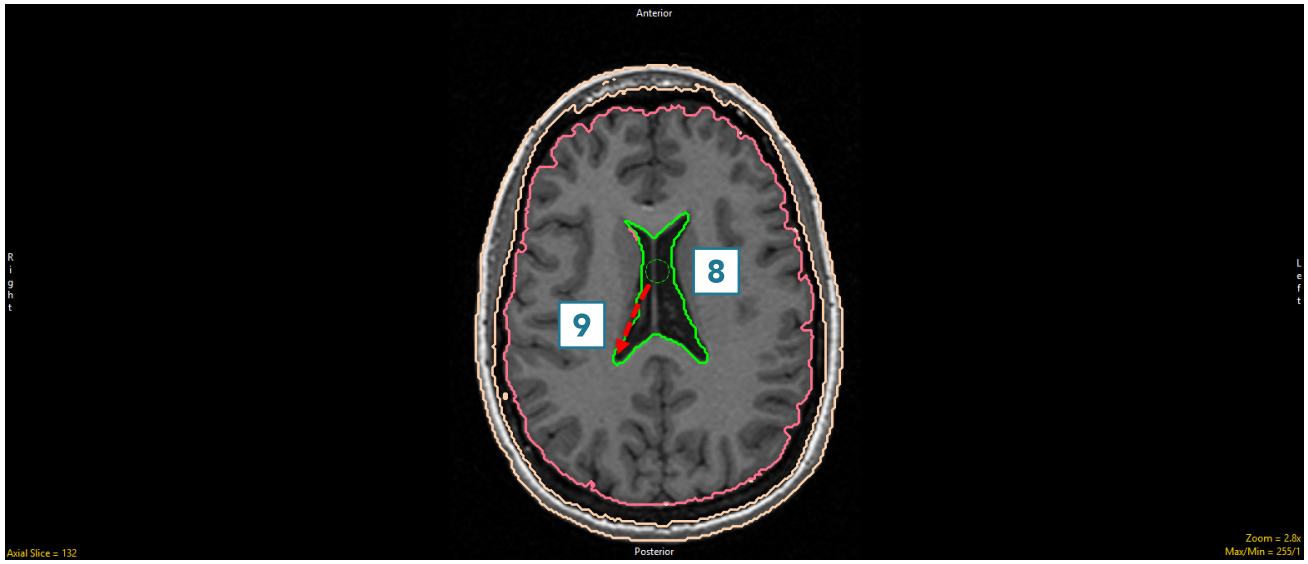
Note the color of the cursor will match the object being nudged.

- Move the cursor to edit the border [6].
- The borders of the Brain and Ventricle objects will be updated as the cursor moves through [7].

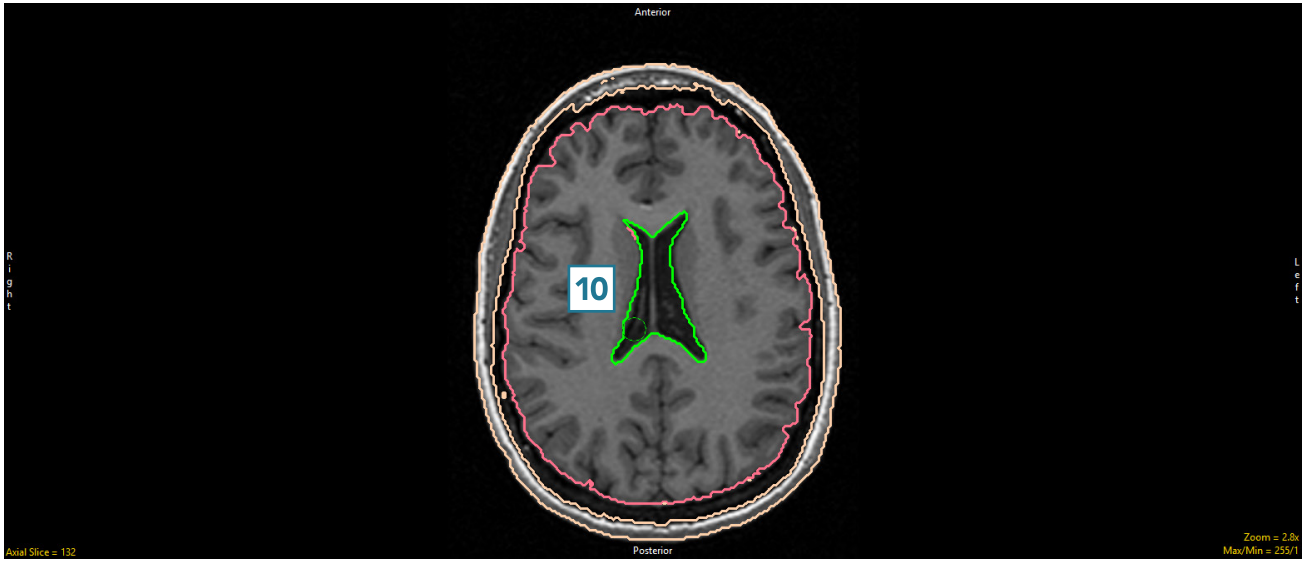


Editing Object Borders using Nudge Edit (continued)

- Click Undo.
- Using the middle mouse button, change the size of the cursor to 5, then click in the Ventricle object [8]. Push the border of the Ventricle object out to edit the object boundary [9].



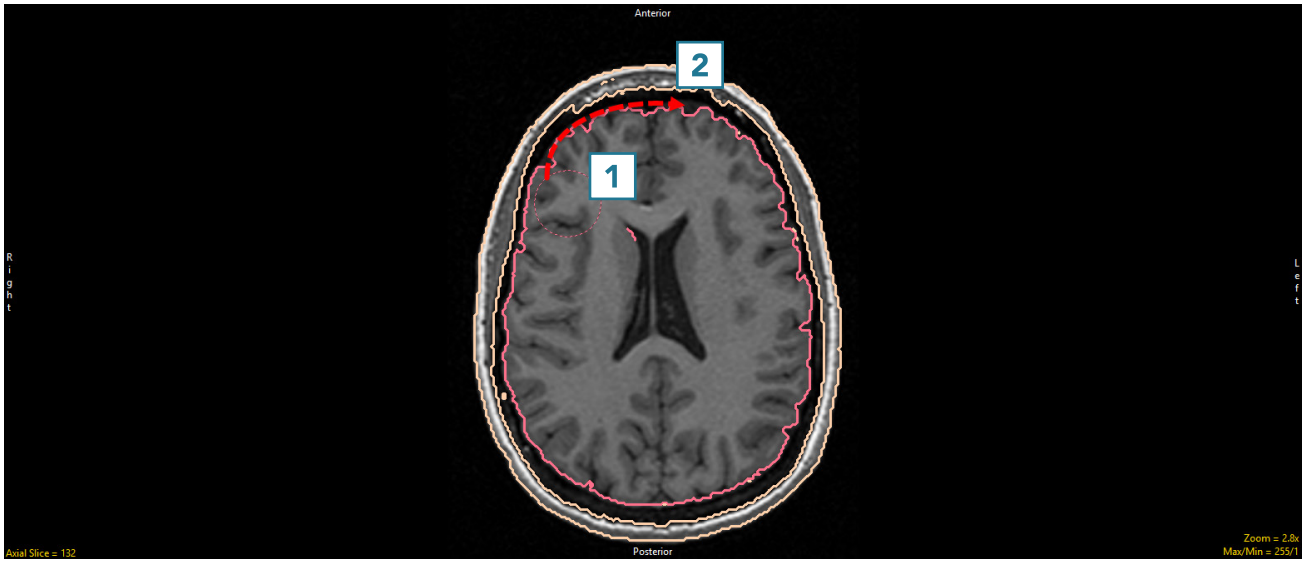
- The borders of the Brain and Ventricle objects will be updated as the cursor moves through [10].

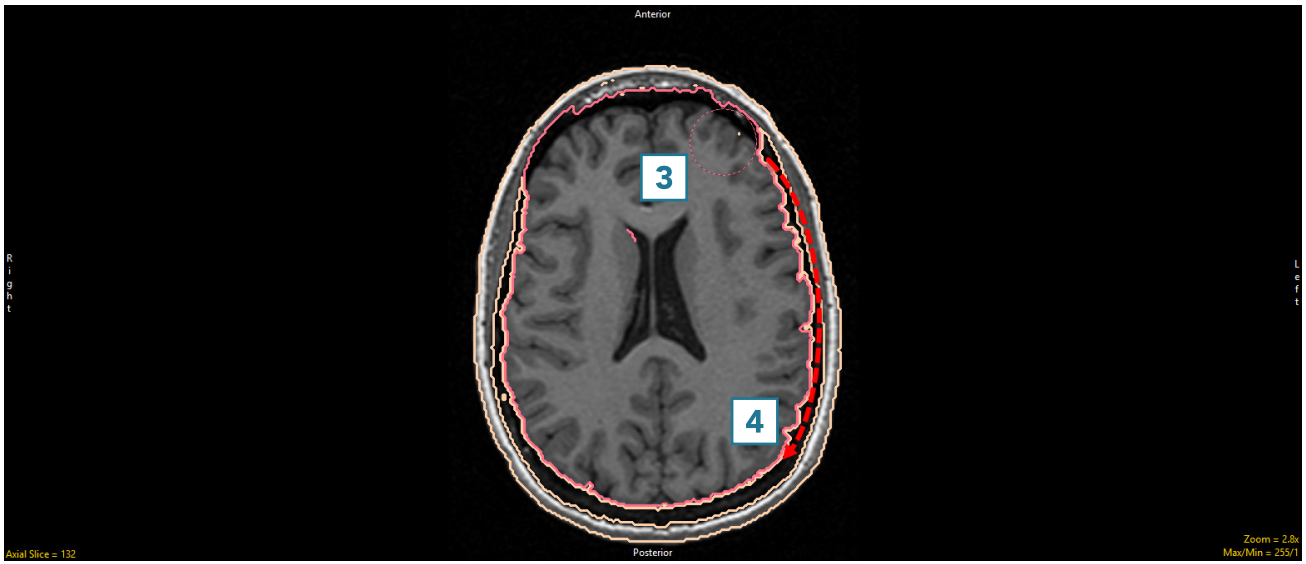


Using the Nudge Edit Tool with Locked Objects

The Nudge Edit Tool can also be used in conjunction with locked objects. When measuring the intracranial area on a certain slice, after reassigning the Ventricle object on this slice to the Brain object using Reassign Object, the Skin object can be locked and the brain object pushed out using the Nudge tool to the border of the skin object.

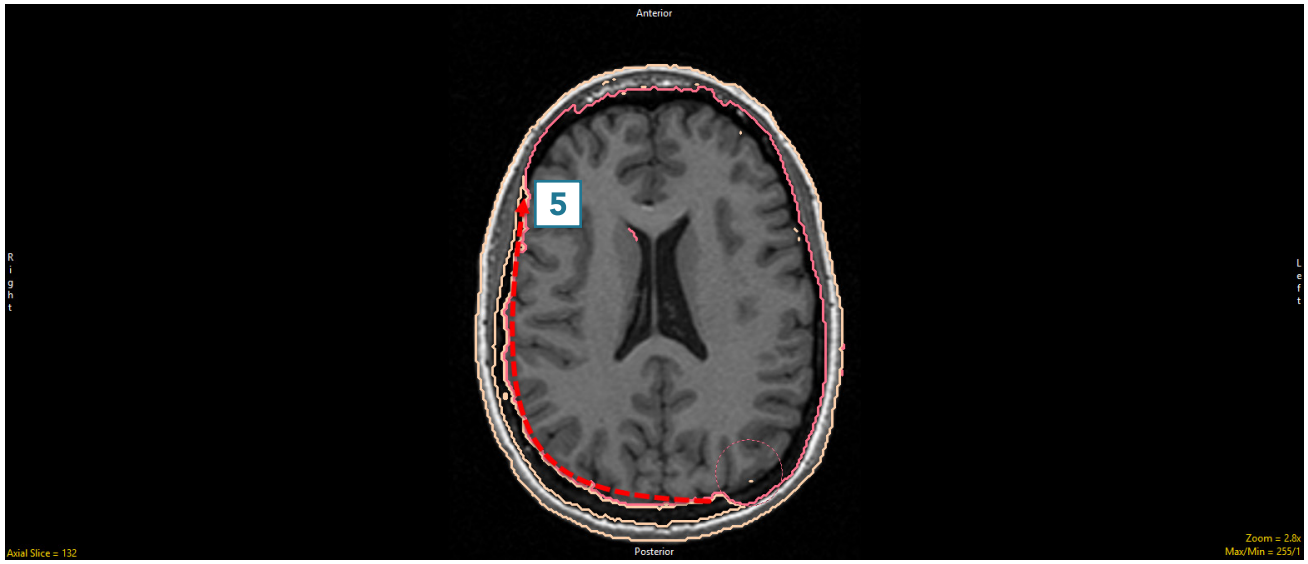
- Use Reassign Object to reassign the Ventricle object on Axial slice 132 to the Brain object.
- Lock the Skin object.
- Select the Nudge Edit tool.
- Click in the Brain [1] and move the Nudge Edit tool into the intracranial space [2] between the Brain and Skin objects.
- Note that the Brain object will be pushed into the intracranial space but not into the locked skin object [3].
- Continue moving the Nudge tool through the intracranial space [4].



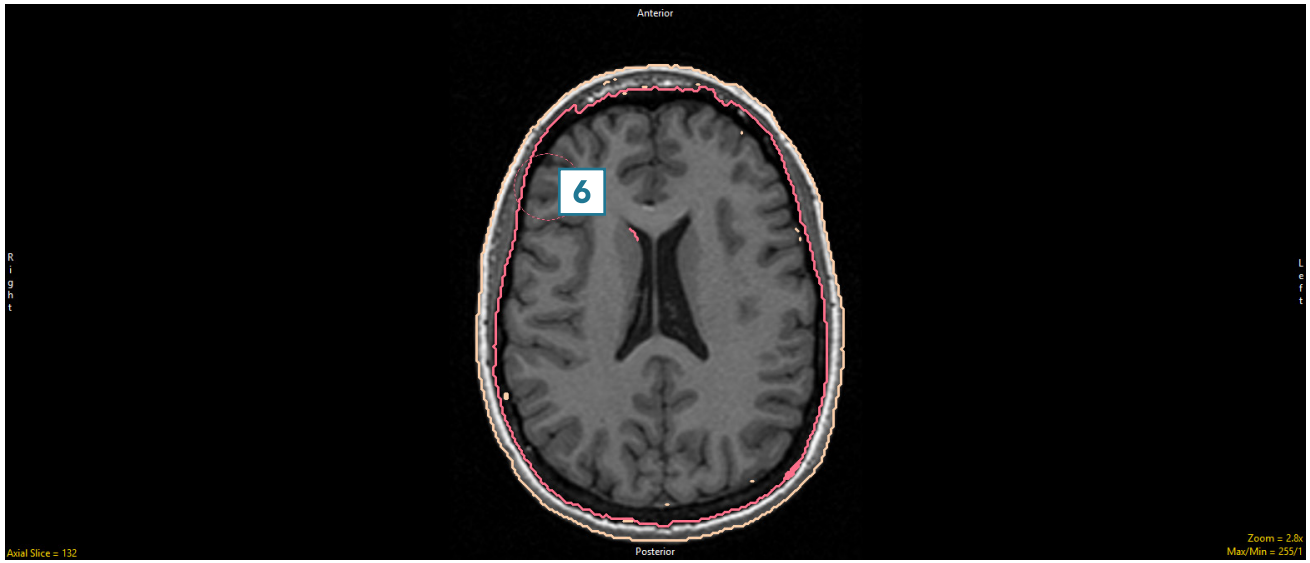


Using the Nudge Edit Tool with Locked Objects (continued)

- Note that if the cursor moves past the Skin object into the Original object, voxels in the Original object can still be added to the Brain object using the Nudge Edit tool. To prevent this, lock the Original object as well.

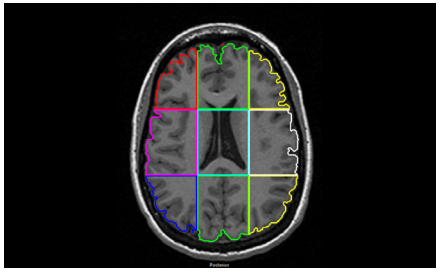
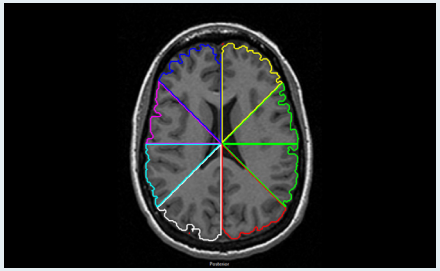
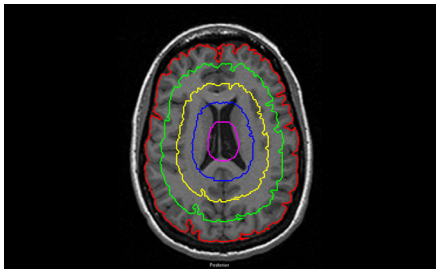


- Continue moving through the intracranial space [5] to complete the edit [6].



Divide Regions

The Divide Regions tool allows users to divide objects into subdivisions based upon the division type selected. Users can choose between Grid, Radial or Between Borders.

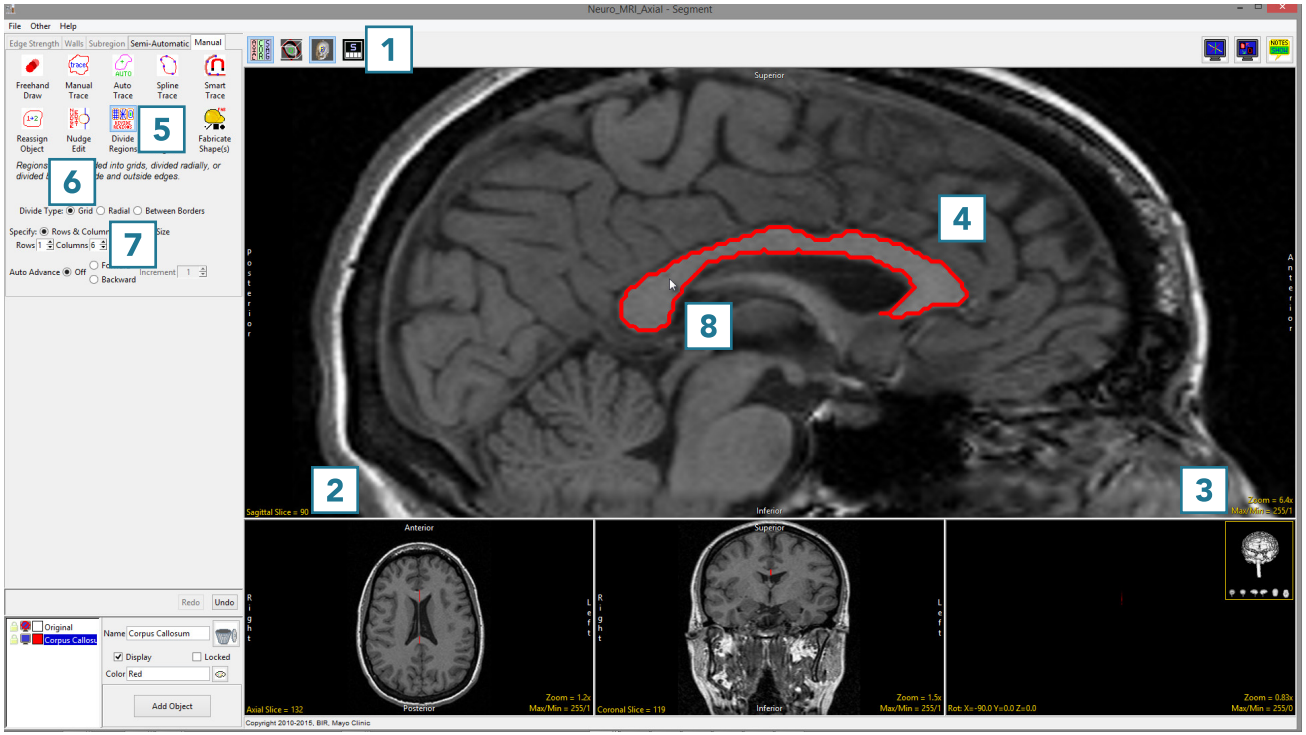
Divide Type	Function	Example
Grid	Divides selected object into rectangles. **Specify:** Controls how the object will be divided by specifying between Rows and Columns or Region Size. **Rows & Columns:** specifies the number of rows and columns the object will be divided into. **Region Size:** specifies the size (in pixels) of the rectangle that will be used to divide the object.	
Radial	Radially divides selected object, splitting the object into pie wedges. **Divisions:** specifies the number of divisions the structure will be split into. **Start Angle:** specifies the starting angle of the first division. **End Angle:** disabled by default., but when enabled, specifies the ending angle for the radial division.	
Between Borders	Divides object into concentric shapes. **Divisions:** specifies the number of concentric divisions the structure will be split into between borders. Enter the number into the text entry box or use the arrow up/down keys to set number.	

Grid Division of an Object

Grid division can be useful for subdividing structures into various anatomical substructures. Here we will perform a grid division of the corpus callosum (CC) on the mid-sagittal slice into its substructures.

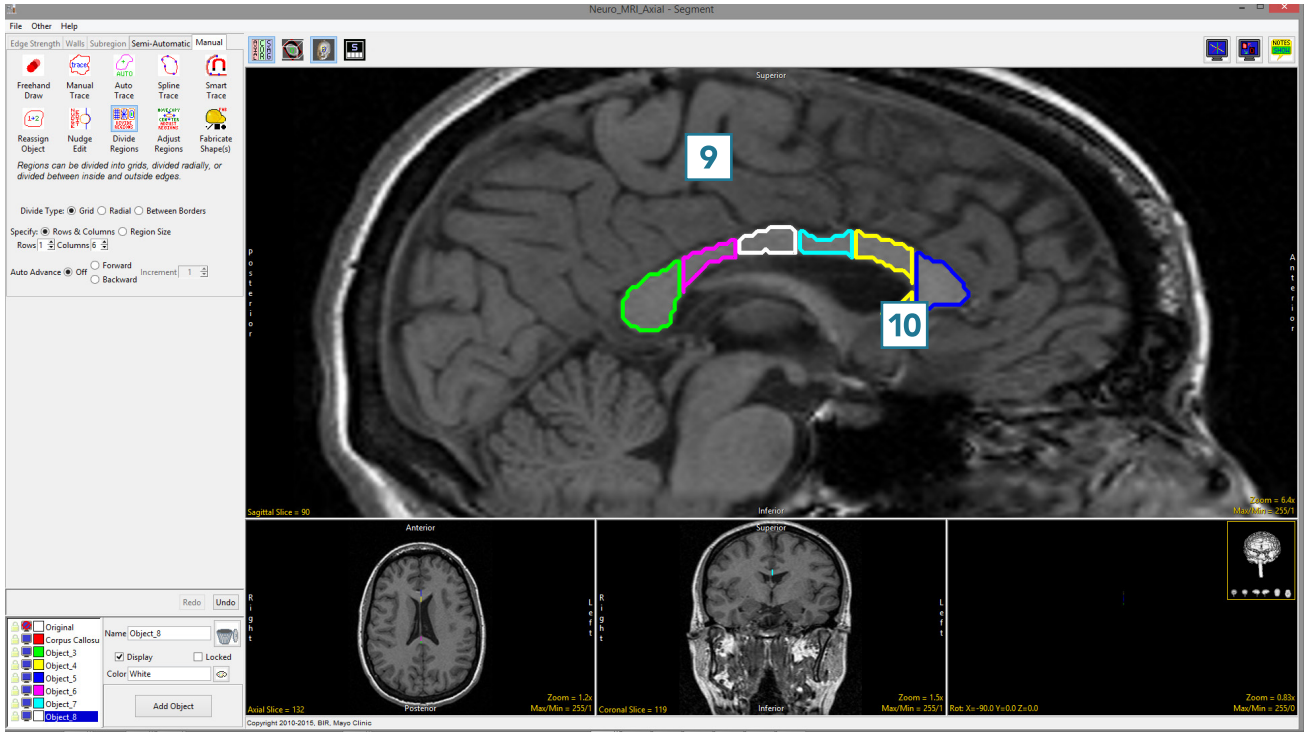
To follow along, download MRI_3D_Head from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the dataset and open Segment.
- Set the primary display to Sagittal, [1] move to the mid-sagittal slice [2] and Zoom to the CC [3].
- Select Manual and use either Smart Trace or Auto Trace to define the CC on the mid-sagittal slice [4].
- Select Divide Regions [5]. Set the Divide Type to Grid [6].
- Set the Number of Rows to 1 and Columns to 6 [7].
- Click in the CC [8].



Grid Division of an Object (continued)

- The CC will be divided into 6 Subregions [9].
- Note that the Rostrum [10] will need to be assigned to a separate object. This can be achieved using the 2D reassignment option in the Reassign Object tool. Objects can be given the correct structural names (Splenium, Isthmus, Posterior Midbody, Anterior Midbody, Rostral Body, Genu and Rostrum) using the Object Control window.
- Use File > Save Object Map to save your work.

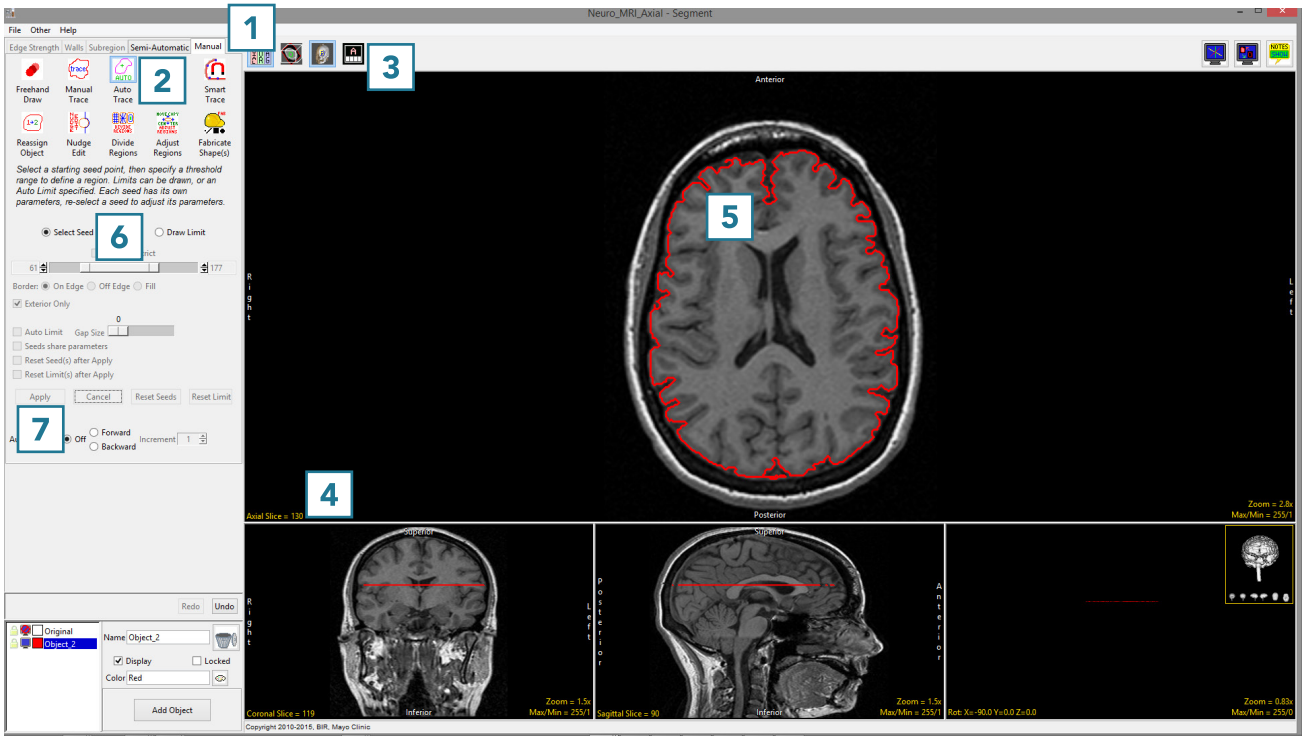


Radial Division of an Object

Like grid division, radial division of objects can be useful for subdividing structures into various substructures.

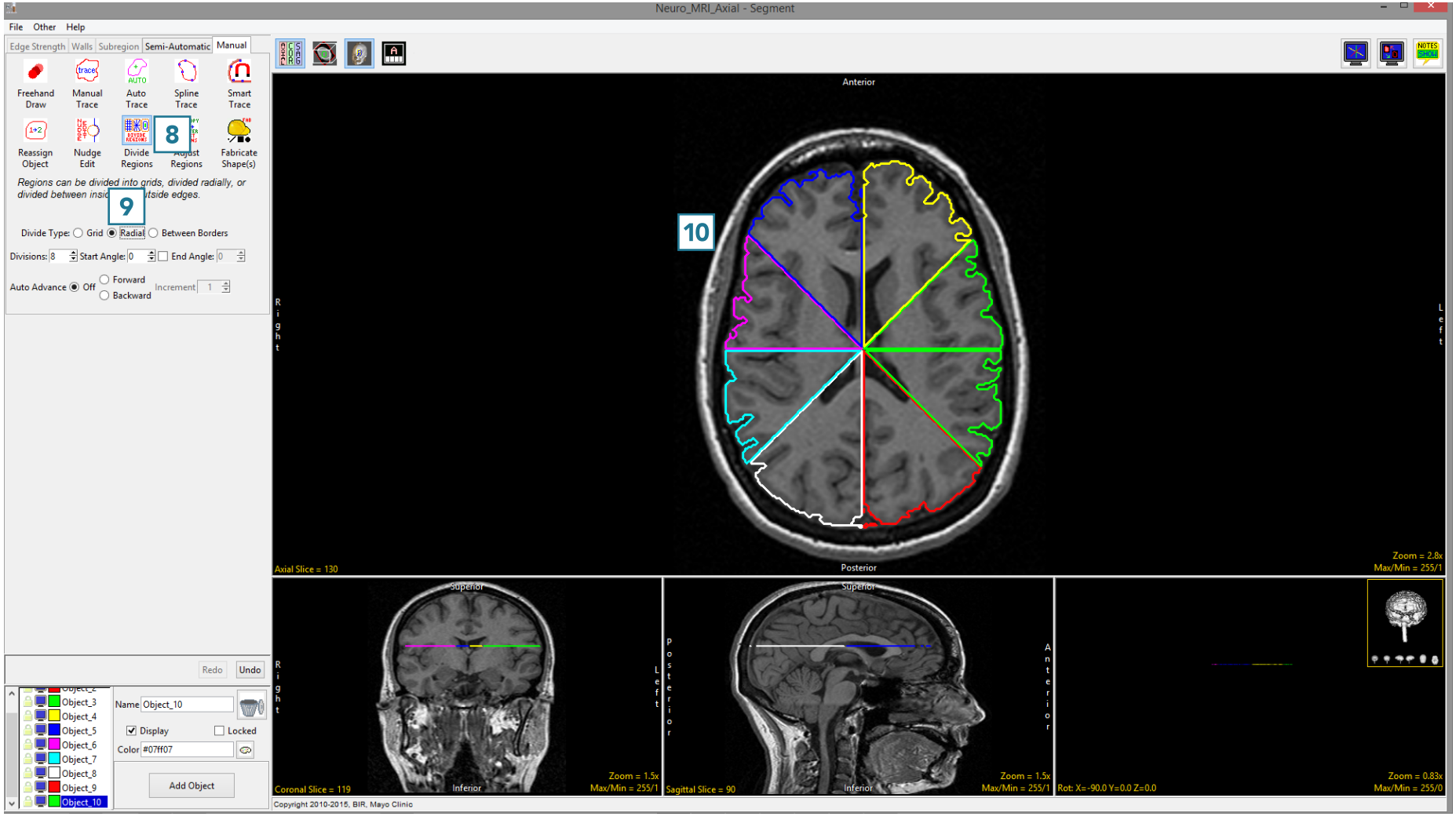
To follow along, download the data set MRI_3D_Head from analyzedirect.com/data and load into Analyze using Input/Output.

- Select MRI_3D_Head and open Segment.
- Select Manual [1] and choose Auto Trace [2].
- Set the primary display to Axial [3] and use Slice [4] to move to axial slice 130.
- Set a seed pixel in the white matter [5] and adjust the minimum and maximum threshold values [6] to define the brain. A min value of 45 and max value of 125 works well for this data set.
- Click Apply [7] to define the brain.



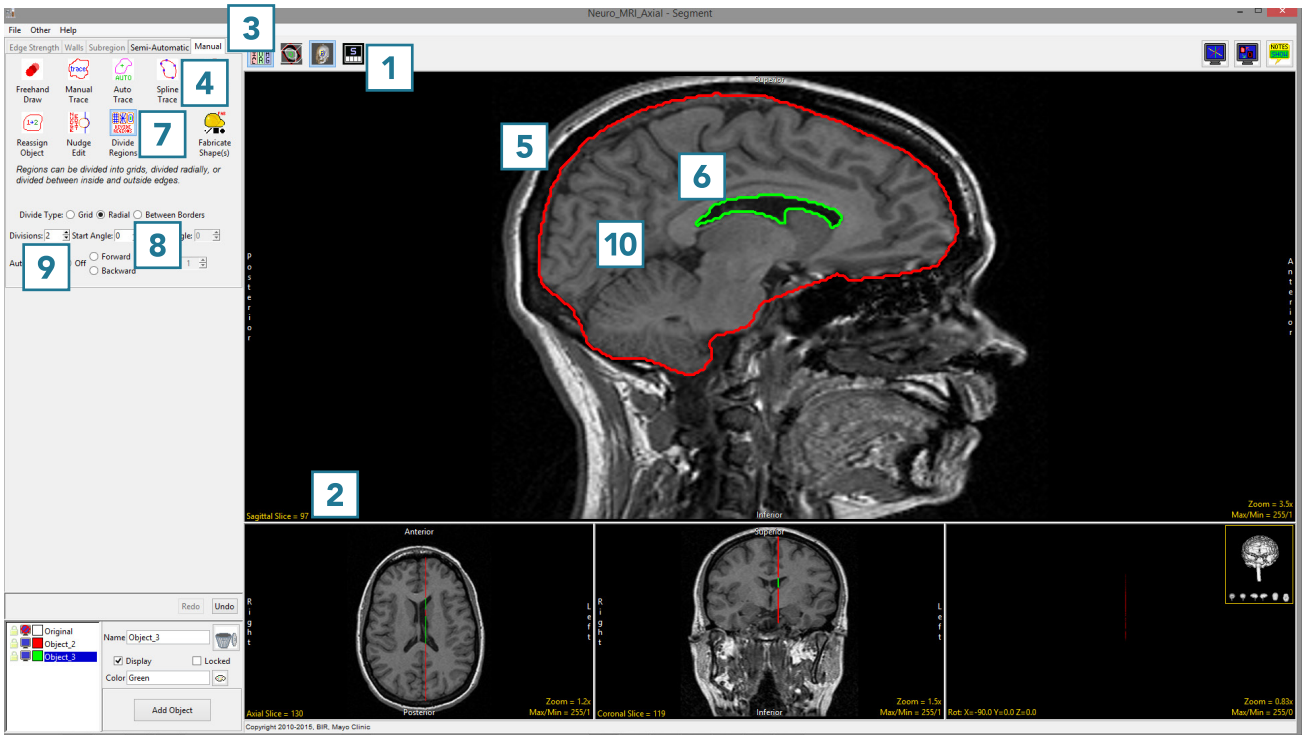
Radial Division of an Object (continued)

- Select the Divide Regions tool [8] and set the Divide Type to Radial [9].
- With Division set to 8, click anywhere in the brain to divide the object into 8 radial divisions [10].



Dividing Regions Between Borders – Interpolating Between Objects

The Divide Regions Between Borders division type allows users to create a concentric set of objects. The tool will divide the area between an inner and outer border into the number of regions specified by the user, which is acheived by interpolating new borders between the inner and outer border.

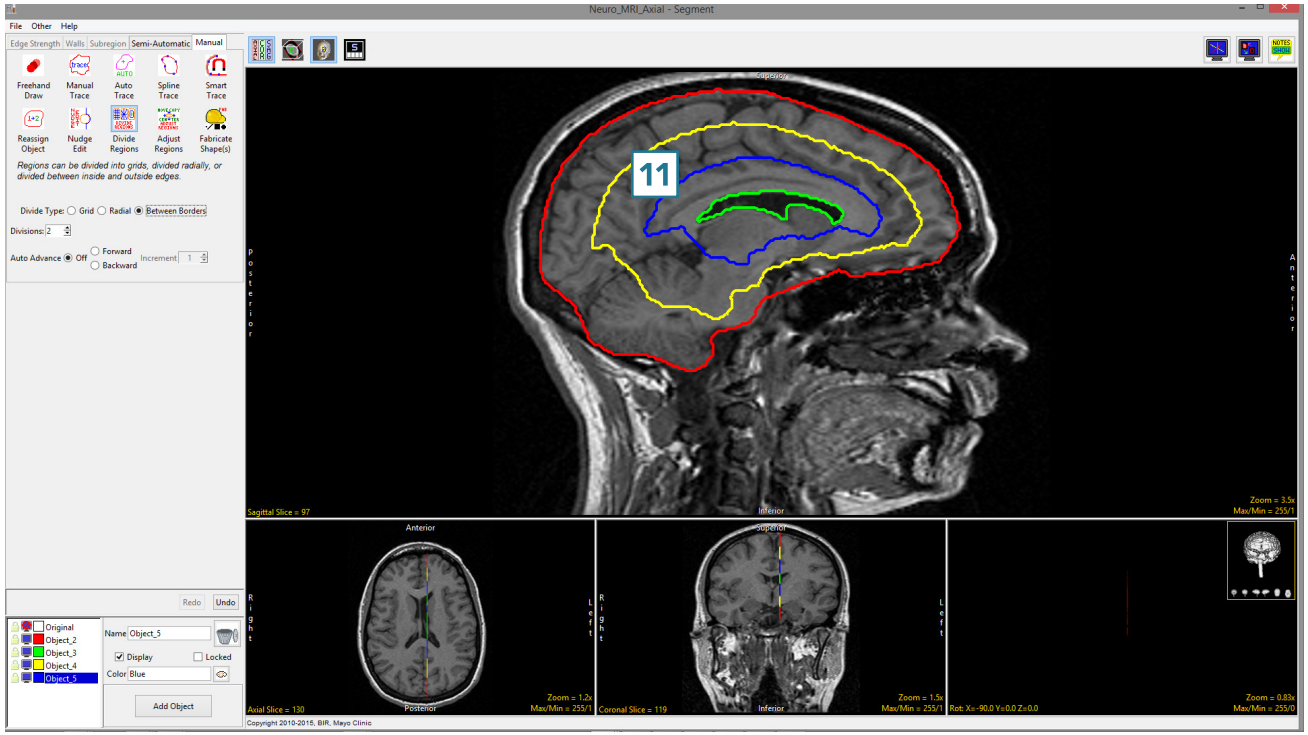


To follow along, download the data set MRI_3D_Head from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the dataset and open Segment.
- Set the primary display to Sagittal [1] and use Slice [2] to move to sagittal slice 96.
- Select Manual [3], and choose Spline [4].
- Use the Spline tool to define a region of interest around the brain [5].
- Add a new object and define a region of interest around the ventricles [6].
- Select the Divide Regions tool [7] and set the Divide Type to Between Borders [8].
- Set the Divisions to 2 [9].
- Click anywhere in the brain between the red brain border and the green ventricle border [10].

Dividing Regions Between Borders – Interpolating Between Objects (continued)

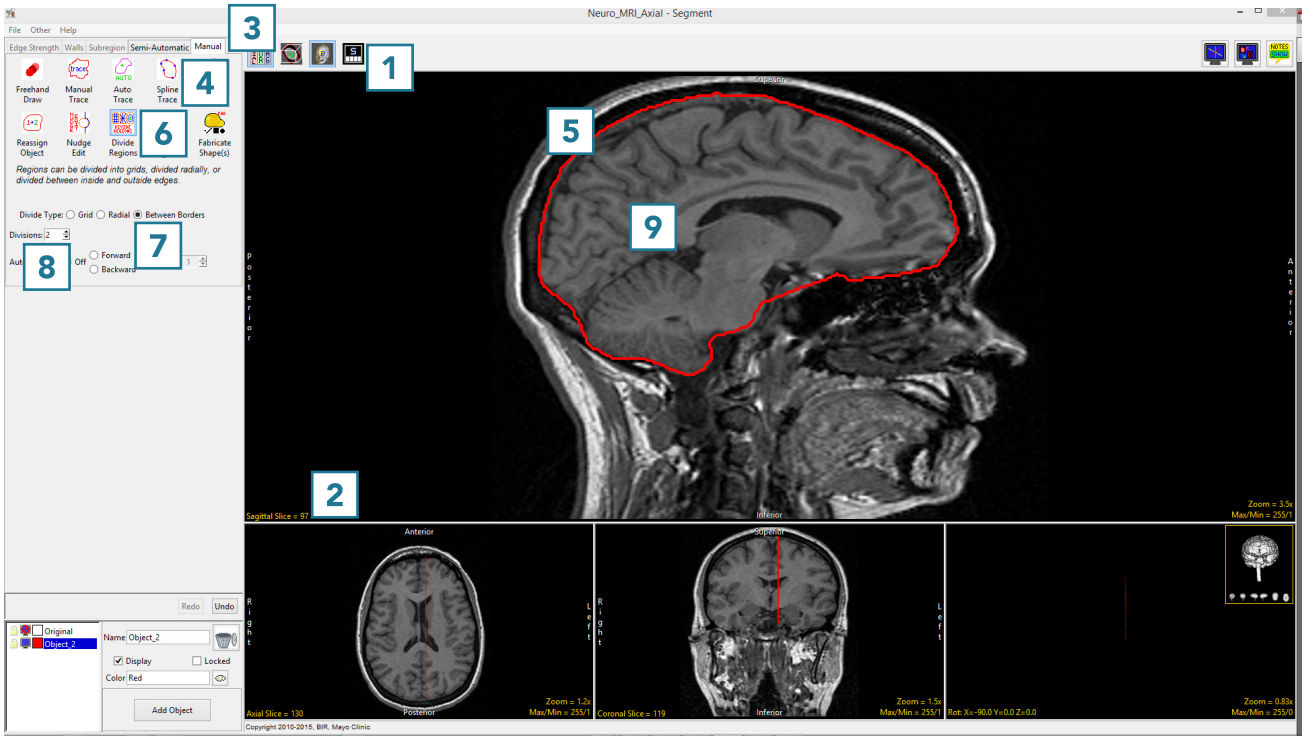
- 2 new regions will be interpolated between the brain and ventricles [11].



Dividing Regions Between Borders – Interpolating Within an Object

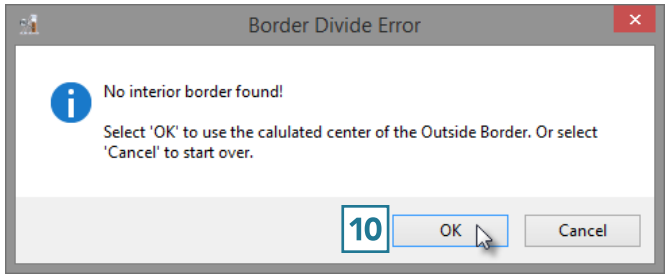
If there is no inner border defined when using the Divide Objects Between Border division type, the tool will calculate the center of the object and use this as an interpolation point, creating new interior object borders from the outer border.

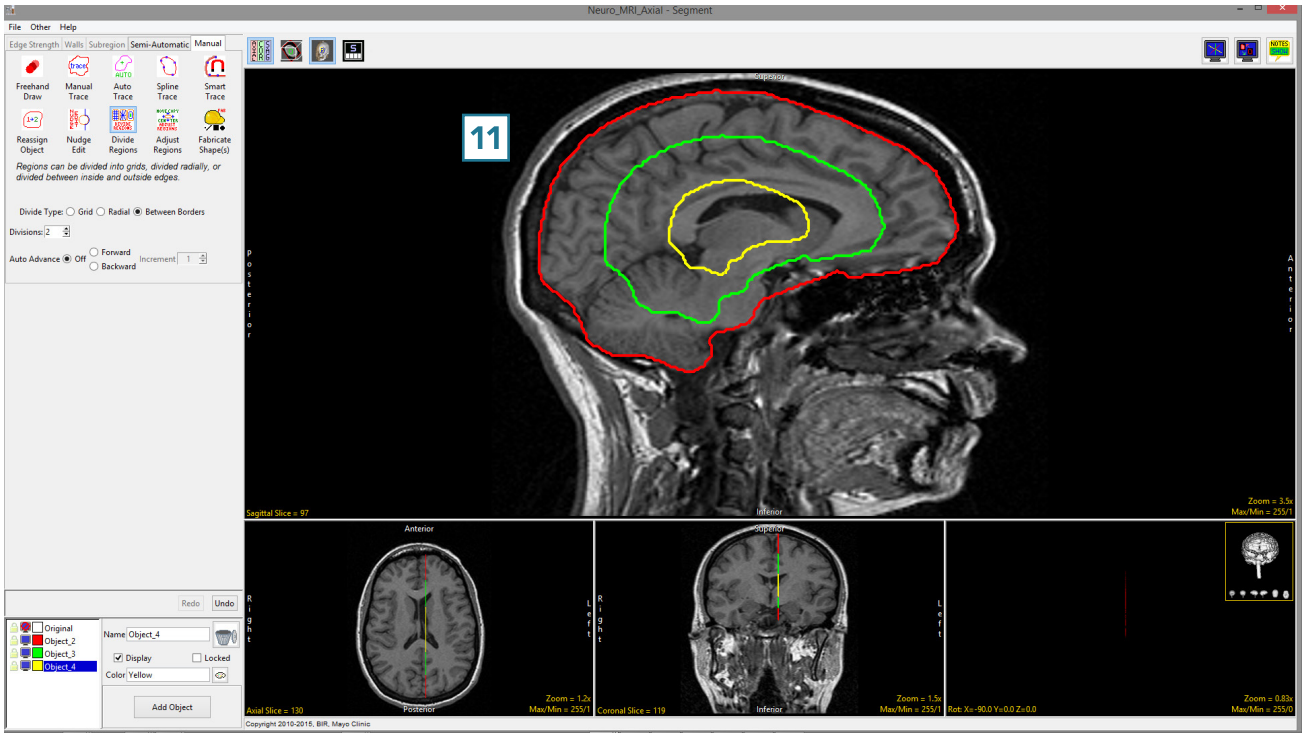
- Select MRI_3D_Head and open Segment.
- Set the primary display to Sagittal [1] and use Slice [2] to move to sagittal slice 96.
- Select Manual [3] and choose Spline [4].
- Use the Spline tool to define a region of interest around the brain [5].
- Select the Divide regions tool [6] and set the Divide Type to Between Borders [7].
- Set the Divisions to 2 [8]. Click anywhere in the brain [9].



Dividing Regions Between Borders – Interpolating Within an Object (continued)

- The tool will detect that there is no interior border and return a Border Divide Error. Click OK [10] to enable the tool to use the center of the outside border as an interpolation point to substitute the interior border.
- The object will be subdivided into regions interpolated from the outer border and the new regions will look like smaller versions of the outer border [11].





Adjust Regions

The Adjust Regions tool allows users to interactively manipulate regions. Users can rotate, translate, scale and deform objects. The adjust option provides users with the following region adjustment options:

Adjust Regions Methods and Functions

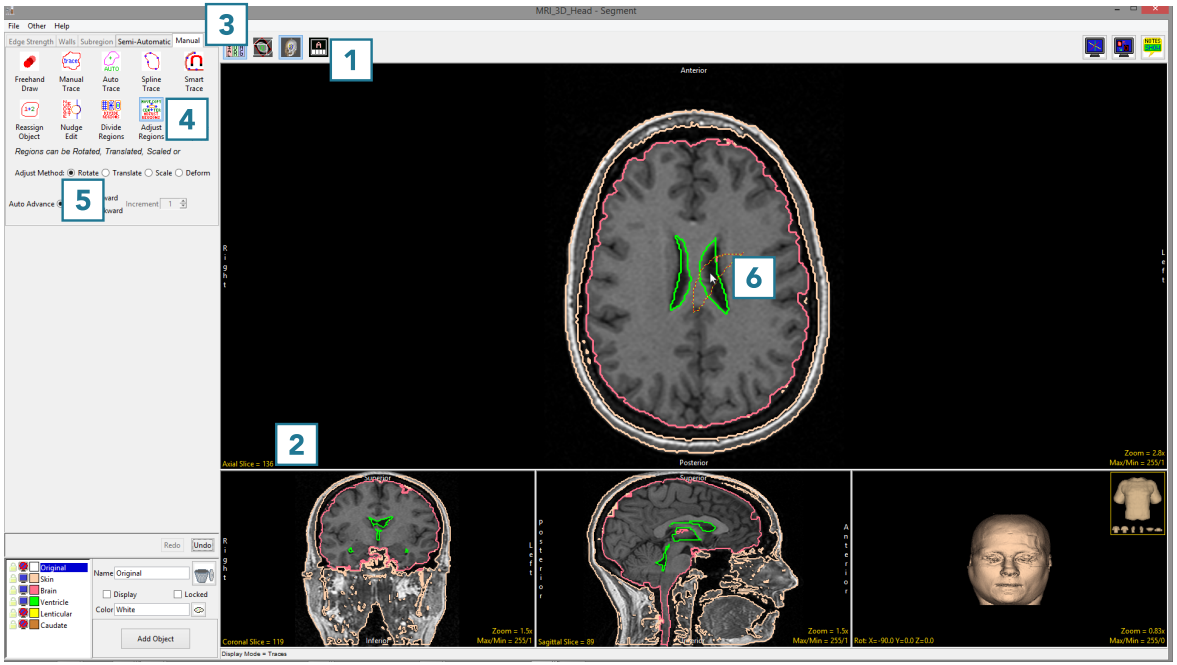
Method	Function
Rotate	The Rotate option allows users to rotate a region. To rotate a region, left click on the region to select it, the region will be outlined with a dashed yellow and red line. With the left mouse button still pressed move the mouse up to rotate the region clockwise and down to rotate counterclockwise.
Translate	The Translate option allows users to translate a region left, right, up, or down. To translate a region, left click on the region to select it, the region will be outlined with a dashed yellow and red line. With the left mouse button still pressed move the mouse up, down, left, or right to move the region. The following options are also available for translate: **With mouse movement:** This is the default option and will allow the user to translate the selected region. **A copy of the region:** Allows users to translate a copy of the selected region. Choose from the following Copied Object options *Same:* Copied object is assigned to the same object as the selected object. *Current:* Copied object is assigned to the currently selected object from the object list. *New:* Copied object is assigned to a new object. **Region so that its centered on brightest point:** This option will shift the selected region so that the brightest pixel in the object is used as the new center point for the object.
Scale	The Scale option allows users to adjust the regions scale by increasing and decreasing it both horizontally and vertically. To scale a region, left click on the region to select it, the region will be outlined with a dashed yellow and red line. With the left mouse button still pressed move the mouse up and down to adjust the scale vertically or move the mouse left or right to adjust the scale horizontally.
Deform	The Deform option allows users to interactively deform regions. To apply a free transform deformation on a region, left click on the region to select it, the region will be outlined with a dashed yellow and red line. With the left mouse button still pressed move the mouse up or down and left or right to deform.

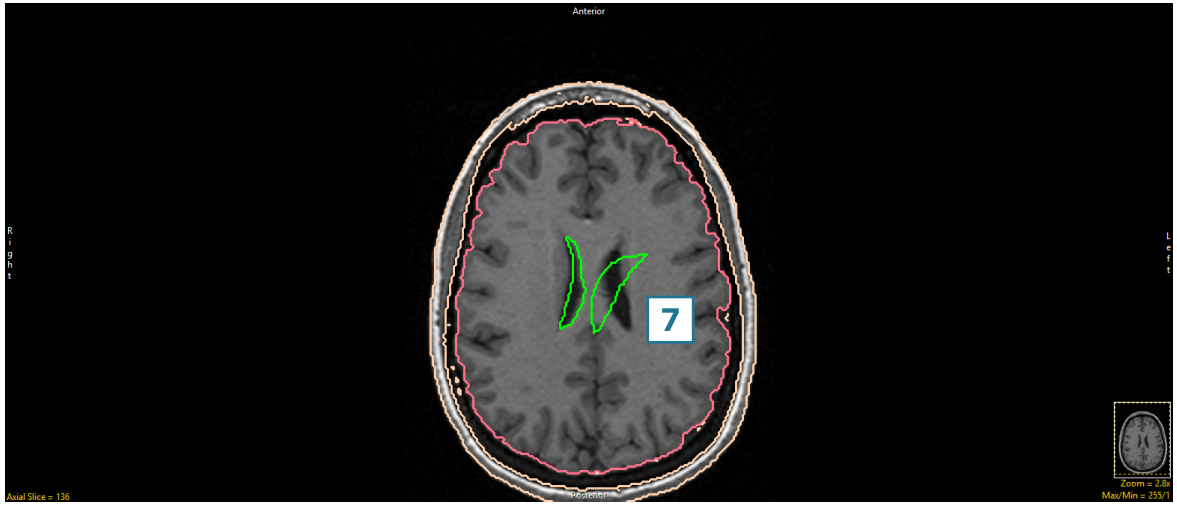
Using the Adjust Regions tool

Here we will rotate, translate, scale and deform objects using the Adjust Regions tool.

To follow along, download the data set MRI_3D_Head from analyzedirect.com/data and load into Analyze using Input/Output.

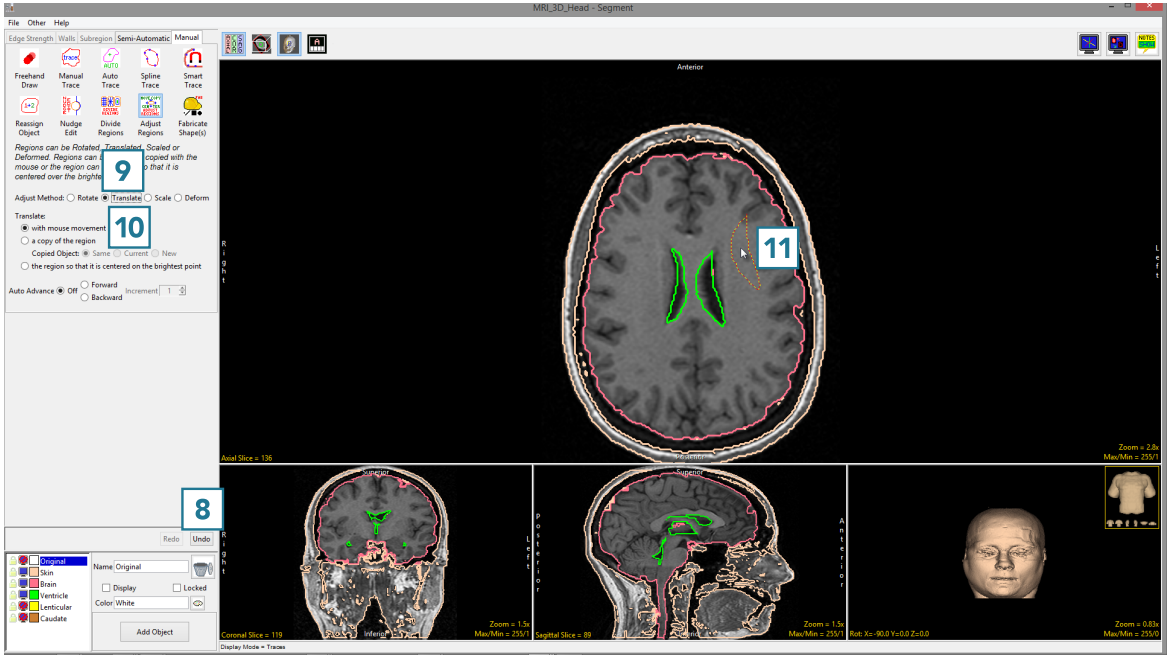
- Select the dataset and open Segment.
- Select File > Load Object Maps and load MRI_3D_Head.obj.
- Set the primary display to Axial [1] and move to Axial slice 136 [2].
- Select Manual [3] and choose Adjust Regions [4].
- Set the Adjust Method to Rotate [5].
- Click in an object to select it and move the mouse up or down to rotate the object [6].
- Release the mouse button to end the rotation and commit the rotation to the object [7].

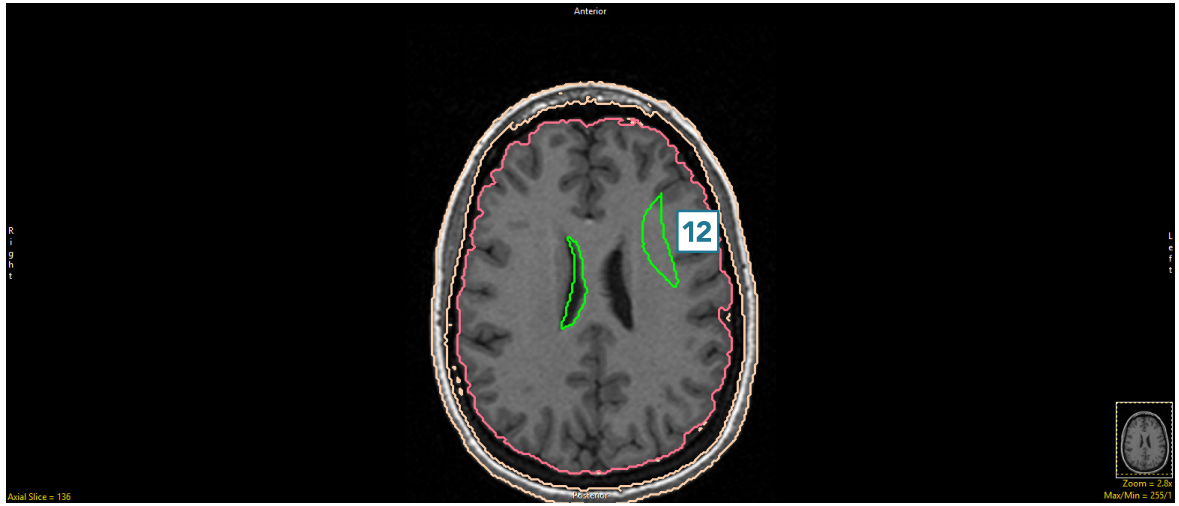




Using the Adjust Regions tool (continued)

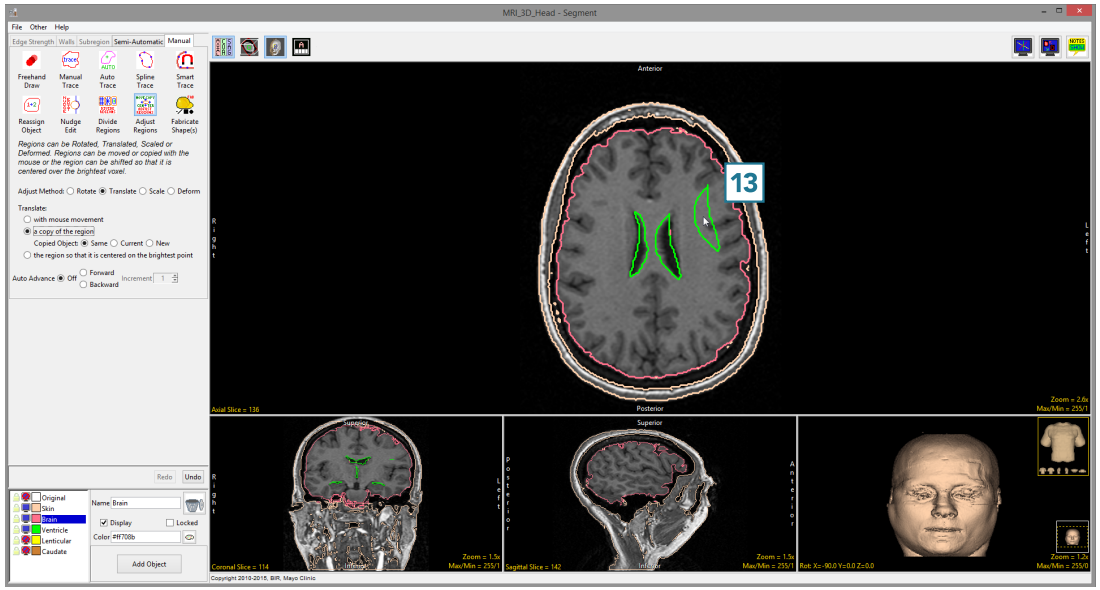
- Click Undo [8] and set the Adjust Method to Translate [9].
- With the Translate option set to with mouse movement [10], click in an object and drag to a new location [11].
- Release the mouse button to end the translation. The object will be moved to the new location [12].



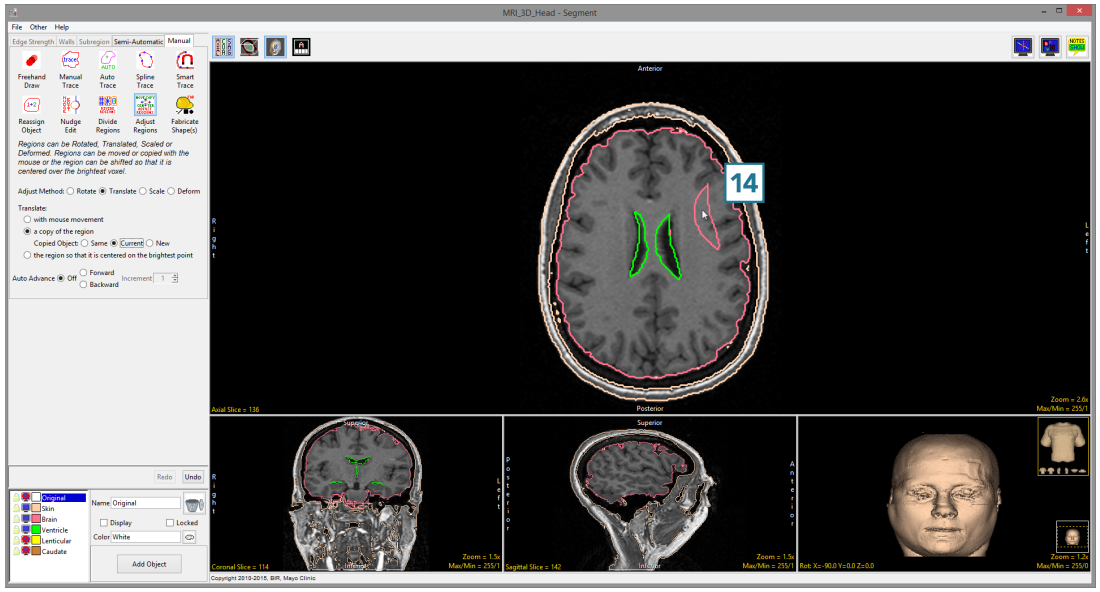


Using the Adjust Regions tool (continued)

- Setting the Translate option to 'a copy of the region' will allow you to make a copy of the selected object and move to a new location.
- Setting Copied Object to Same assigns voxels in the new region to the same object as the parent region [13].

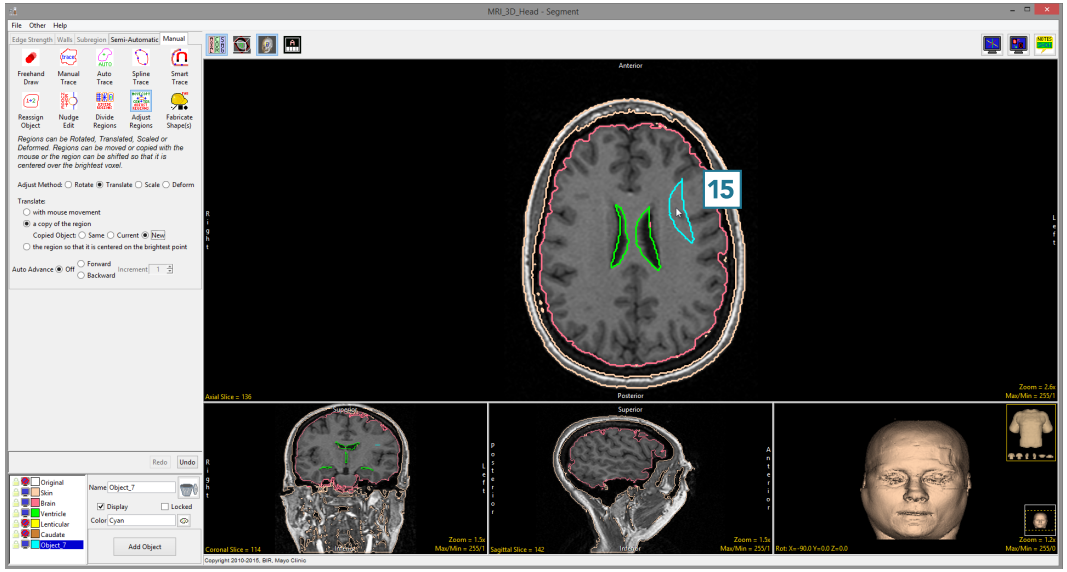


- Setting Copied Object to Current assigns voxels in the new region to the object currently selected in the Object Control window [14].



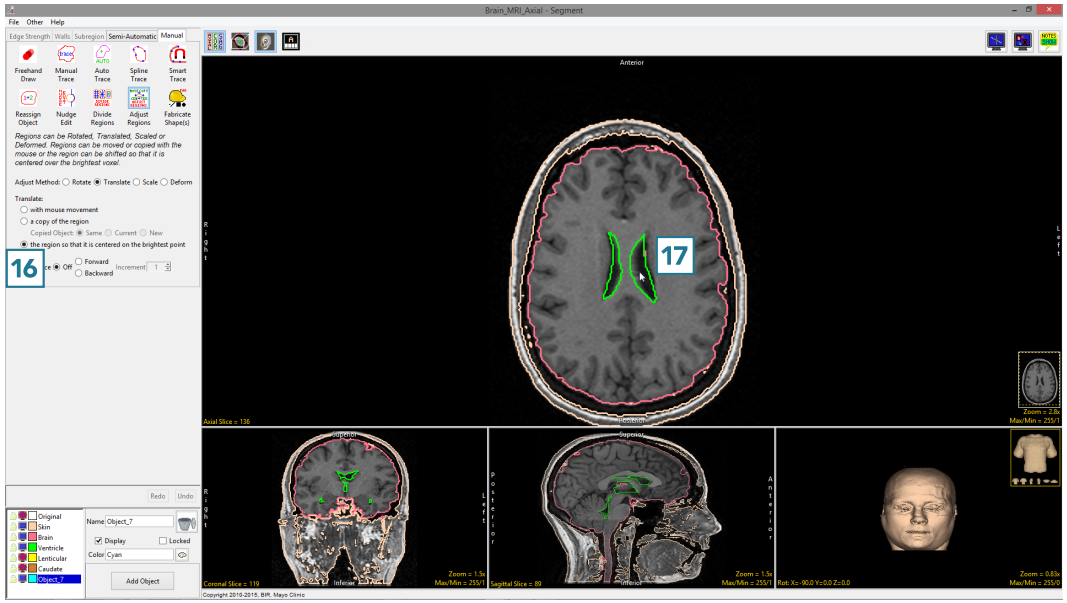
Using the Adjust Regions tool (continued)

- Setting Copied Object to New assigns voxels in the new region to a new object [15].



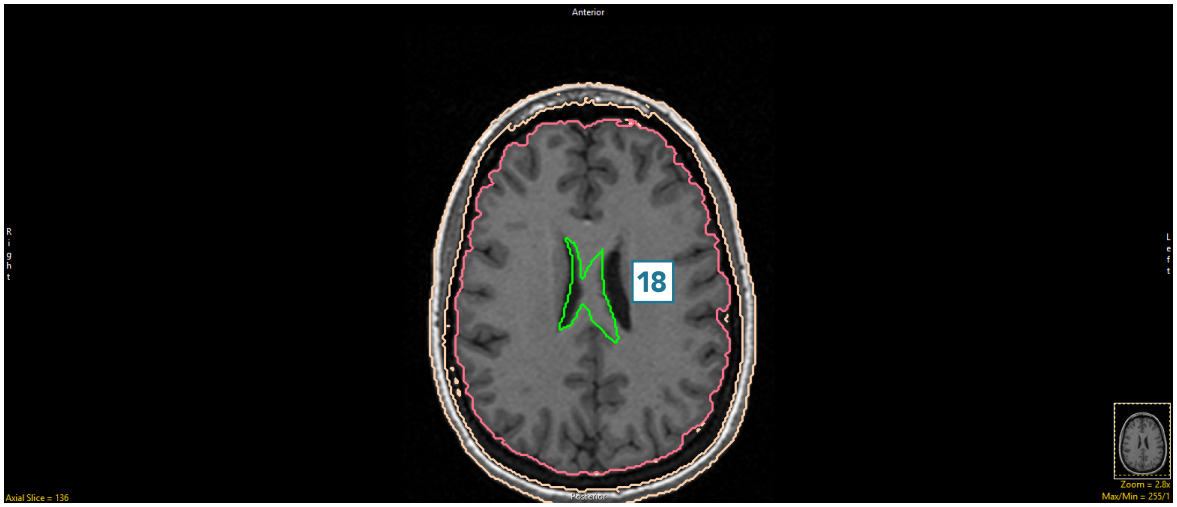
The Translate Adjust Method also allows users to Translate the region so that it is centered on the brightest point. With this option, the tool calculates the brightest pixel in the object and sets that as the the center of the object, translating the object appropriately.

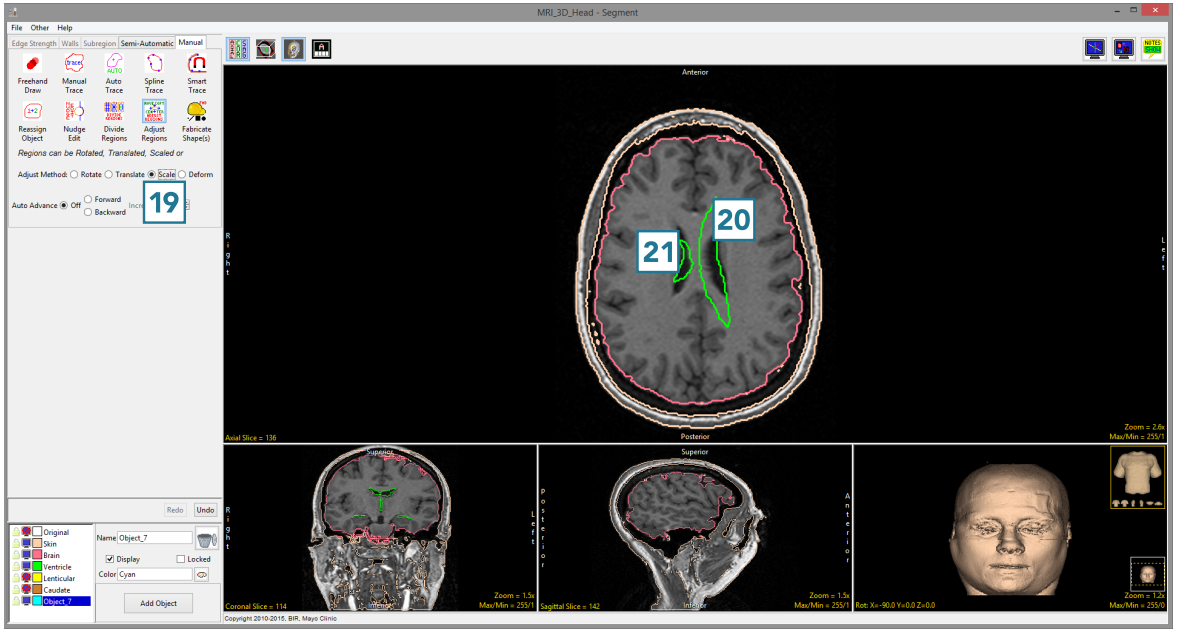
- Set the Translate method to the region so that it is centered on the brightest point [16].
- Click in an object [17].



Using the Adjust Regions tool (continued)

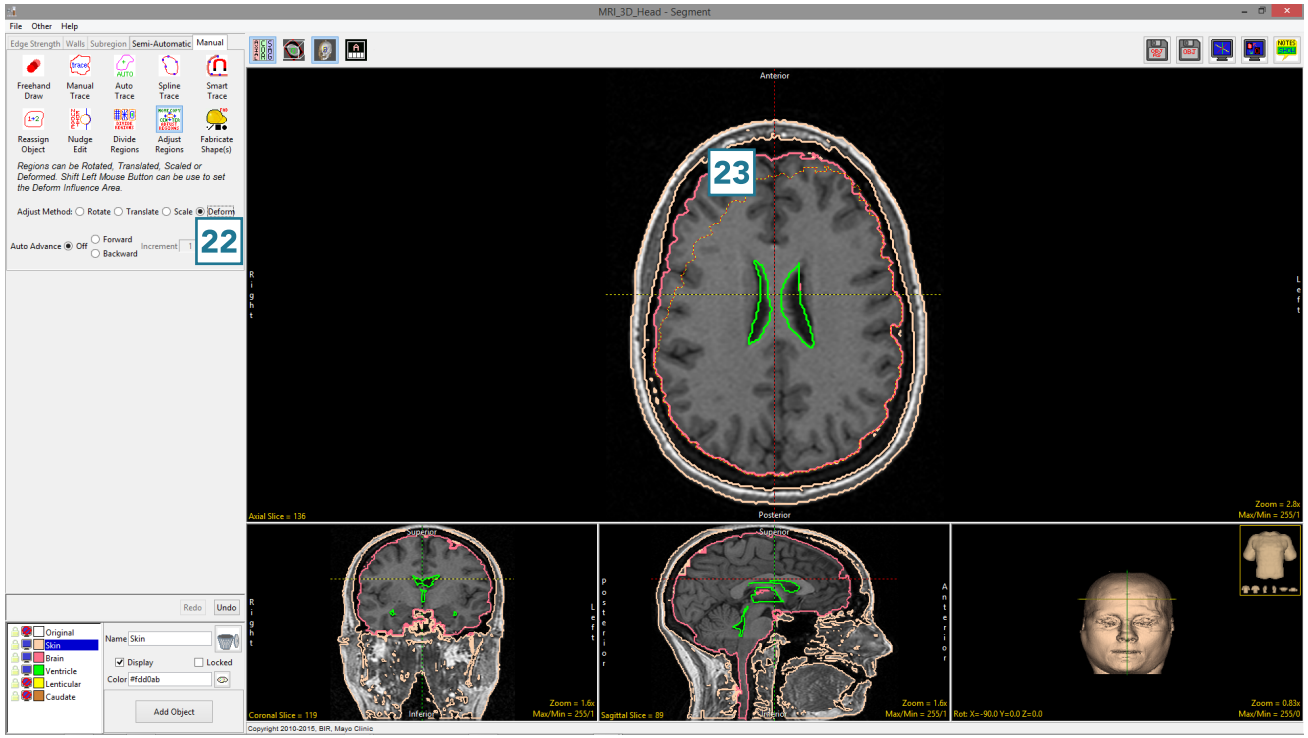
- The region will instantly be recentered around the brightest point in the object [18].
- Click Undo.
- Set the Adjust Method to Scale [19].
- Click in an object and move your mouse to increase the scale of the selected object [21].
- Moving the mouse up and down adjusts the scale in the vertical direction. Moving the mouse left and right adjusts the scale in the horizontal direction. Moving the mouse diagonally adjusts the scale of the object while preserving the shape. Release the button to commit the scale manipulation to the object.
- Click in an object and then move your mouse to decrease the scale of the selected object [21].
- Release the button to commit the scale manipulation to the object.





Using the Adjust Regions tool (continued)

- Undo the previous manipulations.
- Set the Adjust Method to Deform [22].
- Click in an object and move your mouse to experiment with the deformations available [23]. In this example the user is deforming the border of the brain object.
- Releasing the mouse button will apply the deformation to the object.



Fabricate Shape(s)

The Fabricate Shape(s) tool allows users to create 2D and 3D objects in the object map or input grayscale data. The tool provides options for users to create shapes interactively or by loading a list of coordinates defined in a text file.

The **Object to Create** option allow users to specify a set of parameters to create 2D or 3D objects within a data set.

Dimension: Allows users to choose to create a 2D or 3D object.

2-D: The following **Shape** options are available for 2D object creation:

Dot: The Dot option allows user to create a 1-pixel dot on any of the 2D images.

Square: The Square option allows users to create a 2D square on any of the 2D images.

Rectangle: The Rectangle option allows users to create a 2D rectangle on any of the 2D images.

Line: The Line option allows users to create a 2D line on any of the 2D images.

Circle: The Circle option allows users to create a 2D circle on any of the 2D images.

Oval: The Oval option allows users to create a 2D oval on any of the 2D images.

Note the Filled option allows users to enable (default) or disable the application of a fill to the preview of the 2D region, the fill color will correspond to the color of the selected object. Fill is not available for Dot or Line shape options.

Fabricate Shape(s) Options

Draw Slice: The Draw Slice options provide the ability to specify the orientation and slice the shape will be created on. Alternatively, the slice and orientation can be set by clicking on the desired slice in the desired orientation

- 2-D Orient: Choose from Axial, Coronal, or Sagittal.
- 2-D Slice: Use the slice slider or manually enter the slice number to create the object on for the selected orientation.

Location and Size: Provides the ability to specify the location and size of the shape being created. For any of the 2D shapes chosen (Dot, Square, Rectangle, Line, Circle, or Oval), the following shape dependent sub-options are enabled:

Dot Location and Size Options:

- Alt: Set the preferred way to define the size and location of the dot object. Press Alt to choose; pixels (default), real world distances, or X,Y coordinates (X,Y).
- X: Set the X location for the dot. Use the slider to set the value or manually enter the in the text entry box.
- Y: Set the Y location for the dot. Use the slider to set the value or manually enter the in the text entry box.

Square Location and Size Options:

- Alt: Set the preferred way to define the size and location of the square object. Press Alt to choose; pixels (default), real world distances, manually setting the X, Y coordinates for the lower left corner, using sliders to set the X, Y coordinates for the lower left corner, or manually setting the X, Y coordinates of the center of the square.
- Center X: Set the X center location for the square. Use the slider to set the value or manually enter the in the text entry box.
- Center Y: Set the Y center location for the square. Use the slider to set the value or manually enter the in the text entry box.
- Size: Set the size in pixels for the square. Use the slider to set the value or manually enter the in the text entry box. Alternatively, click on the square on the image and drag it to the desired size.

Fabricate Shape(s) Options (continued)

Object to Create > 2D > Location and Size (continued):

Rectangle Location and Size Options:

- Alt: Set the preferred way to define the size and location of the rectangle object. Press Alt to choose; pixels (default), real world distances, manually setting the lower left (X1, Y1) and upper right (X2, Y2) coordinates, using sliders to set X1, Y1, X2, and Y2, double-ended slides to specify the both the X and Y low and high values, or manually entering the lower left rectangle X and Y coordinates and the rectangle Width and Height values.
- Center X: Set the X center location for the rectangle. Use the slider to set the value or manually enter the in the text entry box.
- Center Y: Set the Y center location for the rectangle. Use the slider to set the value or manually enter the in the text entry box.
- Width: Set the width in pixels for the rectangle. Use the slider to set the value or manually enter the in the text entry box. Alternatively, select either vertical side of the rectangle on the image and drag it to the desired size.
- Height: Set the height in pixels for the rectangle. Use the slider to set the value or manually enter the in the text entry box. Alternatively, select either horizontal side of the rectangle on the image and drag it to the desired size.

Line Location and Size Options:

- Alt: Set the preferred way to define the size and location of the line object. Press Alt to choose; setting start X, Y and end X, Y points using sliders (default), double-ended sliders with pixel values, double-ended sliders with real world distances, or entering coordinates manually.
- Start X: Set the X start location for the line. Use the slider to set the value or manually enter the in the text entry box.
- Start Y: Set the Y start location for the line. Use the slider to set the value or manually enter the in the text entry box.
- End X: Set the X end location for the rectangle. Use the slider to set the value or manually enter the in the text entry box.
- End Y: Set the Y end location for the rectangle. Use the slider to set the value or manually enter the in the text entry box.
- Note, users can also manually adjust the end points of the line and drag to the desired location.

Fabricate Shape(s) Options (continued)

Object to Create > 2D > Location and Size (continued):

Circle Location and Size Options:

- Alt: Set the preferred way to define the size and location of the circle object. Press Alt to choose; pixels (default), real world distances, or manually entering the center X, Y coordinates and circle radius.
- Center X: Set the X center location for the circle. Use the slider to set the value or manually enter the in the text entry box.
- Center Y: Set the Y center location for the circle. Use the slider to set the value or manually enter the in the text entry box.
- Radius: Set the radius of the pixels for the circle. Use the slider to set the value or manually enter the in the text entry box.

Oval Location and Size Options:

- Alt: Set the preferred way to define the size and location of the oval object. Press Alt to choose; pixels (default), real world distances, manually entering the center X1, Y1 and X2, Y2 coordinates, using sliders to set the X1, Y1 and X2, Y2 coordinates, double-ended sliders to set both X/Y high/low values, or manually entering the lower left X and Y coordinates and the oval Width and Height
- Center X: Set the X center location for the oval. Use the slider to set the value or manually enter the in the text entry box.
- Center Y: Set the Y center location for the oval. Use the slider to set the value or manually enter the in the text entry box.
- Width: Set the width in pixels for the oval. Use the slider to set the value or manually enter the in the text entry box.
- Height: Set the height in pixels for the oval. Use the slider to set the value or manually enter the in the text entry box.
-

3-D: The following **Shape** options are available for 3D object creation:

Dot: The Dot option allows user to create a 1-pixel dot within the volume data.

Cube: The Cube option allows users to create a 3D cube within the volume data.

Box: The Box option allows users to create a 3D box within the volume data.

Line: The Line option allows users to create a 3D line within the volume data.

Sphere: The Sphere option allows users to create a sphere within the volume data.

Ellipsoid: The Ellipsoid option allows users to create an ellipsoid within the volume data.

Cylinder: The Cylinder option allows users to create a cylinder within the volume data.

Fabricate Shape(s) Options (continued)

Object to Create > 3D (continued):
Note the Filled option allows users to enable (default) or disable the application of a fill to the preview of the 3D region, the fill color will correspond to the color of the selected object. Fill is not available for the Dot or Line shape options.

Location and Size: Provides the ability to specify the location and size of the shape being created. For any of the 3D shapes chosen (Dot, Cube, Box, Line, Sphere, or Ellipsoid), the following shape dependent sub-options are enabled:

Dot Location and Size Options:

- Alt: Set the preferred way to define the size and location of the dot object. Press Alt to choose; pixels (default), real world distances, text file input (see Creating Objects from a Text File for further information), or manually entering the X,Y, Z coordinates (X, Y, Z).
- X: Set the X location for the dot. Use the slider to set the value or manually enter the in the text entry box.
- Y: Set the Y location for the dot. Use the slider to set the value or manually enter the in the text entry box.
- Z: Set the Z location for the dot. Use the slider to set the value or manually enter the in the text entry box.
- Note, users can click on any of the 2D images or the rendering to set the X, Y, Z coordinates for the dot.

Cube Location and Size Options:

- Alt: Set the preferred way to define the size and location of the cube object. Press Alt to choose; manually entering X, Y, Z center voxel coordinates and cube size (default), sliders to define the X, Y, Z, and size parameters of the cube, sliders with corresponding real world distances, text file input, or manually setting the X, Y, Z coordinates for the lower left front corner coordinate and cube size value.
- Center (X, Y, Z): Set the cube center voxel by entering the X, Y, Z coordinates of the center location for the cube. Alternatively, click and drag the 2D display of the cube in any orthogonal orientations to reposition.
- Size: Set the size in voxels for the square. Users can also click on the 2D display of the cube in any orientation and interactively increase or decrease the size of the cube in 3D.

Fabricate Shape(s) Options (continued)

Object to Create > 3D > Location and Size (continued):

Box Location and Size Options:

- Alt: Set the preferred way to define the size and location of the box object. Press Alt to choose; to use slides to enter X, Y, Z and Width, Height and Depth values in voxels for the box (default), manually entering X, Y, Z center and the box Width, Height and Depth values, using sliders to specify the X, Y, Z center values and Width, Height, and Depth values in real world coordinates, use a text file to specify the box parameters, manually specify the X1, Y1, Z1 and X2, Y2, and Z2 values to define the box, use sliders to determine the X1, Y1, Z1 and X2, Y2, and Z2 values, use double-ended sliders the X, Y, and Z upper and lower parameters, or manually enter coordinates for LX, LY, LZ and With, Height, and Depth values to define the box.
- Left (X): Set the X value for the box. Use the slider to set the value or manually enter the in the text entry box.
- Lower (Y): Set the Y value for the box. Use the slider to set the value or manually enter the in the text entry box.
- Front (Z): Set the Z value for the box. Use the slider to set the value or manually enter the in the text entry box.
- Width: Set the width value for the box. Use the slider to set the value or manually enter the in the text entry box.
- Height: Set the height value for the box. Use the slider to set the value or manually enter the in the text entry box.
- Depth: Set the depth value for the box. Use the slider to set the value or manually enter the in the text entry box.

Line Location and Size Options:

- Alt: Set the preferred way to define the size and location of the line object. Press Alt to choose; setting start X, Y, Z points for the line end points using double-ended slider bars, using double-ended slider bars mapped to real work distances, manually entering the XYZ coordinates for both end points, or using single sliders to specify the Start X, Start Y, Start Z, End X, End Y, and End Z coordinates.
- X, Y, Z Sliders: Use the double-ended slider bar to set the X, Y and Z values for each end point of the 3D line. Adjusting the lower end of the slider will adjust the X, Y or Z point location for the first end point of the line while adjusting the upper end of the slider will adjust the X, Y or Z point location for the second end point of the line.
- Note, line end point for the 3D line can be adjusted by selecting and moving the end points on any of the orthogonal images.

Fabricate Shape(s) Options (continued)

Object to Create > 3D > Location and Size (continued):

Sphere Location and Size Options:

- Alt: Set the preferred way to define the size and location of the sphere object. Press Alt to choose; to set sphere parameters in voxels using an X, Y, Z and Radius slider (default), to set sphere parameters in real world distances using an X, Y, Z and Radius slider (default), a text file to define a sphere(s), or manually enter the X, Y, Z and Radius parameters in voxels manually.
- Center X: Set the X center location for the sphere. Use the slider to set the value or manually enter the in the text entry box.
- Center Y: Set the Y center location for the sphere. Use the slider to set the value or manually enter the in the text entry box.
- Radius: Set the radius of the pixels for the sphere. Use the slider to set the value or manually enter the in the text entry box.

Ellipsoid Location and Size Options:

- Alt: Set the preferred way to define the size and location of the ellipsoid object. Press Alt to choose; to set ellipsoid parameters in voxels (default), real world distances, using a text file, manually entering the center X1, Y1, Z1 and X2, Y2, Z2 coordinates, using sliders to set the X1, Y1, Z1 and X2, Y2, Z2 coordinates, double-ended sliders to set both X, Y, and Z upper and lower values, or manually entering the lower left X, Y, Z coordinates and the ellipsoid Width, Height, and Depth values, use sliders to enter the X, Y, Z position information and Width, Height, and Depth values, or coordinates to specify the center X, Y, Z and values for ellipse Width, Height, and Depth.
- Center X: Set the X center location for the ellipsoid. Use the slider to set the value or manually enter the in the text entry box.
- Center Y: Set the Y center location for the ellipsoid. Use the slider to set the value or manually enter the in the text entry box.
- Center Z: Set the Z center location for the ellipsoid. Use the slider to set the value or manually enter the in the text entry box.
- Width: Set the width in pixels for the ellipsoid. Use the slider to set the value or manually enter the in the text entry box.
- Height: Set the height in pixels for the ellipsoid. Use the slider to set the value or manually enter the in the text entry box.
- Depth: Set the depth in pixels for the ellipsoid. Use the slider to set the value or manually enter the in the text entry box.

Fabricate Shape(s) Options (continued)

Object to Create > 3D > Location and Size (continued):
Cylinder Location and Size Options:

- Alt: Set the preferred way to define the size and location of the cylinder object. Press Alt to choose; to set cylinder parameters in voxels (default), use real world distances, to use a text file, to manually entering the center X, Y, Z coordinates and input the radius and length values, or use sliders to input the Center X, Y, Z, Radius, and Length values.
- Center X: Set the X center location for the cylinder. Use the slider to set the value or manually enter the in the text entry box.
- Center Y: Set the Y center location for the cylinder. Use the slider to set the value or manually enter the in the text entry box.
- Center Z: Set the Z center location for the cylinder. Use the slider to set the value or manually enter the in the text entry box.
- Radius: Set the radius in pixels for the cylinder. Use the slider to set the value or manually enter the in the text entry box.
- Length: Set the length in pixels for the cylinder. Use the slider to set the value or manually enter the in the text entry box.
- Axis: Choose which axis; X, Y, or Z (default) to orientate the length of the cylinder.

Apply changes to: Allows users to select the image volume, the object map, or both to defined the fabricated shape(s).

Volume: Applies the fabricated object to the grayscale image data.

- **Set Volume Voxels to:** Choose to assign greyscale voxel values as user defined Specified value, a Random Value, or a Gaussian Value.
  - Specified value: Allows users to select a greyscale value that all voxels within the fabricated shape will be assigned to.
  - Random Value: Assigns voxel values within the fabricated shape to editable random values from 1 to 255.
  - Gaussian Value: Assigns voxel values within the fabricated shape to a Gaussian Value. Default Mu and Sigma values are assigned at 128.0 and 25.6 respectively but can be updated by the user.
- **Object Map:** Allows users to assign the fabricated shape to the selected object in the object list.
- **Both:** Applies fabricated shape to both the Volume and Object Map (see above).

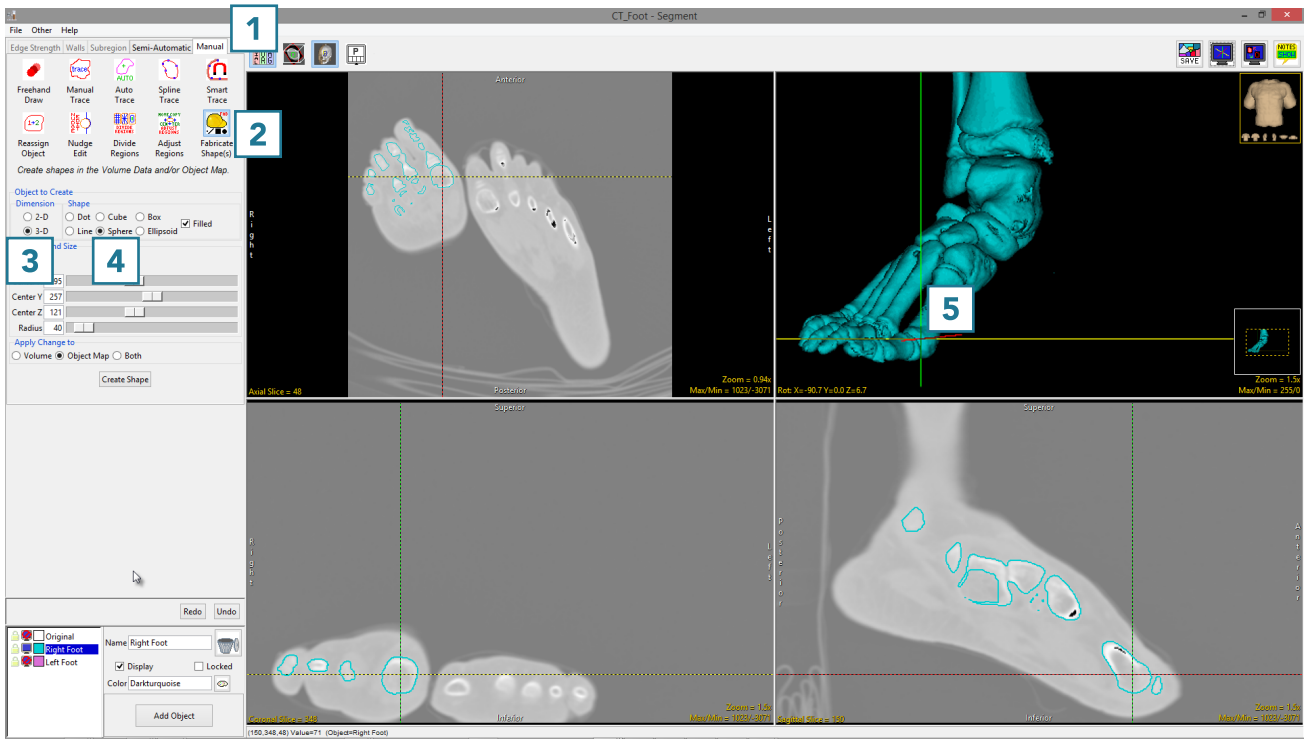
Create Shape: Initiates the Fabrication process.

Using Fabricate Shape(s)

Here we will use the Fabricate Shape(s) tool to create a 3D shape in a volume.

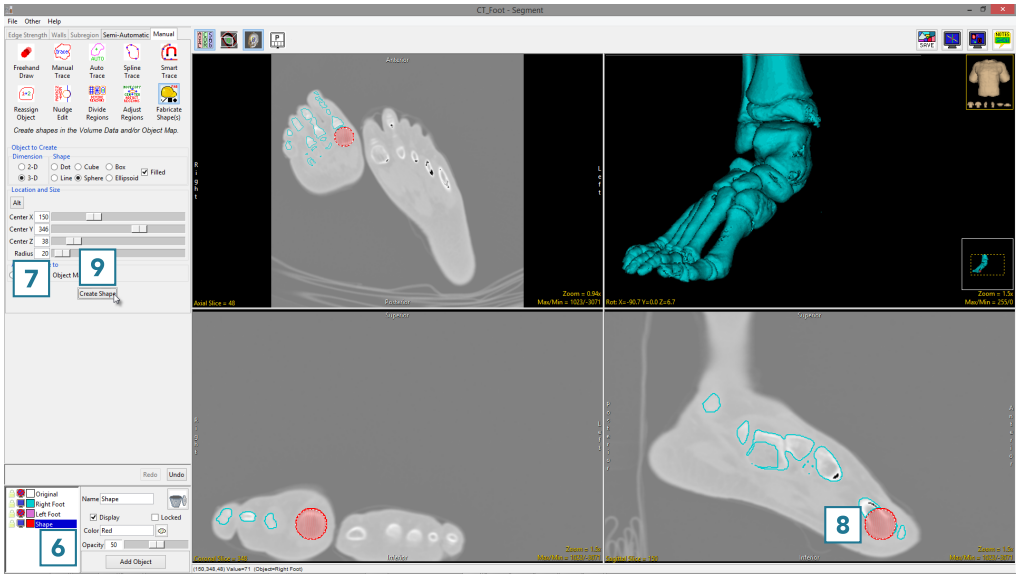
To follow along, download the data set CT_Foot from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the data set and open Segment.
- Select File > Load Object Maps and load CT_Foot.obj.
- Select Manual [1] and choose Fabricate Shape(s) [2].
- Set the Dimension to 3D [3] and set the Shape to Sphere [4].
- Use the linked cursor to navigate to the location where you would like to create the new shape [5].

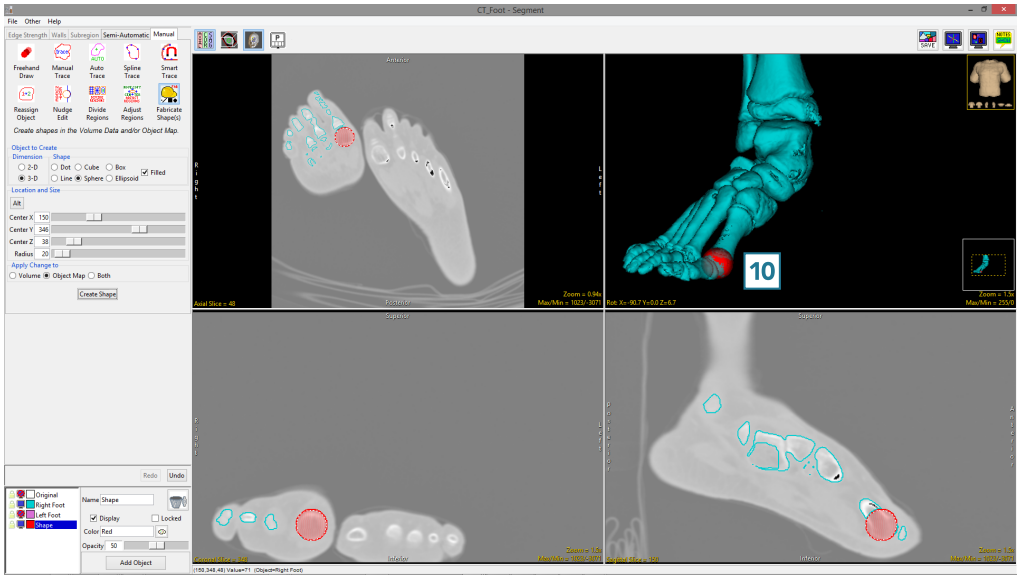


Using Fabricate Shape(s) (continued)

- Add a new object, name it and assign a color [6].
- Change the Radius of the sphere [7] and drag the 2D shape template in any of the images to the location you where you want to create the shape [8].
- Select Create Shape [9].



- The shape will be created and added to the object map. Right-click on the rendering and select Transparency for a clearer view of the object in 3D [10].

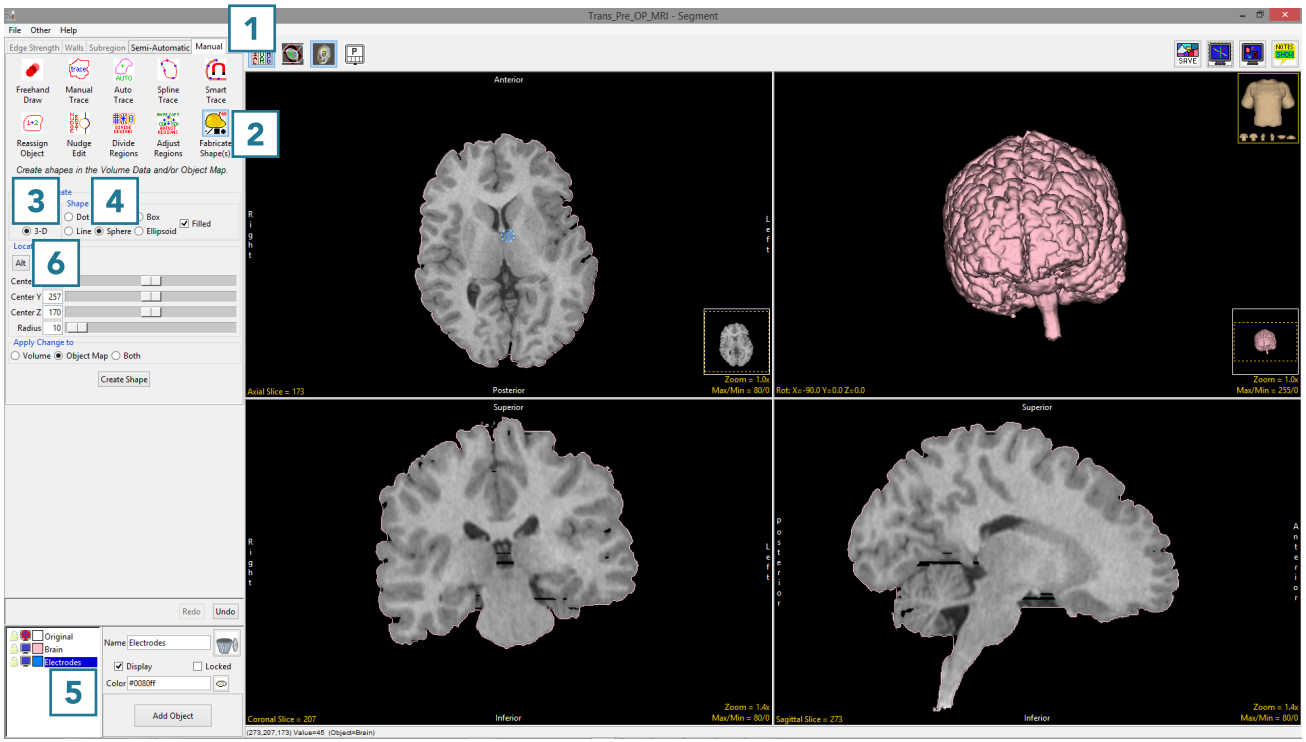


Creating Objects from a Text File using Fabricate Shape(s)

Here we will show how Fabricate Shape(s) can create objects defined in a text file.

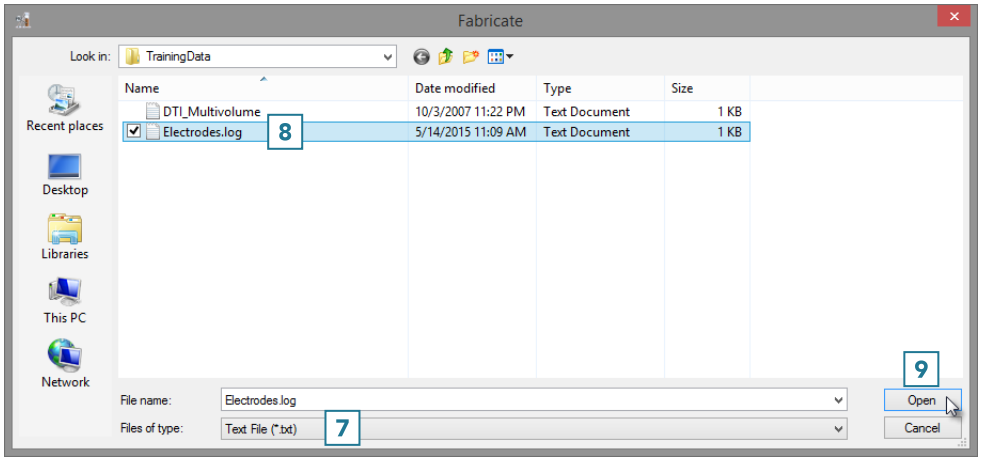
To follow along, download the data set Trans_Pre_OP_MRI from analyzedirect.com/data and load into Analyze using Input/Output.

- Select the data set and open Segment.
- Select File > Load Object Maps and load Trans_Pre_OP_MRI_brain.obj.
- Select Manual [1] and choose Fabricate Shape(s) [2].
- Set the Dimension to 3D [3] and set the Shape to Sphere [4].
- Add a new object, name it Electrodes and assign a color to the object [5].
- Click on the Alt button [6] and select File.

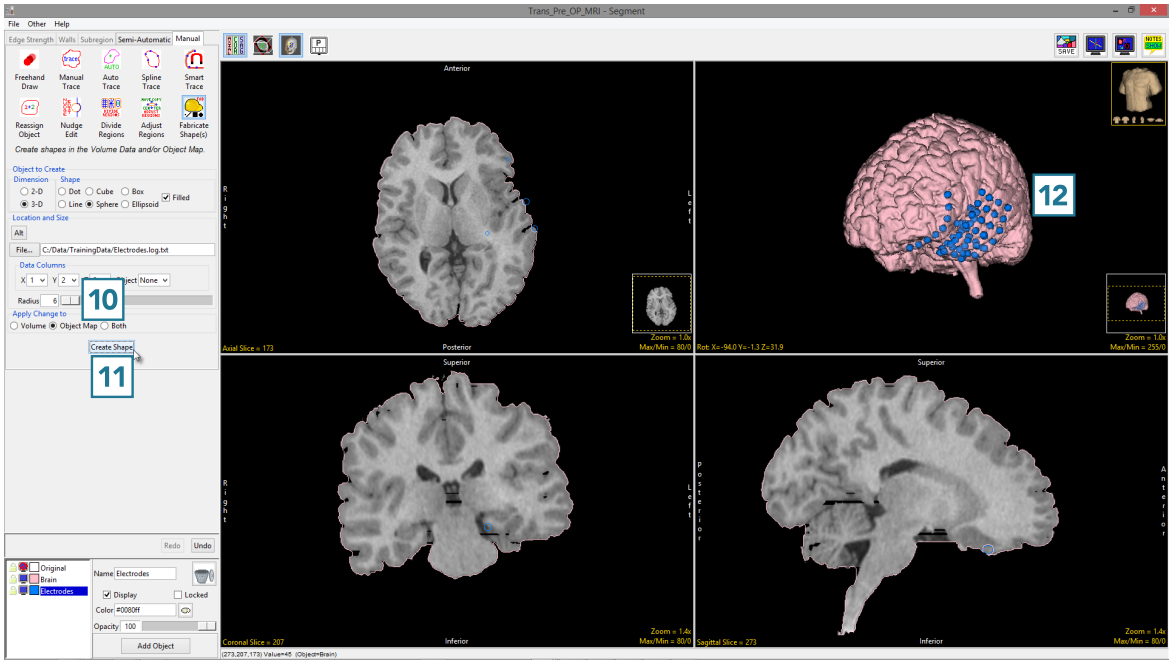


Creating Objects from a Text File using Fabricate Shape(s) (continued)

- In the window returned set Files of type to Text File (*.txt) [7].
- Select Electrodes text file [8] and click Open [9].



- Set the Radius to 6 [10] and click Create Shape [11].
- Once created, the new shapes will be added to the object map and can be viewed overlaid on the 2D images and in the 3D rendering [12].
- Right-click on the rendering and select Transparency for a clearer view of the objects in 3D.
- Select File > Save Object Map and save your object map as Trans_Pre_OP_MRI_brain_and_electrodes.obj.

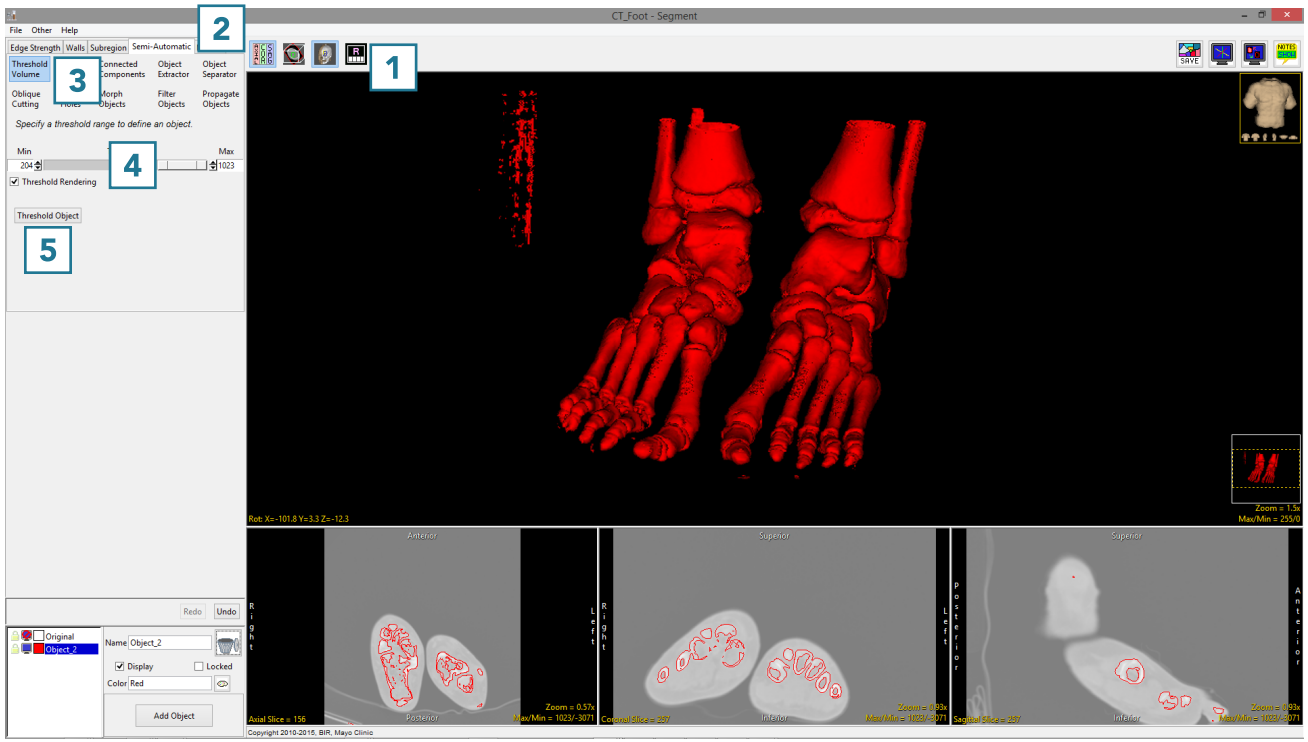


Manual Tools for 3D Editing

Some of the manual tools have the capability to be used to edit objects in 3D. This is achieved by drawing directly on the 3D rendering.

To follow along, download the data set CT_Foot from analyzedirect.com/data and load into Analyze using Input/Output.

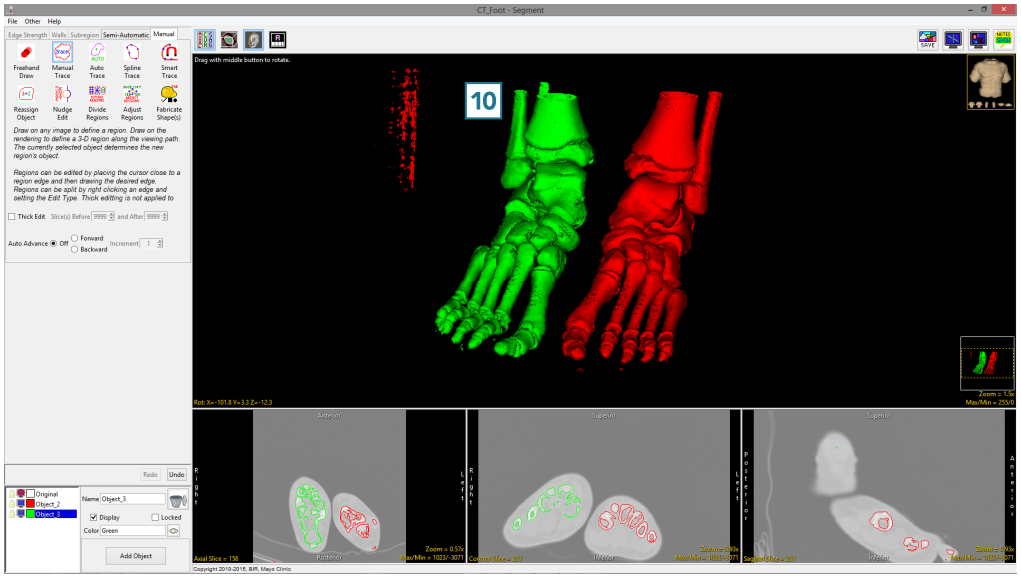
- Select the data set and open Segment.
- Set the primary display to Render [1].
- Select Semi-Automatic [2] and choose Threshold Volume [3].
- Set a Threshold range [4] to isolate the bones of both feet and click Threshold Object [5].



Manual Tools for 3D Editing (continued)

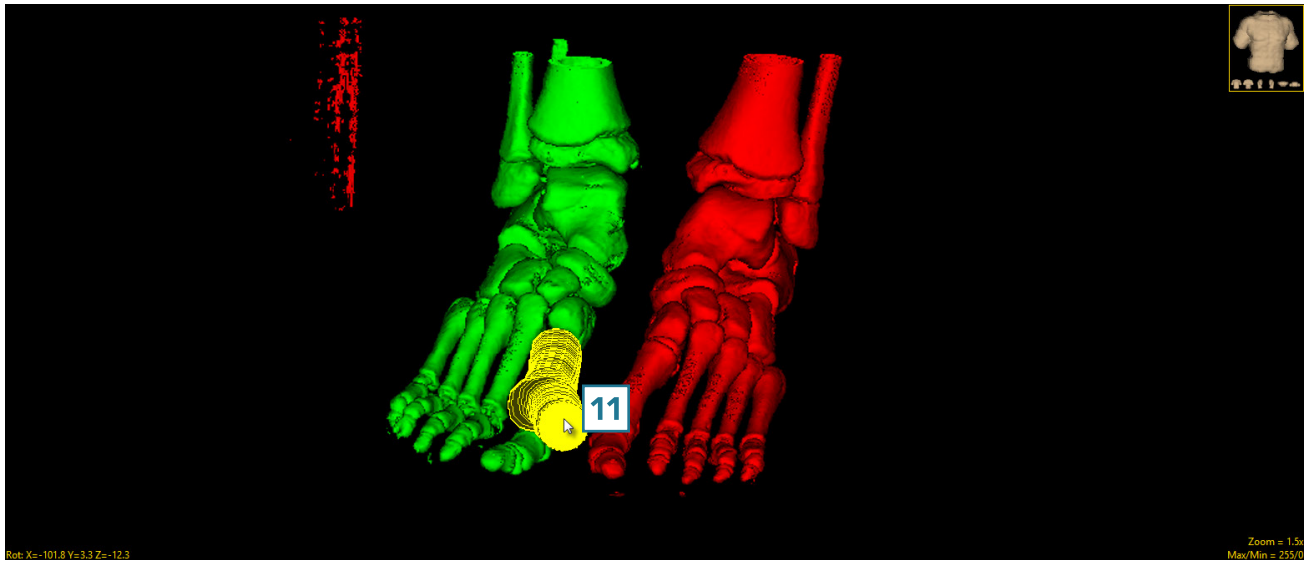
- Select Manual [6] and choose Manual Trace [7].
- Add a new object [8].
- Move the cursor to the Rendering and trace around the right foot [9].

- Complete the trace and release the left mouse button. All voxels not assigned to the Original object within the trace will be assigned to the selected object [9].

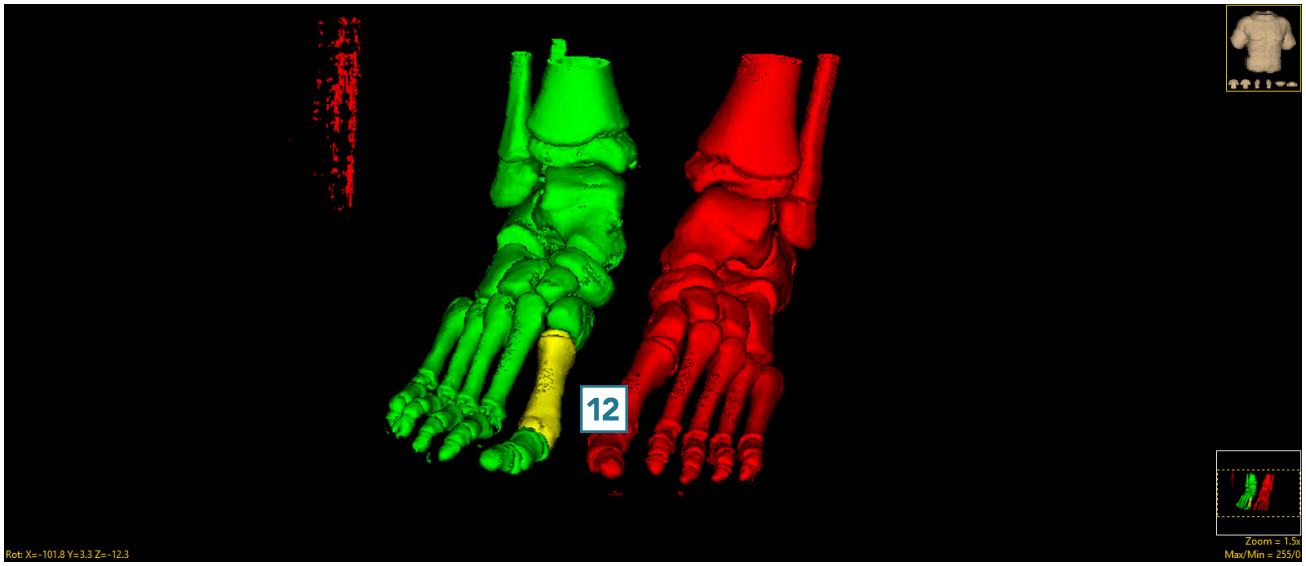


Manual Tools for 3D Editing (continued)

- Add a new object.
- Select the Freehand Draw trace and trace over one of the bones in the right foot [11].



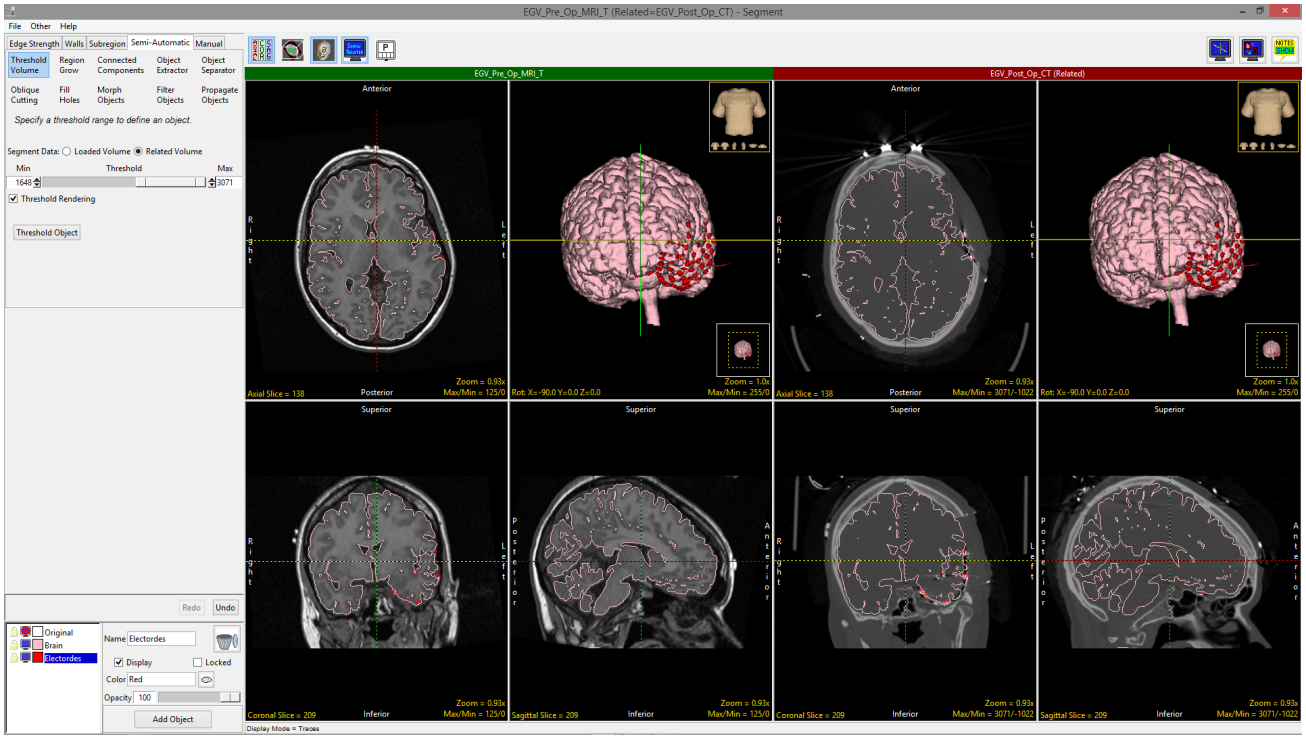
- Everything under the region will be assigned to the selected object [12].



Dual Input Segmentation

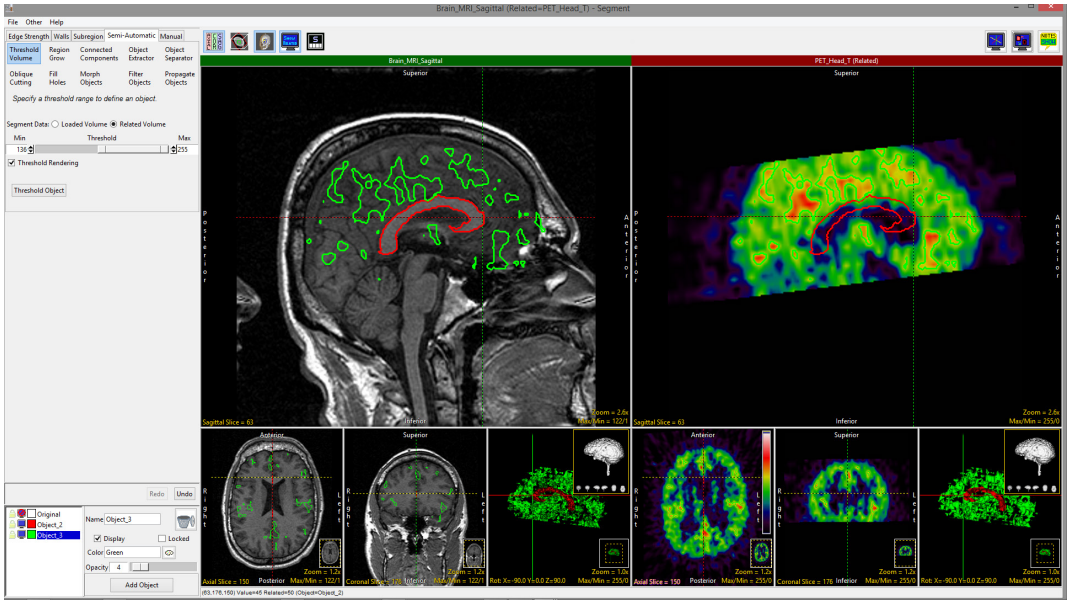
Segment allows users to load two registered input data sets. The ability to load related volumes is powerful and allows users to segment structures from either data set.

- Load registered pre-operative MRI and post-operative CT.
- Segment the brain from the MRI and electrodes from the CT.

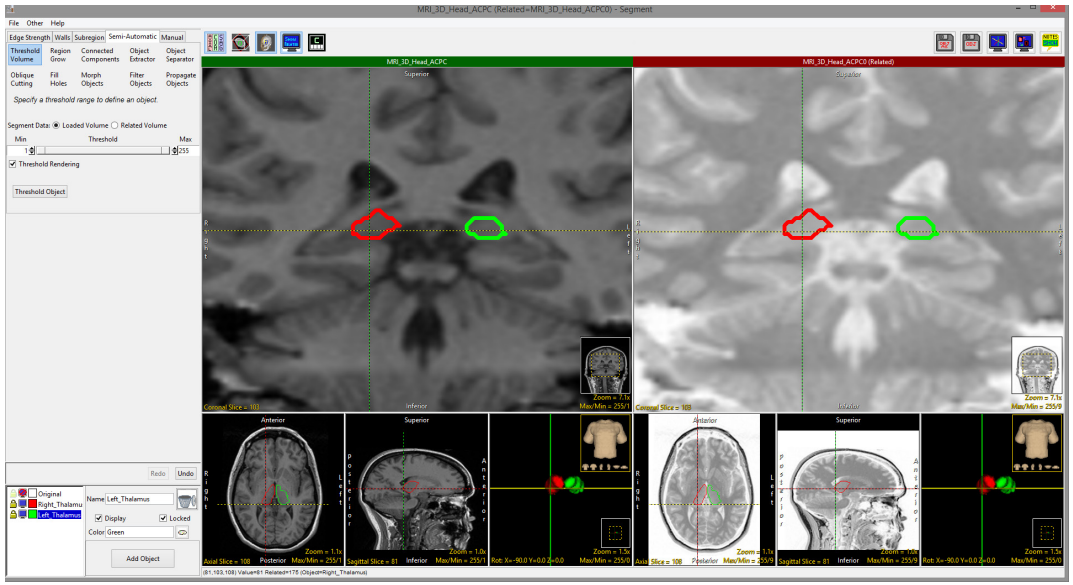


Dual Input Segmentation (continued)

- Load registered structural MRI and functional PET data. Structural regions can be delineated on the MRI and viewed on the PET, while regions of activity or uptake can be viewed on the functional data and displayed on the MRI.

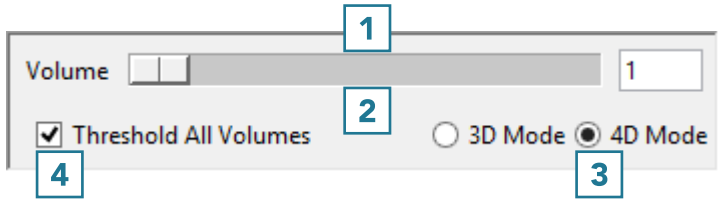


- Loading two copies of the same input data set allows users to adjust or invert intensity display values on the related volume. This can be leveraged to assist with the segmentation of brain structures such as the thalamus.

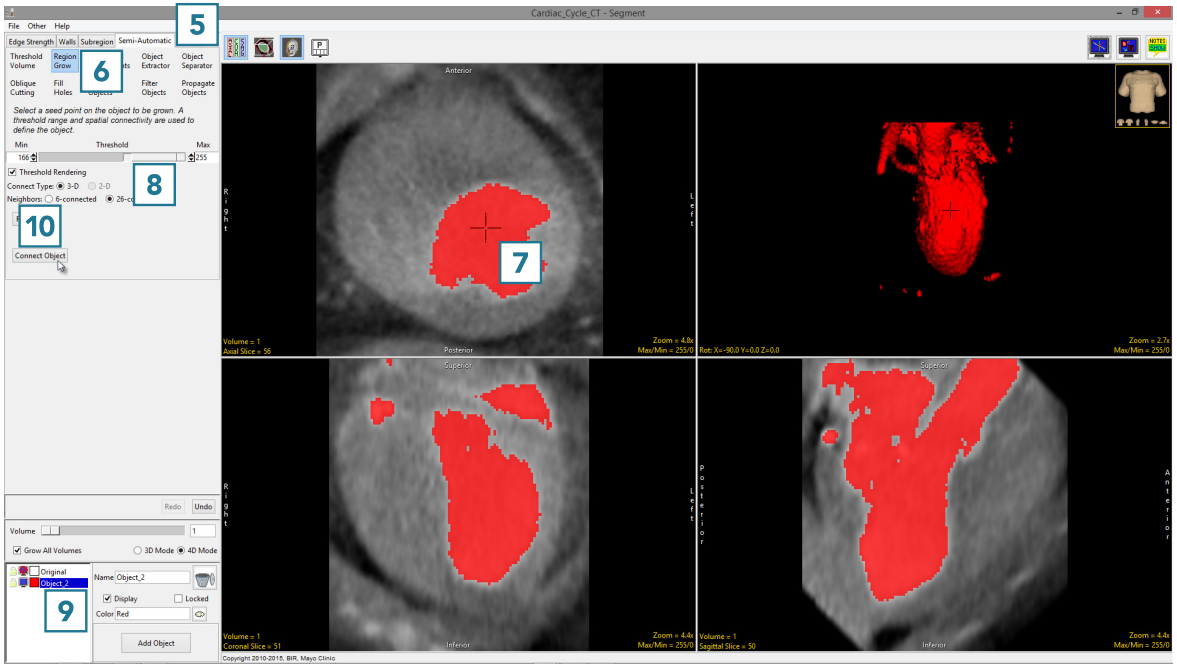


4D Segmentation

Segment supports 4D multivolumes. Users can use all of the segmentation tools to derive 2D, 3D, or 4D regions of interest. Segmentation using many of the Semi-Automatic tools can be configured to automatically propagate to the next 3D volume in the 4D multivolume as soon as the first segmentation is complete. To follow along, download the multivolume data set Cardiac_Cycle_CT from analyzedirect.com/data and load into Analyze using Input/Output.



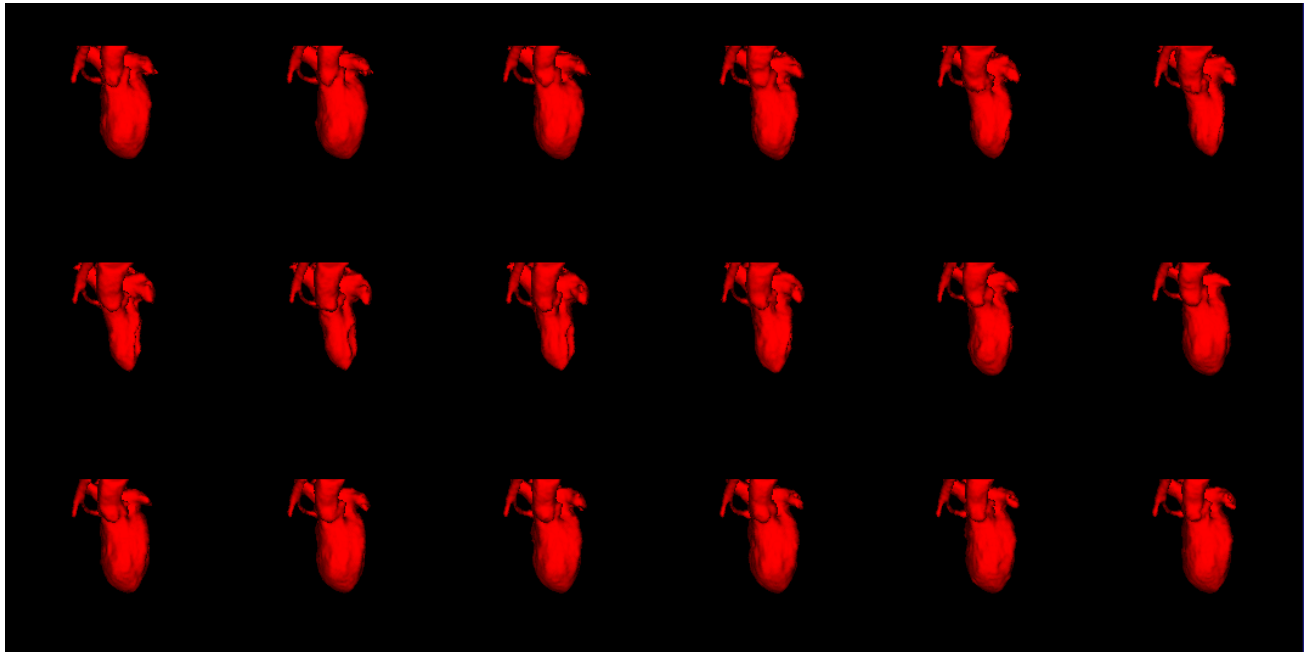
- Select the multivolume data set and open Segment.
- A Volume control window will be available above the object control window [1].
- The slider [2] allows users to navigate through the 3D volumes in the multivolume.
- The window also provides the user with options to create a 3D or 4D object map [3] and to enable or disable the currently selected semi-automatic segmentation tool to be applied to all volumes in the multivolume [4].



- Select Semi-Automatic [5] and choose Region Grow [6].
- Set a seed point in a blood pool [7] and set a threshold range to isolate the object of interest [8].
- Confirm mode is set to 4D and the Grow All Volumes option is checked [9]. Click Connect Object [10].

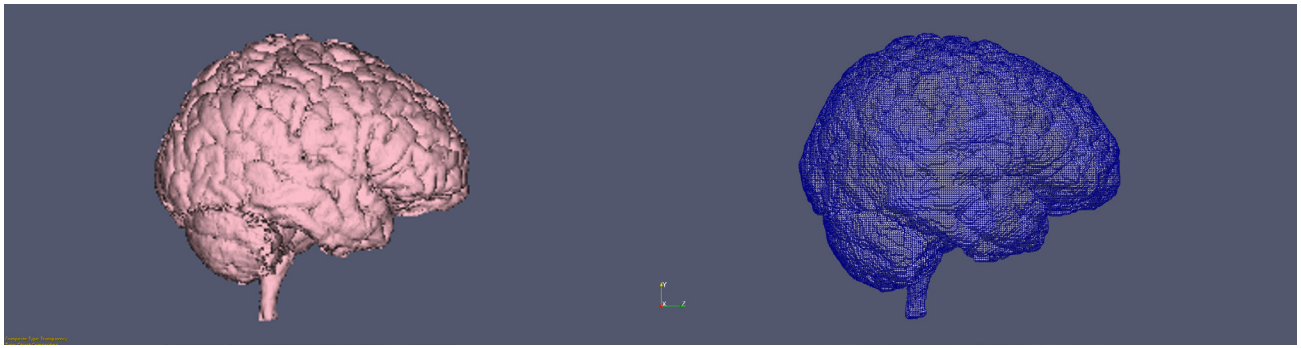
4D Segmentation (continued)

Segment will isolate the object from the first volume of the multivolume. After segmentation is complete, the parameters used to isolate the object from the first volume will be copied to the next volume and the blood pool will be segmented on the second volume. This will continue until all volumes have been processed. Use the volume slider to navigate through the multivolume to review the segmentation results.



Generating Surface Files from Objects

Surface generation offers users the ability to create and export surface files for 3D printing, additive manufacturing, and CAD applications. There is a fundamental transformation that needs to take place between the voxel-based volume image world and an explicit surface description file, for which Analyze provides several helpful algorithms.



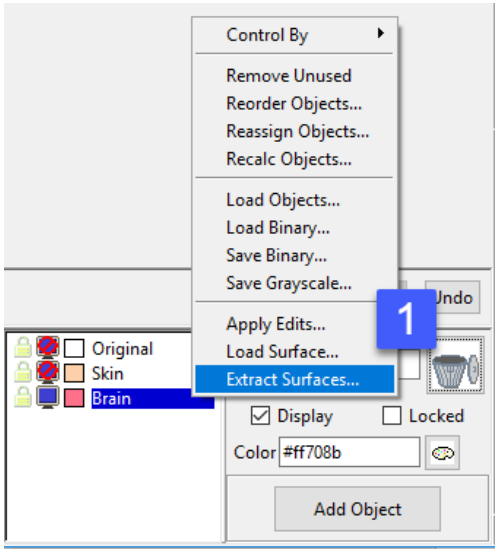
Analyze provides the ability to efficiently and accurately extract and represent a surface from a specific object of interest, exporting this surface in several common surface description formats including STL (see table for a list of supported surface formats).

Format	Extension
Alias Wavefront	.obj
Autocad	.dxf
Compressed IGES	.iges
IGES	.iges
Inventor	.iv
Patran	.out
Ply	.ply
Poly	.poly
3D Systems	.stl
Binary 3D Systems (default)	**.stl**
VRML	.wrl

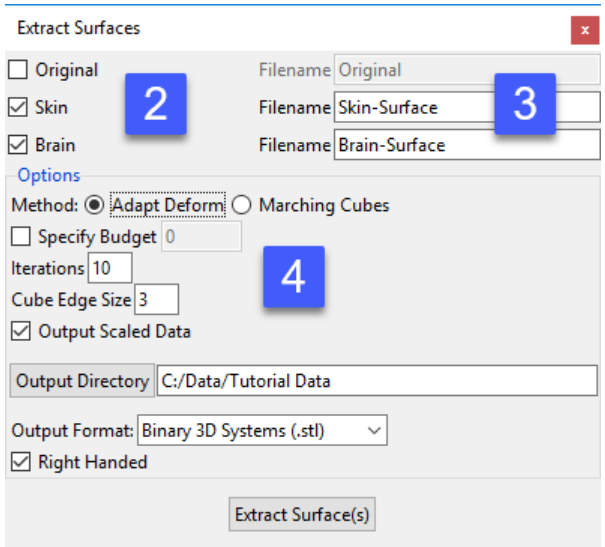
The key to surface generation is to use Analyze to accomplish a segmentation of the particular structure of interest from the volume image data, using any of the available tools provided with Segment, and then use the segmented object to drive the surface extraction process for the optimal definition and output of the surface data.

Surface Generation Options

The Segment module provides the mechanism to extract a surface description of segmented objects from volume image data via two unique Analyze-specific algorithms; Adapt Deform or Marching Cubes. Both Adapt Deform and Marching Cubes extract an optimal description of the surface with as few polygons as possible. Once extracted, the surface can be saved in many common surface description formats and imported into third party 3D printing program, CAD software, or rapid prototyping equipment.



Extract Surface: The Extract Surface window provides users with the interface to generate surface files. To access the window right click in the Object List and choose Extract Surface [1]. The following options are available:



- **Object:** The Object selection area allows users to select objects to generate surfaces for [2]. Note that multiple objects can be selected, each object will be exported to its own surface file. If users wish to combine objects in a single surface file objects either need to be combined prior to surface extraction using the Reassign Object function or combination needs to be conducted after export using a third-party application.

- **Filename:** Surface file names are specified in the Filename field. [3] This field becomes available once an object is selected.

- **Options:** The Options area allows users to specify the surface extraction method for surface generation. When a method is selected method specific options become available. User can choose between Adapt Deform and Marching Cubes:

  - **Adapt Deform:** The Adapt Deform algorithm (enabled by default) [4] specifies that the adaptive deformation algorithm will be used to generate the tiled surface.

Surface Generation Options (continued)

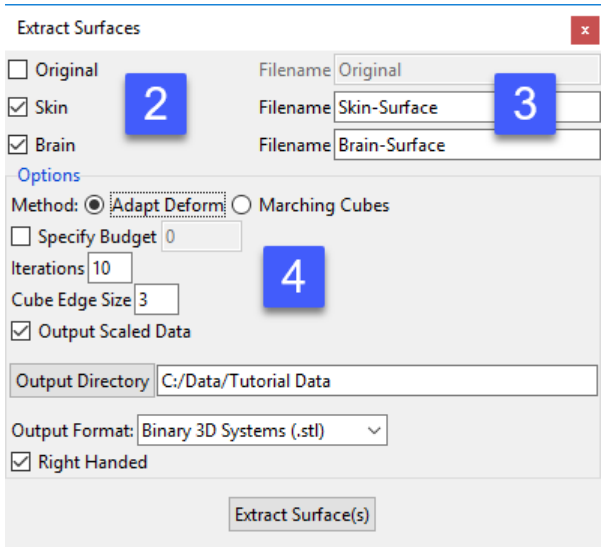
- **Options (continued)**
  - **Adapt Deform (continued):** This algorithm is based on an adaptive mesh model; a discrete dynamic system constructed from a set of nodal masses that are interconnected by adjustable springs. This system is governed by a set of ordinary differential equations of motion (discrete Lagrange equations) that allow the system to evolve to equilibrium.

    In the mass-spring model, the set of coupled equations are solved iteratively in time to update the position of the nodal masses until the masses reach an equilibrium position. For the purposes of surface reconstruction, the equilibrium positions of the nodal masses will approximate the surface of the object. The initial positions of the nodal masses are determined by creating a rough approximation of the surface using a surface tracking technique. A cubic grouping element is used to create a lower resolution version of the data set, which is then systematically triangulated to form the initial approximation of the surface. The following options are available:

  - ***Specify Budget:*** Allows users to specify the maximum number of polygons in the final surface.

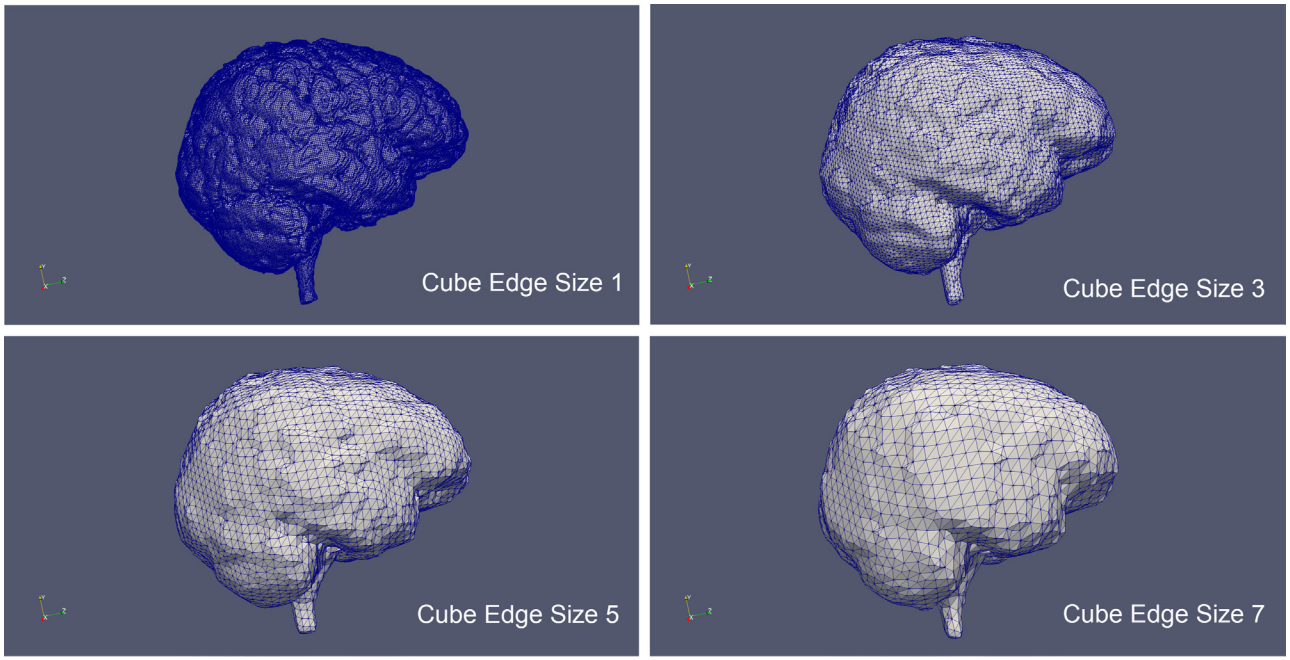
  - ***Iterations:*** Iterations allows the user to specify the number of iterations of the deformation process. While there are a maximum number of iterations beyond which there will be little or no improvement in the quality of the final surface, that point is highly dependent on the data.

  - ***Cube Edge Size:*** The Cube Edge Size option allows users to adjust the length (in voxels) of a side the initial cubic grouping element. This grouping element is used to form the initial surface approximation. If the polygonal budget is set to 0, then smaller cubes will result in higher resolution surfaces, otherwise cube size should be inversely related to the polygonal budget in order to reduce the number of iterations required to reach equilibrium (small polygonal budgets require large cube sizes).



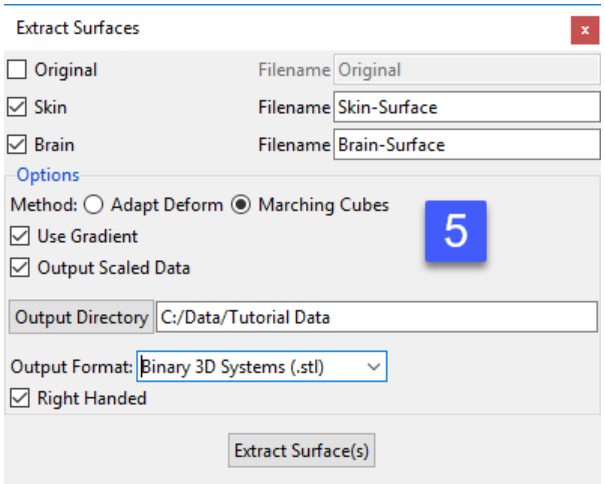
Surface Generation Options (continued)

- **Options (continued)**
  - **Adapt Deform (continued):** The effects of changing the cube edge size on the resulting surface can be seen in this image. The larger the cube edge size the smoother the generated surface is. Note, increasing the resolution (reducing cube edge size) increases the processing time and this is demonstrated by setting the 'Cube Edge Size' to '1'.



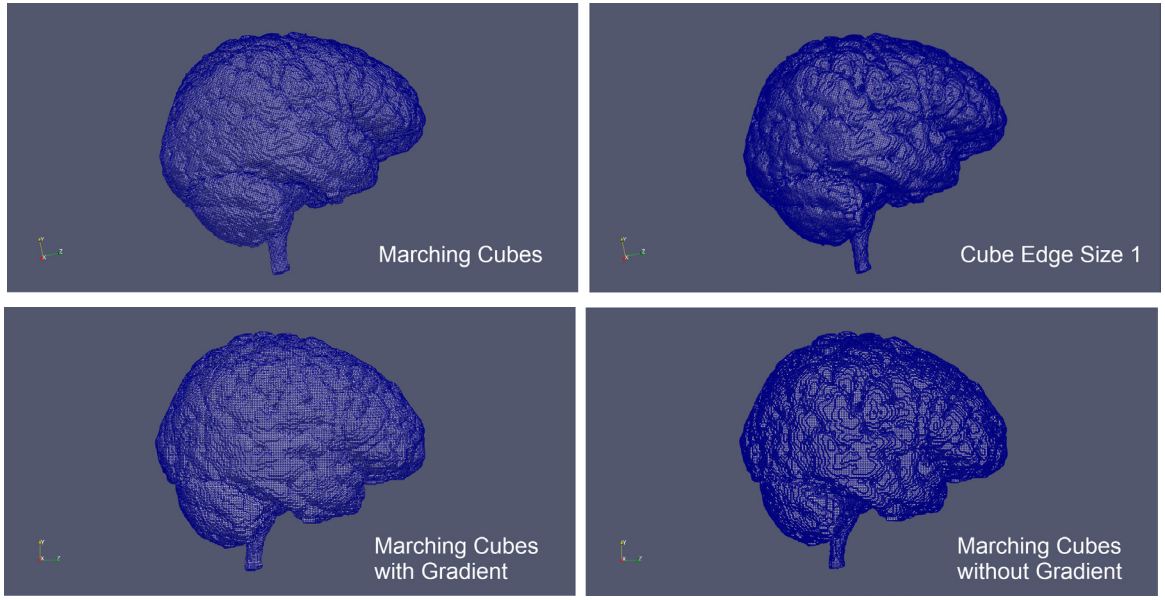
  - In cases where a high resolution (Cube Edge Size of 1) is required, it is recommended that users use the Marching Cubes algorithm.

  - **Marching Cubes:** The Marching Cubes option [5] specifies that the marching cubes algorithm will be used to generate the tiled surface. The algorithm processes the data in scan line order and calculates the polygonal vertices using linear interpolation.



Surface Generation Options (continued)

- **Options (continued)**
  - **Marching Cubes (continued):** As discussed in Adapt Deform if a surface file of the exact segmented object (a cube edge size of 1) is required, then Marching Cubes should be used. This will provide an accurate surface description, in a smaller file, in a fraction of the time of Adapt Deform.
  - ***Use Gradient:*** The Use Gradient option is enabled (checked) by default.

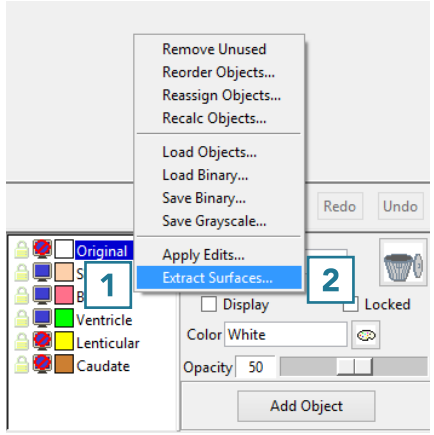


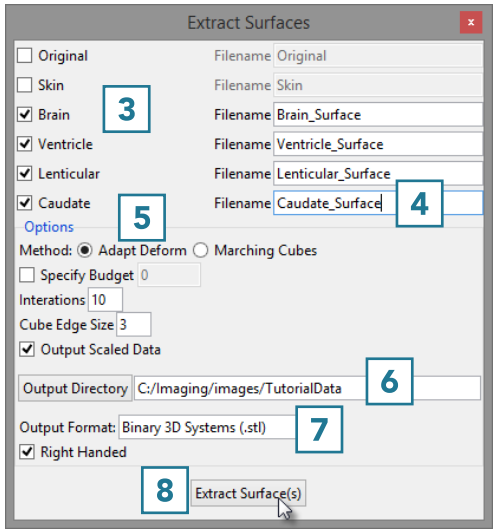
  - *Checked:* When enabled the algorithm will use the gradient information present in the voxel data to estimate surface position. This results in a smooth surface that may have a higher error estimate than the equivalent binary surface extraction.
  - *Unchecked:* When enabled the algorithm will ignore gradient information and generate a surface based on binary thresholding. This will produce a "voxelated" surface that minimizes the error between voxel surface and the reconstructed polygonal surface.
  - **Output Scaled Data:** When selected will scale the surface file into real world coordinates. When the surface coordinates will be scaled from voxel dimensions in the header information of the data to real world dimensions. This requires the VoxelWidth, VoxelHeight, and VoxelDepth parameters be set correctly in the volume's header information.
  - **Output Directory:** Allows users to specify the location where the generated surface files will be saved to.
  - **Output Format:** Allows users to specify the format the generated surface files will be saved in (see previous table for formats)
  - **Right-handed:** For both the Adapt Deform and Marching Cubes extraction processes the surface files created will have a 3D left-handed coordinate system. Checking the right-handed option will flip the surface file to a right-handed coordinate system.
  - **Extract Surface(s):** Initiates the surface generation and export routine. When completed a dialog box will be returned.

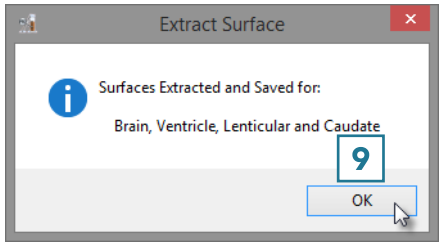
Generating Surface Files from a Selection of Objects

Here we will generate several surface files at once from objects we have previously segmented and which are contained in an object map.

To follow along, download the data set MRI_3D_Head from analyzedirect.com/data and load into Analyze using Input/Output.







- Select the data set and open Segment.
- Select File > Load Object Maps and load MRI_3D_Head.obj.
- Right click on the object list [1] and select Extract Surface [2].
- Select the objects that you will use to generate a surface file [3].
- The output surface name will be the same as the object name. If desired, rename the output surface file name [4].
- Select the surface generation method [5].
- Set the Output Directory [6].
- Choose the ouput format [7].
- Click Extract Surface(s) [8].
- When surface generation is complete a notification will be returned confirming that the selected surfaces have been generated and saved. Click OK [9] to close the window.

The generated surfaces can now be retrieved from the output directory and used in other third party applications such as 3D printing, additive manufacturing, or computer aided design.