THE 3D MIP/VR VIEWER DETAILS

Projections mode

In medical imaging projections are used to go from 3D, 4D, or higher dimension scenes to a 2D rendering (on the computer screen). Horos provides you with three 3D Projection modes: parallel, perspective, and endoscopy (Figure 7.40). The perspective projection uses a one-point perspective with the camera positioned outside the volume data and a 30º view angle. Consequently, objects farther from the camera position appear smaller in the rendered image. The parallel projection, also uses a camera position outside the volume, but uses parallel ray casting, resulting in all objects appearing the same size regardless of distance from the camera point. The advantage of parallel projection is that it is computationally less intensive, and therefore faster to render, and distances can be measured in the rendered image. The disadvantage is that the resulting images is not as realistic a representation of the volume data. The endoscopy projection is similar to the perspective mode except that the camera is positioned inside the volume data and it uses a 60º view angle.


a) Perspective Projection


(b) Parallel Projection

Figure 7.40. The same 3D volume dataset with perspective and parallel projections.

16-bit CLUT Editor

Horos provides you with several 16-bit CLUTs by default. You can see the list by selecting the CLUT dropdown list from the WW/WL & CLUT & Opacity tool. At the bottom of this list is the option to use the 16-bit CLUT Editor. Alternatively, you can select the 16-Bit CLUT Editor tool from the toolbar. Using the CLUT Editor tool allows you to edit existing CLUTs or create a new one. Selecting the CLUT Editor brings up a display drawer at the bottom of the 3D render window (Figure 7.41). The drawer shows a graph of a the current CLUT drawn as a curve with a few key points highlighted.

The x axis of the CLUT Editor graph is a density scale with low density (i.e. air) to the left and very dense material (i.e. bone, steel) to the far right. The y-axis represents the transparency function from 0 to 1, with the top representing completely opaque (1) and the bottom completely transparent (0).

The curve can be edited by clicking and dragging on the small black square in the middle of the colored graph or by clicking and dragging on individual points on the line. You can also add a new curve by right clicking on the graph or by clicking on the + button on the left of the graph.

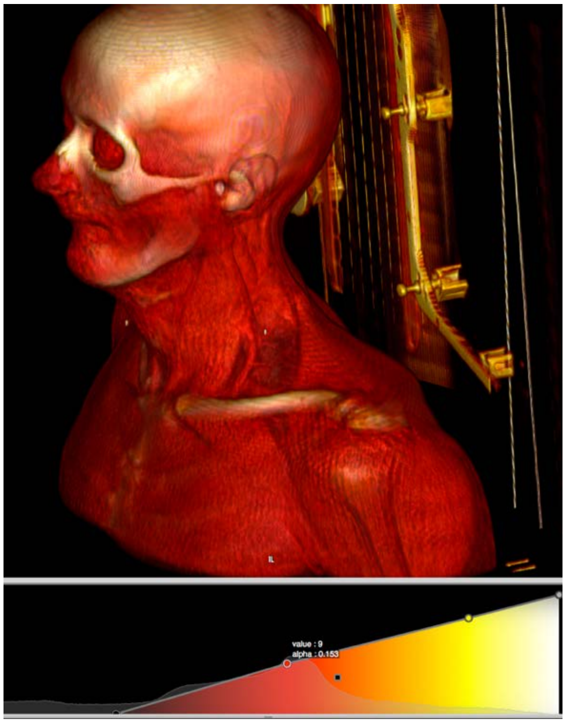
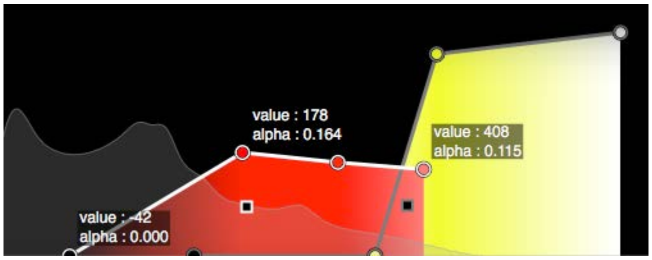


Figure 7.41. 16-bit CLUT Editor at the window bottom

If you want to see the skin you drag the black square to the left. If you want to hide the skin and focus on the bones, you would drag the curve to the right. Moving the entire curve up makes the tissues more transparent and moving it down makes them more opaque.

You can also modify only certain parts of the curve by dragging the individual points on the curve. Clicking on a point brings up information on that point's alpha value (transparency) and its value (density). You can change the color of a point on the graph by double clicking to bring up the Mac OS X Color Picker.

Another feature of the 16-Bit CLUT Editor that can be very useful is that you can add another CLUT graph to the CLUT Editor drawer. This means you can have one CLUT graph set for bone and a second CLUT graph for vessels. To add a new graph right click on the graph and then click on New Curve. This adds another default curve to the drawer which you can now edit (Figure 7.42).



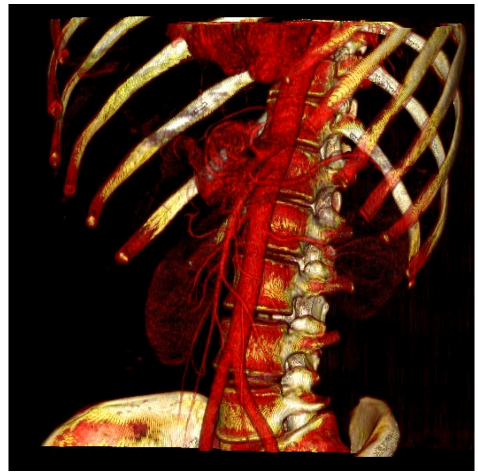


Figure 7.42. The CLUT Editor drawer (above) with two CLUT curves (one red and one yellow) and the resulting rendered image (left) showing the bones in yellow to white colors and the vessels in shades of red.

Once you have a set of CLUTs that you like, you can save them as a new CLUT by right clicking on the graph area and clicking on the Save option in the popup window. Give it a new name and it now appears in the CLUT dropdown list in the tool bar. To remove all the CLUT curves select Remove All Curves from the popup window.

Sculpting 3D image

3D sculpting allows you to remove parts of a 3D volume to better display hidden features. For example, you can remove a portion of the skull to reveal details of the brain or vessels within.

You begin by selecting the scissors tool from the mouse button option sin the toolbar. Then click on several points on the image to create a polygon enclosing the portions of the image you wish to keep (Figure 7.43). Press the return key to delete everything outside the polygon. Pressing eh delete key will remove everything inside the polygon. Use the tab key to reload the pixels from the original dataset or the escape key to remove just the polygon.

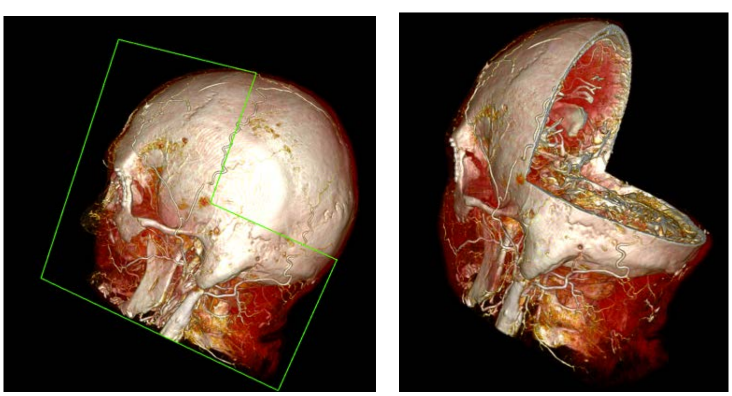


Figure 7.43. The scissors tool is used to create a polygon in green shown on the left. The image on the right is the image after the return key was pressed.

Keep in mind that the scissors tool also removes pixels from the original images (that is the pixels are set to minimum intensity). When you close the 3D/MIP Viewer window and return to the 2D Viewer, you will see only the parts of the image that were not removed by the scissors tool (Figure 7.44). You can get the missing pixels back by using the Revert series command from the 2D Viewer or 3D Viewer menu.

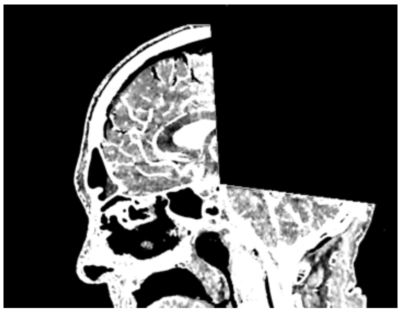
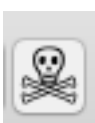


Figure 7.44. The 2D Viewer window showing the missing pixels for the sculpting shown in Figure 7.43.

Sculpting with the scissors tool can take a long time so it is a good idea to save the sculpted dataset so it can be more quickly reloaded again later. You can save it using the 3D Scissors State tool (in the Custom tools set) or by choosing Scissors Editing from the 3D Viewer dropdown list in the menu (Figure 7.45).

Figure 7.45. The Scissor State tool.

You can only save one sculpted dataset in the current series. Horos will save it to the 3DSTATE folder in the Horos data folder.



Bone Removal

Horos provide you with a special tool for removing bone. For most CT images the default Hounsfield values for bone are between 250 and 2000. You can remove bones that are not connected to each other using the Bone Removal tool (Figure 7.46). Clicking on a bone in the image creates a seed point for removing pixels with a defined range of intensity values around that seed point. You can change the default range by holding down the option key when clicking on the bone. This brings up a popup window where you can modify the intensity range (Figure 7.47). Repeating the steps on additional bones removes them as long as they are not connected to other bones.

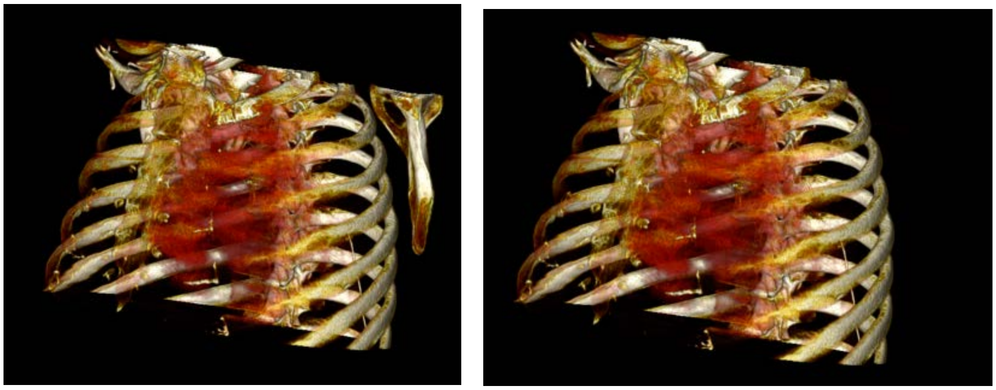


Figure 7.46. The Bone Removal tool. The image on the left is the original image. On the right image the left scapula has been removed.

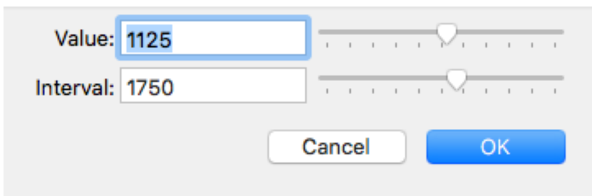


Figure 7.47. The Bone Removal popup window.

Note that you may need to manually remove some bones or fragments using the sculpting tools because they are connected or have intensities outside the range specified. Like the Scissors tool, the Bone Removal tool hides the pixels by setting the pixel intensities to the minimum for the series. Thus, the original 2D images are also modified. To undo the Bone Removal tool select Edit > Undo from the Horos menu

Cropping 3D volume

For large datasets, such as a whole human torso, it may be necessary to crop the data volume you wish to render.

Selecting the cropping tool from the toolbar reveals an X, Y, Z bounding cube with green spheres in the middle of each plane. Click on a sphere and it changes to red to indicate it is an active cropping plane. Drag the red sphere toward the volume to remove portions of the image in that plane (Figure 7.48). You can repeat this for each of the 6 sides of the cube. Cropping significantly increases rendering speed and allows you to focus on the areas of interest. You can click on the cropping tool a second time to remove the crop tool.

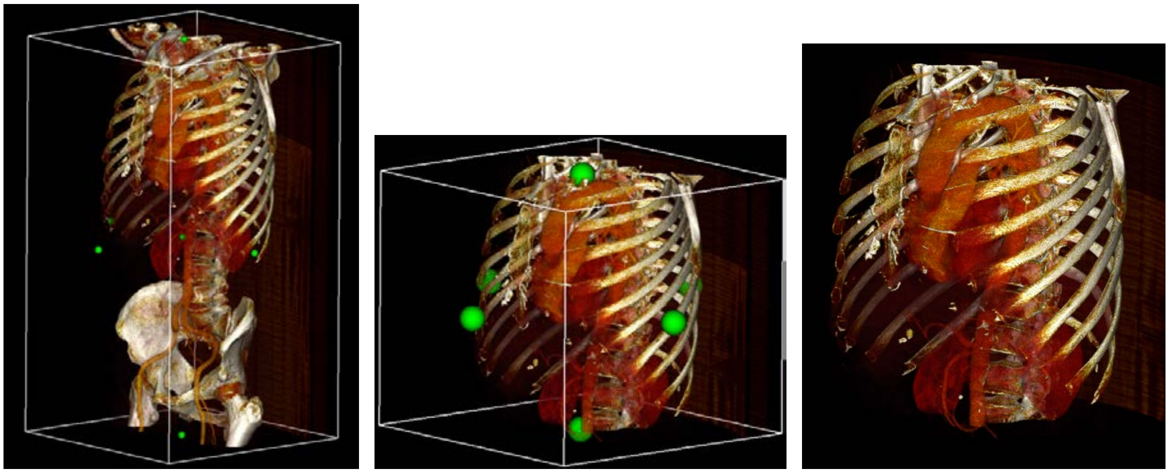


Figure 7.48. The Cropping tool. The left image shows the entire dataset. The middle image show the cropping tool bounding box restricted to just the thorax and abdomen. The right image is the final image with the cropping tool off.

Note that cropping only hides the pixels, unlike the Scissors tool, so the original pixels values are unmodified.

Image Fusion

The 3D MIP/VR Viewer also supports image fusion. If your 2D Viewer series is fused, the 3D Viewer window will display both series in 3D. The fused 3D dataset will be in front of the other dataset and they are locked together so they move and rotate together. Cropping box tools will be applied to both datasets. Fused 3D datasets do not support shading. To adjust the WL/WW of a fused dataset, you must do so in the original 2D Viewer window first. Likewise, you must apply Scissors tool sculpting in the 3D Viewer prior to fusing the two datasets.

4D Dataset

4D datasets include separate temporal series of 3D data (CT or MRI datasets) or they can be combined into a single series (PET and SPECT). You can render and manipulate the images in 3D using the 3D Viewer and maintain the 4th temporal dimension resulting in dynamic images (i.e. a beating heart). To start, you load a 4D set of data using the 4D Viewer button in the database toolbar, create a volume render, and use the 4D player tool in the toolbar (Figure 7.49). Clicking on the play button in the 4D Player tool starts the dynamic sequence of images. You can modify the rate of the cine sequence and select a specific frame with the position slider. Finally, you can export a movie sequence of the 4D dynamic images or export DICOM images as discussed above.

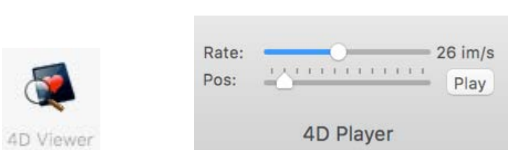


Figure 7.49. The 4D Viewer tool (left) from the database toolbar and the 4D Player tool (right) from the 3D Viewer toolbar.

ROIs

If you have created 3D ROIs in the 2D viewer already, the 3DViewer window can display some of these ROIs (you cannot create 3D ROIs in the 3D Viewer). With your 3D volume render open, select the ROI Manager tool (from the Custom tools) from the toolbar or via the ROI menu tab. This opens a dialog box with information about the ROIs for this series (Figure 7.50).

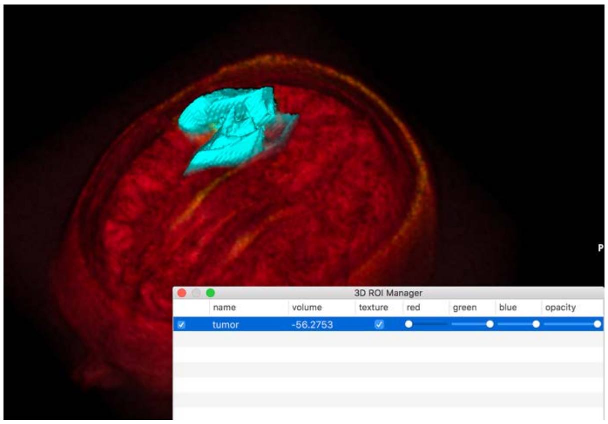


Figure 7.50. A 3D volume rendering of a brain tumor ROI.

If multiple ROIs are available, you can display or hide each one using the checkbox to the left of the ROI's name. You can also modify the ROI color and opacity using the sliders in the 3D ROI Manager dialog box.

Point ROIs can be added directly onto the 3D volume rendered image in the 3D Viewer window. Select the Point tool from the Mouse Button list and click on the image where you want the point to go (Figure 7.30). This point will also be displayed in the 2D Viewer window. Alternatively, you can drop a point ROI onto the 2D image in the 2D Viewer window and Horos will use the points WL/WW setting to determine where to place it in the 3D rendered image (Figure 7.51). The color and size of the point can be edited using the Point Info dialog box.

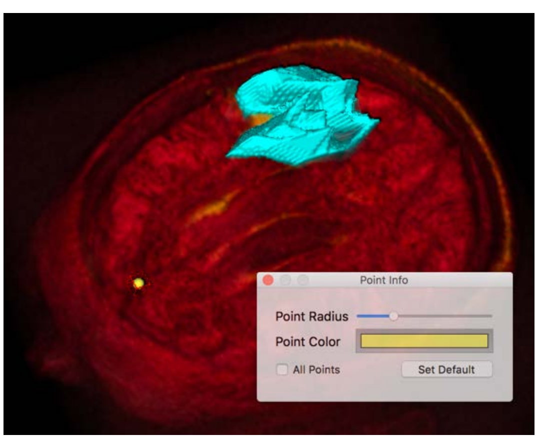


Figure 7.51. A Point ROI (yellow) added to the brain tumor rendering. The Point info dialog box can be used to change the appearance of 3D Points ROIs.

3D Rendering Presets

In 3D volume rendering mode, you can select from a set of predefined color tables and rendering settings. You can also save your own presets. The 3D Rendering presets are activated by clicking on the 3D Preset tool in the 3D Viewer toolbar (or by choosing Select 3D Preset from the 3D Viewer list). This brings up a floating window displaying several thumbnails of basic presets (Figure 7.52) for the currently rendered image. The presets are grouped into three categories. At the top of the floating window is Group for the presets. The default is Basic, but you can also choose from Bone CT or Soft Tissue CT groups using the arrows to the right. Below the groups list are the available presets for the group displayed as thumbnails. Click on the thumbnail to highlight it and then on the Apply button at the bottom to re-render the image using this preset. You can retrieve information about each preset by clicking on the Info button. This brings up a second floating window with information about the preset's WL/WW, CLUT, opacity, etc. For best results, zoom in on the 3D rendered image before choosing a preset to give you a better idea of what the final image will look like.

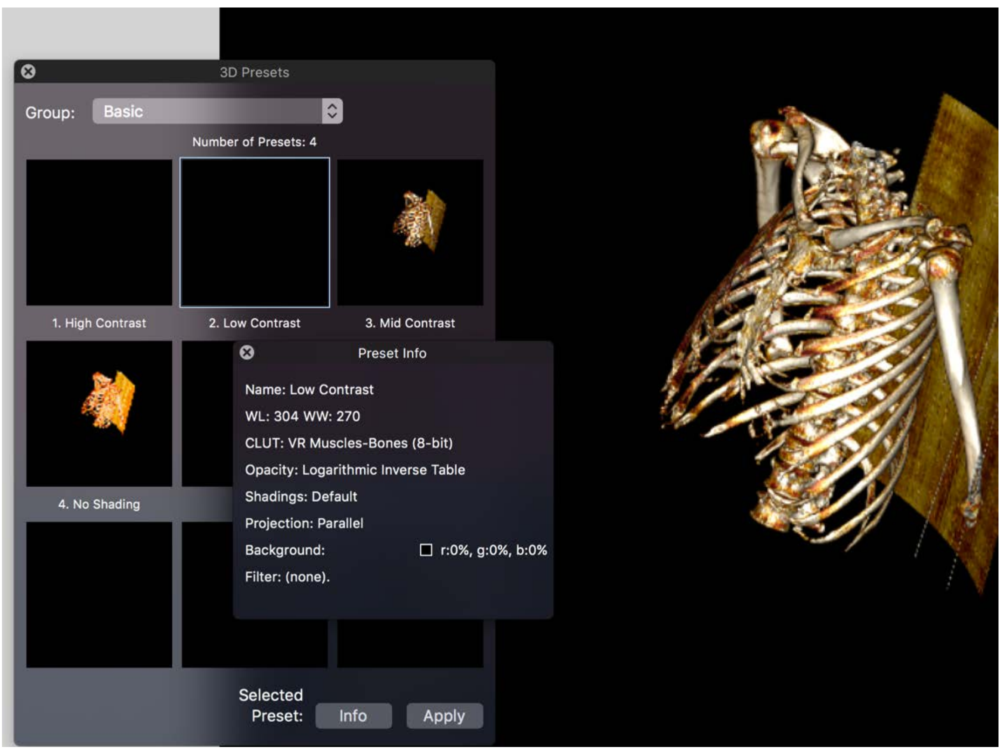


Figure 7.52. The 3D Presets tool with the info panel displayed.

Note that some presets use 8-bit CLUTs while others use 16-bit color tables. If you apply a preset that uses a 16-bit color table, Horos will automatically display the histogram and 16-bit color graphs in the drawer at the bottom of the image window. Presets also record the filter setting, background color, projection, and shading details.

You can save an unlimited number of user-created presets in an unlimited number of groups. To save the current state of a 3D rendered image, choose Current State as 3D Preset from the 3D Viewer menu. A dialog box appears prompting you for a name and a group for your new preset.

EXPORTING 3D IMAGES

Volume rendered images can be export in DICOM format, which generates a new set of DICOM files in the database window for later use or for exporting to a PACS. MIP rendered images also give you the option of exporting with 16-bit depth so you can keep the original pixel intensities.

Volume renderings can also be exported as movies. This can generate very large files if there are many images in the series so it may be useful to reduce the image size (matrix size). You can adjust the image size by clicking and dragging on the X in the lower left corner of the 3D rendered volume (Figure 7.53).

Figure 7.53. To resize the 3D view, drag the X located in the lower left corner (circled in red).

Horos provides several compression options for generating stills and movies. JPEG is often a good choice because it generates high quality still images with smaller file sizes. If you choose a video compression option, such as MPEG4, for a still image the image quality will be reduced.

Exporting QuickTime Movies

You can export 3D volume renderings as QuickTime movies by choosing the Movie Export tool from the toolbar (or via File >Export > Export to Movie from the File menu). A dialog window appears where you can select the number of frames, rotation direction, rendering quality, and movie size (i.e. 512x512 or 768x768). Keep in mind that choosing more frames produces a smoother running movie, but will increase file size.

QuickTime files can be converted into WMV files for native support in computers running Windows.

THE SURFACE RENDERING VIEWER

The 3D Surface Render Viewer is a window displaying an isosurface of a set of DICOM images (Figure 7.54). Surface rendering works well with CT series (less well with MR) because it allows you to see structures such as bone or lungs where there is a sharp and continuous surface. Essentially, an isosurface is a 3D representation of pixels (voxels) of a specific intensity value. Surfaces are identified using an isosurface detection algorithm, such as the marching cubes algorithm [9]. This algorithm uses an assumed illumination pattern and a color is substituted for intensity. The details are complex, but the marching cubes algorithm is an iterative process that extracts polygonal surfaces (mesh) of 3D scalar field (voxels). It works by "marching" over the whole 3D area which has been divided into cubes (voxels), each with 8 vertices, and computes whether a triangular surface passes through the cube (voxel). The adjacent polygons are united to form a surface (Figure 7.54). Horos displays the smooth surface rendering by default, but you can view the underlying mesh by pressing the W key (W = wire mesh) and return to the smooth surface by pressing the S key.

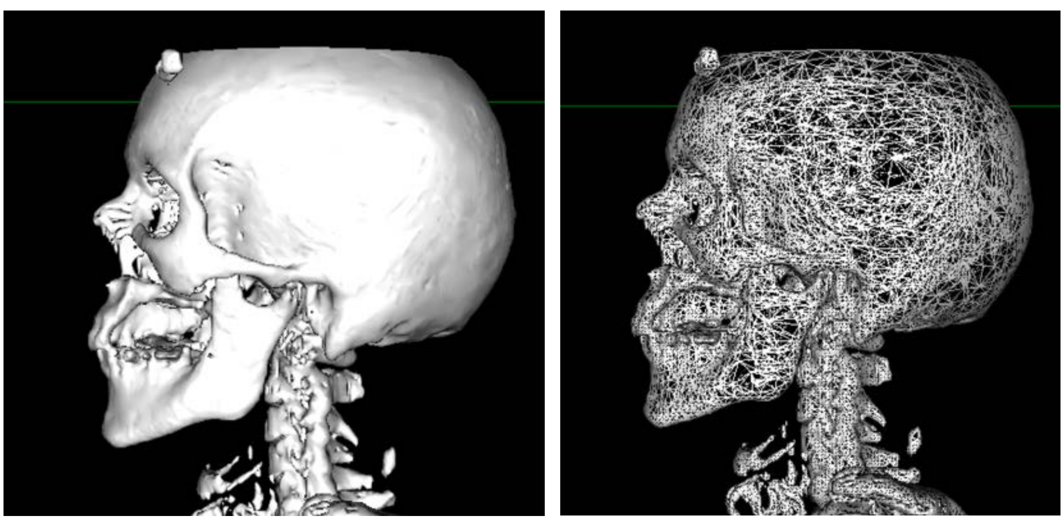


Figure 7.54. You can switch between (a) surface and (b) wireframe rendering.

Horos uses Laplacian smoothing to relax the mesh, by moving each vertex slightly and smoothing the cells shape. Horos supports mesh decimating to minimize the number of triangles in a mesh, while still approximating the original geometry.

Surface rendering occurs in two steps. The first step is to extract the isosurface; This step is CRU intensive, taking several seconds to minutes, so it uses the one of the computer's CPU cores. The