Electrode Grid Visualization with Analyze 10.0

Visualization of subdural electrodes from postimplantation CT relative to the cortical surface from a preoperative structural MRI can be achieved using Analyze 10.0 and these four steps:

1. Co-registration and Transformation of Structural MRI to Postimplantation CT
2. Electrode Segmentation from Postimplantation CT
3. Cortical Segmentation from Structural MRI
4. Visualization of Electrodes and Cortical Surface

Co-registration and Transformation of Structural MRI to Postimplantation CT

1. In the Analyze workspace, select the post-implantation CT and then, while holding down the <**Ctrl**> key, select the pre-operative MRI.
2. Open the **3D Voxel Registration** module (**Register > 3D Voxel**).
3. To help with visual evaluation of the coregistration, select **Generate > Blend** and change the **Blend Type** to **Yellow-Cyan** (figure 1).
4. Then, click the **Register** button or choose **Generate > Register** to attempt to automatically register the match MRI volume to the base CT volume.
5. Once the registration process is complete the registration can be evaluated by inspecting the fused images in the middle column. If the registration is satisfactory, you can continue to Step 12.
6. If you are not satisfied with the registration, then choose **Generate > Undo Register** to reset the MRI back to its original position.
7. To try and improve the automatic registration results, open the **Threshold** window (**Generate > Threshold**).
    a. Select the **Show Thresholding** option (figure 2). The main 3D Voxel Registration window will update to a binary image display, showing only those voxels within each volume's threshold range in white.

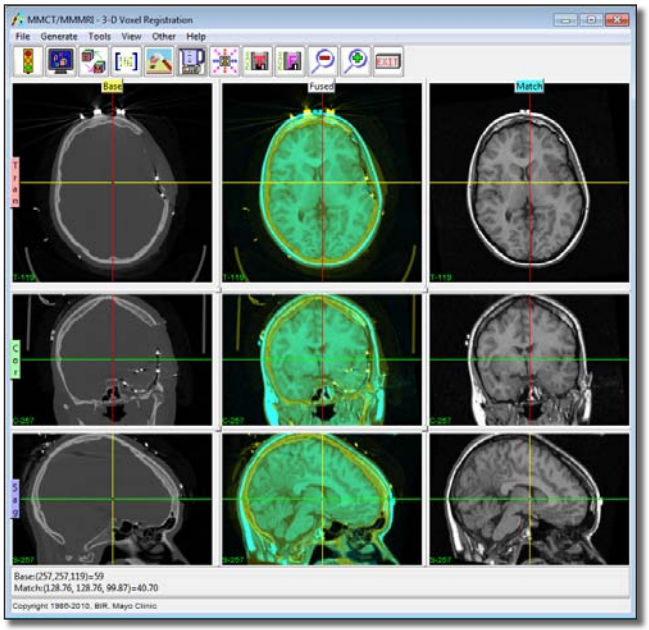

Figure 1

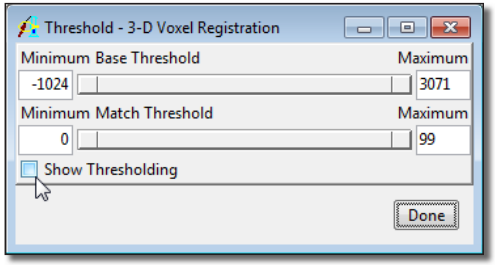

Figure 2

b. Adjust the **Base Threshold Minimum** and **Maximum** values with the double-ended slider bar until the voxels corresponding to background noise and streak artifact in the binary CT images are black.

c. Then, increase the **Match Threshold Minimum** until the background voxels in the binary MR images are black (figure 3)

d. Uncheck the **Show Thresholding** option to convert the image display back to grayscale and then click **Done** to close the Threshold window.

8. Click the **Register** button to attempt to register the MRI volume to the CT volume again, this time based only those voxels within the given threshold ranges.

9. If the registration is satisfactory, you can proceed to Step 12. If the registration is still not acceptable, then you may need to roughly align the MRI volume with the CT volume manually before running the registration process.

10. To manually adjust the registration, open the **Manual Tool** (**Tools > Manual**).

a. To reset the MRI back to its original position, select the **Reset Matrix** button.

b. Use the arrow and rotation keys to manually move the MRI volume into closer registration with the CT. Note that the axis along with the match volume moves or rotates is controlled by the orientation cube selected at the top of the Manual tool (figure 4).

11. Once the MRI volume is more closely aligned with the CT, click the **Register** button in the main 3D Voxel Registration window again. If the registration remains unsatisfactory, please contact support@analyzedirect.com for further assistance.

12. Upon successfully registering the MRI to the CT, you can output the transformed MRI. Select **File > Save Transformed** and output the transformed MRI to the Analyze Workspace (figure 5).

13. Once the transformed MRI has been saved to the Analyze Workspace you may exit the 3-D Voxel Registration module.

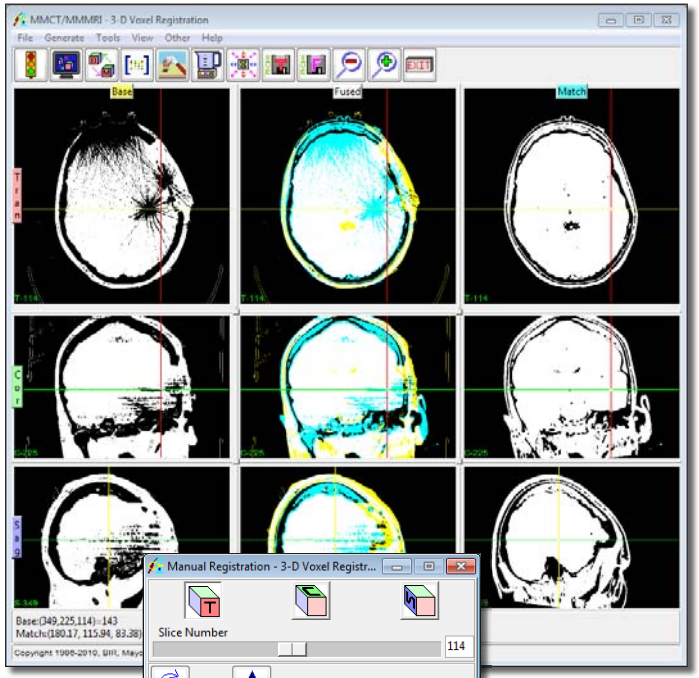

Figure 3

Figure 4

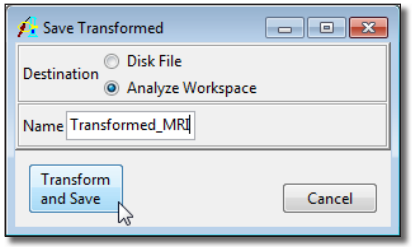

Figure 5

Electrode Segmentation from Postimplantation CT

Segmentation of the electrode grid can be achieved via threshold based segmentation. The following steps demonstrate how to use the Volume Edit module to isolate the electrodes and save them to an object map.

14. Select the post-implantation CT in the Analyze Workspace and open the **Volume Edit** module (**Segment > Volume Edit**).

15. In the Volume Edit window, select the **Semi-Automatic** tab.

    a. Choose the **Threshold** option (figure 6).

    b. A double-ended Threshold slider bar will appear under the options in the Semi-Automatic tab. As the Threshold range is adjusted using this slider bar, the 2D orthogonal images will convert to a binary display, showing only those voxels within the given threshold range in white. The rendering in the upper right pane of the Volume Edit interface will also interactively update to show the voxels within the threshold range.

    c. Adjust the **Threshold Minimum** and Maximum until only the electrodes and leads are displayed in the binary 2D images and rendering (figure 6).

    > *note* | For most CT data sets a Threshold Minimum of around 3000 will work well.

    d. Click **Define Object**.

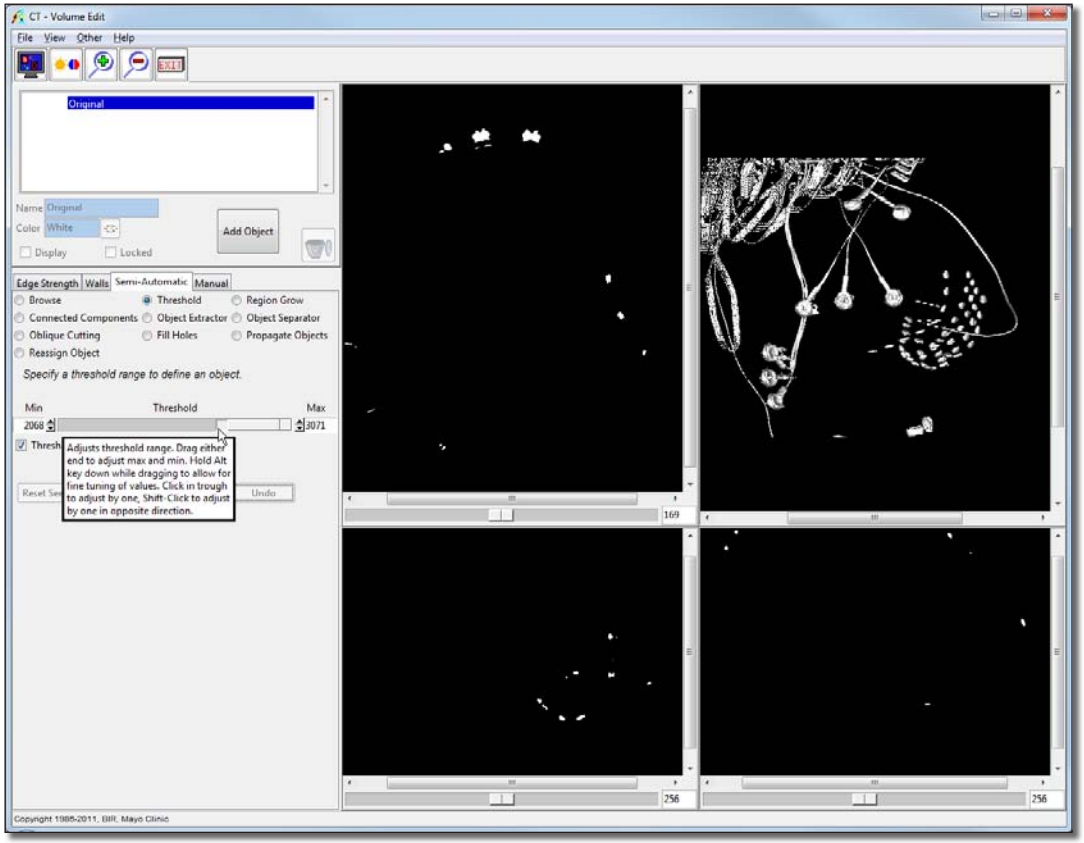

Figure 6

16. To separate the electrodes from the leads, select the **Manual** tab.

    a. Click the **Add Object** button to add a new object named Object_3 (figure 7). Then, rename Object_3 to **Electrodes**.

    b. Choose the **Trace** tool.

    c. Trace around the electrodes in the rendering displayed in the upper right pane of the Volume Edit window (figure 8).

    d. Once you release your mouse button, the trace will close and anything inside of it (i.e. the electrodes) will be reassigned to the Electrodes object (figure 9).

17. Select **File > Save Object Map**, and save the object map to file for use in the next task.

18. After saving the object map, close the Volume Edit module.

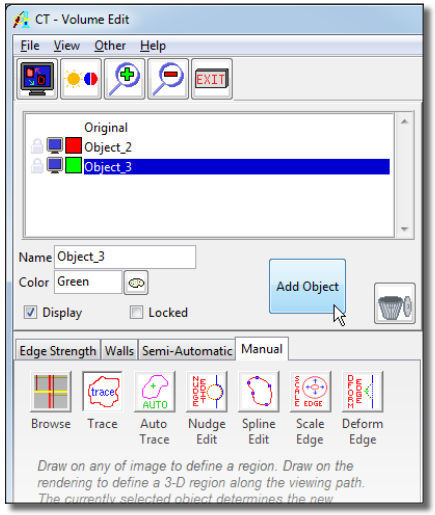

Figure 7

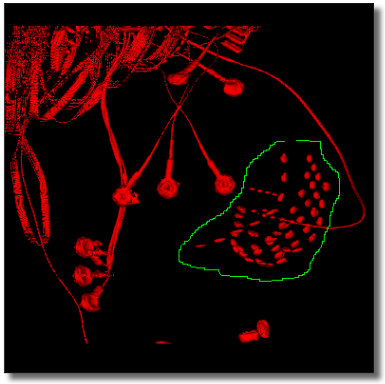

Figure 8

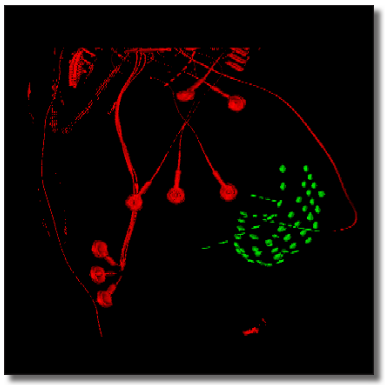

Figure 9

Cortical Segmentation and Visualization with Electrodes

Segmentation of the cortex can also be achieved using the Volume Edit module. The following steps demonstrate how to use Volume Edit to perform an automated segmentation of the brain and then fuse the results with the segmented electrodes from the previous section.

19. Select the **Transformed_MRI** data set from the Analyze workspace, and then open the **Volume Edit** module (**Segment > Volume Edit**).

20. In the Volume Edit window, select the **Semi-Automatic** tab.

    a. Choose the **Object Extractor** option (figure 10).

    b. Use the Slice slider bar under the transverse image [**A**] to navigate to a slice that is above the orbits of the eyes, and in which the brain is spatially connected.

    c. After selecting an appropriate slice, click on a point inside the brain [**B**] to a seed point for the object extraction.

    d. Once you have set a seed point, a double-ended Threshold slider bar will appear at the bottom of the Semi-Automatic tab (figure 11). Adjust the **Min** and **Max** of the Threshold until a red boundary grows out around the surface of the brain [**C**] and the voxels representing the skull begin to turn black in the binary image (displayed as you adjust the Threshold). The voxels representing gray and white matter in the binary image should remain white [**D**].

    e. Click **Extract Object**.

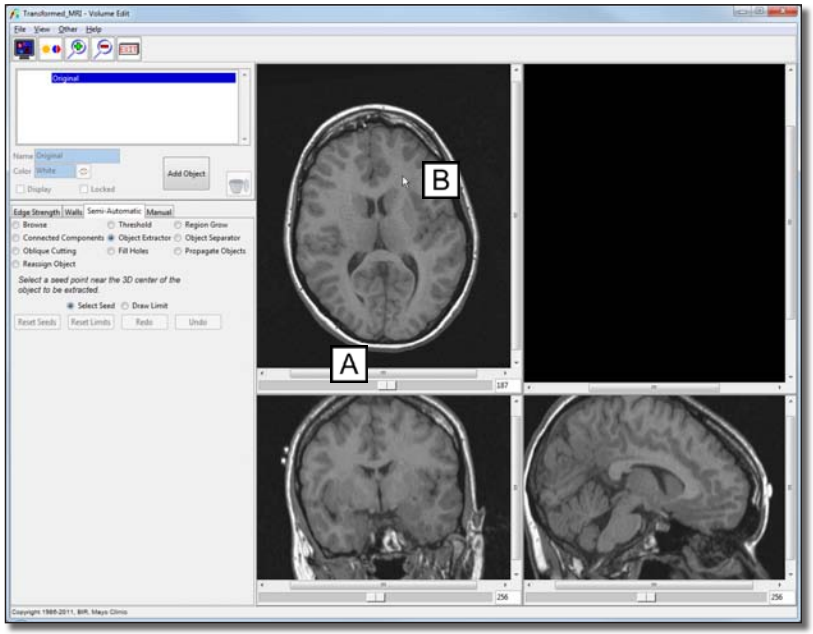

Figure 10

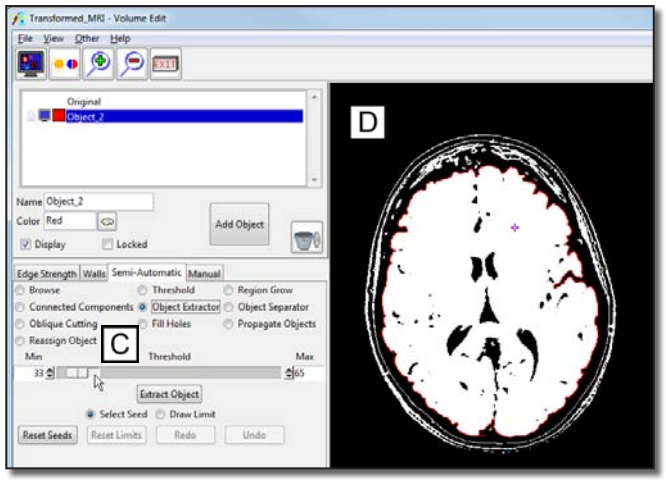

Figure 11

21. The extracted brain will be displayed in the rendering pane of the Volume Edit window (figure 12). To rotate the rendering hold down your middle mouse button and then drag and drop.
22. Rename Object_2 to **Brain** and change the color to **Pink** (figure 13).
23. To load the segmented electrodes into this Object Map, go to **View > Objects**.
    a. In the **Objects** window, click the **Load Object(s)** button (figure 14).
    b. Navigate to and select your Object Map file saved in step 17.
    c. When prompted, select the **Electrodes** object from the list and click **Load Selected** (figure 15).

Figure 12

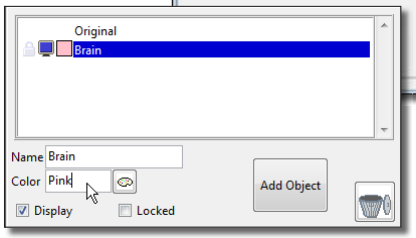

Figure 13

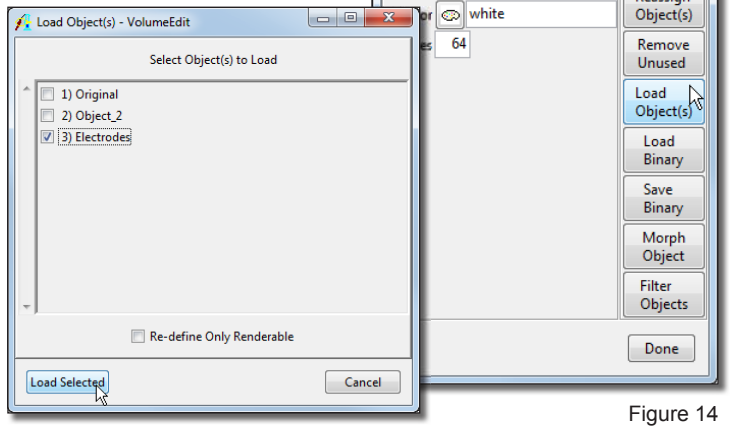

Figure 14

Figure 15

Visualization of Electrodes and Cortical Surfaces

24. Both the brain and the electrodes will now be displayed in the Volume Edit window. To view the electrodes more clearly, right-click on the rendering and choose **Transparency** (figure 16).

25. Once Transparency is enabled, an **Opacity** slider bar will become available for each object in the Objects list (figure 17).

26. Select **File > Save Object Map** to save this merged Object Map for use in other Analyze modules.

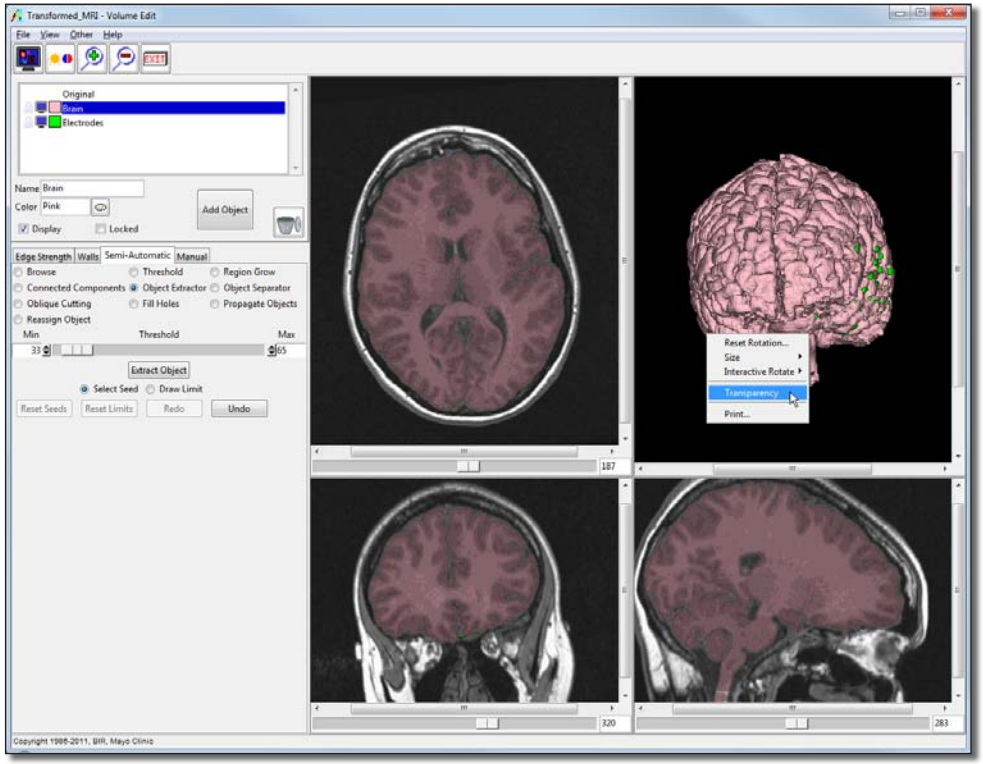

Figure 18

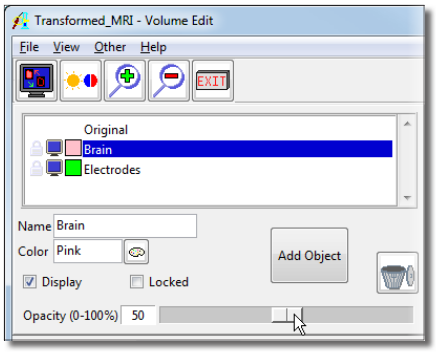

Figure 17