In the Curved MPR view, you can change the following attributes:

- You can use the mouse scroll wheel to change the rotation of the plane.

- You can use the mouse scroll wheel while pressing the option key to move the position of all three A, B, and C lines along the path. Alternatively, you can click and drag the B yellow line to a new position on the path.

- You can change the interval of the three perpendicular views (yellow lines) along the curved plane by using the Command key and the mouse scroll wheel simultaneously.

- You can increase or decrease the interval between the perpendicular views A, B, and C along the curved plane by clicking and dragging the A or C yellow line.

- You can use the right mouse button while dragging the mouse over the Curved MPR view to change the zoom level.

- You can double click on the Curved MPR view to display this view in full-screen. A second double click returns the image to its original size.

- You can hide or show the annotations on the view by pressing the tab key.

- You can measure distances by using the Length ROI tools. If you are in the Straightened Rendering mode, the Length ROI tool can only be used to measure lengths of horizontal or vertical lines. However, if you are in Stretched Rendering mode, you can measure oblique lengths as well. Note that you can add Oval and Angle ROIs to the 3D Curved MPR viewer, but they will disappear when the view is closed or moved. Likewise, any ROIs displayed in the 2D Viewer will not appear in the 3D Curved MPR Viewer.

THE 2D ORTHOGONAL MPR VIEWER

The 2D Orthogonal MPR Viewer is a window opened from the 2D/3D tool in the 2D Viewer. The 2D Orthogonal MPR Viewer is divided into a toolbar (Fig. 7.14) across the top and three orthogonal MPR views on the bottom. You can simultaneously display axial, coronal and sagittal planes intersecting in a given point of the body when selecting the 2D Orthogonal MPR tool (Figure 7.15). By default, the axial view is on the left, the coronal view is in the middle, and the sagittal view is on the right.

Figure 7.14. The default toolbar in the 2D Orthogonal MPR Viewer.

Figure 7.15. The default 2D Orthogonal MPR Viewer window.

Thin green cross reference lines show the position of each MPR view on the two other views. Moving the cross-reference lines on one MPR plane, moves it on the other two planes. You can hide or show these cross-reference lines by pressing the space bar. If you are using the Thick Slab tool, the cross-reference lines are doubled to show the thickness of the slab on each of the three MPR views.

Each 2D Orthogonal MPR view is similar to views of the 2D Viewer window. Double-clicking on one of the three planes displays that plane in full screen mode. A second double-click on the image switches it back to the 3-panel view.

2D Orthogonal MPR Engine

The 2D Othogonal MPR engine uses a simple algorithm that reorders the pixels into columns and rows. Thus, displaying orthogonal images from a 3D dataset is a simple computation requiring little memory. As a result, the process is very fast. As is the case with other viewers, performance is related to CPU performance and number of cores.

Toolbar

The basic tools and the keyboard shortcuts used in the 2D Orthogonal Viewer are identical to those used in the 2D Viewer. As with any other toolbar, it can be customized or re-organized using the Format > Custom Toolbar commands. The default 2D Orthogonal MPR Viewer toolbar provides a variety of tool icons (Figure 7.14). Below each tool is described in the order they appear on the toolbar from left to right, followed by several additional tools in the Custom Toolbar.

Mouse button function

You can choose to assign one of the following ten tools to the left mouse button:

• WL/WW	• ROI Tool Length
• Pan	• ROI Tool Oval
• Zoom	• ROI Tool Angle
• Rotate	• ROI Tool Point
• Scroll	• Cross Position (Default)

The Cross Position tool is the default tool selected. It moves all three MPR planes to a 3D position you select by clicking on one of the planes.

You can display Point, Line, Oval, and Angle ROIs on the 2D Orthogonal MPR Viewer windows. These ROIs will also show up on the 2D Viewer window.

WL/WW & CLUT

This tool set includes three settings. The WL/WW tool applies the selected preset to the MPR views. The CLUT tool applies the selected Color Lookup Table to the MPR views (default is no CLUT). The Opacity tool applies the selected opacity table to the current MPR views. The behavior of these three tools is identical to the 2D Viewer.

Thick Slab

Default MPR views have a thickness equal to the original dataset. You can increase the thickness by clicking on the mode checkbox and using the Thick Slab slider to change the number of slices used in the final image. The thickness you choose is displayed as a number on the left of the slider. The final thickness of the slab is displayed in the lower left part of the MPR view (Figure 7.16).
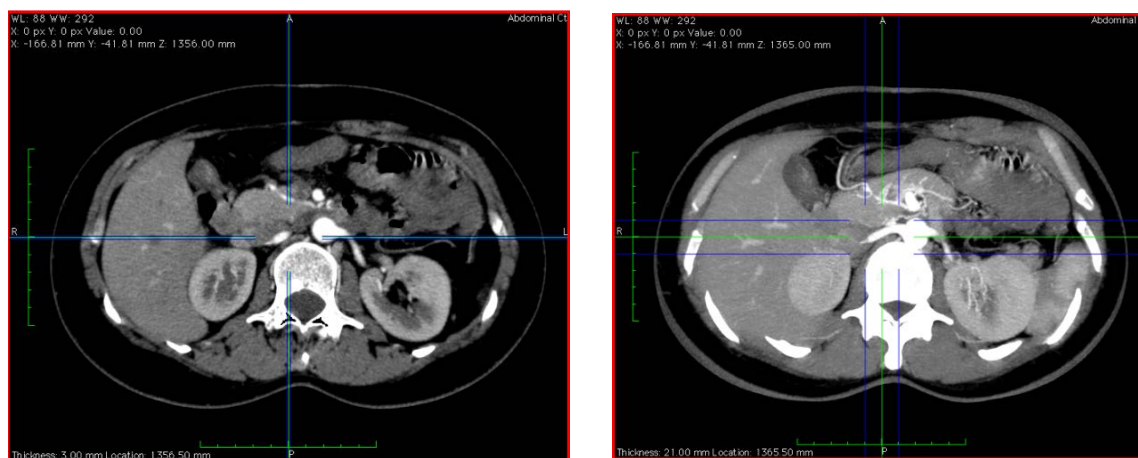

Figure 7.16. The axial plane showing the original slice on the left and the Thick Slab image on the right. Note the final image thickness in the lower left corner of the right image.

The Thick Slab tool also allows you to select from three rendering algorithms: Mean, MIP, and MinIP (Figure 7.17). The Thick Slab tool is not available for use with fused datasets.
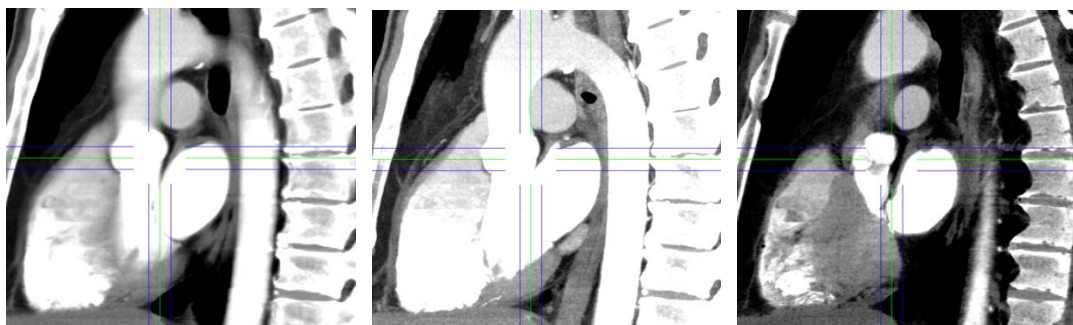

Figure 7.17. The three modes available in Thick Slab: Mean (left), MIP (middle),
and MinIP (right).

4D Player

The 4D Player tool works with 4th dimension data series. It allows you to scroll in the 4th dimension (i.e. temporal dimension). The first step is to load a set of dynamic images (i.e. a beating heart) using the 4D Viewer tool in the database window toolbar. Once it is loaded, open the 2D Orthogonal MPR Viewer window and use the 4D Player tool in the toolbar to play the sequence of images.

DICOM File

You can create snapshots of your MPR views, save them to disk as DICOM files, and add them to the database. Clicking on the DICOM tool opens a popup window (Figure 7.18) where you can create a new series name for the exported snapshots. You can also choose between a screen capture, 16-bit BW image, or all views. You can choose to only export the current image, or a series of images. If you choose all images in a series, you can change the number of frames to render and the start and stop interval. Finally, you have the option to mark the images as key images and the option to send the exported images to a DICOM node.
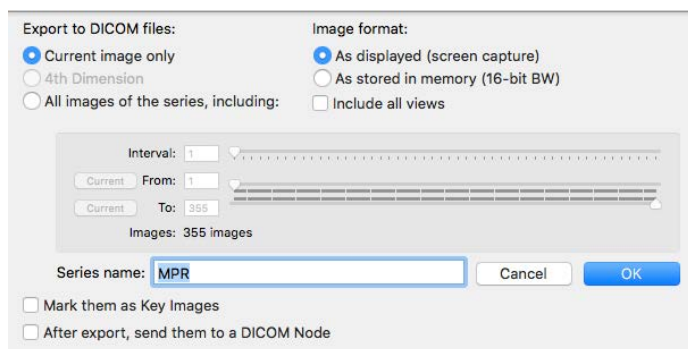

Figure 7.18. The Save as DICOM popup window in the 2D Orthogonal MPR Viewer.

Note that the 2D Orthogonal MPR Viewer cannot export QuickTime movies directly. You can, however, create a new DICOM series and then export it from the 2D Viewer window where you can then export it in QuickTime format.

Email

Selecting the Email tool opens Apple's Mail application, creates a new email message, and attaches the currently selected MPR view as a screenshot (JPEG) file.

Same widths / heights

If you have manually resized one or more of the three MPR views (using the view separators), this tool re-sizes the three MPR views so they all have the same widths or heights.

3D Panel

The 3D Panel tool opens a small window displaying a rotating view of the full volume MIP (by default) or Volume Rendering of the image data. You can stop the rotation by clicking on the image or manipulate the volume interactively using the cube tool. If you double-click a point on the 3D panel image, it automatically positions the orthogonal planes on that point.

Reset

The reset tool (available from the Custom Toolbar) changes the MPR views to their default settings (i.e. it resets the WL/WW, Zoom, Rotation, and Pan setting).

Flip Volume

This tool vertically flips the coronal and sagittal MPR views. It functions identically to the Flip Volume tool of the 2D Viewer. It doesn't flip the order of the images in the 2D Viewer. This tool is not available with a fused dataset.

2D ORTHOGONAL MPR VIEWING DETAILS

Image Fusion

The 2D Orthogonal MPR Viewer supports image fusion. If you open a fused series from the 2D Viewer, and then open the 2D Orthogonal MPR Viewer, you will see nine orthogonal views (Figure 7.19). The left column of images are the three orthogonal views from the CT, the middle column of images is the fused CT-PET, and the right column are the PET series. The fused datasets
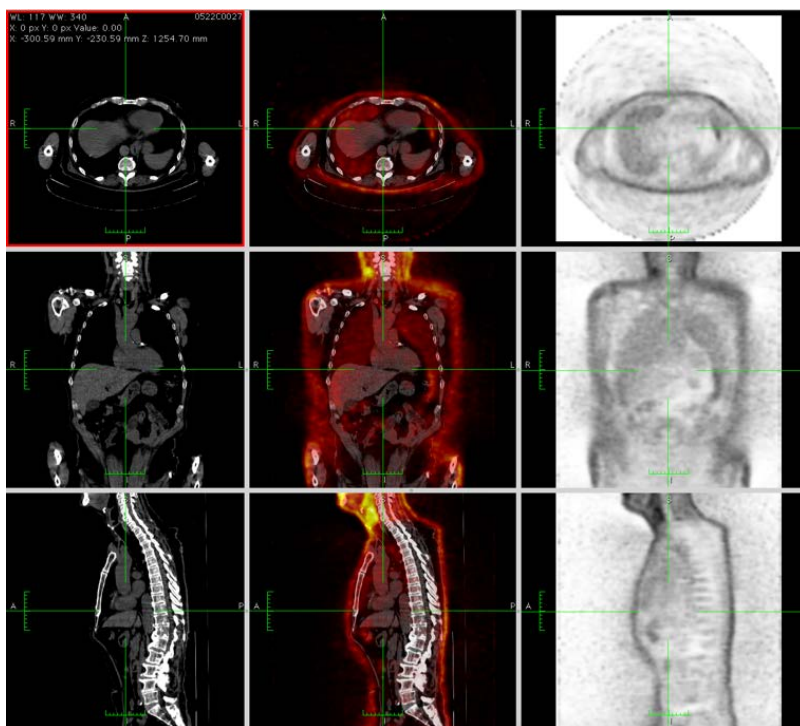
Figure 7.19. The nine views for a fused CT-PET series.

Moving the cross-reference lines on one image, moves them on all images as they are locked together. You can change the fusion percentage and mode with the Fusion tool in the toolbar (Figure 7.20). You can choose from Linear, High-Low-High, Low-High-Low, Log, Inverse Log, or Flat modes. You can also use the Oval ROI tool on a fused dataset to calculate the SUV.
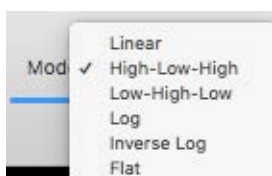

Figure 7.20. The mode options in the Fusion tool.

4D Dataset

You can display 4D datasets in the 2D Orthogonal MPR Viewer window. Begin by loading your 4D dataset from the database using the 4D Viewer tool in the toolbar. Once it is loaded you can select the 2D Orthogonal MPR from the 2D/3D tool. You can now use the 4D Player tool on the toolbar to dynamically display the 3D images using the play button. You can manually move between frames by dragging the Pos (i.e. Position) slider. You can export dynamic 4D images as DICOM files or as QuickTime movies.

THE MIP/VR VIEWER

Volume Rendering

CT and MRI scanners generate stacks of parallel 2D images usually acquired at regular intervals (i.e. 1mm slices). This yields a regular grid of pixel intensities. Each image in a stack contains pixels with an intensity that represents the density of tissues, bones, or air. Typically, a zero pixel is represented as black and a pixel of 255 is assigned white, with shades of gray for the intervening pixel values between 0 and 255.

All the 2D slices taken together yields a regular volumetric grid with voxels instead of pixels. A variety of 3D techniques have been developed to view (from any angle) 3D volumes on 2D computer screens. One such technique is volume ray casting or volume rendering.

To render a 2D projection of a 3D data volume, you first need to establish a "camera" position relative to the volume. Then you cast a ray from that viewpoint through the volume, sampling as you go, and define the opacity and color of every voxel along the ray's path. This yields an RGBA (red, green, blue, alpha) transfer function for each voxel in the 2D projected image (Figure 7.16).

Volume ray casting is complex. Briefly, it involves 4 steps:

1. Ray casting – for every pixel in the final image, a line of sight or "ray" is cast through the volume. The ray is clipped off at the boundaries of the volume to reduce processing.
2. Sampling – the "ray" is sampled along its path through the volume. The path need not be aligned with the volume and so the sampled points may fall between voxels requiring the samples to be interpolated from surrounding voxels.
3. Shading – an illumination gradient is computed for each sampling point, taking into consideration the color and intensity (CLUT, opacity, etc.) of the RGBA transfer function, and the sampled point is shaded.
4. Compositing- after all the sampling points along a ray are shaded, a final color value is composited from the rendering equation and deposited in the corresponding pixel (on the computer screen) that represents that ray.

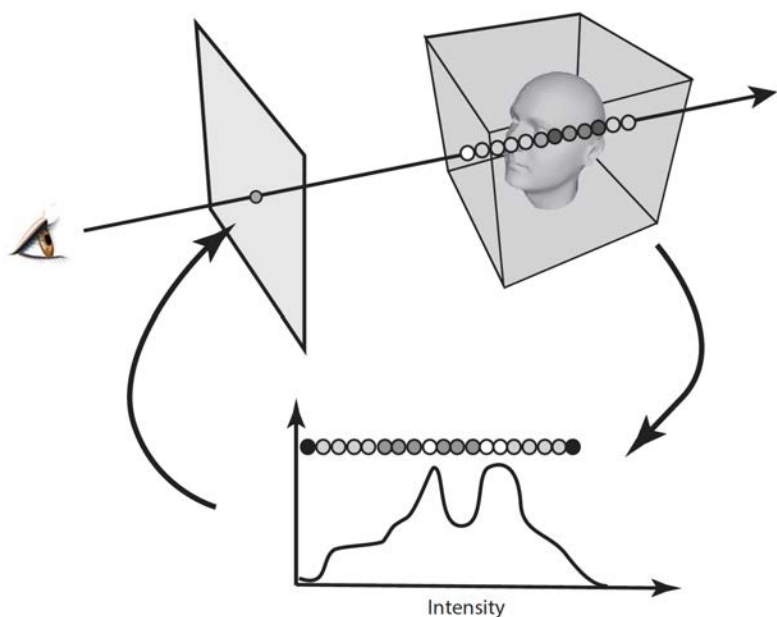The process is repeated for each pixel on the computer screen to form the final image (Figure 7.21).

Figure 7.21. A ray cast from the viewer's eye through a 2D computer screen and then through the 3D volume where algorithms calculate RGBA values and deposit the final pixel on the computer screen.

Maximum Intensity Projection (MIP)

The 3D MIP/VR Viewer includes a Maximum Intensity Projection mode, which is similar to volume rendering in that it uses a ray casting technique. However, instead of assigning a color and opacity to each voxel along the ray, this mode keeps only the pixel with the maximum value (Figure 7.22). The resulting image is not RGB and may have poor depth of field because both front-to-back and back-to-front viewpoints result in the same pixel value (Figure 7.23). MIP images can be saved as 16-bit images with the entire dynamic range of the original DICOM dataset.
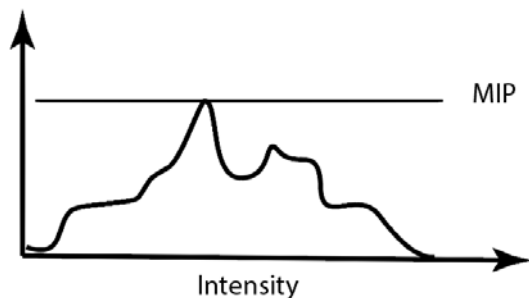

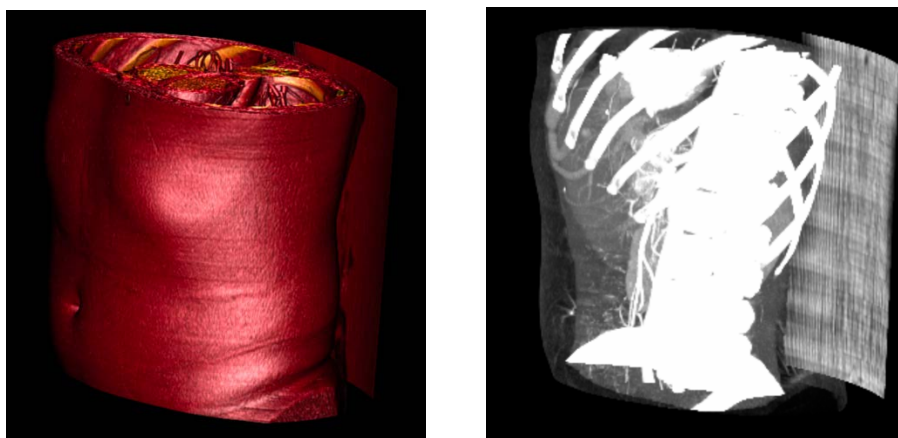Figure 7.22. The MIP returns only the maximum intensity value.

Figure 7.23. A volume rendering (VR) on the left and a MIP rendering on the right.

Images are created using either the CPU or GPU engine. In the CPU mode, the image is rendered in real-time on the computer's central processing unit or CPU. Many of today's computers use multi-processor and multi-core CPUs. Even so, this is a CPU intensive task and the more processors and cores the better the performance.

The graphics processor unit or GPU utilizes the computer's graphics board and requires an ATI or nVidia graphics board (at the time of writing). Using the GPU mode requires sufficient graphics board VRAM memory (usually 1 GB or more) to store the entire dataset. With the proper GPU and VRAM installed, the GPU mode is a faster rendering engine than the CPU.

You can use the 3D MIP/VR Viewer window to render DICOM series as a 3D volume. These rendering techniques assign different colors and transparency values to different pixel intensity values. They are routinely used for examining soft tissue in CT and MRI data sets and rendering them as pseudo-realistic 3D medical images.

There are a number of predefined settings that allow you to quickly and easily create useful 3D images. Typically, you will adjust the contrast and intensity values in the image to set the thresholds for the rendering algorithm. The algorithm then assigns an opacity value to the lowest intensity displayed. Using this simple method, you can easily render tissues of different densities, such as bone, muscles, and skin. For example, soft contrast will show only skin and muscles, while high contrast will show only bone.

The 3D MIP/VR Viewers are divided into a Toolbar across the top (Figure 7.24) and an Image View at the bottom (Figure 7.25). The Toolbar contains many of the same buttons described in Chapter 6 for the 2D Viewer window. As with other Toolbars in Horos, you can customize the tools by choosing Format > Custom Toolbar from the main Horos menu. This brings up the custom toolbar window (Figure 7.26) from which you can choose to add or remove tools from you Toolbar.

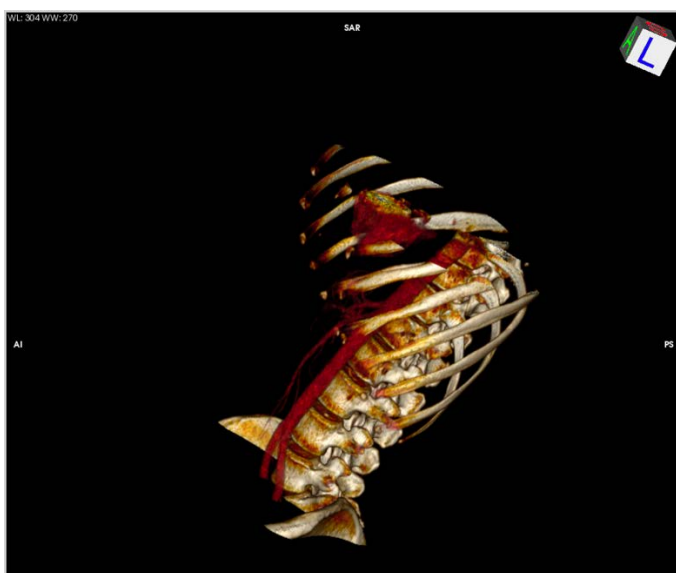Figure 7.24. The Toolbar for the 3D Viewer.

Figure 7.25. The Image window of the 3D MIP/VR Viewer showing a 3D rendered volume of the thoracic cavity.

Figure 7.26. The custom toolbar options for the 3D MIP/VR Viewer.

The Toolbar

You can access the tools in the 3D MIP/VR Viewer window through the toolbar icons or, in some cases, via items in 3D Viewer menu. Each of the available tools and functions is described below from left to right of the default toolbar, followed by custom tools in alphabetical order.

Mouse button function

You can select from 11 tools to use for a mouse left-click. The default tool is the Volume rotate tool (small cube):

- *WL/WW levels*
- *Pan*
- *Zoom*
- *Rotate*