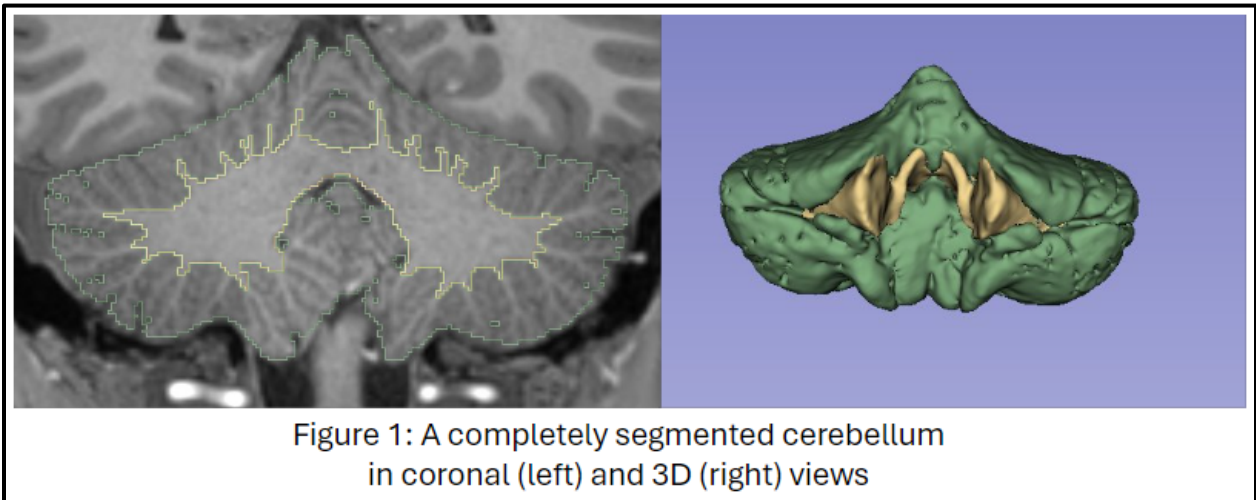# Manual Segmentation of the Cerebellum on T1w MRI Scans

A method for segmenting the cerebellum using 3D Slicer

Figure 1: A completely segmented cerebellum
in coronal (left) and 3D (right) views

The cerebellum is a large brain structure connected to the brainstem. It consists of an outer layer of gray matter that comprises numerous folds, and an inner core of white matter. The gray matter is segmented as the cerebellar exterior, and the white matter is segmented as the cerebellar white matter. Both segments are divided into left and right.

The segmentation process for the cerebellum is divided into four phases: 1) outlining the exterior and interior borders of the cerebellum, 2) removing white matter islands, 3) extending white matter branches, and 4) separating the cerebellum into left and right. The result of this method should reflect what is shown in Figure 1 above.

Phase I: Outlining the Exterior and Interior Borders of the Cerebellum

Select a **coronal** section from the middle of the cerebellum. Select the *Cerebellar Exterior* segment label/color. Open the Threshold tool menu (Figure 2A), click on the *Local Histogram* tool, and drag open a circle over the top or bottom edge of the cerebellum (Figure 2B) - whichever is more distinct. Under the local histogram tool, click and drag the mouse between the two peaks, click *Average - Maximum*; then click *Use for Masking* (Figure 2A).
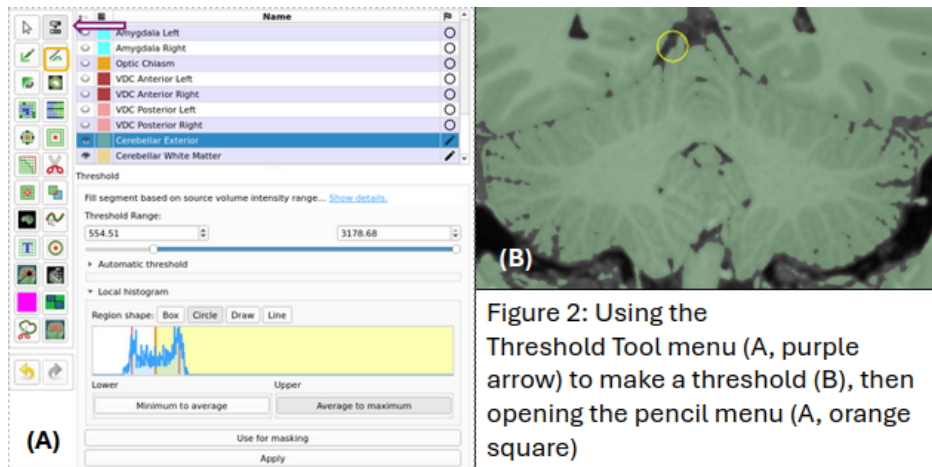
Figure 2: Using the Threshold Tool menu (A, purple arrow) to make a threshold (B), then opening the pencil menu (A, orange square)

After you have set the threshold, change from the painting tool to the drawing tool (Figure 2A, orange square) and change *Editable Area* to *Outside All Segments* in the drawing tool menu (Figure 3). Use the *drawing tool* to draw an outline around the cerebellum, making sure not to include any cerebrum, dura matter, or other, non-cerebellar structures. This should result in an outline like the yellow line shown in Figure 3. Using the same threshold, draw an outline of each slice of the cerebellum, right-clicking after the outline is complete to fill in the cerebellum.
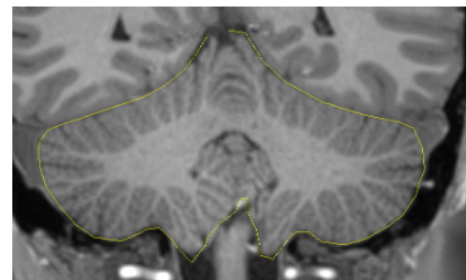

Figure 3: Outlining the exterior of the cerebellum

Figure 4 shows a representative slice of the cerebellum following segmentation of its exterior.
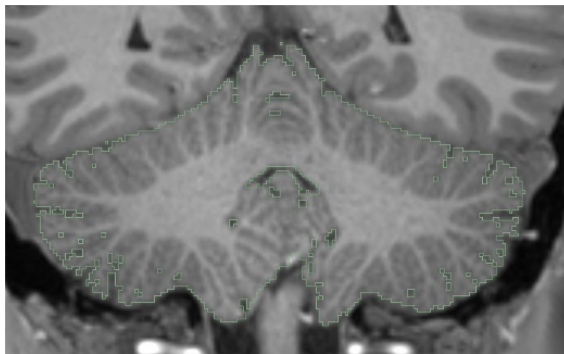

Figure 4: A coronal slice of cerebellum as expected after the cerebellar exterior has been segmented

The next step is to segment the cerebellar white matter (WM). Select a **coronal** section in the middle of the cerebellum. Select the *Cerebellar White Matter* segment label/color. Open the threshold menu, select the *local histogram* tool and draw a circle on the edge of the main body of the cerebellar white matter where it touches the cerebellar grey matter, as shown in Figure 5. After the circle is drawn, click and drag the mouse between the two
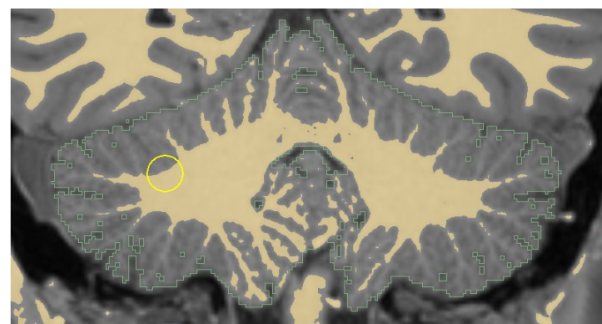

Figure 5: Placing the Threshold circle for the Cerebellar White Matter segment

peaks on the local histogram, click *Average – Maximum,* and select *Use for Masking*. Change the *Editable Area* to *Inside Cerebellar Exterior*. Using this threshold, use the *painting tool* on each slice of the cerebellum; a larger paint brush (size: 10-15) is best for this step. The result should resemble Figure 6 on the next page.
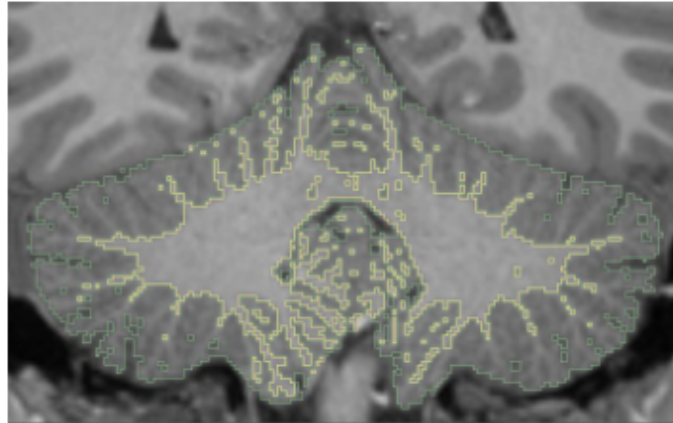

Figure 6: Completely outlined cerebellum slice with islands

Phase II: Removing Islands

This phase consists of removing islands of white matter and filling in holes in the white matter that were missed by the first threshold.

Keeping the **coronal** section open, open the *eraser tool*, keeping the editable area as Inside Cerebellar Exterior in the masking menu. Check that the Cerebellar White Matter segment label/color is selected. Using the eraser tool, remove any islands (Figure 7, red square) in the brain tissue of each slice.

Switch to the paint tool, keep using the Cerebellar White Matter segment label/color, and un-check the *editable intensity range* function. Using the paint tool, pull up each slice and fill in any holes (Figure 7, blue circle) in the cerebellar white matter, ensuring that only holes fully encompassed by the alternate segment are filled in. Do not extend the main body of the white matter beyond what the first threshold provided.
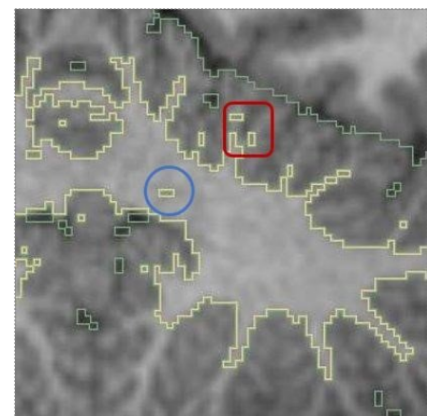

Figure 7: Island removal (red square), and filling in holes (blue circle)

Phase III: Extending Branches

View the **coronal** sections and bring up a slice that looks like Figure 8. Select the Cerebellar White Matter segment label/color, open the threshold menu and click on the local histogram tool. Drag a circle at a point around halfway down

one of the branches, as shown in Figure 8. Click *Average–Maximum* and select *Use for Masking*. Re-check the *editable intensity range* function and select Inside Cerebellar Exterior. Using a smaller paint brush (1-3), click and drag the mouse down each branch on each slice of the cerebellum.
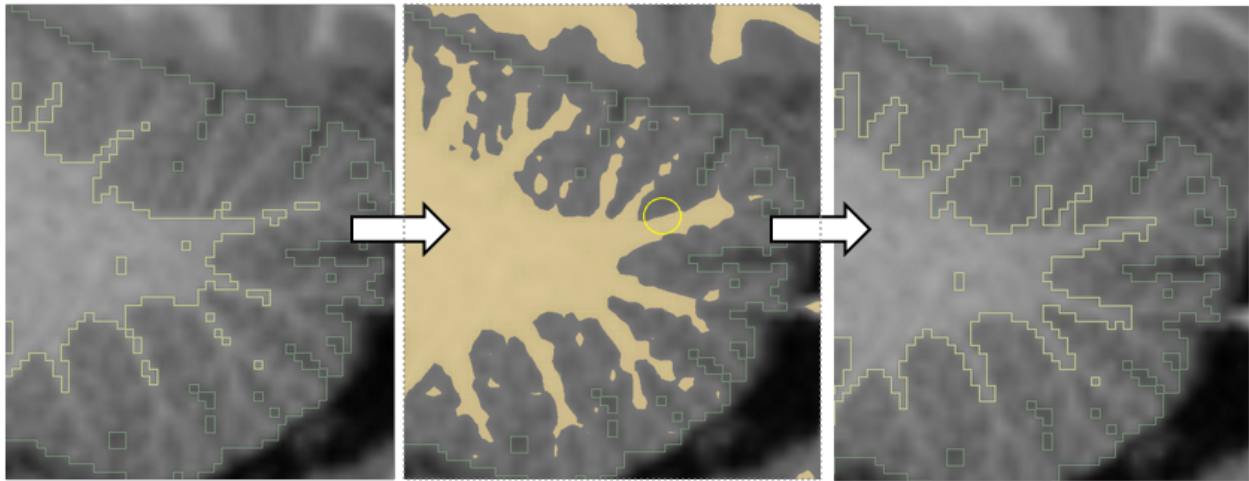

Figure 8: Extending the white matter branches using the threshold tool

After extending the branches, close the sagittal section and open the **coronal** sections. Select the *Cerebellar Exterior segment label/color*, and turn off the *editable intensity range* function. Using the *eraser tool*, remove any extraneous Cerebellar Exterior voxels which may have been missed by the island tool earlier. Common locations requiring this step are along the white matter tracts connecting the cerebellum to the brain stem, around the brain stem, and along nerve tracts that might have been included in the first segmentation of the cerebellar exterior.

The last step is to examine the 3D structure of the cerebellar white matter for irregularities on the orthogonal plane that need to be corrected, as seen in Figure 9 (blue circle). To find these intersectional variabilities, return to the *four-up view*, which includes the 3D structure, coronal view, sagittal view, and axial view. Click on the visibility icon next to the Cerebellar Exterior segment label/color to remove it from the 3D projection. Using the Crosshair tool found at the top of the screen, place the crosshair at the base of the irregularity on the 3D structure. The location of the irregularity should appear on the other three views; using the eraser tool, remove the irregularity in one of the other views using the crosshair as a guide. Repeat this process for any irregularities that you find on the 3D structure.
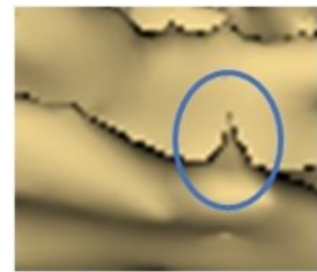

Figure 9: Addressing irregularities in 3D view

Phase IV: Separating the Cerebellum into Left and Right

To separate the Cerebellar Exterior and Cerebellar White Matter segments into left and right, open the **coronal** view. Place a crosshair on the mid-sagittal slice. This divides the coronal view into left and right portions. Edit segment labels such that the existing cerebellum labels now state Cerebellar Exterior Right and Cerebellar White Matter Right, and two new labels state Cerebellar Exterior Left and Cerebellar White Matter Left. Then, open the **scissors tool** and select *fill inside* and *rectangle* from the scissors menu as shown in Figure 10. On the coronal view, select the new Cerebellar Exterior Left label, ensure the editable area is set to its right-side companion, and click and drag the rectangle so that it encompasses the Right Side of the Coronal view. Do this again for Cerebellar White Matter Left.
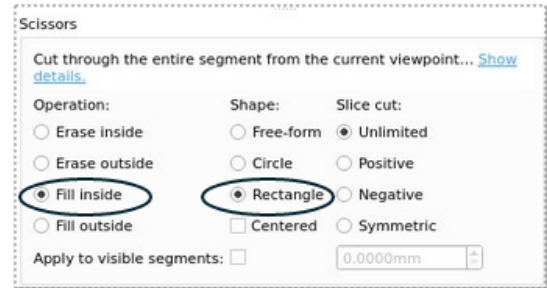
Figure 10: Scissors tool