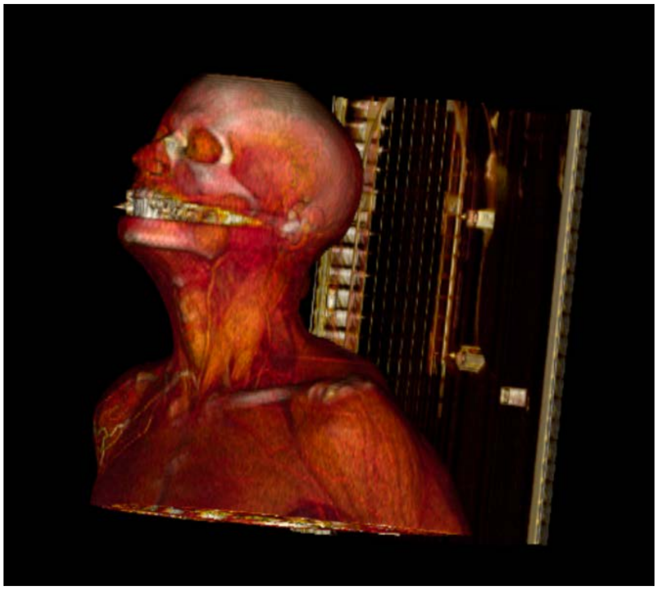

Figure 6.103. A 3D Volume rendering of the same series shown in Figure 6.102.

3D Surface Rendering

This 3D rendering technique provides a 3D view of the surface of an object (Figure 6.104) based on a threshold value of image intensities. See Chapter 8.

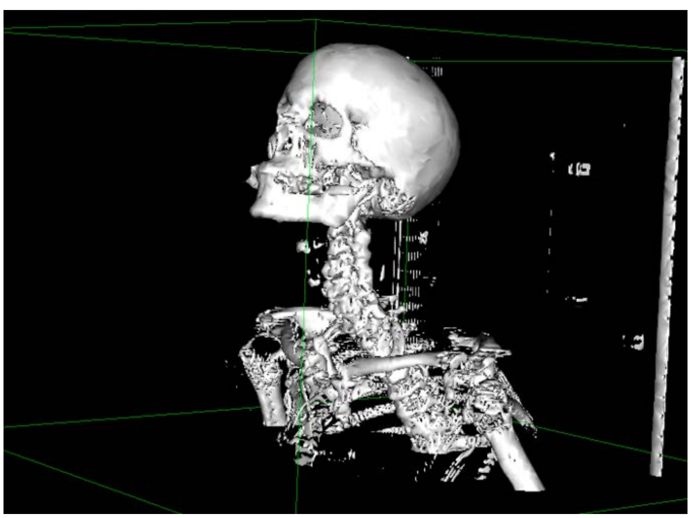

Figure 6.104. A 3D surface rendering of the series with surface settings set to a predefined threshold for bone.

3D Endoscopy

This tool is designed to be used with hollow structures such as the colon or aorta. It can be used with interactive navigation to "fly" down the inside of the tube (Figure 6.105).

3D Panel

You can use the 3D Panel tool (available from the Custom Toolbar) to quickly visualize the series in 3D while still working with the images in the 2D Viewer. By clicking on the 3D Panel tool a small floating window appears with the series shown in 3D. This window is set to display a 3D MIP by default and to rotate. When you clicking on a point in the floating 3D MIP, it updates the 2D Viewer to display the slice where that point is located (Figure 6.106).

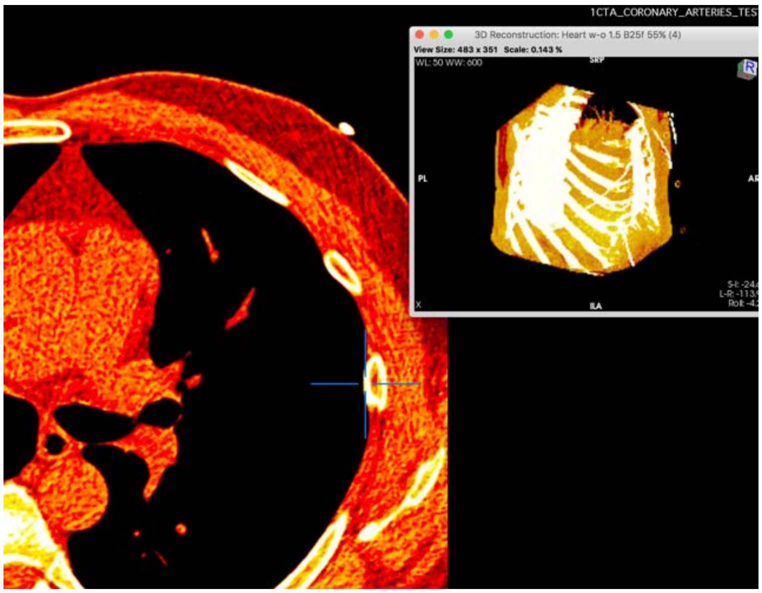

Figure 6.106. The floating 3D Panel, displaying a specific point on the 2D Viewer window (denoted by the cross hairs).

Chapter 7

3-D Image Processing

There are many high-performance imaging modalities, such as high-resolution MRI, multidetector and microCTs, capable of capturing 2D/3D image data. Once captured, these image datasets can be manipulated to the provide 3D anatomical renderings. These software tools improve interpretation and communications among radiologist, physician and patient. Once captured, these patient datasets can be post-processed to create volumetric renderings, multiplanar reformations, and the like.

Additionally, modern imaging devices may provide temporal acquisition of dynamic images (referred to as 4D data). Horos was purposely designed to handle 4D images. In Horos, multiple data series can be fused to yield 5D, 6D or more dimensions. These data can be manipulated and displayed interactively in real-time.

To generate 3D renderings from a group of 2D slices requires that the slice images have a regular, constant interval (3D dataset). To achieve this, Horos uses two DICOM fields to define a 3D origin and a valid 3D orientation cosine matrix with the same 3D world origin.

The DICOM field ImagePositionPatient (0x0020, 0x0032) is used for the 3D origin values and the ImageOrientationPatient DICOM field (0x0020, 0x0037) is used for the 3D orientation cosine matrix. This field contains the X and Y 3D vectors, while the Z vector of the direction cosine matrix is calculated from the X and Y vectors as:

Z = X x Y

The distance between the origins of each slice is used to calculate the interval between slices. An error message will be displayed if one parameter is not available or is incorrect (i.e. if the interval between each slice is irregular or no direction cosine matrix is available). If you receive an error message, you can use the Calibrate Resolution tool to manually correct or define these parameters.

Horos supports the following 3D rendering techniques:

Name	*Basic Description*	*Technique Used*
3D MPR	Multiplanar reformatting	3D resampling based on a rotational matrix
Curved MPR	Multiplanar reformatting	3D resampling based on an arbitrary curved 2D plane
3D SR	Surface rendering	3D isosurface visualization
3D VR	Volume rendering	3D volume ray casting with opacity and shading tables
3D MIP	Maximum intensity projection	3D Volume ray casting for maximum intensity computation
3D Mean	Mean intensity projection	3D Volume ray casting for mean intensity computation
3D MinIP	Minimum intensity projection	3D Volume ray casting for minimum intensity computation
3D Endoscopy	Volume rendering	Similar to 3D VR, except camera is inside the volume

All of these techniques use the VTK engine 5.0, except Curved MPR and 2D Orthogonal MPR, which use built-in algorithms.

The 3D VR engine is used in four viewers:
3D Viewer
2D MPR Viewer when used in 3D VR thick slab mode
3D Panel, if set to VR mode
Endoscopy Viewer

The 3D MIP engine is used in three viewers:
3D Viewer
2D MPR Viewer
3D Panel, when set to MIP mode

The 2D Orthogonal MPR quickly computes orthogonal views without requiring extra memory and is complementary to the 2D MPR Viewer.

The Curved MPR uses a specific algorithm to create a final image according to the path defined by the user (not in real-time) and displays the resulting image in the standard 2D Viewer window.

THE 3D VIEWER

There are seven viewers for processing 2D/3D image series. Each viewer is described in detail in order from the top to bottom of the 2D/3D tool (Figure 7.01).

Figure 7.01. The options for processing 3D image series.

THE 3D MPR VIEWER

Multiplanar techniques clarify the anatomical details of complexly shaped structure, such as vessels or heart chambers. Consequently, MPR methods aide physicians in making appropriate diagnostic decisions and treatment plans. In addition, MPR is quicker and easier than 3D rendering.

Multiplanar reformatting (MPR) allows you to create nonaxial 2D images from axial CT or MRI images. That is, you can create sagittal, coronal and oblique views from a series of original sections. The best image quality occurs when you use small slice intervals, as larger intervals creates geometric distortions along the z axis (Figure 7.02). In general, the slice interval of the original series should be less than two times the pixel resolution (X and Y axis). You can display pixel resolution information from the 2D Viewer > Calibrate Resolution item in the 2D Viewer window.

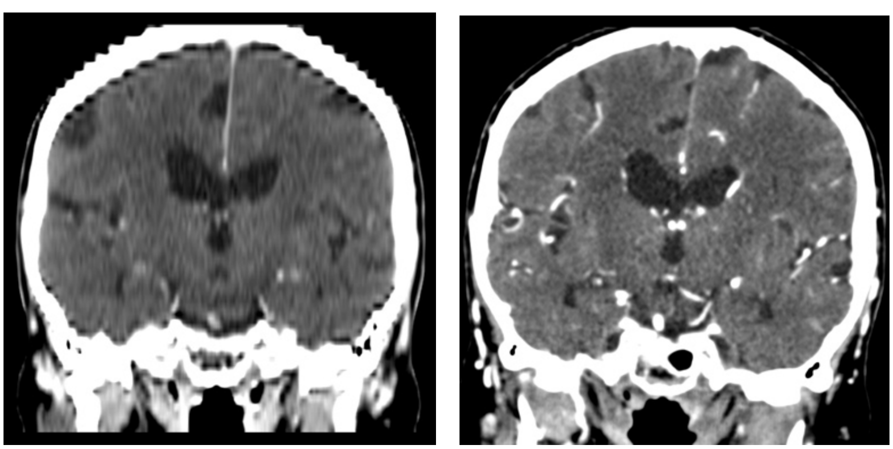
Figure 7.02. MPRs of two series. The left series has a large slice interval, while the series on the right has a small slice interval.

3D MPR Engine

The 3D MPR Viewer uses a different computational engine (based on the VTK engine) compared than the 2D Orthogonal MPR Viewer because the 3D MPR displays oblique planes. Thus the 3D MPR engine is slower than the 2D Orthogonal MPR Viewer. The 3D MPR engine, like the 3D Viewer, uses a ray-casting algorithm. The 3D MPR engine can utilize multiple processors and multiple cores so its performance is linked to CPU performance. Processor performance is especially important if you choose to use the Thick Slab item in the 3D MPR Viewer toolbar (i.e. use a high performance processor with multiple cores).

Plane Position and cross reference lines

The 3D position of a plane is mathematically defined by a 3D point and two orthogonal angles or by three 3D points. The position of one MPR view is displayed on the two other views as a thin cross reference line. You can position an oblique plane by changing the orientation of the axis lines on the coronal view, followed by correcting the orientation on the axial view, and then the sagittal view. Moving the orientation of one view changes the other two views. You may need to repeat this several times to get the exact plane you are looking for.

You can hide (or show) the cross reference lines by pressing the spacebar or by using the Axis tool from the toolbar. If you are using Thick Slab mode, there are double cross reference lines that denote the thickness of the slab. The color and transparency of the cross reference lines can also be modified using the Axis Colors tool (from the Custom Tools). Axis colors are chosen from the standard Mac OS X Color Picker. Finally, you can visualize the mouse position on screen by selecting the Mouse Position tool. This displays the mouse position as colored dots which correspond to the color of the planes.

The 3D MPR Viewer also supports a unique tool called the Plane Rotate tool. You can use the Plane Rotate tool (green sphere) in the Mouse Tools to incline the plane around a 3D point. If you have the cross reference lines displayed, the Plane Rotate tool will incline the 3D planes around the point where the three planes cross. If you have hidden the cross reference lines, the tool will incline the 3D planes around a point you click on in the view. The Plane Rotate tool is useful for rotating the plane around a curved structure such as a vessel.

You can open the 3D multiplanar reconstruction (MPR) Viewer from the 2D Viewer by clicking on the 2D/3D tool in the 2D Viewer toolbar and selecting 3D MPR from the list. The MPR Viewer allows you to reconstruct images in arbitrary oblique planes rather than just orthogonal planes. This allows you to visualize anatomy that would not be possible using axial, coronal, and sagittal planes alone.

The 3D MPR Viewer is divided into a toolbar (Figure 7.03) across the top and three orthogonal views are displayed below (Figure 7.04). You can reorient the planes in any oblique direction.

The toolbar buttons allow you to access the most useful functions and it can be customized to suit your needs using the Format > Custom Toolbar from the Horos menu. Each tool in the toolbar is described below beginning with the default tools from left to right and then the custom tools in alphabetical order.

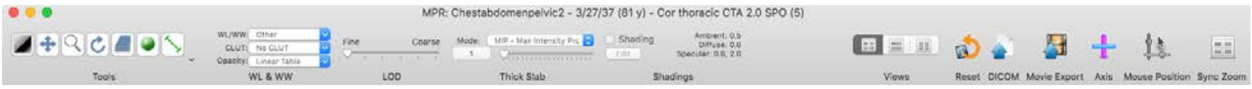

Figure 7.03. 3D MPR Viewer Window Toolbar

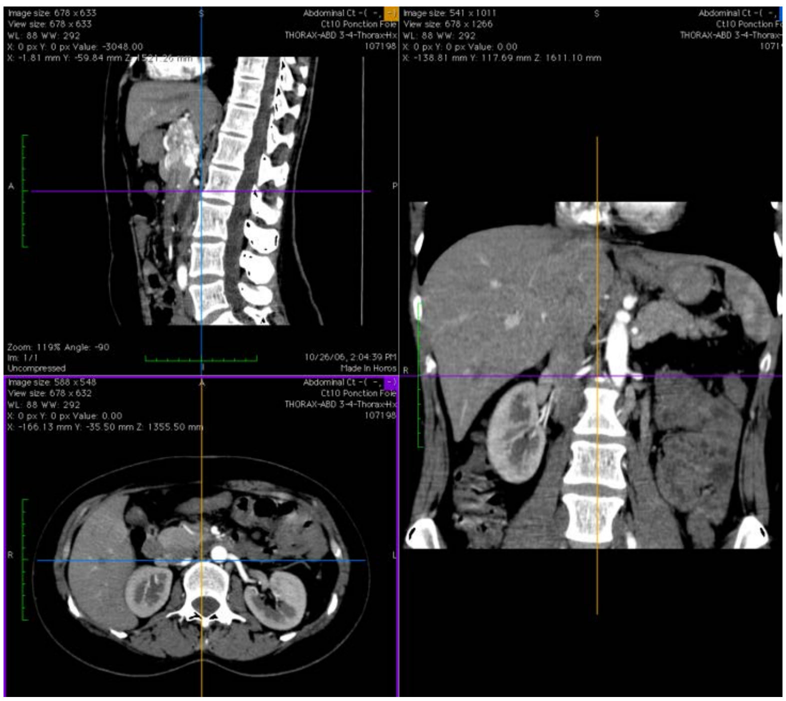
Figure 7.04. The 3D MPR window showing the three orthogonal views.

For example, you can change the orientation of the planes in each MPR view by clicking on the axis lines and dragging them to a new angle (Figure 7.05) or moving both axis lines to a new position by clicking and dragging on the intersection of the two axis lines.

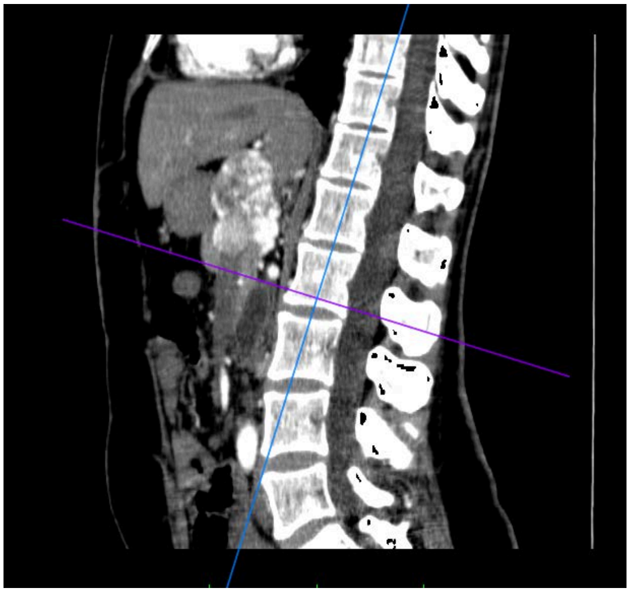

Figure 7.05. The axis lines have been moved to the center of the vertebral column and tilted along its length.

Tools

Mouse tools allow you to assign a function to the left mouse button. The tools include six tools for manipulating the images and 11 ROI tools. The first six tools are described in detail in Chapter 6 and include:

- *WL/WW [default]*
- *Pan*
- *Zoom*
- *Rotate*
- *Scroll*
- *Plane Rotate*

The ROI tools are also described in detail in Chapter 6 and include:

- *Length*
- *Angle*
- *Rectangle*
- *Oval*
- *Text*
- *Arrow*
- *Opened Polygon*
- *Closed Polygon*
- *Pencil*
- *Point*
- *Brush*

You can create and display Point ROIs in the 3D MPR Viewer window. However, unlike the 3D Viewer, the MPR Viewer cannot display 3D ROIs. To create a Point ROI in the MPR Viewer, click on the Point tool in the Mouse Button tools list in the toolbar. Now you can drop a point anywhere on an image in the MPR views. Point ROIs created in the MPR Viewer are also created in the 2D Viewer. You can add line, oval, or angle ROIs in the MPR Viewer but they will not be displayed in the 2D Viewer window and they will disappear from the 3D MPR views if the position of the view is changed (i.e. they are temporary ROIs).

WL & WW

You have three options under the WL & WW tool: WL/WW, CLUT, and Opacity. Each has several additional settings that are accessed from a dropdown list.

The WL/WW option allows you to adjust the window brightness and contrast by clicking in the image window and dragging the mouse. Moving the mouse right or left adjusts the window width and dragging the mouse up or down adjusts the window level.

The CLUT options allows you to choose from a number of pre-set color lookup tables (CLUTs). The default is no CLUT. When you choose a new CLUT, Horos assigns a color to each pixel intensity (see Chapter 6)

The Opacity option allows you to change the opacity table for the image. Each pixel is assigned an opacity according to a transfer function.

LOD (Level of Detail)

You can adjust the level of detail used when rendering images in the three MPR views by moving the slider from fine to coarse. This operation is also available for Thick Slab rendering.

Thick Slab

By default, the MPR views are rendered as thin slices with a thickness set by the user when the scan was completed. You can increase the thickness of the MPR views using the Thick Slab function in the toolbar. This allows you to modify the number of slices used to produce the image. The final thickness in mm is displayed in the box to the right of the slider. Modifying the slab thickness also displays outer and inner lines on each of the three MPR views (Figure 7.06). There are four rendering algorithms available in Thick Slab: MIP, MinIP, Mean, and Volume Rendering.