Horos User Guide

Version 0.5

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About

This Horos User Guide was developed to assist users with the operation of Horos, a Free Open Source Software (FOSS) program. All information is provided without warranty of any kind and has been produced on a best efforts basis, as the code for Horos continues to change and evolve. The version you are using is current as of the date indicated. This electronic document is licensed, not sold. New updates are available electronically to users who pay the then current annual fee and is valid for a period of twelve months from their original purchase.

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This document was created by a joint effort of the following professionals who spent a great deal of time, effort and diligence to create this work.

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Chapter 1

The History of Horos

Horos was originally released on the 14th of February 2015, Valentine's Day in many parts of the world. It arose as a fork of the OsiriX project. Version 5.8 of OsiriX™ was its predecessor code base. Horos was born out of the desire to continue to perpetuate a fully open source professional medical image viewer. Named after Horus who was the son of Osiris and was thought to be made from his body parts, Horos was similarly originally constructed from the open source code of OsiriX as well as several other projects.

Horos Today

Horos continues to be an open source project. It is licensed under the GNU LGPL 3 license, specifically inviting community involvement in improving and adding to its capabilities. Software developers have added plug-ins that they provide (either at a charge or free) to the community.

Horos may come from several different sources. Be sure you know which version you are downloading. The authentic and curated latest version of Horos can be found exclusively at **www.horosproject.org**

Horos operates on an Apple Macintosh computer running OSX Version 10.11or later. It is intended to be a viewer for medical images produced by virtually any modality that generates a DICOM format image including MRI, CT, PET, PET-CT, SPECT-CT, Ultrasound, Nuclear or X-ray. Horos enables the display, review, interpreting, post-processing, reporting and routing of medical images studies.

Using Horos

Horos is not FDA approved or otherwise certified for use as a primary diagnosis tool. An effort is underway to gain certification. However, until that is available, Horos is not intended to be used for that purpose. However, as a secondary viewer, a display tool, a teaching tool, for veterinary use, forensics, or otherwise, Horos can be very useful.

System Requirements

Horos only runs on an Apple Mac running Mac OS X. It will not operate on a Windows-based PC or Linux system.

The minimum system requirements are as follow

Mac OS X 10.11 or later
4GB of RAM (8 GB recommended)
Minimum of 1280 × 1024 pixels

Horos supports the use of two display monitors.

Backing up your Data

No matter how many images or studies you handle, we always recommend you have a backup solution (offsite preferably) in the event of a disaster, whether natural or man-made. As such, we suggest you connect your Horos viewer to a proper PACS (Picture Archive and Communication System) in the cloud or locally usually configured with a RAID or similar resilient storage option.

Downloading the Software

The latest version of the Horos software is available at www.horosproject.org. By pressing the DOWNLOAD button near the top of the screen, you will be redirected to enter your information so that you become registered as a user and then the software will be downloaded to your DOWNLOAD folder on your Mac.

If you double click on the downloaded file icon you will then see the Horos Software License. After carefully reading the license you may proceed by pressing the AGREE button. That will display the screen shown below on which you can drag the Horos icon near the left over the Applications Folder Icon on the right to complete the installation process.

If you already have an earlier version of Horos on your computer, it will ask if you want to replace that version. You can do this without any risk of losing your prior data. Once Horos is installed on your computer, you can access it from the Applications Folder. From there you can either open Horos or drag it to your application bar at the bottom of your screen so that it is more easily available.

Plug-Ins and the Horos Cloud

Plug-Ins

From time to time the Horos community as well as Purview, publish small applets that can extend the functionality of Horos. These may be found in the Horos pull-down menu at the top of the Horos screen under "Plugins." Any plugins that are already installed will be indicated. Available plugins not yet installed, will display in the "Plugins Manager" selection, by choosing that selection and then clicking on the up/down carats at the right of the display box.

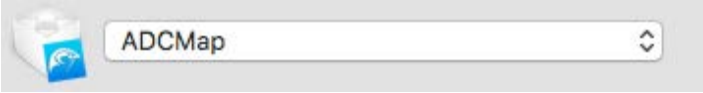


Figure 1.1

Horos Cloud (Optional)

The Horos Cloud is a specialized plugin that provides a set of additional functionality for Horos. Today, it has three functions. The first is a **cloud repository for generating and storing radiological reports**. Reports can be created in a web browser environment and then emailed to recipients or securely stored and archived. The cloud also is a way to **share studies**. With the Horos cloud an email with a secure pointer to the study can be sent to anyone, whether or not they are using Horos, to enable them to view the study. And third, the cloud may be used as a **storage, offsite PACS or archive**.

The Horos cloud, once enabled, should appear to the left of the menu icons on the main Horos screen.

Chapter 2

Setting Up Horos

To set up Horos for the first time, or make subsequent modifications, pull down the Horos menu tab and select Preferences. Horos Preferences will enable you to set defaults for how your Horos desktop will operate. These are detailed below.

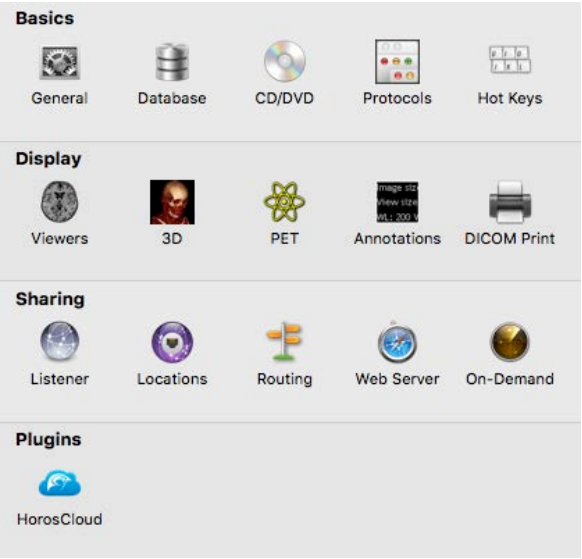


Figure 2.1

Basics

General

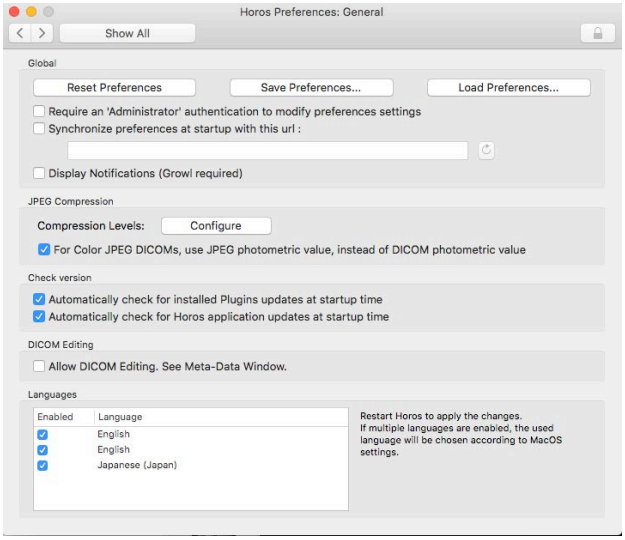


Figure 2.2

Global

This option restricts the ability to change Preference setting to only an administrator. It will prevent other users from changing any of these parameters that may affect Horos's operation. The default is unchecked or "off."

You also have the option of synchronizing preferences when Horos starts with that designation in a specific url shown. The default is that this box is not selected.

Compression

These options enable you to change the level and type of image compression for DICOM images depending upon the user's priorities – creating smaller file sizes. Horos always recommends using compression that is NOT LOSSY – meaning that upon later expansion no image fidelity is sacrificed. Settings can be changed for each modality. Compression is helpful when selecting from the file menu, when burning a CD or when using Horos in the listener function. Please be sure to check with your local regulatory and compliance agency to ensure that selecting compression does not cause you to be out of compliance.

Check Version

This check box allows the user to select whether the program should automatically check for updates of both Plug-Ins and newer versions of Horos. You can turn this off; the default is "on" for both.

DICOM Editing

If this box is checked, the user can modify a DICOM header using Horos. While this is a powerful function that allows you to anonymize a file, change parameters and fix errors introduced at the time the scan was performed, we recommend the user be quite careful when using this function lest he or she corrupt a file or change the context of medical procedure.

Languages

Horos is currently only available in the English language. However, this option will change from time to time as new language submissions are validated.

Database

This is a very detailed set of preferences that allows the user to organize his or her images database location and other parameters, including the choice of native reporting software (See Cloud Reporting Options elsewhere.) The screen below illustrates all of these options. We recommend the novice user accept the default values and only change items if they are completely familiar with them.

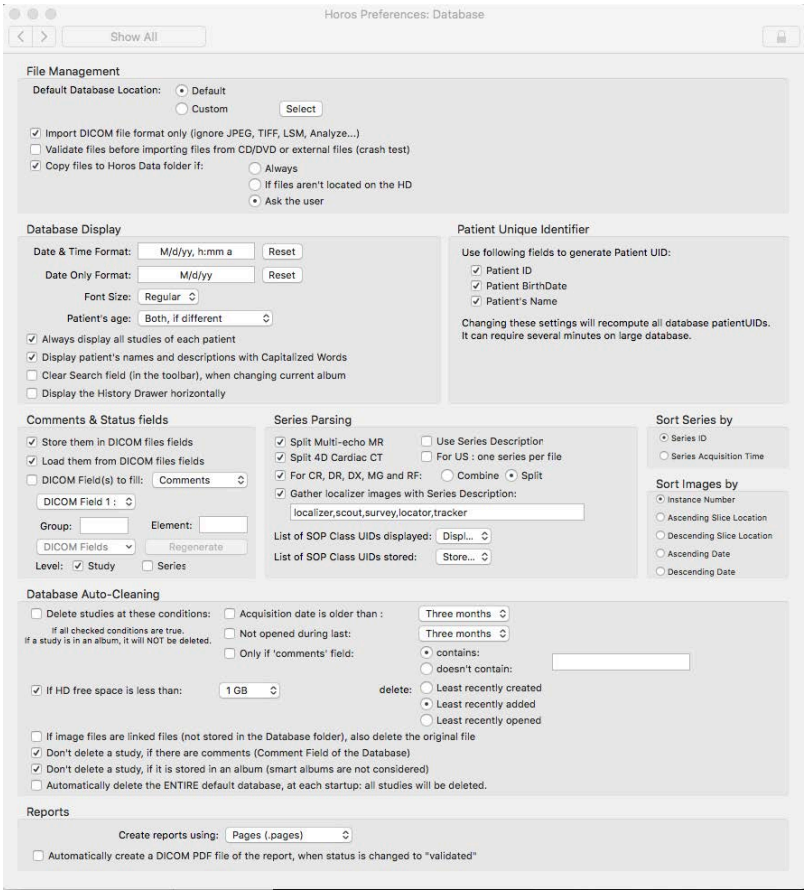


Figure 2.3

File Management

Default Destination for Horos Files

By default, Horos is set to create Horos a folder called Horos Data in your Documents folder. This folder is where Horos will locate the images database and other files used for your settings, preferences, etc. Alternatively, you select another location for thee files by selecting Other and specifying a different location.

Import File Formats

You can set Horos to only import DICOM files, or you can allow it to import other formats. The default is DICOM If set in this manner, Horos will ignore other files that are not DICOM format.

Validate files before importing

If you activate this option, Horos will validate files prior to beginning an import. With this option, you avoid this risk of a system crash that might be caused by a corrupted DICOM file. Normally

Horos can detect corrupted files and will not try to read or open them. However, with this option, Horos will specifically test each DICOM file in advance. Typically, you would use this option if you were importing files from other than a trusted source. When you turn on this option, the time required for an import increases.

Copy files to Horos Data folder

You can specify whether you want to copy DICOM images into Horos's local database. Alternatively, Horos can link to the current location of the images, which avoids using extra storage space on your local disk. Most users prefer to copy studies into the local database folder ensuring they always know where your files are located.

When accessing files from a CD or DVD, choosing to not copying the files to a local database will automatically delete the link when you eject the disk.

Database Display

You can set the way certain DICOM tags are displayed in your list of studies with these options.

Date and Time, Font Size, Patient Age

You can select the formats displayed by specifying the parameters and separators for how you would prefer to view dates. Once set this format will be used globally. In addition, you can choose the font size as well as whether you wish to see the patient's age at time of scan or current age.

Display All Studies for Patient

If selected, all studies for the selected patient will display. Selected studies will be in bold font and related studies are displayed in normal font.

Capitalized Display, Clear Search Field, and Horizontal History

These setting enable changes to the default view that are apparent. The default is that all patient names and descriptions will display in uppercase font.

Comments and Status Fields

You can select this option to store comments as a field directly in the DICOM files. Only comments made in the default comment field (Comments) will be saved.

Comments already found in the Study Comments field can be used to populate the Comments field.

Alternatively, you can specify another DICOM field to automatically fill the Comments field, using the comments field as more of a custom DICOM field. This field will be filled only when the file is received or imported in Horos. This enables you to modify this comments field later. The user can 'regenerate' this field for the entire Horos database by clicking the Regenerate button. When this is selected, all the comments fields will be deleted the files will be parsed to read the corresponding DICOM field. This may take some time if there is a lot of data.

Series Parsing

These options modify the way Horos "parses" studies, when adding and indexing new files. By default, each image belongs to a unique series according to its SeriesInstanceUID field.

You can alter that as follows:

> ***Split Multi-echo MR*** *Multiple echo time (TE) acquisitions will be separated in multiple series, one for each echo time. The echo time is is found in the field EchoTime.*
>
> ***Split 4D Cardiac CT*** *Each cardiac phase percentage will be a separate series as read from the field ScanOptions.*
>
> ***For CR, DR, DX and RF*** *Combine or Split If any of these modalities is the source of the study, the images of each separate modality will either be combined in a unique series or split into multiple series, with only one image. The modality is found in the field modality.*
>
> ***Gather localizer images with Series Description*** *Any image type field containing one of the words entered in the box (separate them by commas) will be combined with any other using the same word in a single series.*
>
> ***Use Series Description*** *A separate series will be created for each series description found in the field SeriesDescription.*
>
> ***For US*** *one series per file For ultrasounds (US), each series will contain images belonging to a single file - US studies often contain multiple frames in a file.*
>
> *The final two Series parsing drop-down menus available at the end of this group display the list of SOP Class UIDs that are used by Horos. If you have a file with a class not in this list, it will be rejected.*

Sort Series By

You can either sort and order each series in the Database window and the 2D thumbnails by their Series ID field SeriesNumber or by their Acquisition Time fields: SeriesTime, AcquisitionTime or ContentTime. Series ID and Series Time fields often correlate in order anyway.

Sort Images By

Images within a series can be viewed in the 2D Viewer Window in the order specified:

> ***Instance Number*** *- field InstanceNumber*
> ***Slice Location*** *– field SliceLocation : either ascending or descending; or*
> ***Acquisition Date*** *- field AcquisitionDate either ascending or descending*

Database Auto-Cleaning

This option, when selected, enables databases to be automatically cleansed of specified studies, based upon acquisition date, when they were last opened, or if certain comments are found (specified). It also allows auto cleansing if there is no longer sufficient local disk space. And, will even enable purging of the entire default database at startup.

There are also specific parameters that can be set to ensure studies are not deleted: if there are comments in the Comment field or if it is stored in an Album or otherwise Locked.

Of course, studies can always be manually deleted.

Reports

There are two types of reporting in Horos. The traditional method enables the use of a word processor and was historically the way that most people use Horos for reporting. The newer option enables the user to select cloud-based reporting. That requires a subscription to the cloud that is described later and is not part of this preference.

For traditional reporting, this option selects the particular brand of word processing program that will automatically be launched once the user has begun to report on a study.

You can also choose to automatically generate a PDF copy of the report when the study status is changed to validated.

CD/DVD

In this section of Preferences, you can designate Horos's behavior upon inserting a CD or DVD into a connected drive for reading or writing to/from the disc. When a disc is inserted you can select whether to automatically add the images to your database. If you would prefer to do this manually, then do not select this option.

Discs with images usually contain a DICOMDIR file. Horos will use this file, if it is present, to identify the images on the CD. This is a relatively faster solution than scanning the disc for all DICOM images. The slower method is a bit more trustworthy.

For writing to discs, you can override the standard JPEG2000 compression that is normally used. JPEG2000 is more modern than this JPEG selection. Only use this option if you need to remain compatible with older DICOM viewers. The level of compression Is defined in the General Preferences Window.

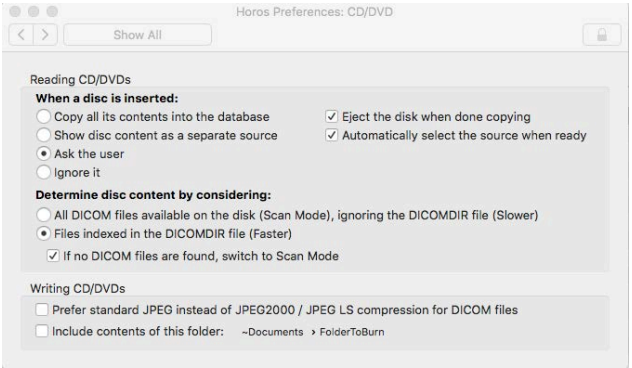


Figure 2.4

If you wish to add the contents of the directory to the CD, you can select the bottom option.

Protocols

You can preset protocols in this preference selection. This can be done based upon both the modality and the study description. The modality pull down is shown in the top left corner of the screen. Here you can select among the various modality types. Upon selecting a particular modality, you can then enter a description tag in the database field studyName, DICOM field StudyDescription and the associated desired protocols. Doing so will enable the default protocol configuration to automatically be the presented view.

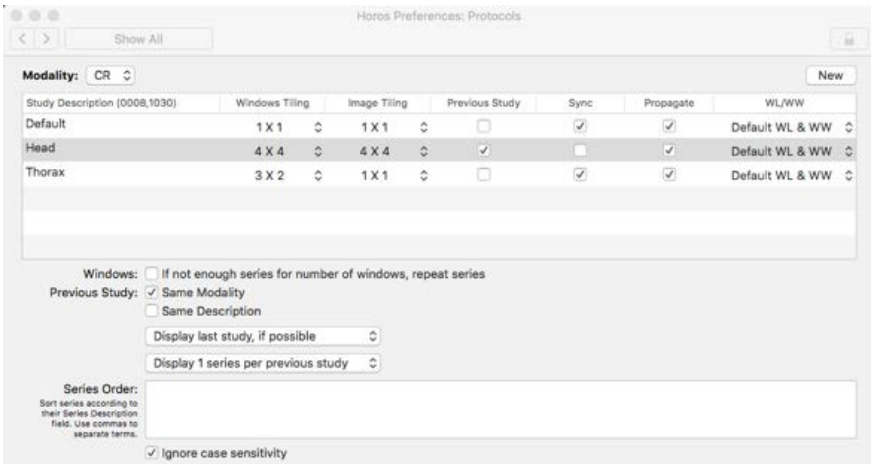


Figure 2.5

If you would prefer all studies from a particular modality type to utilize the same protocol, you can enter Default as the Study Description and the will share the same default protocol.

You can also decide if you wish previous studies of this patient scanned on the same type of modality or with the same description (or both) to appear when you summon a particular study for viewing.

Hot Keys

You can change the shortcut keys using this preference. To change the key, select the line of the tool and press the desired key. This preferences pane allows the user to modify some of the default shortcut keys in order to access certain tools, such as the 2D Viewer mouse tools or the WL/HOROS presets. To modify the key associated with a tool/function, select the line corresponding to the tool and hit the desired key. The default will change to show the key you selected.

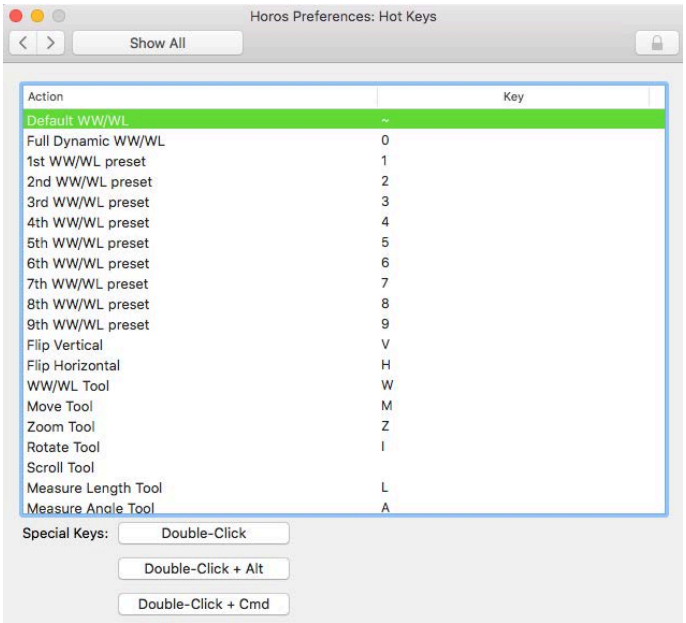


Figure 2.6

The default hot keys may be found in Appendix A

DISPLAY

Viewers

Here you can customize the behavior of your 2D viewers.

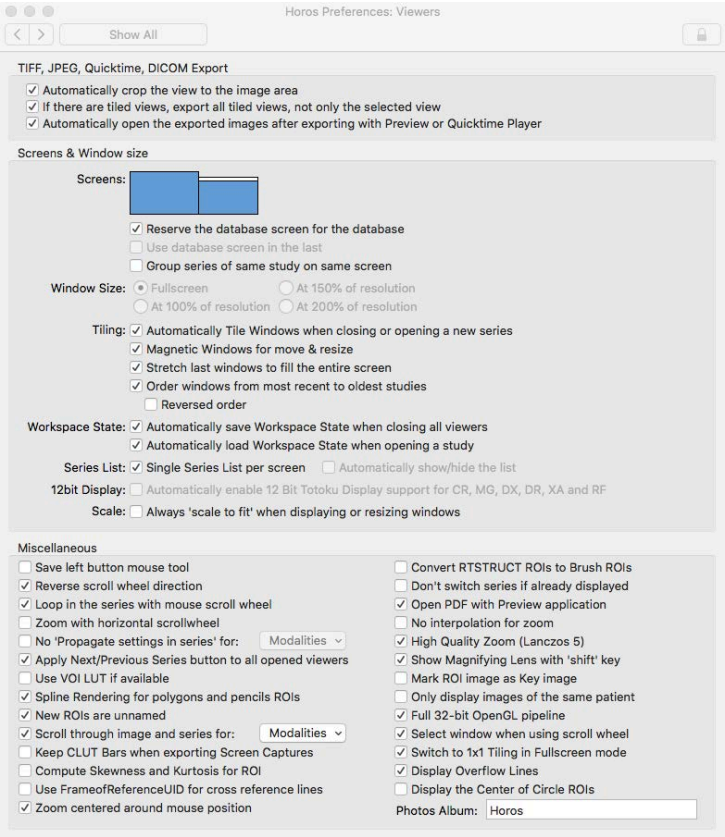


Figure 2.7

TIFF, JPEG, QuickTime, DICOM Export

Setting these options will affect the way these types of images will be displayed.

Automatically crop the view to the image area

This will remove any black area surrounding an image.

If there are tiled views, export all tiled views

If this option is selected and you are using image tiling, all visible tiled images will be exported.

Automatically open the exported images

If this option is selected, exported images will automatically open with Preview or Quick Time video player.

Screens & Window size

This set of preferences is useful when you are using multiple screens to view Horos. Each option is described below:

> *You can set Horos to open 2D Viewers on one or both of your screens. To select a screen simply click on the selected screen and choose to Use this screen for viewers.*
>
> *Below the screens diagram, you can select either to Reserve the database screen for the database which means that this screen will not be used for a viewer or alternatively to Use database screen in the last if other screens are already used as a viewer.*
>
> *Another option also allows you to always reserve the screen where the database window is located for the database: no 2D Viewers windows are displayed on this screen. Or you can select the database window screen in the last, only if all others screens are already used for 2D Viewers. Lastly, you can select grouping of a series of the same study on the same screen.*

As long as you have <u>not</u> selected Automatically Tile Windows when closing or opening a new series, the Window Size option allows you to force Horos to open series in windows that fit the selected size or to fill the whole screen.

When using more than one screen for your 2D Viewer, the toolbar will display as a floating panel. Even with just one screen you can select this same behavior.

By selecting the Automatic Tiling option, Horos will resize and rearrange windows to fill the available screen. Selecting the Magnetic Windows option will cause windows to appear at the edges of the screen as well as the edges of other open windows. Tiling and Magnetic Windows are described in more detail in section 2.

You can select that upon closing viewers you wish to save your workspace and upon opening a study you wish the workspace to open automatically.

The scale to fit option makes the whole image is visible even when resizing the window.

Miscellaneous

The last group of options contains settings for various aspects of the 2D Viewers. These options are described below:

> *Save left button mouse tool - The default is unchecked. Checking this box will cause Horos to remember the last tool used with the left mouse button. Leaving this button unchecked will mean the left mouse button will be set to WL/HOROS when the 2D Viewer is opened.*
>
> *Reverse scroll wheel direction - Reverses scrolling direction through a series.*

Loop in the series with mouse scroll wheel - When this option is checked, if you scroll beyond the last image of a stack the first image will loop back and you will start again in a continuous loop. If this box is not checked, you will not be able to scroll beyond the last image of a stack.

Zoom with horizontal scroll wheel – Certain computer mice allow you to scroll horizontally. Clicking this box enables zooming in and out.

No 'Propagate settings in series' for - modalities (CR, DX, DR, RF, XA , MG, US) Clicking this selection disables propagation of settings for and of the selected modalities.

Apply Next/Previous Series button to all opened viewers - Clicking this enables you to move to the next and previous series in all viewers.

Use VOI LUT if available – Clicking this box enables the loading and applying of the VOI LUT sequence stored in the DICOM file [if available (VOI LUT Sequence, 0x0028, 0x3010)]. The VOI LUT sequence is a non-linear intensity curve applied to the image, enabling improved rendering of soft tissues.

Spline Rendering for polygons and pencils ROIs – Clicking this box enables spline smoothing in polygons and pencil ROIs.

New ROIs are unnamed - When clicked ROIS will not be automatically named.

Scroll through images and series - when this box is clicked you may scroll beyond the last image of a series to automatically load the next series. When this option is enabled, the "Loop in series…" option described above will be automatically disabled.

Keep CLUT Bars when exporting Screen Captures – By clicking this option any displayed CLUT Bars will be captured with the screen image.

Compute Skewness and Kurtosis for ROI – Skewness is a measure of (lack of) symmetry. Kurtosis is the average of the standardized data raised to the fourth power. Computing these will give you better information about the image view within the region of interest. Clicking this will enable this computation.

Use FrameofReferenceUID for cross reference lines – When checked, Horos will see if the FrameofReferenceUID (0x0020, 0x0052) of the displayed series are the same prior to presenting cross-references lines.

Zoom centered around mouse position – Click this button to center zoom in and out around the mouse click location rather than the window center.

Convert RSTRUCT ROIs to Brush ROIs - this option, when selected converts RSTRUCT ROIs to Brush ROIs enabling display of these ROIs

Don't switch series if already displayed – When checked, you will not switch between series if displayed.

Open PDF with Preview application - Horos will accept and store PDF files and open them in the 2D Viewer. However, if this box is checked, PDF files will display instead in Preview.app.

No interpolation for zoom - Checking this box enables interpolation when you zoom. When enabled, the pixels of the images will be clearly visible.

High Quality Zoom (Lanczos 5) - Clicking this option enables high quality interpolation based on the convolution algorithm.

Show Magnifying Lens with 'shift' key - When this is clicked, pressing the shift key while viewing an image in the 2D viewer will display the Loupe tool.

Mark ROI image as Key image – When this box is checked, any image containing an ROI will automatically be labeled as a Key Image.

Only display images of the same patient – Checking this box means that only images of the same patient will be displayed. Images of other patients will be closed.

Full 32-bit OpenGL pipeline – Selection of this option uses 32-bit floating point pixels instead of 8-bit pixels in the 2D Viewer, Orthogonal 2D MPR and 3D MPR windows. This option is faster and enhances image quality while using less memory.

Select window when using scroll wheel – When clicked, scrolling with a mouse on a window will always make it the front-windows.

Switch to 1 × 1 Tiling in Fullscreen mode – When clicked, during full screen mode, the selected image will display on the entire screen.

Display Overflow Lines – When clicked, this enables the display of lines that overflow a screen display of an image.

Display the Center of Circle ROIs – Checking this option displays an annotation for the center of a circle ROI

ROI color rotation – Checking this box rotates the colors selected each time a new ROI is added.

Photos Album - Designate the name of the photo album used by Horos when exporting images.

3D

Setting these preference options enables the customization of 3D viewer settings.

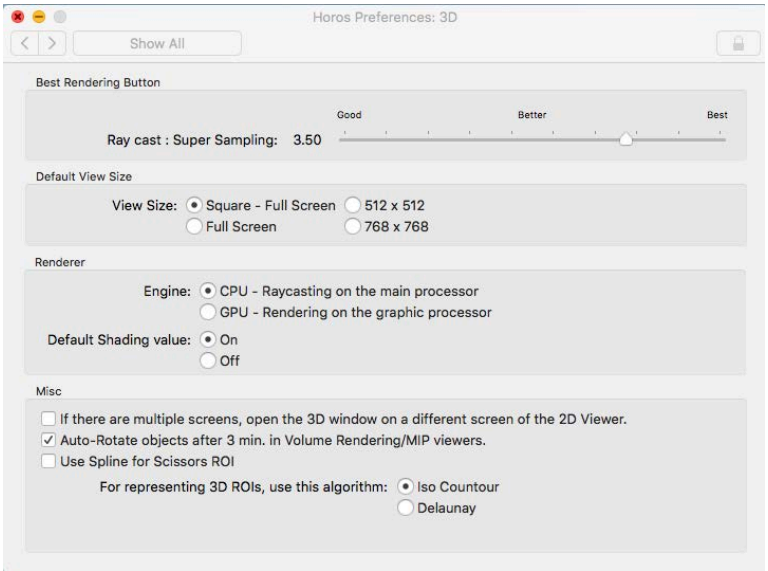


Figure 2.8

Best Rendering Button

Select the quality of the 3D volume rendering by moving the slider along this bar. The higher the value the better quality the image will be. Better quality images take longer to display.

Default View Size

Select between a square window or the full screen for the default view size. Higher resolution can be selected as well. Higher resolution and larger windows will take longer to display.

Renderer

Should you wish to change image rendering from the GPU to the CPU or vice versa, to enhance your computer's processing, you can click on one of the radio buttons. Similarly you can select the default sharing value on or off.

Misc

Multiple screens – *If this is selected, Horos will open the 3D viewer on a separate screen from the main program.*

Auto-Rotate after 3 minutes - *In order to avoid screen burn-in from the continuous display of an image, you can select this option to automatically begin to rotate this object after 3 minutes.*

Use Spline for Scissors ROI *- checking this box will smooth the spline for a 3D Scissors path.*

3D ROIs algorithm *- this option enables you to set the triangulation algorithm for 3D ROIs rendering. Available algorithms are: ISO Countour or Delauney.*

PET

This preference screen relates to setting for PET or NM images. PET values can be automatically converted to SUV value or PET-CT studies can be set to automatically fuse with PET over CT.

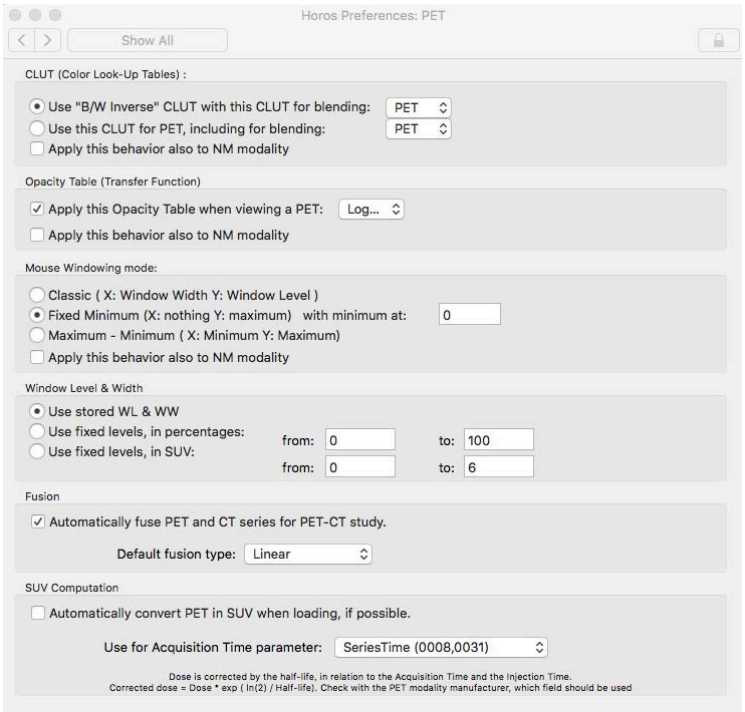


Figure 2.9

CLUT

By making these selections, these Color Look Up Table selections can be applied to PET series displayed in the 2D viewer when fused on another series. The same CLUT can be selected for both PET and CT. These settings can also be applied to NM by clicking the third box.

Opacity Table

Select the Opacity Table to use for PET series and select NM to also apply this same table for NM.

Mouse Windowing Mode

Chose the mouse behavior from amongst these options:

Classic - *Change the WL by moving the mouse vertically. Change the width of the window by moving the mouse horizontally.*

Fixed Minimum – *this fixes the window size. Moving the mouse vertically changes this value.*

Maximum – Minimum - *With this option, vertical mouse movement changes the maximum value while horizontal mouse movement changes the minimum value of the window.*

Choose this last setting to apply these mouse setting to NM as well.

Window Level & Width

Use this preference selection to set the window level and width for both PET and NM.

Use stored WL/HOROS – This is the default selection; values come from the DICOM tag itself.

Alternatively, you can use one of the next two selections to set the fixed levels in percentages or numbers.

The options are: Use fixed levels in percentages – where the values are entered in percentages or Use fixed levels in SUV – where the values are set as integers.

Fusion

Fusing will occur automatically if this button is clicked. Then a fusion type may be set to one of the choices shown below.

Figure 2.10

Linear - represents a linear transfer. Low intensity pixels will have a low opacity (transparency); High intensity pixels will have a high opacity.

High-Low-High - This transfer function produces high opacity for pixels with both low and high intensity and low opacity for intermediate values.

Low-High-Low - This is the opposite of the prior function. Low opacity for pixels with low and high intensity; high opacity for intermediate values.

Log - This will use a logarithmic curve.

Inverse Log - This will use an inverse logarithmic curve.

Flat - All pixels will have the same medium opacity: 50%.

SUV Computation

Selecting this button will automatically convert PET in SUV if it is possible.

Normally this next selection of the fusion type will not be changed. Please check with your modality manufacturer before changing this value.

Annotations

The Horos Preferences: Annotations screen is where you can control the textual annotations that display on the 2D viewer. The screen is organized as shown below, with the top section a graphical rendition of where and what will display. You can select, delete and edit the text overlays that are displayed on the 2D Viewer.

Each corner holds a set of descriptions that come from the DICOM descriptive tags. Each of the edges includes the "orientation."

Each corner set can contain up to six lines of annotation descriptions that will each display on a line.

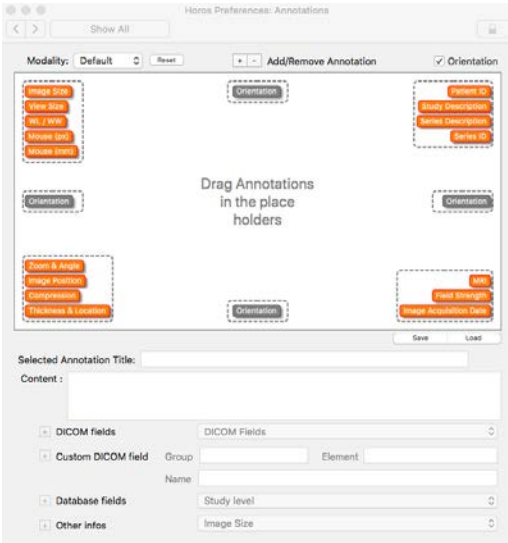


Figure 2.11

These annotations can be selected from amongst:

- *Any standard DICOM field*
- *Any custom DICOM field, defined by its group and element numbers*
- *Any of the database fields: study level, series level, image level, or Album*
- *Any of the following:*

Image Size	*View Size*	*Window Level / Window Width*
Image Position	*Zoom*	*Rotation Angle*
Mouse Position [px]	*Mouse Position [mm]*	*Thickness / Location / Position*
Patient's Actual Age	*Plugin*	*Patient's Age At Acquisition*

The orientation annotations on each edge can display the orientation of the image that is defined independently for each type of modality.

To **change a tag**, select the tag from one of the four corner boxes. It will then appear in the: Selected Annotation Title box. You may edit the Title of the tag by typing in that box. This title will correspond to the Content: shown below the title in that named box. The content of the Content box is changed by pressing the "+" next to any of the fields below.

To **move a tag** from one location to another, simply drag and drop it. To delete a tag, highlight it and press the "-" button at the top center of the screen.

To **add a new tag**, highlight the "+" box near the top center of the screen and a new annotation will appear, waiting to be dragged and dropped into one of the corner boxes.

To **reset annotations**, press the "Reset" button near the top left of the screen and all tags will go back to their default items.

DICOM Print

Horos Preferences: DICOM Print can be used to add and enable DICOM printers for use with Horos. In general, a DICOM printer is defined as standard DICOM nodes. To address a printer, you will its ***IP address***, ***AE Title*** and ***port number***. Each DICOM printer can have separate default parameters for its layout and film type. The default setup values can be changed on a job by job basis.

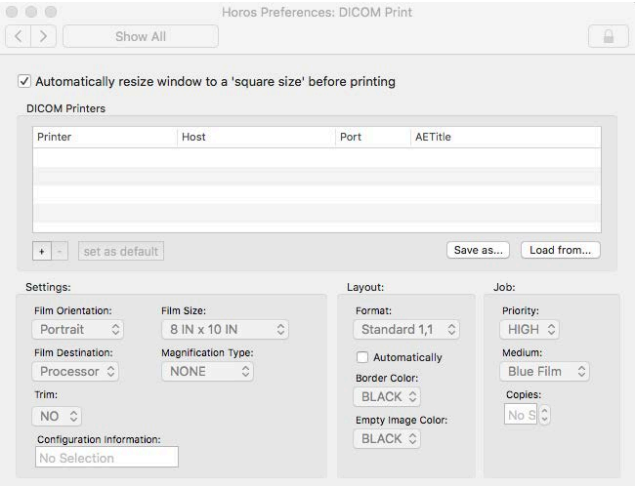


Figure 2.12

Once created, the entire list of DICOM printers can be exported as an XML file and then imported into another Horos workstation.

To ***add a printer*** press the "+" button below the box, then set the parameters accordingly. To ***remove a printer***, press the "-" button while the particular printer you wish to remove is highlighted.

SHARING

Listener

This Horos Preferences: Listener setup screen is where you setup how your Horos workstation will connect with other network nodes. You can also modify other options such as DICOM TLS, file compression handling and Bonjour on this screen.

Basic Settings

Horos is set up as a listener by default. However, this setting can be changed. You may chose to remove the listener setting when you want to use Horos as a third-party C–STORE SCP client.

The following settings can be modified:

> ***AE Title*** *- The AE Title is a unique name (string of characters) used on a DICOM network to identify a DICOM entity. As per the existing DICOM standard, this string can be composed of up to 16 characters excluding the backslash "\". Often this will default to the Horos computer's name set during the computer setup process.*

Port Number *- The TCP/IP port number is set in this box. That parameter will be used by the listener to receive DICOM communications. Valid entries are between 1 – 131072. Usually, it is advisable to select a value above 1024.*

Address(es) *- The address(es) are an exhaustive list of whatever your computer's IP addresses were set and can be found in Mac OS X System Preferences setting under Network.*

Host Name *- This setting should be set to the host name of the computer which can be found in your Mac OS X System Preferences setting under Sharing.*

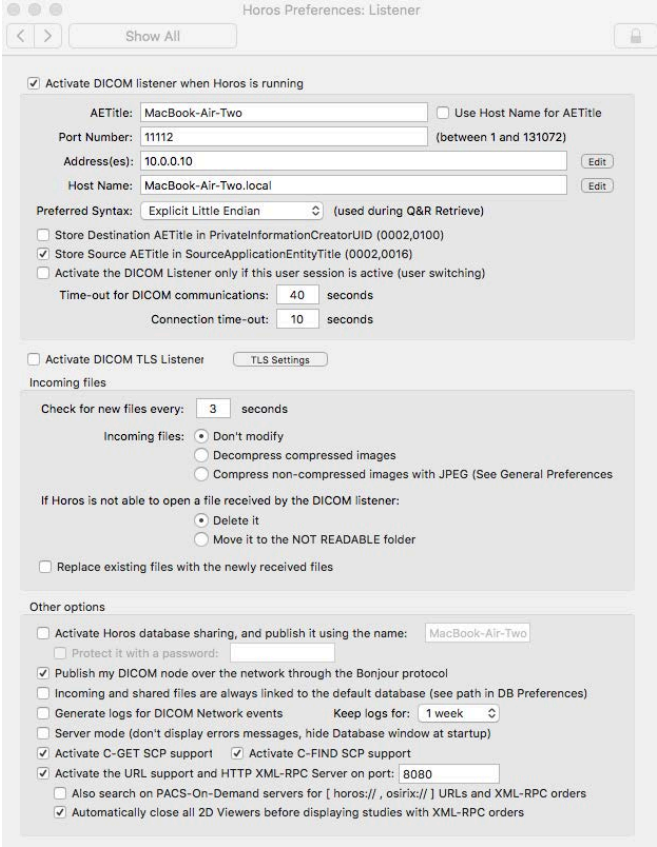


Figure 2.13

Preferred Syntax

A list of the available syntax for incoming DICOM communications is shown on the screen below, with "Explicit Little Endian" as the default selection.

Figure 2.14

The next two boxes below starting with ***Store Destination AETitle in PrivateInformationCreatorUID*** and ***Store Source AETitle in SourceApplicationEntityTitle*** are options for storing the AETitle within the DICOM tag in the specified location. Check one of these boxes if recording of the AETitle in this manner is desired.

If the computer on which you are running Horos is going to be used by multiple users at the same time, please check the ***Activate the DICOM Listener only if this user session is active*** option. Anyone running Horos on this machine can have the same network settings (AE Title/port number) for DICOM communications. The DICOM Listener itself will only be activated by the current user avoiding conflicts between multiple Horos sessions running on this machine.

DICOM Communications and Connection Time-out

If you are using a relatively slow network or perhaps a wireless connection, you may wish to set the time-out for DICOM communications and the connection time-out to be longer than the default. The number is in seconds.

DICOM TLS Listener

The TLS Listener is a second listener option that can be used that enables encrypted communications. It can be enabled independent of the other listener and can optionally share all of it settings. If the “TLS Settings” button is pressed all of the TLS options will appear on a separate screen shown below.

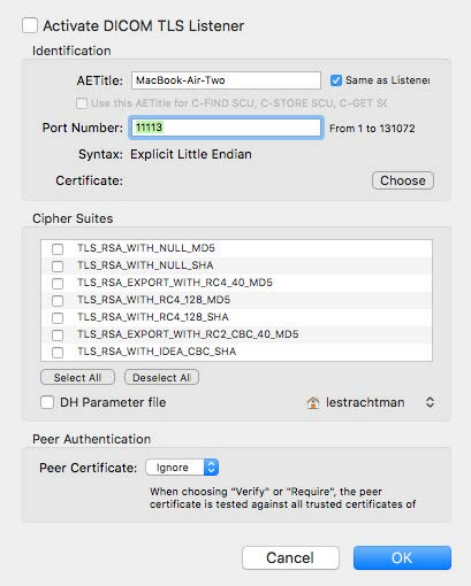


Figure 2.15

Just like the other listener, the TLS listener needs an AE Title and a port number, which can be the same as the other AETitle. The port number will have to be set to a unique setting, different for each listener.

It should be noted, that the TLS listener requires a valid Certificate with the associated private key.

Incoming Files

These parameters enable you to alter the frequency of checking for new files as well as compression. You can select the delay (in seconds) for checking for new files.

You also can choose the decompress compressed images or compress non-compressed images by making these radio button selections. Select either:

- *Don't modify incoming files*
- *Decompress compressed images*
- *Compress non-compressed images with JPEG algorithm*

The compression settings for the JPEG algorithm are designated in General preferences.

Unreadable Files

If Horos is not able to read in incoming file, it will not be able to index it. You can choose to automatically erase these files as they are encountered. However, we recommend that you keep these files so that you will later be able to determine why the file was not readable. As such you can optionally store them in the NOT READABLE folder.

You also can check the box to replace existing files with new ones if they are otherwise identical.

Other Options

Activate Horos database sharing

Horos can be configured to make its database available to other users remotely through an embedded proprietary protocol. Authorized remote access users can view and transfer images from the Horos database. To share the database you will need to publish it using the designated name. Protect access to your database by clicking the box and adding a password.

Publish my DICOM node over the network through the Bonjour protocol

Horos can communicate over a network using Bonjour. Other workstations connected to the same network (subnet) and using Horos workstations can send images without having to enter the listener parameters.

Incoming and shared files are linked to the default database

Incoming images can be stored in the currently loaded database, or elsewhere. The default Database is set in preferences. If this box is checked, the new images will be stored in that default database.

DICOM Network Events Logs

An important feature of Horos is its ability to store logs of DICOM Network events. The logs can have durations of up to one year. They are set using the pull down option.

Server Mode

Although we don't recommend it for large data sets, Horos can be set to run as a server. Doing so, will change certain Horos behaviors including:

• Don't display error messages. Since no error messages will be generated, Horos will not have to wait for a user to accept of cancel an error message to continue to operate.

• When a new version of the software or a new plugin is available, this message will not appear and will therefore not interrupt operation waiting for a user to accept the message or take other action.

• The database window will be hidden.

• The Database Engine will be purged every 4 hours, optimizing memory usage.

C–GET SCP

You can activate C–GET and/or C-FIND support by checking this box.

XML–RPC Server

The XML–RPC Server can be activated by checking this box. You can also set Horos to search other Horos or OsiriX servers as well as close all 2D viewer before displaying studies with XML-RPC orders by checking that box.

Locations

This screen enables you to change DICOM nodes settings and add other nodes to your DICOM network like other workstations, modalities, PACS, DICOM printers and more.

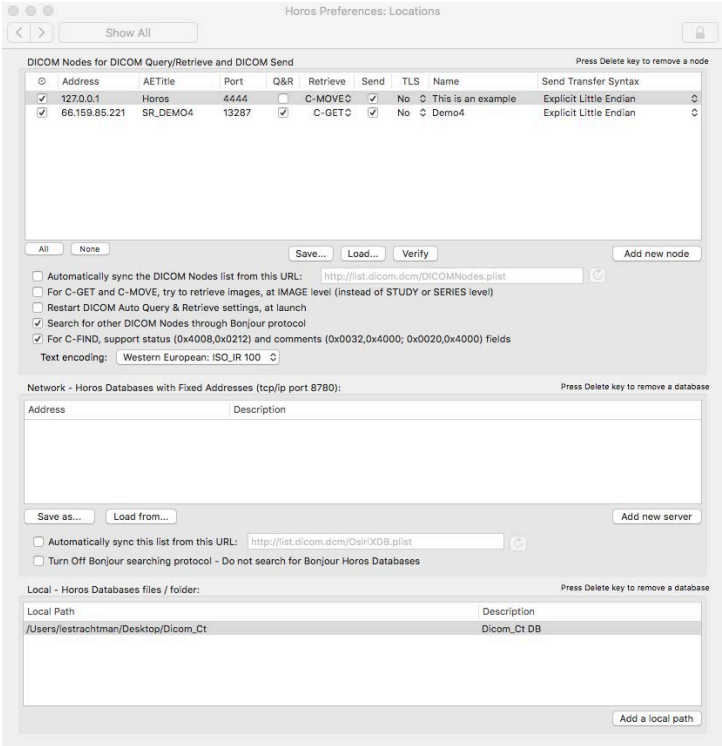


Figure 2.16

DICOM Nodes (DICOM Query/Retrieve and DICOM Send)

This is where you can automatically manage your list of DICOM nodes. Alternatively, you can set to manually enable the following actions:

- ***Add a new entry*** *– click on the Add new node button. This will add a new node to the list. You can then modify each entry.*
- ***Add a new generic entry*** *to the list. First, click on the Add new node button to add a new line, then modify each field.*
- ***Remove an entry*** *from the list by highlighting an existing node and pressing the "delete" key*
- ***Modify a field****, double click on the text and then enter the new desired text.*

Each DICOM node line will contain the following fields:

- *IP address*
- *AE Title*
- *Port number*
- *Query & Retrieve: should be set to either on or off. This option enables querying of the node from this station.*
- *The Retrieve mode with be set to any of: C–MOVE, C–GET or WADO*
- *Send: check to enable. This enables sending DICOM objects to the node from this Horos workstation.*
- *TLS: Set this to either YES/NO. If set to YES, you have enabled TLS communications between the node and this Horos workstation and a new screen will appear enabling you to set the TLS settings.*
- *A text description (human readable name) of the node.*
- *The Send Transfer Syntax can be selected from the pull down list shown below.*

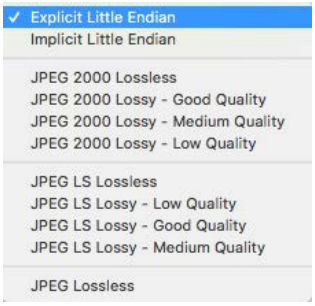


Figure 2.17

You can change the order of the DICOM nodes on the list by clicking on the entry and dragging it up or down the list. Nornally, you would move a node up the list if it is the one you most frequently use.

Your easier alternative is to manage the DICOM nodes list automatically. Click the box next to Automatically synch the DICOM Modes list… and choose the URL that contains the plist of these nodes. Manual settings will be disabled. Instead Horos will use the information from this URL containing information about your DICOM nodes.

The list of DICOM nodes can also be manually loaded from an XML file. Additionally, checking the boxes below will chage the the parameters shown.

Check the box next to: For C-GET and C-MOVE, try to retrieve images at IMAGE level (instead of STUDY or SERIES level) to force Horos to retrieve images themselves

Check the box next to: Restart DICOM Auto Query & Retrieve settings at launch to enable this function.

Check the box next to: Search for other DICOM nodes over Bonjour to use that protocol to find other nodes.

Check the box next to: For C-FIND, support status to set C-FIND protocol as indicated.

You may also set the Text encoding to any of the following encoding schemes shown on the following screen.

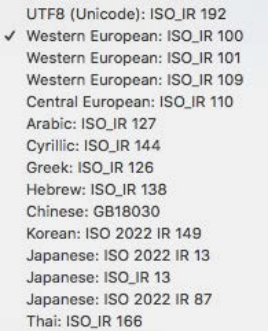


Figure 2.18

Shared Network of Horos Databases

This is where you can add or edit a list of additional Horos databases. Again, you can do this either manually or automatically. This is done automatically if you select the button next to: Automatically sync this list from this URL and enter the URL address. You can manage the list manually by pressing the button to the right below the list: “Add new server”. Doing so adds a new address and description that you can manually edit by double clicking that text. You can delete databases by highlighting a database and pressing the “delete” key.

Again, you can export this list in XML format or you can load a new list in the same format.

Local Horos Databases files/ folder

Here you an manage a list of locally accessible databases. Similar to above, you can add a new local database by clicking the “Add a local path” button near the bottom right of the box. You can then edit the database by double clicking on it or highlight it and press the “delete” key to remove it.

Again, you can select the box next to Turn off Bonjour searching protocol, to disable this access protocol.

Routing

Horos has the ability to auto route a study to another DICOM node based upon a rule that you can set. To activate auto routing, check the box to the left of Activate AutoRouting. Then check the box if you would like to generate an error if an auto routing rule fails. Auto–routing rules can be used to synchronize and archive other types of data like comments, secondary captures and the like.

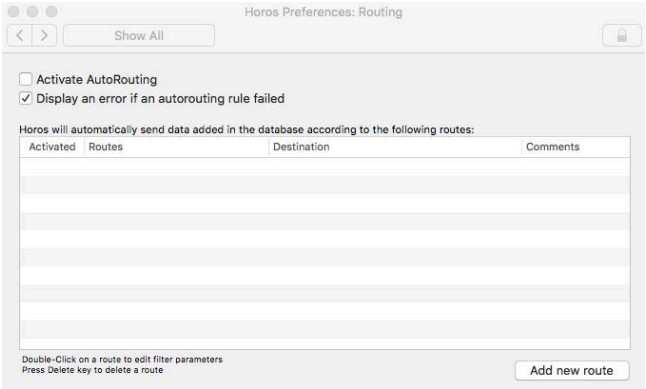


Figure 2.19

Each route has a destination node and an attached rule. If the rule is satisfied, the images will be sent to that destination node.

You can choose any destination that was set in the Locations preference. Rules governing the routing can be composed of a SQL filter or ALL DATA generated by Horos can be routed. In addition, you can send previous related studies.

If the routing fails, you can set Horos to automatically retry the routing. And further, Horos can determine if the images that are to be sent are already present at the destination and refrain from resending, using a C-FIND SCU test.

To add a new route, press the "Add new route" button near the bottom right of the list. This will display the following new screen.

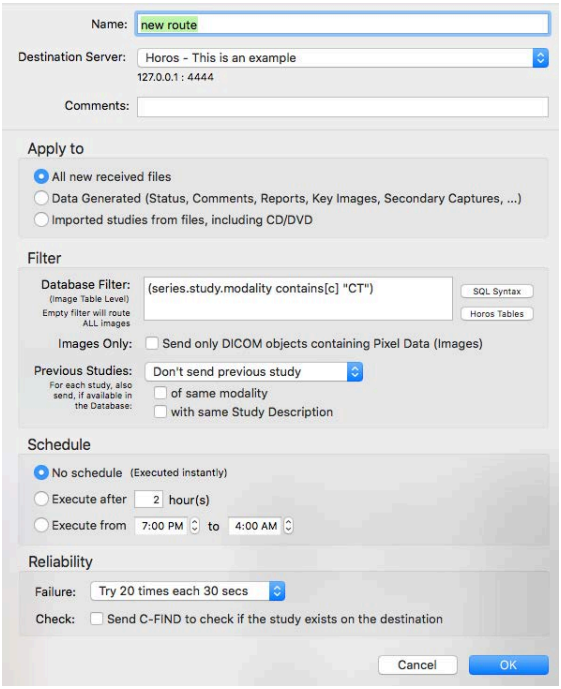


Figure 2.20

Enter a new name for routing and the destination server. The choose from the boxes to describe what you would like to apply this rule to, what the actual filter to be used to test whether to route the study or not, whether you wish to send prior studies and then designate the schedule for routing. You can also alter the number and frequency of retries as well as whether you wish to see if the study has already been sent prior to sending.

Once this information is complete, press the "OK" button.

Web Server

Horos contains a built-in web server. This can be activated in this screen's settings top option check box.

The remainder of the options for the web server set up can then be selected.

> *You can choose the web server port. The default is set to 3333.*
>
> *You can choose to active secure HTTPS connections with a choice of certificate from a list that will then be displayed.*
>
> *You can choose to active WADO server and only accept the WADO request from an identified user.*
>
> *You can activate Weasis support which is a built-in Java DICOM viewer.*
>
> *You can set your preference for Flash instead of QuickTime and then set the number of frames and pixel values.*

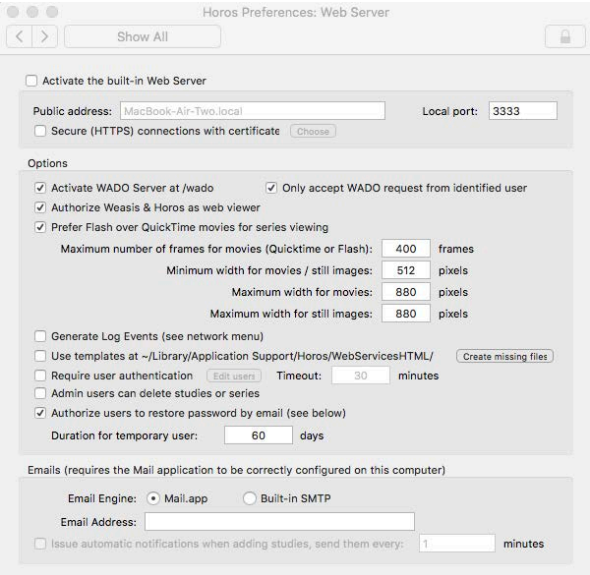


Figure 2.21

You can choose to enable the logging of events

You can choose to use custom web pages.

You can authorize Admin Users to delete studies or series

You can choose to activate users to restore passwords via email as well as the duration (in days) of a temporary user.

You then can choose the email sender engine Mail.app or Horos built-in SMTP server and can designate the email address for that account.

On-Demand

With this screen, Horos enables you to activate PACS on Demand, by clicking the button near the left top of the screen. This allows you to select the DICOM nodes that Horos will use to try to find available studies. All of the nodes listed in the window are defined in the Location preferences settings.

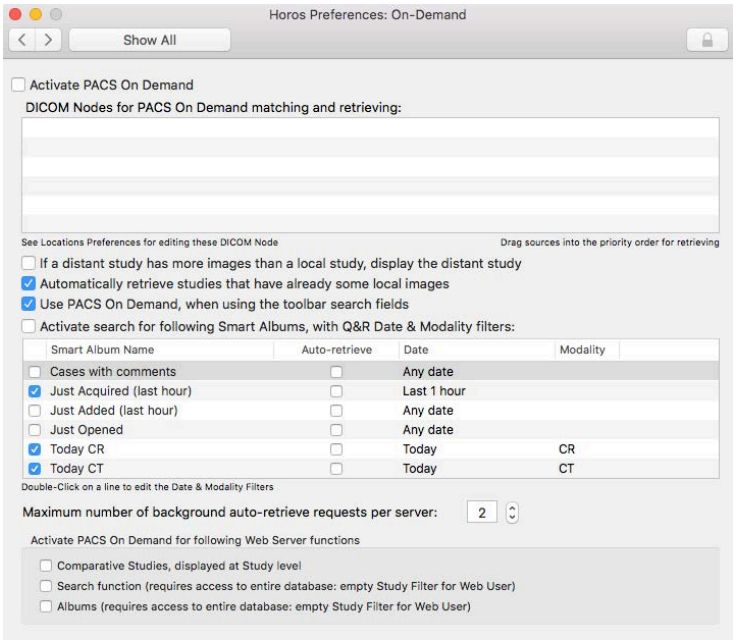


Figure 2.22

You can then set the parameters for the order and priority in which Horos will search from images. This screen also allows you to search smart albums with the designated parameters in the smart album's list. You can activate *PACS on demand* for certain web server functions shown on the bottom of the screen, including Comparative Studies.

Chapter 3

Menus and Navigation

THE HOROS MENU SYSTEM

Throughout the software, there are menus that help with the fundamental navigation of the system. These are described in this chapter. Typically, if a menu selection is not active, it will appear in grey font and will not be accessible from the menu. To the right of many menu functions are shortcut key combinations that will perform the same role as a selection from the menu.

We start from the very top of the screen that appears when Horos is launched. Beginning left to right we will pull down each menu and describe its function.

Figure 3.1

Next to the apple logo which includes information specific to your particular workstation and operating system is the "File" pull down menu.

Figure 3.2

That menu is shown above. The "About Horos" pull down includes a set of three embedded screens shown below that: describe the version of Horos you are using as well as: (1) information on the derivation of Horos and the open source projects that have contributed to the software, (2) release notes for the latest version you are using and (3) our partners in the Horos Project.

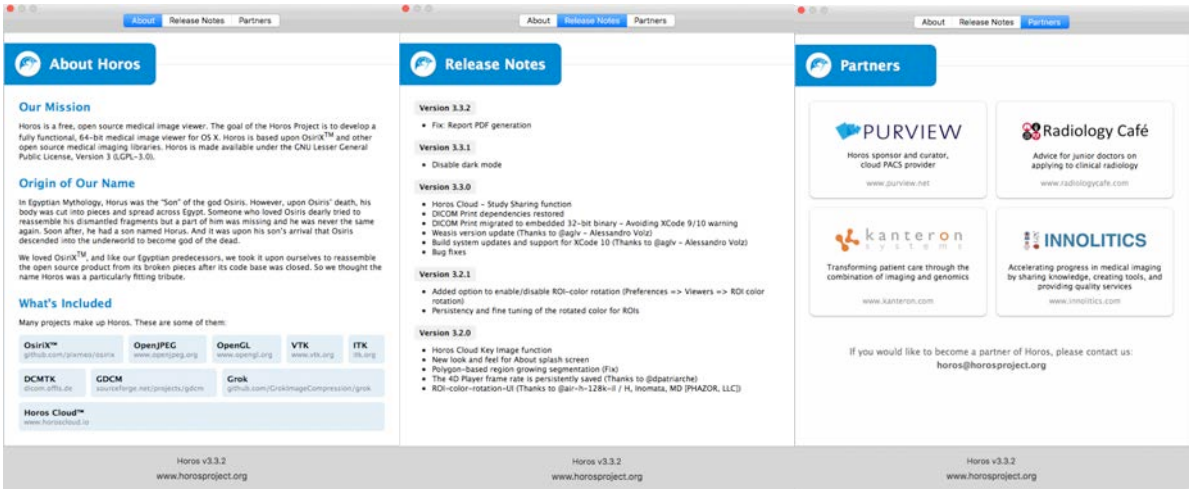


Figure 3.3

The ***Preferences*** pull down menu provides a whole set of options for customizing your particular use of Horos. This is detailed in Chapter 4.

Check for Updates will automatically check back with the Horosproject.com website to ensure you have the most up to date version of the software. What you want is the screen shown below that tells you your current version is correct.

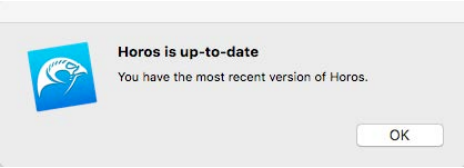


Figure 3.4

Hide Horos

This function hides Horos on your machine. You will need to click on the Horos icon on the "dock" near the bottom of your screen to enable viewing of Horos on your screen

Hide Others

This hides all applications except Horos. To have your other applications reappear, return to the drop down menu and that selection will now say: "Show All." By selecting that option, any other applications you previously had on your screen will reappear.

Quit Horos

This selection shuts down Horos completely. This is different than just minimizing Horos. If image transfers occur during the shutdown process, warnings will appear on the screen, enabling you to abort this shut down. When Horos is not enabled, any images not transferred may be lost.

THE FILE MENU

This pull down menu includes the functions required to manage files, import files, store and export files. Many of these functions have an icon in the Toolbar that is described later in this chapter.

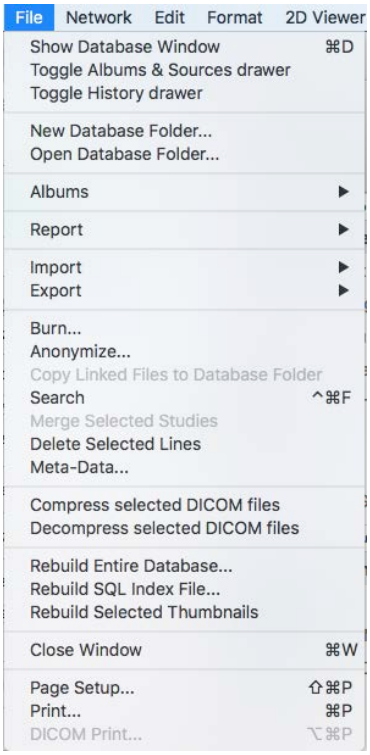


Figure 3.5

Show Database Window

If it is not already, this selection displays the Database Window on the front tile. Usually this window stays open enabling you to access other studies as well as the patient list. However, if it is closed, this selection will cause it to redisplay. You can also access this same function in the 2D Viewer toolbar.

Toggle Albums & Sources drawer

This selection will hide or display the Albums & Sources drawer, shown on the left of the screen below.

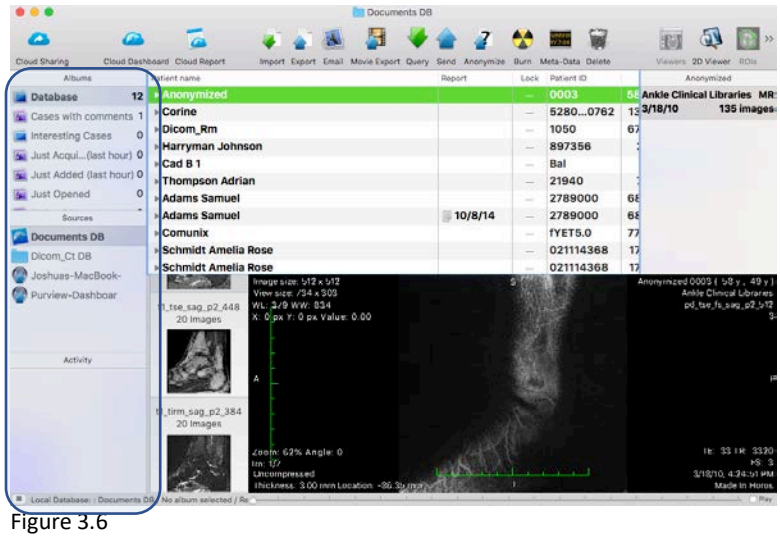


Figure 3.6

Toggle History drawer

This selection will either hide or display the History drawer on the right of the screen shown below.

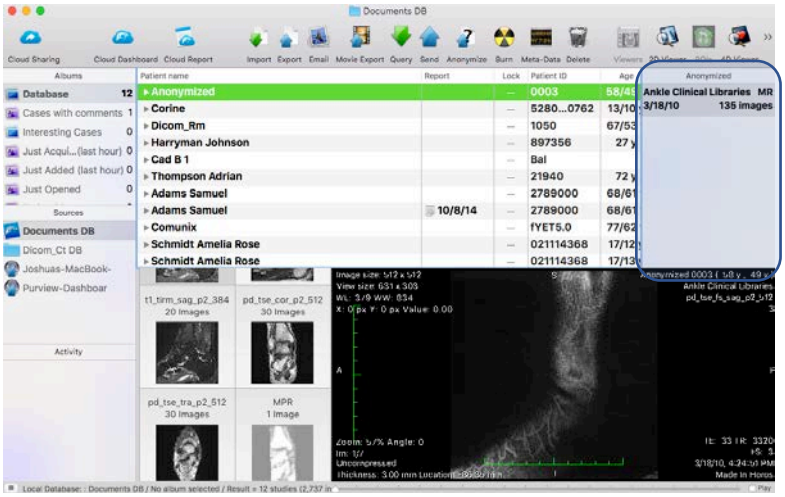


Figure 3.7

New Database Folder. . .

When you make this selection a new database folder will be created. Horos will manage multiple image database folders that you can switch between using the Open Database Folder… function – the next selection on this menu below New Database Folder. By default, a new folder will be located in your home directory.

The newly created database folder will appear in the Sources list of the Database window above. This function is also available in the Preferences Menu – Locations selection.

Open Database Folder. . .

This selection will open whatever specific database folder you specify enabling you to switch between database folders.

Albums

This menu item contains the submenu shown below.

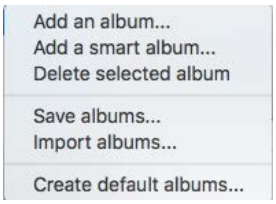


Figure 3.8

Add an album. . .

This allows you to create and name a new album. You may not name two albums the same.

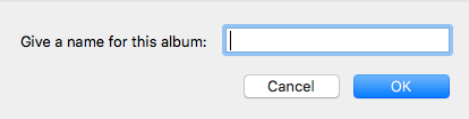


Figure 3.9

Once created, the album will appear in the list on the left hand side of the screen.

Add a smart album. . .

Similar to adding an album, this option enables you to create and name a new smart album. A smart album is different in that it filters studies to match the criteria that is selected from the list shown. Depending upon the selection made, you will be prompted to enter the content for the filter category selected.

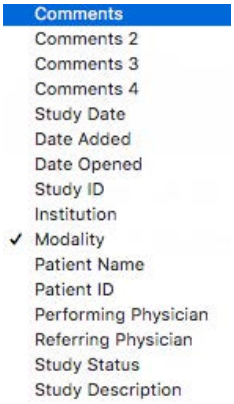


Figure 3.10

Delete selected album. . .

This option will enable you to delete the album currently selected from the Album list.

Save albums. . .

This option enables you to save your albums as a named file in a designated location on your computer or storage device.

Import albums. . .

This option enables you to import a list of albums from a selected file location.

Create default albums. . .

This option will create a list of default albums, such as 'Today CT' or 'Yesterday MR' for a set of potential modalities.

Report

There are two ways you can report in Horos. The first is a basic reporting system that uses your default selected word processing software (generally MS Word or Pages). You may only associate one report with a single study. This report file is document file created by Horos using a template that already includes the patient's demographic data generated from its DICOM tag. This may then be edited using your page editor.

The second way of reporting in Horos is to use the Cloud Reporting system. This is a plug-in feature that is detailed in Chapter 10. Horos Cloud Reporting is accessed via the icon shown in the Menu Bar below.

Figure 3.11

Your menu may appear a bit different depending upon whether you have customized the tool bar.

Open Report

This option enables you to open the existing report that has already been begun for this study. If there has not yet been a report started, using this option will cause a new one to be created.

Delete Report

This option enables you to delete the report related to this study. If there is not existing report, nothing will occur.

There are two other options from this sub menu: **Covert to PDF** and **Convert to DICOM PDF**. Converting to PDF will do just that – it will convert your editor file to PDF format and store it in that format. Converting to DICOM PDF does the same but inserts it into the study.

Import

This option generates a sub-menu with three different methods for importing images into your database.

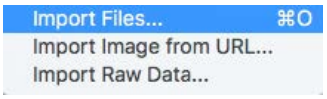


Figure 3.12

You can import a file located on your computer or another designated storage location. You can import an image from a specified URL (you will be prompted to enter the URL address) that will then be downloaded. You may use any supported file transfer protocol for imports from a URL. You also can import raw data (binary or pixel data) also from a file on your computer or another designated storage location. When you do so you will be prompted for the Patient Name, pixel spacing and other related information.

This function supplements standard DICOM communication query and retrieval.

Export

The Export selection will display a sub-menu as shown below.

Figure 3.13

The functions associated with selections from this sub-menu are described below.

Export to DICOM Network Node

You can use this selection to send images to a PACS or workstation by directing the selected study to a predefined DICOM node (from the list of DICOM destinations set in Preferences) using the DICOM communication protocol.

Export to Movie

This selection enables you to send a series of images that can be displayed as a movie sequence in either a Quicktime movie or an MPEG64 movie.

Export to JPEG/TIFF

This selection enables you to save images in either a JPEG or TIFF image formats in a designated location on your computer or another selected storage location. These JGEP files can then be displayed as an ordinary picture file using a program or can be printed on a standard printer.

Export to Raw

This option enables to you create images in a raw format image matrix.

Export to DICOM file(s)

This option enables you to send images as DICOM files to any other program that uses that format file. You can also use this option to send the file to another database.

Export to Email

This option enables you to send an encypted .ZIP file using your default email program. You will be prompted to enter a password of 8 or more characters that will be used to decrypt the image.

Export to iPhoto

This option enables you to send image files in JPEG format to your iPhoto directory.

Export Displayed Database List as. . .

This option, useful for analyzing studies or patient populations, creates a TAB delimited file of the database selected. This file can then be imported into a program that translates delimited files into a spreadsheet or database.

Burn. . .

Use this function to create a CD or DVD of the images and studies selected. When you choose Burn, the following sub-menu appears.

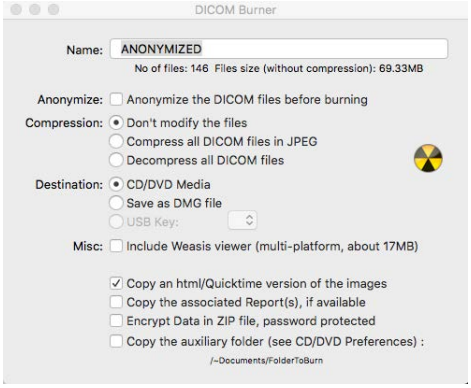


Figure 3.14

From this sub-menu select the options you desire to burn a CD or DVD with these images and an optional embedded viewer. This CD or DVD may be encrypted and named.

Anonymize. . .

Use this option to create an anonymized copy of the DICOM image selected. It does this by stripping all of the patient demographic information from the DICOM tag. As you can see from the selection window below, you can change the DICOM tags shown or you can decide to change other selections from the entire set of DICOM fields.

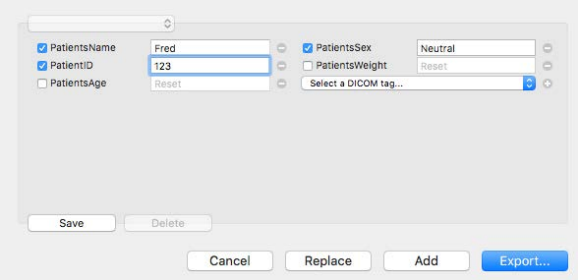


Figure 3.15

When anonymizing a file, please be sure that no private information has been embedded in the images themselves as well.

Copy Linked Files to Database folder

If you would prefer to actually copy the image files of selected studies that are not currently stored in a Horos Data folder, this option will permit you to copy these and store them in Horos.

Search

This selection allows you to enter a string (a word or a sequence of characters) in a search field to identify any study that matches that string in any of its DICOM fields. If the string is found, all studies that meet that criteria will display. Until you remove that string from the search field, only those studies will display.

Merge Selected Studies

You can use this option if you need to merge two or more studies together. You will need to highlight two or more studies in the study list. The warning box shown below will then appear. From this box you can select whether you wish to merge the database only or also the DICOM file headers.

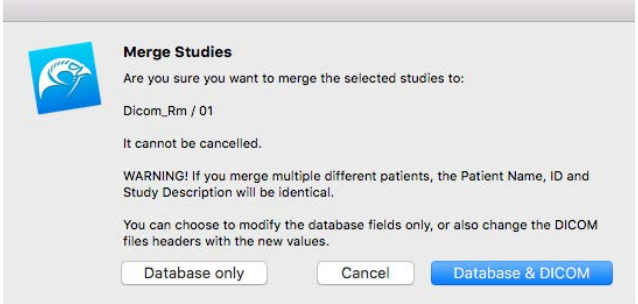


Figure 3.16

Delete Selected Lines

This option enables you to deletes a selected study from the list. This is the same as if you pressed the delete key. A warning box will appear ensuring you wish to continue with this deletion.

Meta Data

This option allows you to display and edit (if enabled in Preferences) the DICOM file's metadata. When you select this option a screen of the fields, their tag descriptions and content will appear.

Compress selected DICOM files

If you need to conserve space on your computer or storage device, you may want to store your DICOM files as compressed. You can use either JPEG or JPEG 2000 compression formats

(whichever is set in Preferences) to compress these files. Compressed files take up less disk space but increase the time required to reload.

Decompress selected DICOM files

This is the opposite of the selection above. Use this if a file is currently stored in a compressed format.

Rebuild Entire Database. . .

There are times when your database SQL file may become corrupted. If this happens, use this selection to rebuild the SQL file index. When you do so the following warning screen will appear. You can select either a complete rebuild or a re-import and clean.

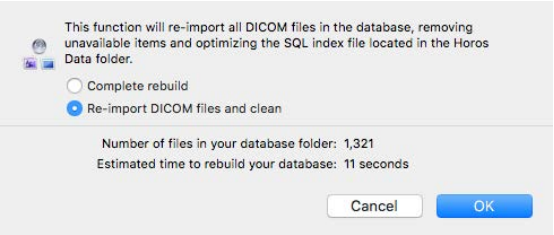


Figure 3.17

Rebuild SQL Index File. . .

For similar reasons as the Rebuild Entire Database, this option enables you to rebuild the files index.

Rebuild Selected Thumbnails

If the thumbnail views are not displaying correctly for a particular study, you may wish to use this option.

Close Window

If you wish to close the display on the screen, use this option. This is the same as pressing the red radio button on the top left hand corner of the screen.

Page Setup. . .

This option invokes the standard Apple printer selection box allowing you to select your printer and page orientation.

Print. . .

Use this selection to for images you wish to print.

DICOM Print. . .

When you make this selection a submenu shown below will appear enabling you to set the standard DICOM printing functions. You can print on any DICOM printer that has been setup in your Preferences.

THE NETWORK MENU

This Network menu pulldown displays the following sub-menu containing the functions required for DICOM communications.

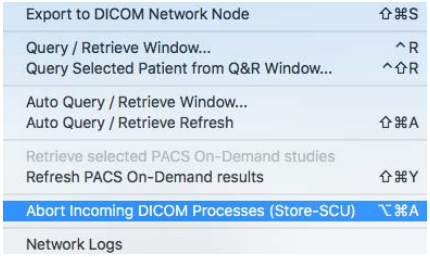


Figure 3.18

Export to DICOM Network Node

Use this selection to send images to a PACS, workstation or other DICOM devise. It will send selected studies or images to any DICOM device previously defined with a Preferences selection. using the DICOM communication protocol.

Query / Retrieve. . .

To find and/or retrieve an image from a DICOM devise previously setup in the Preferences selection, use this option. It will use the DICOM Query & Retrieve communication protocol. When selected, a dialog box will appear enabling you to set the query criteria. You can query one or more DICOM devices at the same time. The order of DICOM nodes will set which images are retrieved where.

Query / Retrieve Selected Patient. . .

To find a study associated with a specific patient (currently displayed or selected in the Horos viewer) use this option.

Auto Query / Retrieve Window

Use this option to find and retrieve any study matching the query criteria entered. You can query multiple notes simultaneously with the order of the nodes determining which images are returned.

A window will appear enabling you to enter the query criteria.

Auto Query / Retrieve Refresh

This option will refresh all 'Auto Query / Retrieve' instances. If any new studies matching the criteria are found they will be retrieved.

Retrieve Selected PACS On-Demand Studies

This options enables you retrieve specific results that you have defined from a connected PACS. This will enable you to see the entire list of studies stored on the PACS. If the same image is found locally it will display the local image. Specific setting include: comparative studies, smart albums and global patient names search.

Refresh PACS On-Demand results

This function will refresh the PACS On-Demand results enabling finding new results.

Abort Incoming DICOM Processes (Store-SCU)

Use this selection to abort a transfer request from a PACS. This will issue and A-Abort message to the DICOM notes stopping all transfers.

Network Logs

This selection displays a list of the recent DICOM sends and receives, assuming the option was previously set in Preferences.

THE EDIT MENU

The Edit menu is shown below.

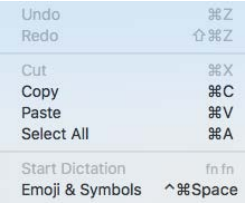


Figure 3.19

The functions for this menu are reasonably straightforward and are described below.

Undo

The undo selection allows you to reverse the prior action, if possible. Not every function can be reversed.

Redo

This selection is the reverse of Undo. It re-does the action that was reversed using Undo.

Cut

This option allows you to cut (and copy or delete) text strings, graphic annotations and ROIs.

Copy

This option allows you to copy (and leave in place) text strings, graphic annotations and ROIs that can later be pasted.

Paste

This option allows you to paste previously copied or cut text strings, graphic annotations and ROIs.

Select All

This option enables to select all available text, graphic annotations and ROIs.

Start Dictation

This option enables you to start dictation if you are using this to enter information into Horos.

Emoji & Symbols

This option enables you to enter special symbols or Emojis from a pull down list of icons.

THE FORMAT MENU

The format menu has several important functions. These are described below.

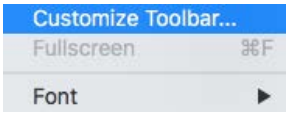


Figure 3.20

Customize Toolbar. . .

Use this option to change or add new functions to the toolbar. Details of the toolbar are described in Chapter 4. You can set the functions you commonly use in the order in which you would like them to appear.

Fullscreen

This option changes the current window to display over the entire screen of the device in use. This will hide the toolbar, the window borders, and sidebars to give you the very largest space available to view images.

Font

This option enables you to select the font you prefer for your entries. It will enable you to select the fonts available on your computer including italic and bold and other special character aspects, as well as the type-fonts themselves and their color.

THE 2D VIEWER MENU

This section includes a description of the functions applicable to the 2D Viewer. The 2D pull-down menu is shown below.

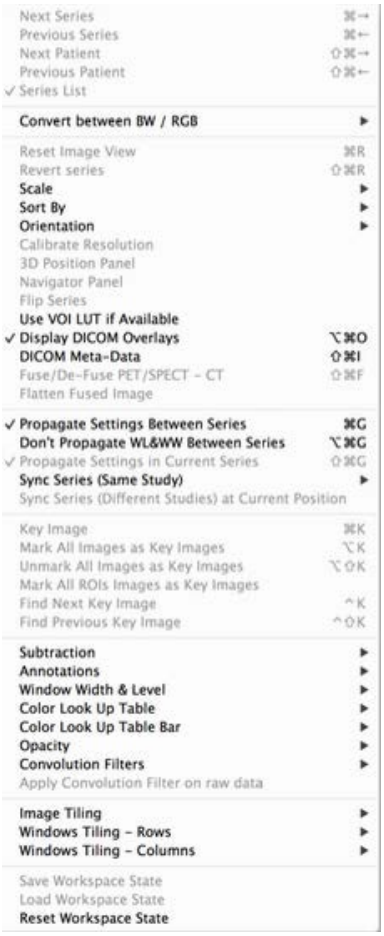


Figure 3.21

Next Series

Selecting this option will move the user to the next series which will then display as active.

Previous Series

Same as above (Next Series) only in reverse. It will move to the prior series and then display it as active.

Next Patient

This option enables you to move to the next patient and display it as active.

Previous Patient

Same as above (Next Patient) but in reverse. It will move to the prior patient and display it as active.

Series List

This option toggles between hiding and displaying the thumbnail series list on the left side of the 2D viewer window.

Convert Between BW / RGB

This option enables you to specifically assign the colors Red, Green or Blue to a black and white image.

Reset Image View

Using this option resets the image being viewed to its default settings.

Revert series

Similar to the reset, this option enables you to revert back to the originally loaded file settings. Any changes made to pixel values or 3D sculpting will be lost and can't be undone.

Scale

This selection enables a sub-menu with three selections shown that can help you change the zoom-in or out of the displayed image.

Figure 3.22

No rescale size (100%) – this sets the zoom level to 100%. Image pixels map one to one with screen pixels.

Actual size - Horos displays the image at the actual real size. This function requires a monitor that supports this function specifically.

Scale to fit – The image will be displayed to fit within the current window.

Sort By

Selecting this function from the pull-down menu will display this submenu from which you can select a field for resorting the displayed series

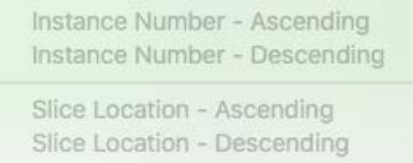


Figure 3.23

The default behavior for sorting is by Instance Number which can be modified within the Database Preferences section.

Orientation

This menu selection displays the following sub menu. From it you can select a flip or rotation of the image.

Figure 3.24

Flip Image Horizontal

This enables you to horizontally flip the active image pivoting on the Y axis. All of the left, right, head and foot orientations will also be adjusted similarly.

Flip Image Vertical

This enables you to vertically rotate the active image pivoting on the X axis. Again the left, right, head and foot orientations will also be adjusted similarly.

Rotation 0 degrees

This selection will return the image to its original view.

Rotation 90 degrees

This selection will rotate the image by 90 degrees in a clockwise direction.

Rotation 180 degrees

This selection is similar to Flip Image Vertical by rotating the image by 180 degrees in a clockwise direction.

Calibrate resolution

This selection enables you to modify the image calibration parameters including pixel size, slice spacing, slice interval, orientation angles and center of origin. You can assign also calibration parameters for images that don't include this information in their DICOM header.

A warning will arise prior to allowing you to make any changes since changing any of these values will impact the measurements computed on this data.

Figure 3.25

Once you press "I agree" you will see the window below appear:

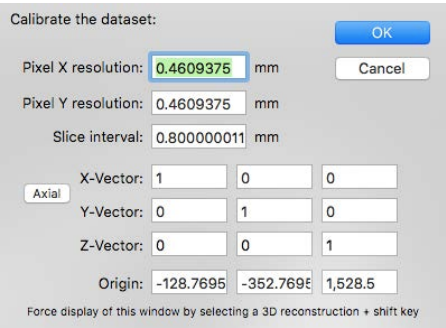


Figure 3.26

On this screen you will be able to manually adjust the dataset.

3D Position Panel

Making this selection will display the following screen enabling you to manually adjust image registration among two modalities (for example PET and CT).

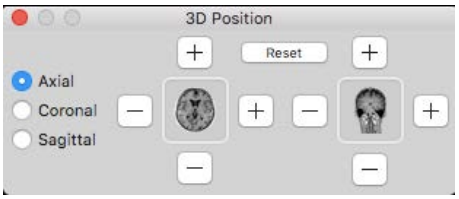


Figure 3.27

Navigator Panel

This selection will display a window below the current window listed all the images in the series.

Flip Series

This selection reverses the order in which the images appear in the series.

Use VOI LUT

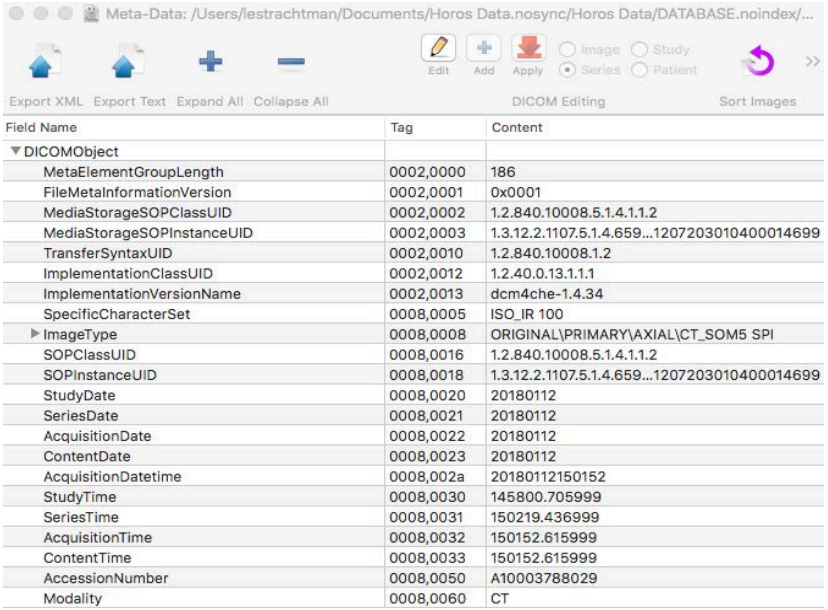
If this option is available, it will load and apply the VOI LUT sequence that is stored in the DICOM file. The VOI LUT sequence is a non-linear intensity cure that can be applied to the image for better rendering of soft tissue.

Display DICOM Overlays

When this is selected the graphic overlays will be display on the image. Some third-party vendors use this to display graphic overlays, annotations and ROI indications on the image itself. DICOM overlays are stored as bitmaps. This can also be manipulated by the “annotation” button on the tool bar.

DICOM Meta-Data

Making this selection will display a detailed window describing the DICOM Object, its tag and a description of its content, similar to the image below.



Field Name	Tag	Content
DICOMObject		
MetaElementGroupLength	0002,0000	186
FileMetaInformationVersion	0002,0001	0x0001
MediaStorageSOPClassUID	0002,0002	1.2.840.10008.5.1.4.1.1.2
MediaStorageSOPInstanceUID	0002,0003	1.3.12.2.1107.5.1.4.659...1207203010400014699
TransferSyntaxUID	0002,0010	1.2.840.10008.1.2
ImplementationClassUID	0002,0012	1.2.40.0.13.1.1.1
ImplementationVersionName	0002,0013	dcm4che-1.4.34
SpecificCharacterSet	0008,0005	ISO_IR 100
ImageType	0008,0008	ORIGINAL\PRIMARY\AXIAL\CT_SOM5 SPI
SOPClassUID	0008,0016	1.2.840.10008.5.1.4.1.1.2
SOPInstanceUID	0008,0018	1.3.12.2.1107.5.1.4.659...1207203010400014699
StudyDate	0008,0020	20180112
SeriesDate	0008,0021	20180112
AcquisitionDate	0008,0022	20180112
ContentDate	0008,0023	20180112
AcquisitionDatetime	0008,002a	20180112150152
StudyTime	0008,0030	145800.705999
SeriesTime	0008,0031	150219.436999
AcquisitionTime	0008,0032	150152.615999
ContentTime	0008,0033	150152.615999
AccessionNumber	0008,0050	A10003788029
Modality	0008,0060	CT

Figure 3.28

Convert from/to SUV

SUV is the standardized uptake value or the dose uptake ratio. It is widely used as a simple PET quantifier. In Horos SUV only adjusts to the patient's body weight (not surface area or adjusted to lean body mass). This option enables the computation to or from SUV.

Fuse/De-Fuse PET/SPECT-CT

This selection is only available when displaying a window including a fusion of two modalities. You can turn on or off the fusion of the modalities.

Flatten Fused Image

This selection enables you to merge two series that are currently fused using a color overlay. To accomplish this you would first superimpose the two images and adjust the registration. Then use this option to merge the two series from the same modality, superimpose them, adjust the registration and then use this option to merge the two series together.

Propagate settings between series

This option will enable you to use the same settings for pan, zoom, window leveling and origin for the entire series. You can use this option to turn this off or on.

Don't propagate WL/WW between series

This will enable you to turn on or off the use of the same settings for image contrast and intensity (window level and window width) for all series displayed on the screen.

Propagate settings in current series

This option will turn on and off the propagation of image adjustments to all the images in the current series. This option enables you to either adjust individual images of the series using different settings or make the settings apply to the entire series.

Propagate Zoom Level Only if Planes are Parallel

This option lets you propagate zoom levels if you are viewing parallel planes.

Sync Series (same study)

Selecting this option will display the submenu shown below:

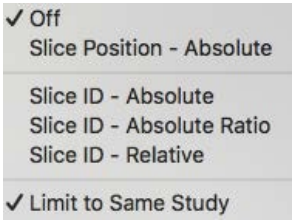


Figure 3.29

You can use this option to enable the synchronization of images from multiple series simultaneously by the slice's position or ID.

Sync Series (different studies) at current position

This allows you to synchronize among two series from different studies using the starting position of the image displayed on each series window.

Key Image

Use this option to mark an image as a key image. When marked, the image will display a yellow frame.

Mark All Images as Key Images

If you want to mark all images of a series as key images, use this option.

Unmark All Images as Key Images

This option unmarks all of the key images that have been marked in this series.

Mark All ROIs Images as Key Images

This option marks quickly identifies every image containing an annotation of a graphic ROI as a key image.

Find Next Key Image

This option jumps you from the current key image to the next key image in the series.

Find Previous Key Image

Use this option to jump back to the previous key image in the series.

Subtraction

This menu selection will display the sub-menu below.

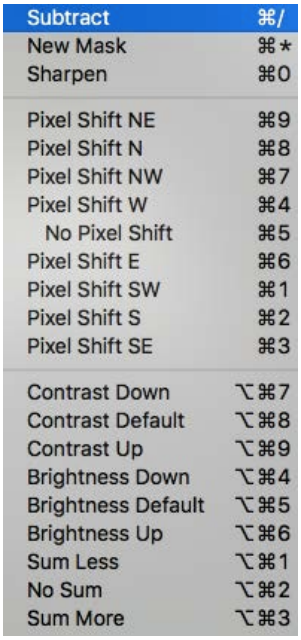


Figure 3.30

From this submenu you can select the option of your choice to subtract an image from the other images in the series in different ways. Specifically, the first three options from the submenu do the following:

Subtract

Turns on or off the subtraction operation.

New Mask

Enables you to use the current image as a new mask.

Sharpen

This makes an edge enhancement by using a sharpen filter applied to the results of the image subtraction.

The remainder of the selections from this submenu operate as follows:

Pixel Shift

This option from the submenu shifts the mask image by one pixel in the identified direction.

Contrast Down

This option from the submenu reduces the contrast of the mask image used to be subtracted from all images in the series.

Contrast Default

This option resets the default contrast of the mask image that is being subtracted from all of the other images in the series.

Contrast Up

This option increases the contrast of the mask image being subtracted from the other images in the series.

Brightness Down

This option reduces the brightness of the mask image being subtracted from the other images in the series.

Brightness Default

This option resets the brightness of the mask image being subtracted from the other images in the series.

Brightness Up

This option increases the brightness of the mask image being subtracted from the other images in the series.

Sum Less

This option reduces the sum of multiple contiguous images used as a mask for subtraction.

No Sum

This option cancels the use of the sum of multiple contiguous images used as a mask for subtraction.

Sum More

This option increases the sum of multiple contiguous images used as a mask for subtraction.

Annotations

Using this set of options enables you to turn on and off parts of the displayed annotations. You can use the "tab" key to switch between these different modes: none → graphic only → full → basic → none. Annotation options appear on the submenu shown below.

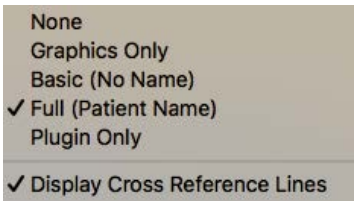


Figure 3.31

None - turns off all the annotations and overlays.

Graphic Only – turns off only the annotations and retains the graphic overlays.

Basic (No Name) – only turns off the patient name display. All other annotations will still display.

Full (Patient Name) – all annotations and overlays will appear.

Plugin Only – only graphics and annotations that were created using plugins will display.

Display Cross Reference Lines – turns on or off cross reference lines. Note that if the slice image of the front most window has cross lines they may still be displayed.

Window Width & Level

Selecting this option displays the following submenu, enabling you to select predefined WL and WW values. You can also add custom presets to this list by adding the "current WL/WW" as shown.

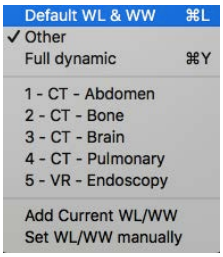


Figure 3.32

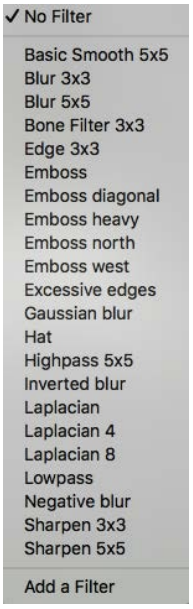


Figure 3.33

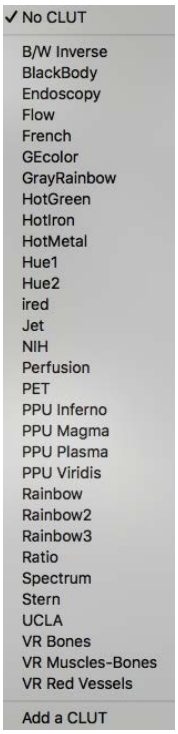


Figure 3.34

Color Look Up Table (CLUT)

This applies preset color schemes to images. These schemes appear on the submenu to the right and can be selected from the list.

Color Look Up Table Bar

By selecting this option, the following sub-menu will appear. Selections from this submenu enable you to show or hide the color lookup table scale.

Figure 3.35

Opacity

Selecting this option displays the submenu shown below. From this submenu, you can select one of the options to adjust the blending of fused images. Custom opacity tables can be created as well.

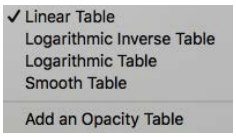


Figure 3.36

Convolution Filters

Selecting this option displays the submenu shown below. From the submenu, you can select a convolution filter.

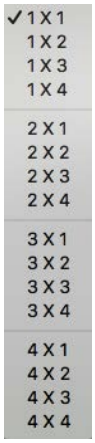
A convolution filter is a function that transforms the display of the image. It does not change the image itself. Depending upon the filter selected, a formula will run against each pixel of the source image one by one to compute the values of each pixel in the resulting image using the values of the surrounding pixels.

Custom filters can also be created. Filters are applied to the images in real-time on the display, but the original data remains unaltered. This item is also available as an icon in the 2D Viewer toolbar.

Apply Convolution Filters to raw data

If you want to apply the convolution filter to the image data itself (not just the display) you can select this option. It will apply the selected convolution filter to alter the image data. This should be done with caution, since it cannot be undone.

Image Tiling



You can select the grid display for your screen windows from this option. Selections of the display configurations shown on the submenu to the left will be displayed.

Alternatively, you can select the number of rows or columns (from 1 – 9) that you wish to display from the next two options on the 2D pull down menu:

Windows Tiling - Rows ,
Windows Tiling Columns.

Figure 3.37

Save Workspace State (as DICOM SR)

By selecting this option, you can save the current workspace display including the images being displayed as well as their layout on the screen. The “SR” option saves these as a structured report.

Load Workspace State (as DICOM SR)

This option enables you to restore a workspace screen configuration previously saved, including those saved as a structured report.

Reset Workspace State

This option resets the default workspace configuration that may have been previously changed.

THE 3D VIEWER MENU

Figure 3.38

Certain studies that have sufficient resolution and are scanned with modalities capable of generating a 3D image or various other rich views can be reproduced in Horos as an MPR or 3D image.

3D MPR

Selecting this option, displays an oblique multiplanar formatting of the series of images in a separate window as shown below.

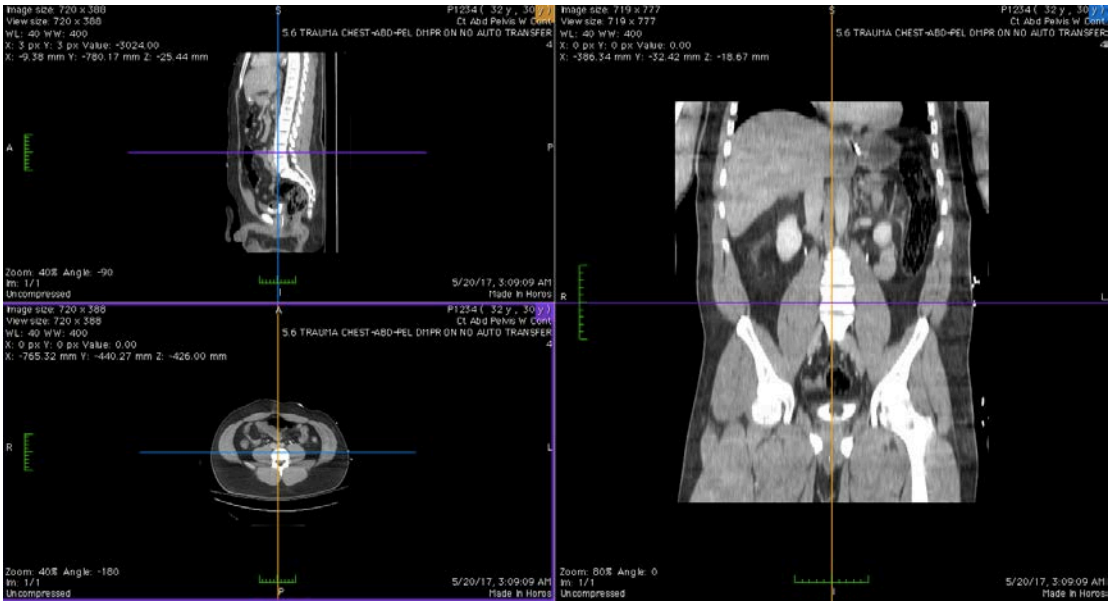


Figure 3.39

3D Curved MPR

This option is an alternative to the plain MPR. It displays a 3D Curved MPR Viewer format also in a separate window.

2D Orthogonal MPR

Selecting this option displays a 2D Orthogonal MPR Viewer format of a series also in a separate window.

3D MIP

Selecting this option displays a Maximum Intensity Projection (MIP) image in a separate window.

3D Volume Rendering

Assuming there is sufficient information included with a scan, this option enables the display of a 3D rendered image using the embedded Volume Rendering capability. The 3D image will be displayed in a separate window where it can be manipulated, turned and processed.

3D Surface Rendering

This generates a 3D rendered image using the Surface Rendering capability. When this option is selected, the following box displays requesting information to customize the view.

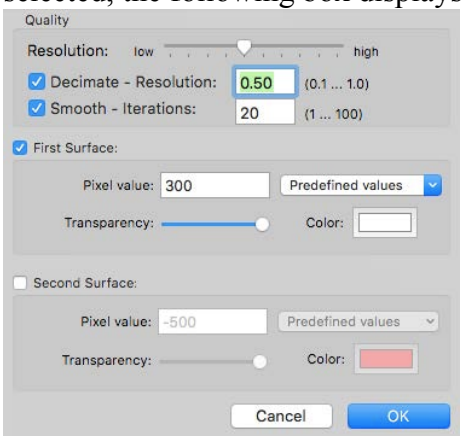


Figure 3.40

Once selected the screen displays appear similar to that shown below.

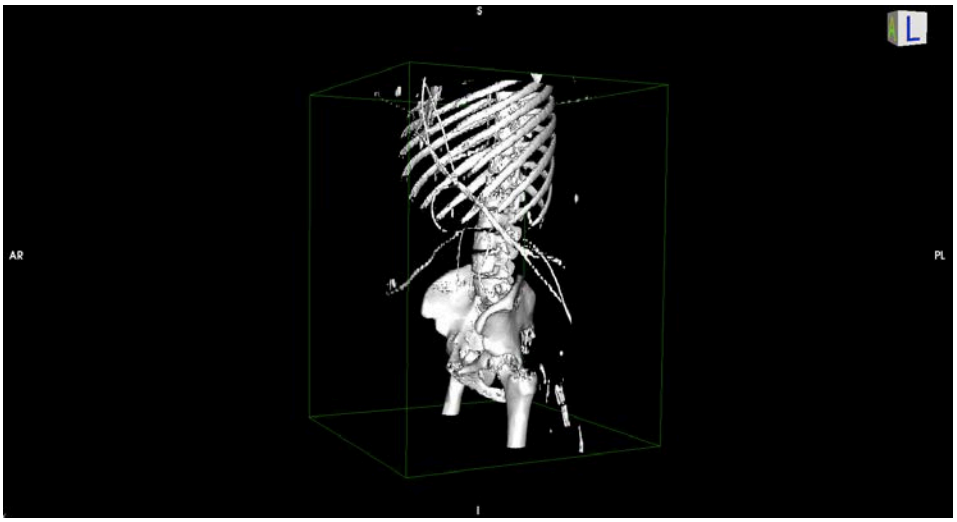


Figure 3.41

3D Endoscopy

Assuming you have an appropriate scan from an endoscopic CT modality, this features enables the display of a navigation window with an endoscopic view.

Reset to initial view

If you wish to restore the display to the system's original settings including orientation and zoon, use this option.

Revert series

This is a hard reset that returns the view to the original file's settings, unless pixel values were changed.

Changing Views

Coronal View - This changes the display to a coronal view of the images in the current 3D window.

Left Sagittal View - This changes the display to left sagittal view in the current 3D window.

Right Sagittal View - This changes the display to right sagittal view in the current 3D window.

Axial View - This changes the display to an axial view in the current 3D window.

Add FlyThru Point/Remove Fly/Thru Point

If you wish to add the current image as a point on the fly through sequence or remove an existing point on the sequence, select the appropriate option amongst these two.

Reset FlyThru Path

In order to entirely reset the fly through sequence, select this option.

3D Curved Path

You can choose either to load and existing 3D curved path or save a 3D curved path from this menu. The file will be saved with a .curvedPath extension that is unique to Horos and can only be read with this software.

Scissor Editing

This menu option will enable you to Save, Load or Delete the volume editing generated with the scissors tool function. Scissors tool is used for removing portions of a 3D volume.

Select/Save 3D Preset

While using 3D volume rendering, you can either select a preset from a list of presets by using that selection or you can save the current view as a preset.

THE ROI MENU

The ROI menu is a pulldown of various functions that you can perform for regions of interest. The pull down menu is shown below with each of its selections described.

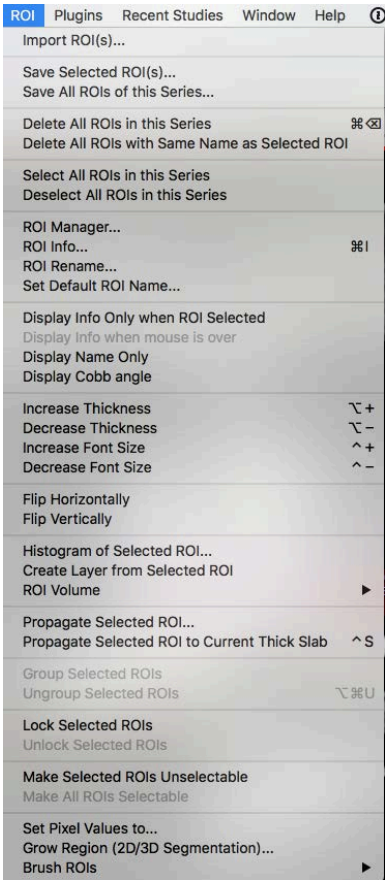


Figure 3.42

Import ROI(s). . .

Using this function you can import previously stored ROIs for this study.

Save Selected ROI(s). . .

This function enables you to save a currently created ROI in this slice to be saved in a file.

Save All ROIs of this Series. . .

Using this function enables you to save the entire series' ROIs that have been created.

Delete All ROIs in this Series

This option will remove all the existing ROIs in the entire series.

Delete All ROIs with Same Name as Selected ROI

Selecting this option enables you to remove all ROIs in this series that have the same name as the one selected.

Select/Deselect All ROIs in this Series

This option enables you to select or deselect all ROIs in the current series at the same time.

ROI manager. . .

This option displays a dialog box as shown below with a list of ROIs that can be edited.

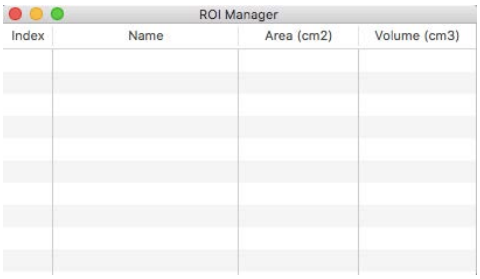


Figure 3.43

ROI info. . .

This selection displays a dialog box (as shown below) with information related to the selected ROI.

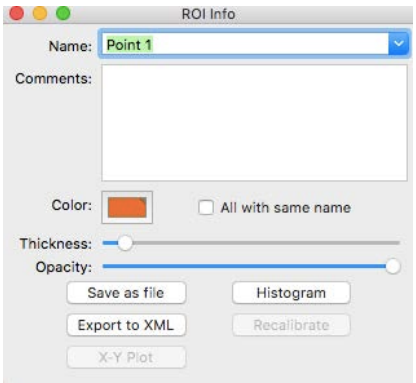


Figure 3.44

ROI Rename. . .

Selecting this option pops up the window shown below that enables you to rename a single or multiple ROIs.

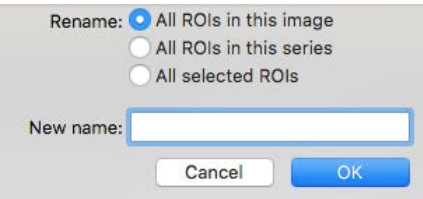


Figure 3.45

Set Default ROI Name. . .

This selection enables you to set a default name for all ROIs that are created in this study. The box below is how this name is entered

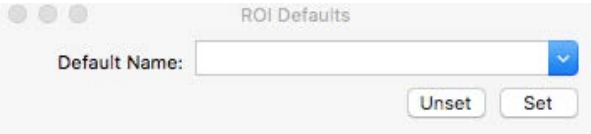


Figure 3.46

The following four options change the way ROI information is displayed. Each can be checked or unchecked.

Display Info Only when ROI Selected – When this is selected, it will display the label and ROI data that is available.

Display Info when mouse is over – When checked the ROI information will only be visible when the mouse hovers on the ROI.

Display Name Only – when this is checked, it will display the ROI name only.

Display Cobb Angle – when checked the Cobb Angle will be displayed.

The following four options let you edit the way the ROI information displays.

Increase Thickness – selecting this option increases the thickness of an ROI line. Selecting this repeatedly, continues to increase the thickness.

Decrease Thickness – selecting this option decreases the thickness of an ROI line. Selecting this repeatedly, continues to decrease the thickness.

Increase Font Size - Selecting this option enables you to increase the size of the ROI's descriptive text. Selecting this repeatedly, continues to increase the size of the font.

Decrease Font Size - Selecting this option enables you to decrease the size of the ROI's descriptive text. Selecting this repeatedly, continues to decrease the size of the font.

Flip Horizontally/Vertically

These options enable you to flip the currently selected ROI either horizontally (around the Y axis) or vertically (around the X axis).

Histogram of Selected ROI. . .

By selecting this option, you will see a display in a pop up window similar to the one below, of a histogram of pixel gray levels from the area within the selected ROI.

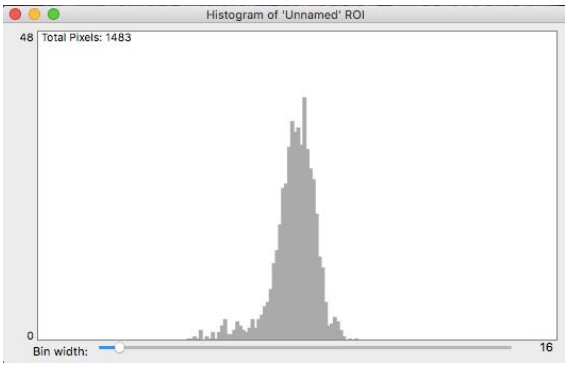


Figure 3.47

Create Layer from Selected ROI

Selecting this option captures the selected ROI into a graphic overlay bitmap.

ROI Volume

Making this selection pops up a submenu (shown below) with functions to manage the ROI volume.

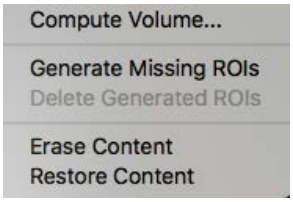


Figure 3.48

Compute Volume. . .

This computes the total volume of all ROIs with the same name as the currently selected ROI in order to computer volume. The result is then shown in a separate window displaying the 3D rendering.

Generate Missing ROIs

This option automatically interpolates ROIs in slices between ROIs of the same name. This helps with the computation of volume from multiple slice data.

Delete Generated ROIs

Use this option to undo the interpolation from the "Generate Missing ROIs" function.

Erase content

This option erases all pixels within an ROI (either 2D or volume).

Restore content

Use this option to undo the "Erase Content" option above to reset all the pixels back to their original (last stored) value.

Propagate Selected ROI. . .

Making this selection opens a pop-up submenu (shown below) that enables you to manage the propagation of ROIs onto other designated slices in the series – either the entire series of a designated number of slices. The resulting ROIs can be designated as independent or as aliases of the current ROI.

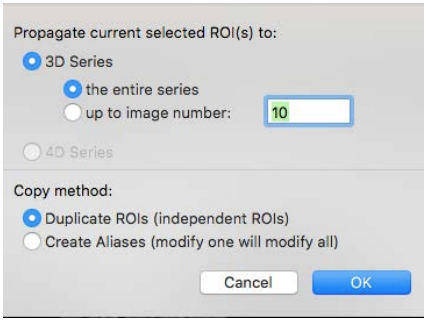


Figure 3.49

Propagate Selected ROI to current Thick Slab

This option enables the propagates of the selected ROI to all the slices in the current thickslab setting.

Group Selected ROIs

Making this selection connects all selected ROIs. Thus moving one will cause all of them to move simultaneously.

Ungroup Selected ROIs

This option disconnects a group of ROIs previously connected with the "Group Selected ROI option above.

Lock Selected ROIs

Making this selection locks the ROIs selected making them uneditable.

Unlock Selected ROIs

This selection undoes the ***Lock Selected ROIs*** selection above.

Make Selected/All ROIs Unselectable

Choosing this option sets selected or all ROIs to be unselectable.

Make All ROIs Selectable

This option undoes the action above from ***Make All ROIs Unselectable***.

Set Pixel Value to. . .

This option enables you to set the pixels values inside or outside of a specific ROI. When selected, the following submenu appears. Doing so will highlight the ROI to make it standout from the remainder of the image.

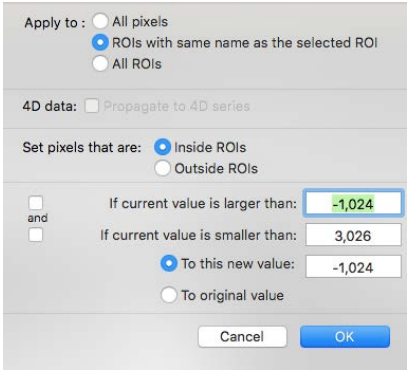


Figure 3.50

Grow Region (2D/3D Segmentation). . .

This selection enables an automatic segmentation tool based on a Region Growing algorithm that can be applied either in 2D or 3D mode. The submenu window shown, provides a way for you to change a range of pixel intensities that are used to set the Region Growing algorithm. The resulting ROI can be set to be either a polygon or an irregularly shaped brush mask.

Brush ROIs

This selection displays the following options:

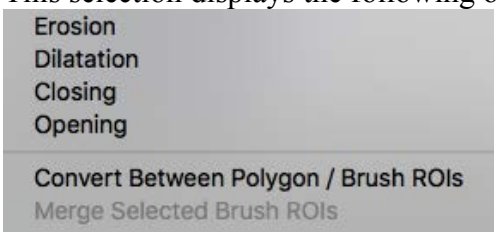


Figure 3.51

Enabling the application of morphological filters to an irregular brush ROI. You can select from amongst the four filters shown. Or you can choose between polygon and brush ROI or to merge selected brush ROIs into one single ROI.

THE PLUGINS MENU

The functionality of Horos is continually extended by members of the community to build functionality and enable it in Horos through a Plug In. The Plug In pull-down menu has a list of the Plug Ins that have specifically been added to your version of Horos.

The menu lists the plugins that you have loaded.

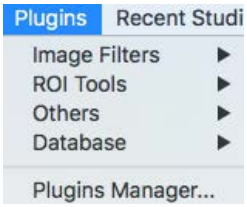


Figure 3.52

Once installed, plugin files can be found on your local disk in a folder that is located in the Application Support/Horos folder in the Library folder of your computer. A Horos tool allows you to update and retrieve new plugins from a central repository on the Horos web site. Currently plugins are divided into four categories listed as individual list items in the plugin menu:

• Image Filters • ROI Tools • Others • Database

Plugins Manager. . .

Making this selection opens a dialog box with a list of currently installed plugins similar to that shown below.

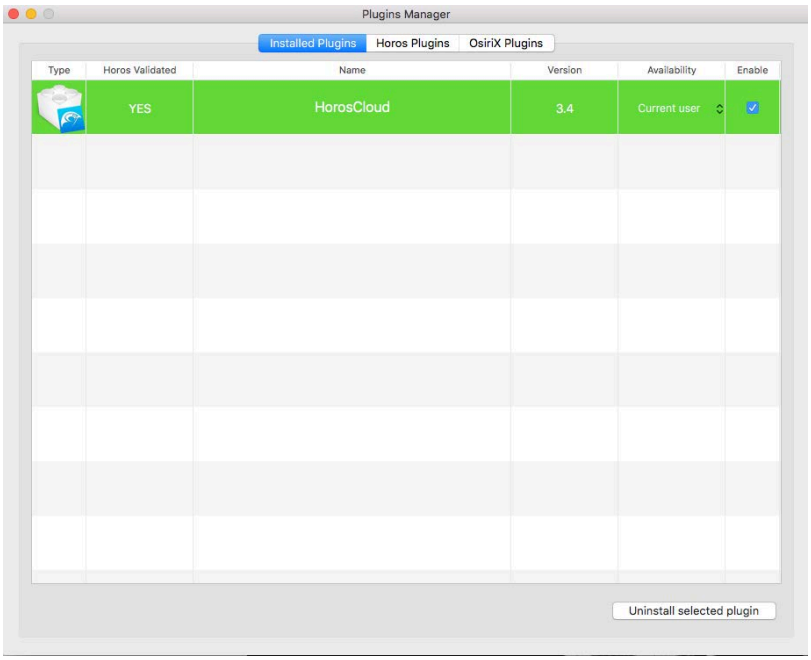


Figure 3.53

There are a set of plugins that have been installed displayed in the left tab: Installed Plugins. But there are additional plugins that are available in both Horos and Osirix that you may also find helpful. Check back often to see if there are new plugins that have been validated for your use with Horos.

RECENT STUDIES

Pulling down this menu will display a set of the last several studies you have viewed. This is a shortcut way to enable access to a recent study.

THE WINDOW MENU

The Window menu selection (shown below) is similar to most Apple Macintosh applications that enables you to manage the multiple windows of an application.

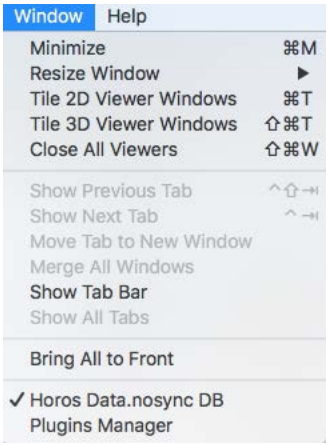


Figure 3.54

Minimize *– hides the current window and minimizes it into a thumbnail shown near the bottom of your screen in the dock.*

Resize Window *– this option reduces the size of the current window.*

Tile 2D Viewer Windows - *This option arranges all of the 2D windows that you have open into an orderly set.*

Tile 3D Viewer Windows - *This option arranges all of the 3D windows that you have open into an orderly set.*

Close All Viewers *– this closes all windows, except for the main database*

The Tab Functions

The middle 6 functions on this pull down menu are formatting for windows. They are self explanatory and will only change the way multiple windows are displayed. Tabs generally provide additional information about the study – either the file name or the database. Changing one or more of these just will not do anything detrimental to your studies but may provide you with more detailed information.

Bring All to Front *– this prioritizes all of your Horos windows in front of any other applications' windows that may be open.*

Horos Data.nosynch DB *– this is the indication of the database currently in use.*

Plugins Manager *– this will summon the Plugins Manager window.*

THE HELP MENU

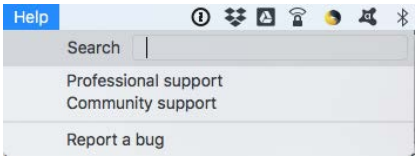


Figure 3.55

The Help pull-down menu provides links to various services.

Professional Support – enables you to connect with Purview to provide you with professional services personnel who, for a fee, can help you with your use of Horos**.**

Community Support – sends you to the Google Board for the Horos Project where you can find answers to common questions.

Report a bug – sends you to the Horosproject Github site where you can provide a description of a potential bug in the software that you have identified.

Chapter 4

Managing Data

The Database Window

When opening Horos, the main window which displays the database of images is known as the ***database window*** (Fig 4.1). It is also referred to as the browser window. Here you will find the content of the local database which is used by Horos to store image files and related data. Whilst Horos is open, it is possible to switch between different stored databases, whether located on the local disk or in remote locations. See Chapter 3 for more information.

The database window is divided into three main sections, study list, series list and preview area. An history section is displayed, visible in the top right quadrant. A toolbar and side panel also form component parts of the window.

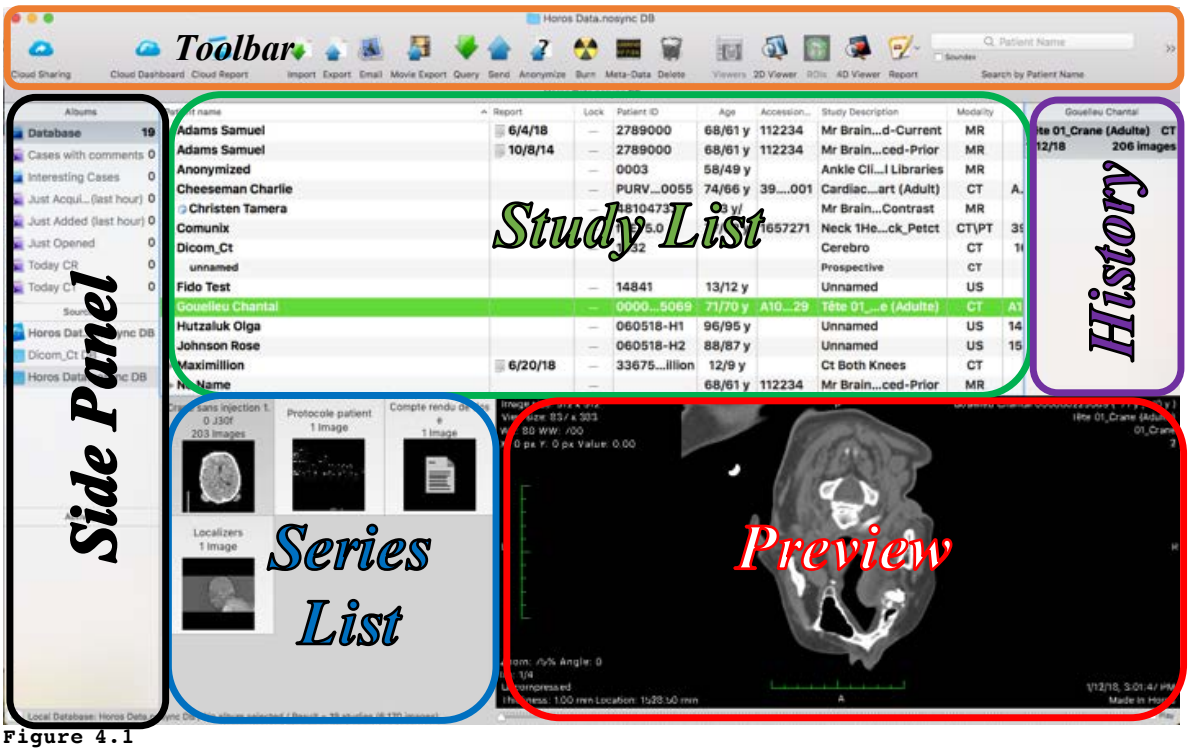


Figure 4.1

The database window displays the study list (upper left quadrant), history (upper right quadrant), series list (bottom left quadrant) and preview area (bottom right quadrant). A toolbar with graphical icons runs along the top of the window, with a side panel displaying albums, sources and activities running down the left hand side.

Using the 'File' menu all operation, such as importing, deleting, archiving and sending of images, are performed through the database window (Fig 4.2)

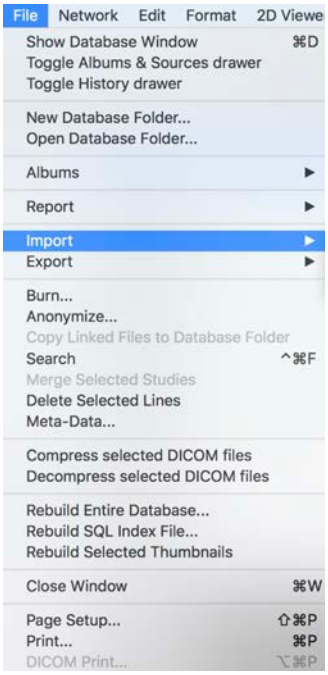


Figure 4.2 The contextual file menu where key functions can be selected

Toolbar

The toolbar is located at the top of the window and displays graphical icons of the key tools which can be selected (Fig 4.3). The toolbar is described in greater detail later in this chapter.

Figure 4.3 The default toolbar

Left hand panel

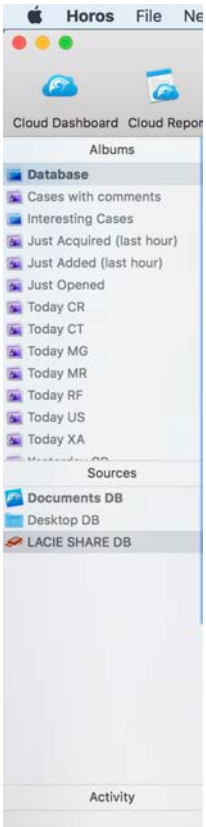


Fig 4.4 Left hand panel displaying 'Albums', 'Sources' and an 'Activity' panel

A panel on the left hand side, with subsections labelled 'Albums' and Sources', provides access to collections of studies known as 'image albums' (Fig 4.4). These are filtered to allow for ease of access and recognition. External sources of images are also accessed through this panel.

An activity bar is also visible in this panel which displays a list of processing threads running in the background. These processes could include database maintenance or sending threads for example. It is possible to cancel a 'thread' if a cross button is displayed to the right.

Toolbar

Located at the top of the database window, the toolbar displays graphical icons of the key tools which can be selected (Fig 4.5). Hovering the cursor over the icon will display a short description of each feature.

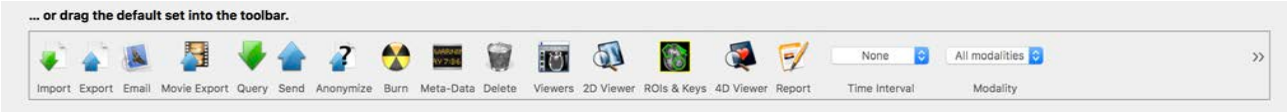


Figure 4.5 The default toolbar

A default set of toolbar icons will be displayed when Horos is first used. It is possible to restore the default toolbar at any time. To do this pull down the 'Format' menu tab and select 'customize toolbar' (Fig 4.6). A screen will appear which allows you to drag the default set of toolbar options onto your own toolbar.

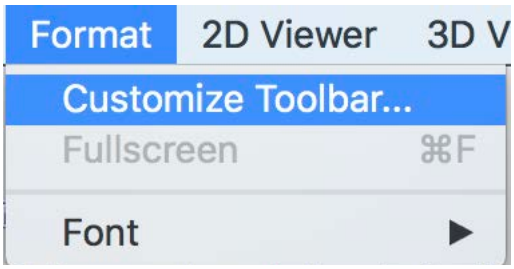


Figure 4.6 Format menu showing 'Customize Toolbar'

The toolbar is also customizable and the location of the icons can be designated by the user. To do this pull down the 'Format' menu tab and select 'customize toolbar'. A screen will appear which allows you to drag toolbar icons onto your toolbar at the top of the database window (Fig 4.7).

Figure 4.7 Screenshot of the icons available to customize the toolbar

In the proceeding sections you will find a complete description of the functionality of each tool, listed in alphabetical order.

2D viewer

The 2D viewer tool opens selected studies or series in the 2D viewer. This is described in more detail in Chapter 5.

When opening a study, the first series within the study will be displayed in the 2D viewer.

Consecutive cases can be selected by highlighting the first case, then holding down the 'Shift' button on your computer or laptop and highlighting the remaining cases by scrolling the cursor. Holding down the 'Command" button whilst moving the cursor, to select the required cases, can highlight non-consecutive cases.

To select only a subset of images, click on the 4D viewer icon whilst simultaneously holding down the option key. A dialogue box will open allowing you to select either:

A set of images taken at a given time point
A succession of the same image taken at different time points

4D viewer

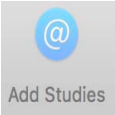
The 4D viewer tool is designed to display image series which contain multiple dimensions. For a series to be considered 4D it must contain multiple series with the same number of images, each with the same matrix size (dimensions). This could be, for example, an abdominal CT exam with 20 phases: 20 x 512x 512 images. Other examples would include, MR perfusion series or CT cardiac gated series.

When selecting this icon, Horos scans the selected series before opening a 2D viewer window with four dimensions.

To select only a subset of images, click on the 4D viewer icon whilst simultaneously holding down the option key. A dialogue box will open allowing you to select either:

A set of images taken at a given time point
A succession of the same image taken at different time points

Add Studies



This tool is only available if the web server is activated and must be authorized by the administrator. It allows you to share selected studies or series with a specific user, through the web server. Add Studies is equivalent to the 'Share' button, which is displayed at the end of the study html, which is available when browsing on the web server. More information on activating the webserver is available in Chapter 9)

Albums and Sources

This displays or hides the 'Album and Sources' panel, visible on the left hand side of the database window. This panel is described in further detail later in this chapter.

Anonymize

Where it is necessary to remove all demographic information (patient's name, ID, age etc.) from the DICOM headers of all images in a series, this can be performed using this tool.

A pop-up dialogue box allows you replace some fields with a specific value (Fig 4.8). Once you have selected the fields you wish to anonymize you can choose to either replace the original ones or export the anonymized files, onto a CD/DVD for example, without adding them to your database.

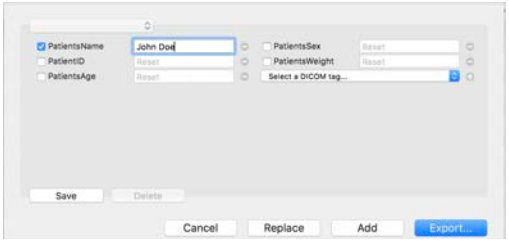


Figure 4.8 The Anonymize dialog box. Specific header fields can be replaced with default values to replace and anonymize patient demographic data

Burn

The Burn tool allows the user to save a hard copy of a selected study or series by writing them to a CD or DVD. This may be useful, for example, if the patient is being referred to another hospital.

When this tool is utilized it is possible to select from a number of options (Fig 4.9), for example:

-Anonymization
-Image compression
-Including Weasis as the software viewer

-Adding a HTML mini-website which includes a Quicktime versions of the images contained within study

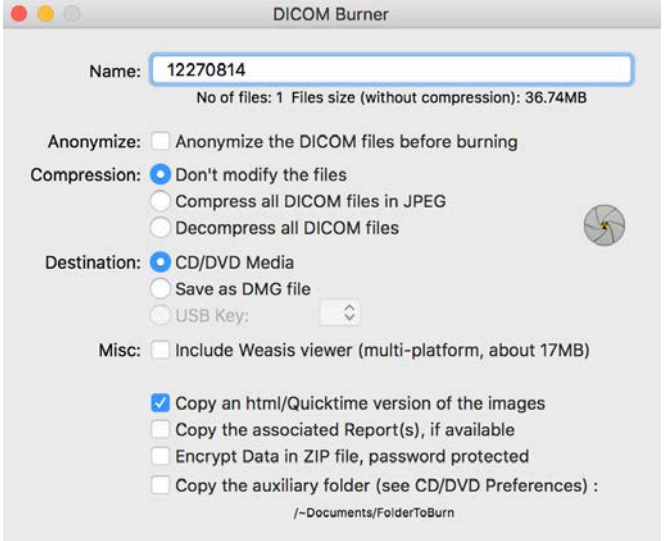
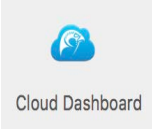


Fig 4.9 Dialogue box for the BURN icon, displaying the options for Anonymization, Image compression, Destination and other add-ons

Cloud Dashboard



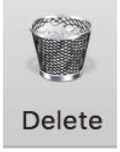
This provides access to Horos Cloud. Horos Cloud is a specialized plug-in that provides a set of additional functionality for Horos. This feature is available on a subscription basis

Cloud Reporting

This enables you to generate reports that are stored in the Horos Cloud. This is a plug-in that is available on a subscription basis.

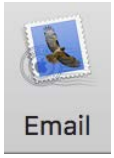
Delete

NOTE: Once a study or series has been deleted it will no longer be available for viewing and cannot be recovered



To delete, first select the desired image, study or series. Consecutive cases can be selected by highlighting the first case, then holding down the 'Shift' button on your computer or laptop and highlighting the remaining cases by scrolling the cursor. Holding down the 'Command" button whilst moving the cursor, to select the required cases, can highlight non-consecutive cases. Select the 'Delete' icon. Once deleted the study information and associated DICOM files are permanently removed from the database index.

Email



It is possible to send studies via email. It is essential for data protection purposes that any files sent electronically are encrypted. To this end once the 'Email' icon is selected, you will be prompted for security reasons to enter a password. You will need to provide the email recipient with the chosen password in a separate email. By selecting the 'Mail' icon, the mail application is launched (Fig 4.10). You can add text to the email and a zip file is added. You must remember to select 'SEND'.

Figure 4.10 Launch of mail application to email selected studies

Export

By selecting this icon, images can be exported in DICOM format to a nominated local directory or external storage device. It is possible to export either single or multiple studies or series. Where it is the later, hierarchical folders or a single directory can be used.

Consecutive cases can be selected by highlighting the first case, then holding down the 'Shift' button on your computer or laptop and highlighting the remaining cases by scrolling

the cursor. Holding down the ‘Command” button whilst moving the cursor, to select the required cases, can highlight non-consecutive cases.

Note, files which have previously been compressed into JPEG will still be exported as a DICOM file.

Import

Images can be manually imported from DICOM files, by selecting this icon. These may be files within a local directory, an external storage device or a remote web based or networked source.

To import images first click on the ‘Import’ icon. When the pop-up window appears, select the location of the images you wish to import from the menu on the left of the window. Use the cursor to select the desired study/studies or series.

Consecutive cases can be selected by highlighting the first case, then holding down the ‘Shift’ button on your computer or laptop and highlighting the remaining cases by scrolling the cursor. Holding down the ‘Command” button whilst moving the cursor, to select the required cases, can highlight non-consecutive cases.

Meta-Data

Meta-Data describes the associated data which is stored with the DICOM image, study or series. This includes image acquisition time, physician name and study center, for example, as well as other data around image quality. A screen shot example is displayed below (Fig 4.11). Further information on Meta-Data is described later in the chapter.

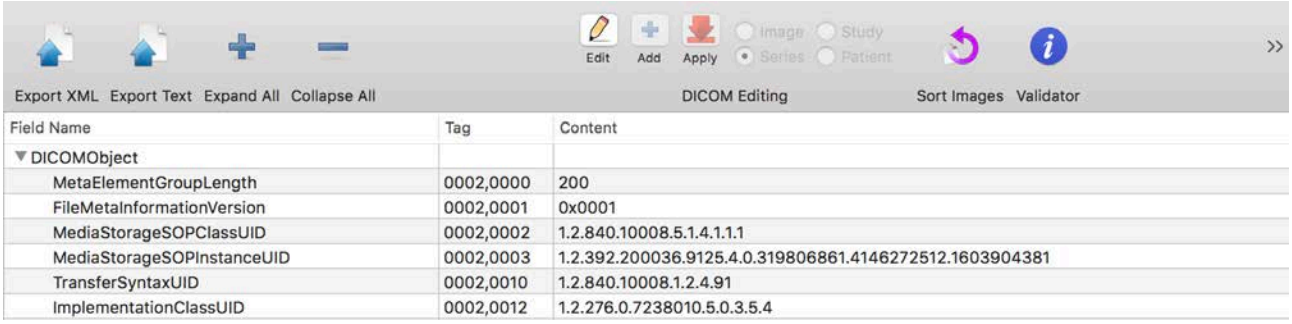


Figure 4.11 Snapshot example of Meta-Data associated with a DICOM file

Migration Assistant

Select this tool to migrate images currently stored within Osirix™ to a Horos database.

Movie Export

Select this tool if you wish to export a study or series in movie format. To do this first select the file(s) or case(s) you wish to export.

Consecutive cases can be selected by highlighting the first case, then holding down the 'Shift' button on your computer or laptop and highlighting the remaining cases by scrolling the cursor. Holding down the 'Command" button whilst moving the cursor, to select the required cases, can highlight non-consecutive cases.

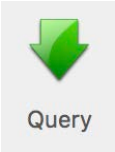
Select the 'Movie Export" icon and when the pop up window appears select the desired location either on a local or external drive. Horos will save a copy of the movie in a folder in the chosen location. It is possible to attach an optional HTML description of the files.

Notification

This feature requires the web server to be activated as well as correct configuration of the mail settings, see Chapter 1. To send a notification to a user on the web server, select the desired series or studies then click on the 'Notification' icon. The notified user then receives an email notification containing a direct link to the selected studies.

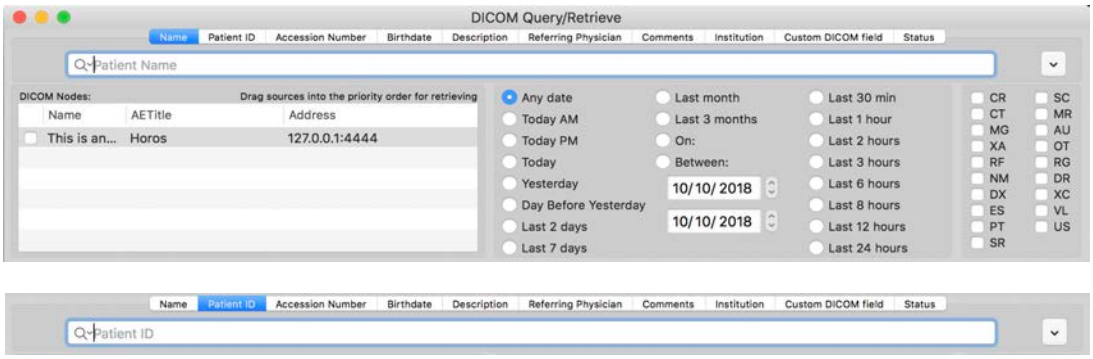
Consecutive cases can be selected by highlighting the first case, then holding down the 'Shift' button on your computer or laptop and highlighting the remaining cases by scrolling the cursor. Holding down the 'Command" button whilst moving the cursor, to select the required cases, can highlight non-consecutive cases.

Query



The query tool allows you to search for, and retrieve, images from any source which is DICOM compliant (4.12a). The default search criterion is patient name. When all or part off the name is entered, Horos searches all compliant sources for matching DICOM files. These may be local, external or on a networked server. It is possible to set limiting criteria to narrow the search results, such as acquisition time or study type.

By using your cursor to select an alternative field option, from those listed along the top of the search window, you can change the search field, for example to patient ID or Referring Physician (4.12b). Matching files will be displayed in a list at the bottom of the search window. Further information on DICOM compliance can be found later in this Chapter.

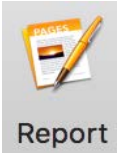


(a)

(b)

Figure 4.12 (a) DICOM 'Query' window with (b) enlarged image of the search fields

Report



If a report has been entered for a selected study it can viewed by selecting the 'Report' icon. If a report has yet to be entered, a report template will automatically open and text can be input and then saved (Fig 4.13). Multiple templates are available and can be the 'Report' icon.

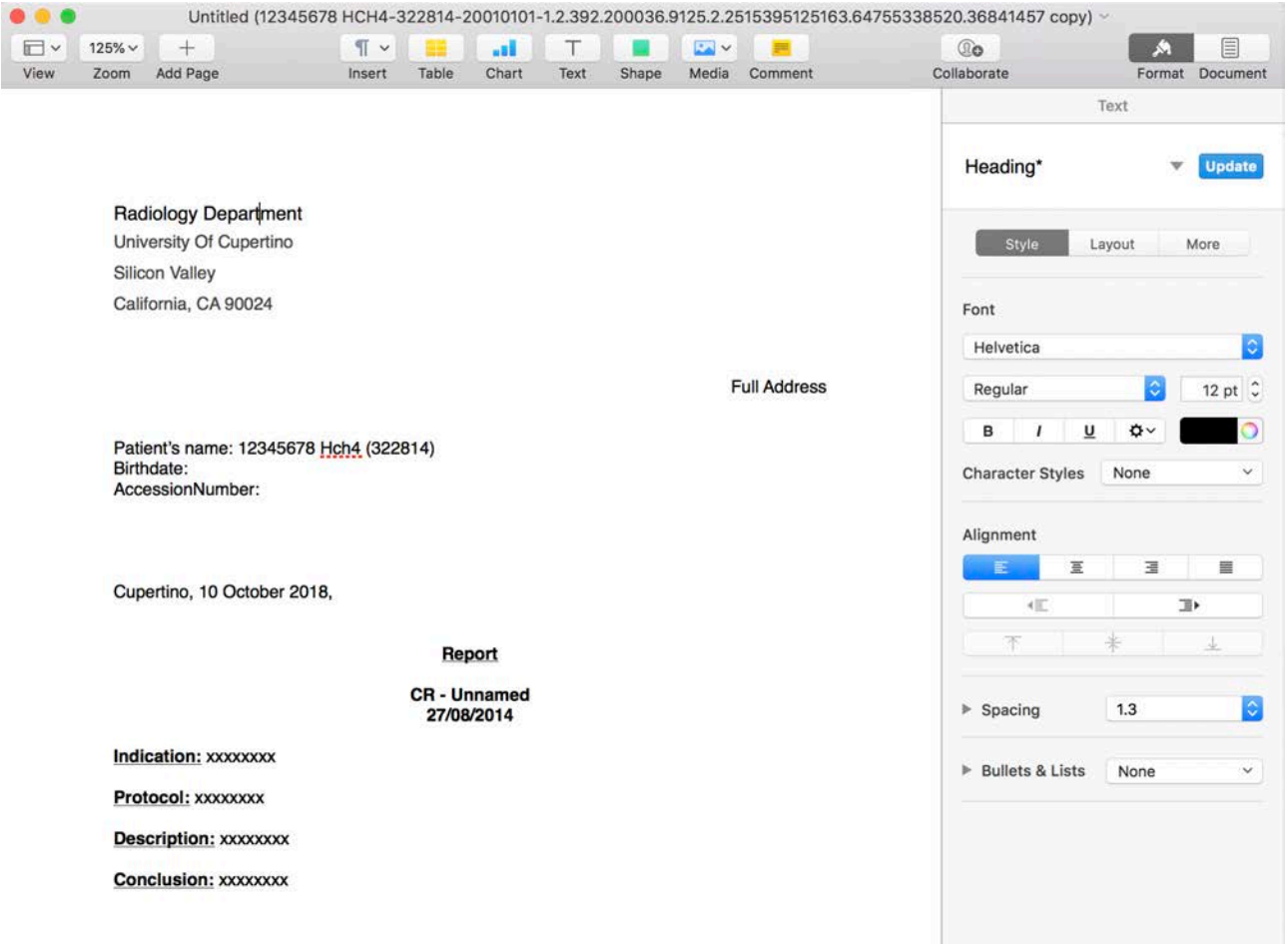


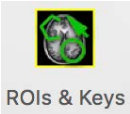
Figure 4.13 Example report template

Reports can also be generated within Horos Cloud, an optional specialized plugin. One of the functions of Horos Cloud is as a **repository for generating and storing radiological reports.** Reports can be created in a browser environment and then emailed to recipients or securely stored and archived. Further information on cloud reporting can be found in Chapter 2.

Restore views

This tool allows the user to restore views to their original state.

ROIs and Keys



Within a selected study, images containing regions of interest (ROIs), or those labelled as 'key' images, can be selected independently of other images within the Horos database.

To open only those images containing either ROI's or labelled as 'key images' select the ROIs and Keys icon.

To select only images with ROIs, select the ROI & Keys icon whilst simultaneously holding down the 'shift' key on your keyboard.

Alternatively, should you wish to select only 'key' images, select the ROIs and Keys icon whilst simultaneously holding down the 'option' key on your keyboard. If this is the first time you have performed this function a pop-up window will appear (Fig 4.14)

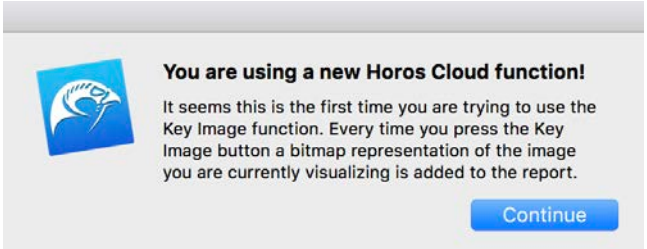


Figure 4.14 Pop-up window attached to the ROIs and Keys icon

To label images as 'key' images. double click on the image to bring up the viewer. At the top left of the toolbar, click on the 'Keys' tool. The image will also automatically be added to a report for the study in Cloud reporting. If this is the first time you have used this feature a pop up box will appear as above.

ROIS and key images are described in more detail in Chapter 6.

Search

To quickly access specific studies or series, use this tool which is located on the far right of the toolbar at the top of the database window (Fig 4.15).

To do this enter part or all of a field entry, for example patient name. The database will then be searched for all entries containing those characters, which are made in strict comparison of the character string. Horos will search the entire database, including distant DICOM nodes, if the PACS on Demand feature is activated, see Chapter 9

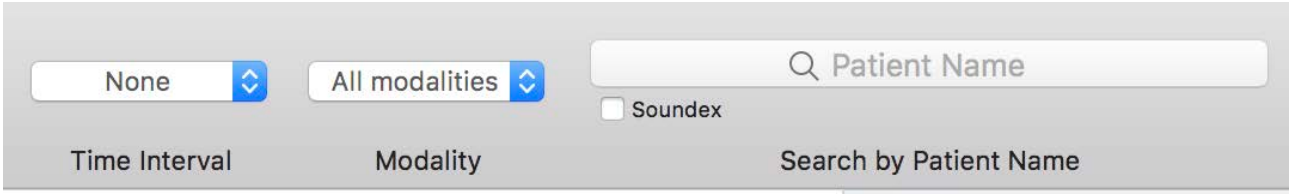


Figure 4.15 The search toolbar, located at the top right of the database window

It is possible to narrow the search to a specific field by using the drop down menu. This is accessed by clicking on the downward facing arrow between the magnifying glass and field box (Fig 4.16)

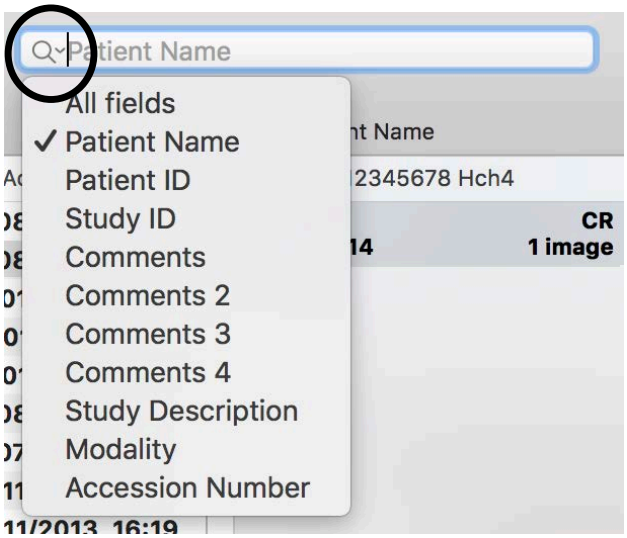


Figure 4.16 Drop down menu in the 'Search' box

If the correct spelling of a name is unknown the Soundex algorithm can be utilized to identify the best available match (Fig 4.17). When using this algorithm, the sonority of the character string is used as opposed to the strict comparison of the characters.

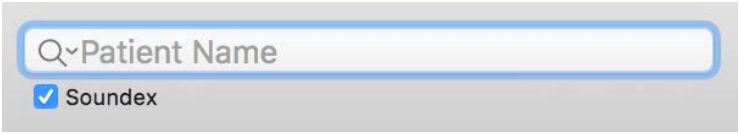


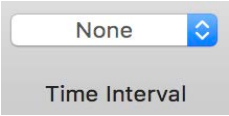
Figure 4.17 Location of the 'Soundtex' algorithm function

Send

To send a selected study to a specific location, select this tool by clicking on the 'Send' icon. The study is then sent to a DICOM node using the DICOM Send protocol (C-STORE SCU). Further information on sending studies or series can be found in Chapter 9.

Consecutive cases can be selected by highlighting the first case, then holding down the 'Shift' button on your computer or laptop and highlighting the remaining cases by scrolling the cursor. Holding down the 'Command" button whilst moving the cursor, to select the required cases, can highlight non-consecutive cases.

Time Interval



It is possible to filter the database study list, visible in the top left quadrant of the database window, to show only those files acquired within a set time protocol. To do this, click on the drop down menu labelled 'Time interval' visible on the right hand side of the tool bar. The time interval can be adjusted using pre-defined intervals from a drop down list (Fig 4.18).

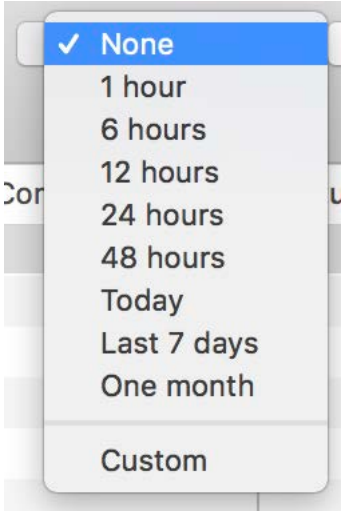
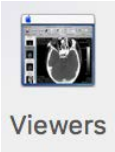


Fig 4.18 Time interval filter for the Study List

Viewers



Clicking on this icon will bring opened viewers windows to the foreground. This feature is only activated if a viewer is opened. More information on this can be found in Chapter 5

Study list

The database window displays the Study list in the upper left quadrant (Fig 4.19). DICOM images belonging to the same patient within the study list, are automatically sorted and grouped by patient, study and series.

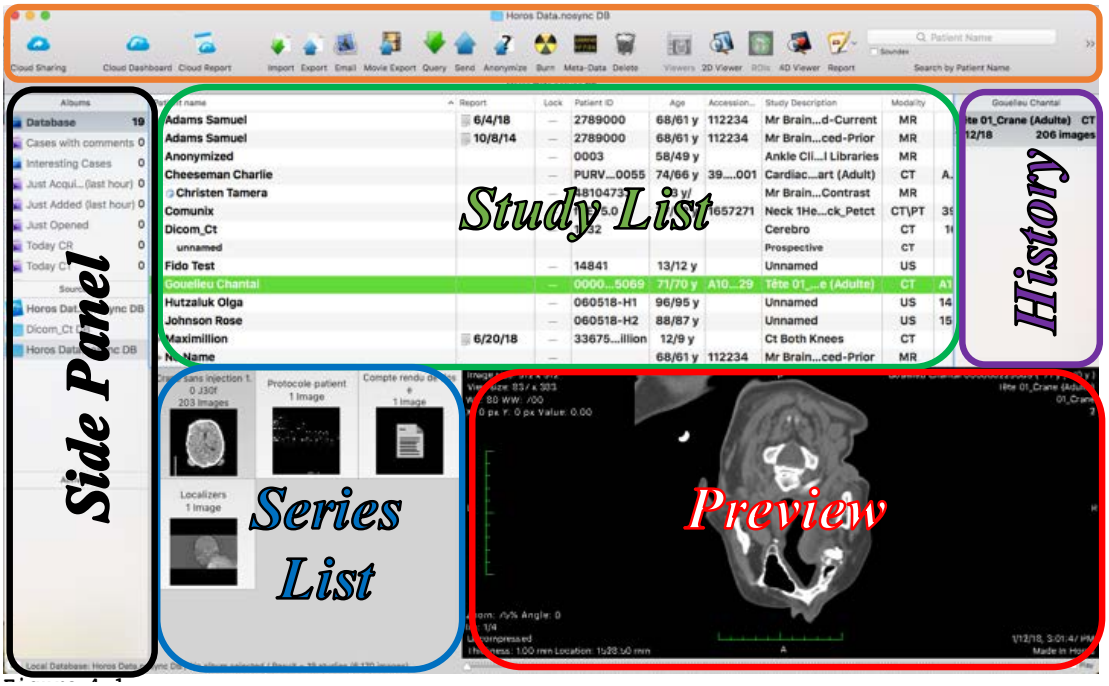


Figure 4.19

The column information for each study working from left to right of the default display is as follows:

Patient name	
Report	A small icon is displayed if a report is attached
Lock	Identified by a padlock icon, this prevents against deletion
Patient ID	
Age	This is computed automatically by Horos when a D.O.B is entered
Accession number	Unique identifier
Study Description	For example 'Chest'
Modality	The imaging modalities utilized in the studies
ID	Patient ID number
Comments	Up to 4 rows of comments can be input

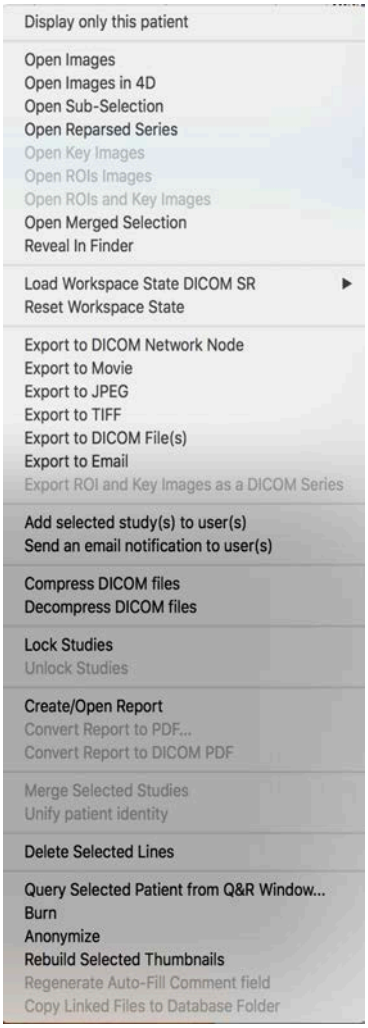
Status	Can be set to: empty, unread, reviewed or dictated
Date Acquired	Acquisition date of the study

To sort the studies and images in the 'Study List', simply click on the corresponding header. It is also possible to adjust the order in which the columns are displayed by dragging the column header to an alternative position. Additional column headings are available by right clicking the mouse over one of the column headers.

The additional fields available are; #im, number of images in the study, #series, number of images in the series, date added, the date the study was added to Horos, date opened, when the study was last opened in Horos, Date of Birth, Institution, Performing Physician and Referring Physician.

Opening a study or series

Move your mouse to hover over the corresponding line of the required study or series within the study list, then double click your mouse.



Deleting an image, series or study

Select the desired image, series or study from the study list and then press either the delete button on your keyboard or the 'Delete' icon from the toolbar.

Copying or exporting

To copy or export selected studies to a remote database for example, or to the desktop as files, drag and drop the desired lines. To do this, first select the desired images, studies or series using your mouse. Then drag the selected cases to the desired location.

Consecutive cases can be selected by highlighting the first case, then holding down the 'Shift' button on your computer or laptop and highlighting the remaining cases by scrolling the cursor. Holding down the 'Command" button whilst moving the cursor, to select the required cases, can highlight non-consecutive cases.

A contextual menu, accessed by right-clicking your mouse in the area of the study list, is available for functions such as merging studies or burning to CD/DVD (Fig 4.20)

Figure 4.20 Contextual menu for the 'Study list' accessed by right clicking the mouse over the study list

History

Displayed within the 'History' view are all available comparative studies of the series. It is possible to select studies from the History view or the study list.

Series List

The series list is located in the bottom left quadrant of the database window. Here, small image thumbnails represent each of the series of images within the study on display. To select a series to view, move the cursor over the thumbnail of the desired series and click or double click the mouse/mouse pad. The series will then be visible in the Series Preview area, in the bottom right quadrant of the Horos database window.

A contextual menu containing a set of functions, for example merging cases or deleting a series, are available by performing a right mouse click on the thumbnail of an image or series within the series list (Fig 4.21).

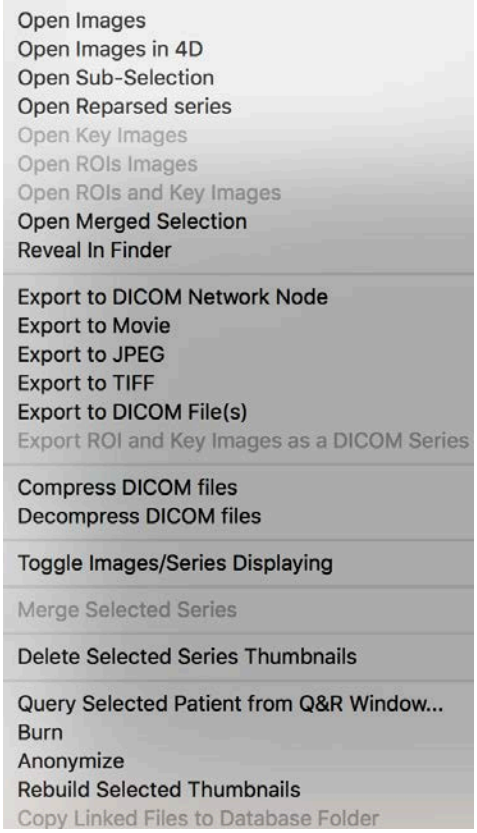


Figure 4.21 The contextual menu available for the Series list

Moving a series

To copy a series, drag and drop one or multiple image thumbnails (insert detail) to an alternate local or remote location. To do this, first select the desired images, studies or series using your mouse. Then drag the selected cases to the desired location.

Consecutive cases can be selected by highlighting the first case, then holding down the 'Shift' button on your computer or laptop and highlighting the remaining cases by scrolling the cursor. Holding down the 'Command" button whilst moving the cursor, to select the required cases, can highlight non-consecutive cases.

Exporting a series

To export a series in DICOM format to a nominated local directory or external storage or networked device, select the desired thumbnail(s) and click on the 'Export' icon. Images can also be exported to the desktop, where they will appear in a folder. It is possible to export either single or multiple studies or series. Where it is the later, hierarchical folders or a single directory can be used.

Consecutive cases can be selected by highlighting the first case, then holding down the 'Shift' button on your computer or laptop and highlighting the remaining cases by scrolling the cursor. Holding down the 'Command" button whilst moving the cursor, to select the required cases, can highlight non-consecutive cases.

Note, files which have previously been compressed into JPEG will still be exported as a DICOM file.

Series Preview

A quick overview of this feature is described here. Series preview allows a quick preview of the selected Series. These are viewed in the 'Series' Preview' section of the main database window, visible in the lower right quadrant of the window.

Basic image manipulations, for example zoom, pan, rotate and WL/WW (Window Length/Window Width) are available using this function.

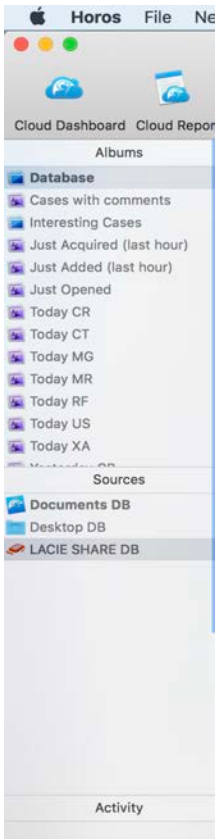
To preview a series, move the cursor over the thumbnail of the desired series and click or double click the mouse/mouse pad. The series will then be visible in the Series Preview area, at the bottom right of the Horos window.

To browse through the stack of images in the previewed series, a scroller is available in the preview panel. This provides the option to directly select a given image.

Auto-play will loop through the image stack continuously. To select this, click on the 'Auto-Play' button.

Chapter 5 provides more detail on image manipulation.

The Side Panel



A panel on the left hand side, with subsections labelled 'Albums' and 'Sources', provides access to collections of studies known as 'image albums' (Fig 4.22). These are filtered to allow for ease of access and recognition. External sources of images are also accessed through this panel.

An activity bar is also visible in this panel which displays a list of processing threads running in the background. These processes could include database maintenance or sending threads for example. It is possible to cancel a 'thread' if a cross button is displayed to the right.

Figure 4.22 The side panel

The Albums

Studies and images can be organized into different albums within a database. This section provides an overview of albums and smart albums. Albums and Smart Albums can also be created using the 'File' menu (see Chapter 3). To start, select the desired database.

Selecting an album

Once you have identified the desired album within the left hand side panel, double-click and the album will appear in the database window.

Creating a new album

Right-click within the 'Albums' area of the side panel and select 'Add Album' from the contextual drop down menu (Fig 4.23).

You will be prompted to enter an album name, by a 'drop down' menu, which will appear in the center of the database window. Once created, the album appears in the 'Album' list within the left hand side panel.

Adding studies or images to an album

To add a study or an image to an alternative album, drag and drop the study from the study list into the album icon of the desired album.

Removing a study from an album

Select the desired study from the given album and either select the delete button on your keyboard or click on the 'Delete' icon.

A dialogue box will appear allowing you to verify whether you wish to delete the study completely. Alternatively, you can delete the study only from the album, in which case it will remain in the database list.

Deleting an Album

NOTE: Once a study or series has been deleted it will no longer be available for viewing and cannot be recovered

To delete an entire album, select it by placing the cursor over the album name and clicking on the album. Right-click the album and select delete from the contextual menu which appears (Fig 4.24). You will be asked to confirm this procedure in the dialogue box which appears.

This function can also be achieved from the 'File' from down menu, and selecting 'Delete Selected Album'.

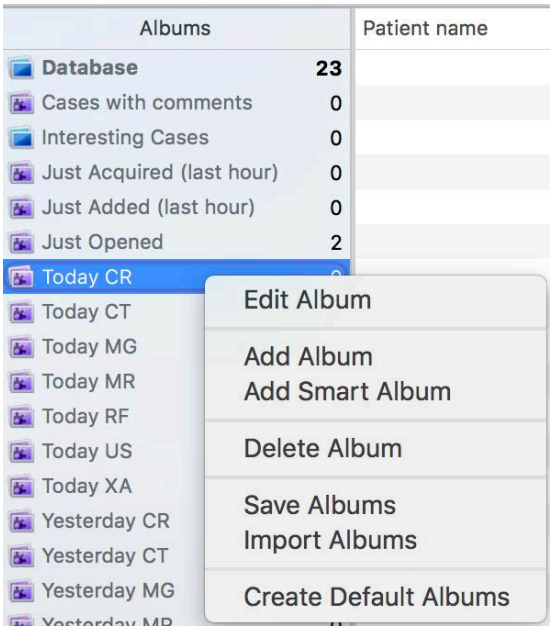


Figure 4.24 Contextual menu used to create and delete albums

Smart Albums

Horos supports smart albums, in a similar way to iTunes®, which allows rules to be set up to automatically store images in selected albums.

To do this, select 'Add Smart Album' from the contractual menu by right-clicking within 'Albums'. These are located within the panel on the left hand side of the database window (Fig 4.25).

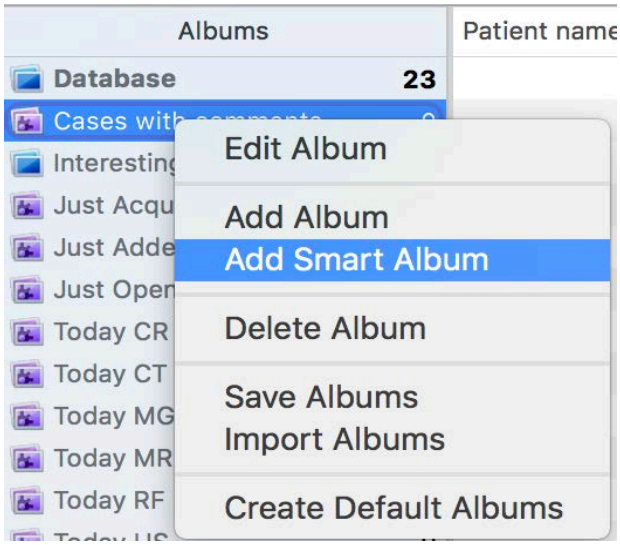


Fig 4.25 Contextual menu for creating a Smart Album

When a dialogue box appears (Fig 4.26), enter the desired album name. A list of criteria can be selected from such as imaging modality, time interval or a key word of your choice, to create rules to enable automatic study selection.

It is possible to select more than one criterion, by selecting the '+' button (Fig 4.26).

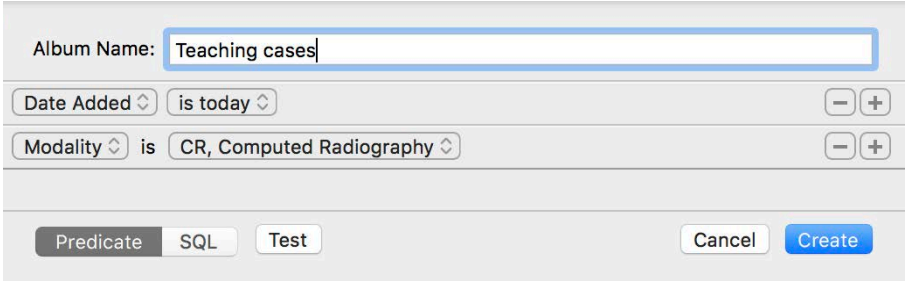


Figure 4.26 Dialogue box for naming and setting criteria for a 'Smart Album'

Once created, Horos will automatically search and import case studies or series matching the selected criterion into the appropriate Smart Album.

Any new studies imported into the database will automatically be sorted and imported into the appropriate smart album.

It is therefore possible to create dynamic albums with rules for example on time constraints. For example, an album containing Ultrasound studies of the current week. Studies will automatically disappear from the smart album if more than one week old, whilst new studies will automatically be added.

It is possible to edit Smart Album rules at any time. To do this, first double-click on the required smart album. A pop-up window will appear containing the SQL query, this is essentially the set of rules associated with that Smart Album which you selected when the smart album was created. It is possible to edit these rules, also known as a query, according to the fields available (Fig 4.27). It is important to know that these sets of rules apply only at the study level. This is unlike rules set through a SQL filter auto-routing rules, see Chapter 9

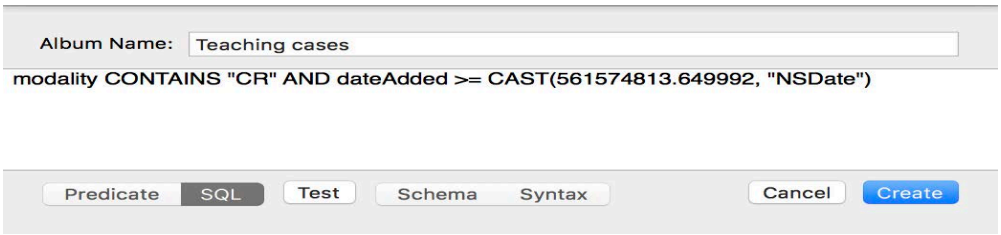


Fig 4.26 SQL Query for a SMART Album

Sources

Within the left hand side panel, a list of remotely accessible external sources is displayed. Four categories are visible:

Local Default Database
Desktop DB (Database)
MINIPACS
Remote user DB (Database

By dragging and dropping image files and studies from the database list to the desired source, it is possible to send or copy images to any of these destinations.

Local Default Database

Upon setup Horos will, by default, create a folder called Horos data to store and organize images. This is located in the Documents folder of your home directory. It is possible to change the location of this folder using the 'System Preferences' described in Chapter 2.

Database Folders

The list of folders in this subsection correspond to any database folders located either on the computer's hard drive or within an external device, including an iPod.
This list can be amended, by removing or adding items. Details on how to do this can be found in Chapter 2.

Shared Horos Database

These are identified by a 'Bonjour' icon. A shared Horos database is one which corresponds to a database located on a shared workstation which has been set up to allow access to other users. Once these databases have been discovered, through the Bonjour protocol (see Chapter 2), Horos will automatically display them in this section of the Sources panel.

If a shared database is available to view, double click on the named database to open the list of images in the database window. These images can be displayed and manipulated in the same way as a local database. Studies and series can be added or deleted from the shared database. This is done by editing the list within *Location Preferences.* More details on this can be found in Chapter 2.

Your own local database can also be shared with other users by activating the database sharing function. More detail can be found in Chapter 2.

DICOM nodes

These are identified by a 'network sphere' icon.

Databases located at a distant DICOM node can be added to, or items removed. This can be done by editing the list using the *Locations Preferences.* See Chapter 2 for more details. It is not possible however, to browse images stored at these remote locations.

It is also possible to share images, series or studies with databases at distant Dicom nodes. To do this, first select the desired images, studies or series using your mouse. Then drag the selected cases to the desired location.

Consecutive cases can be selected by highlighting the first case, then holding down the 'Shift' button on your computer or laptop and highlighting the remaining cases by scrolling the cursor. Holding down the 'Command" button whilst moving the cursor, to select the required cases, can highlight non-consecutive cases.

Activity bar

An activity bar is also visible in this panel which displays a list of processing threads running in the background. These processes could include database maintenance or sending threads for example. It is possible to cancel a 'thread' if a cross button is displayed to the right.

Horos is able to perform multiple simultaneous operations and is described as a multi-threaded software. Some of these operations, such as sending images, compressing images and database auto-cleaning, can be performed in the background. These background operations are displayed in the activity panel. It may be possible to cancel an operation. If this is the case a small 'x' will be visible adjacent to the operation, and can be clicked to cancel.

File Management

Images are stored as files within a specific database folder either on a local directory or a remote device. The default folder name is Horos data, and is located in the home directory within the 'Documents' folder. It is possible to change the location of this folder by selecting *Preferences* from the Horos menu.

DICOM Files

The default file type supported by Horos are DICOM files, with the extension dcm. A DICOM file contains not only the image, but also fields describing the image and other related information. The descriptors include for example resolution, matrix size and orientation and the related information includes for example the physicians name. Currently, thousands of fields are described by the current DICOM format [10].

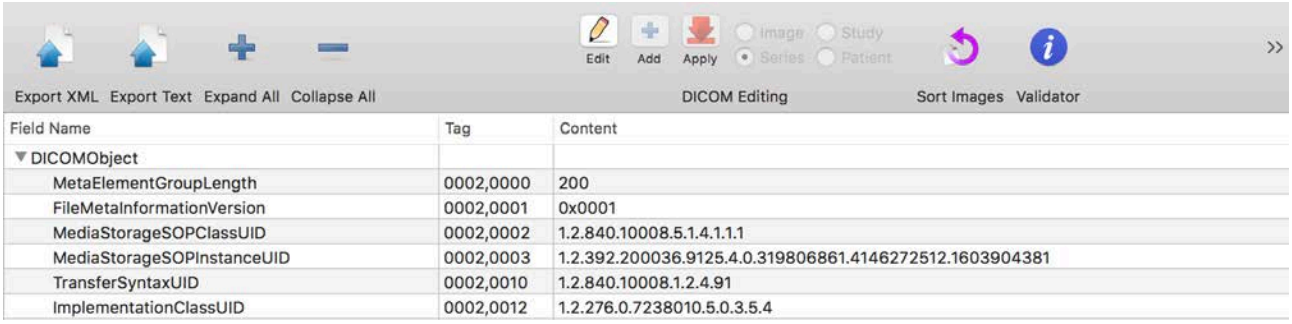
A single DICOM file classically stores one image, however in a multi-frame protocol multiple images are stored in a single file. Multi-frame protocols would typically be used for ultrasounds or angiograms for example.

DICOM files may contain a simple matrix of pixels, or could be another encapsulated format such as JPEG or JPEG2000. Files, such as reports (Structured Reporting objects) are also covered by the DICOM protocol and would be stored in a DICOM file. Horos can load and import any of the described DICOM files whether single images, multi-frame protocols or reports.

It is possible for Horos to support other types of image formats, including JPEG and TIFF. For further information on this see Chapter 2.

Meta-Data Window

Meta-Data describes the associated data which is stored with the DICOM image, study or series. This includes image acquisition time, physician name and study center, for example, as well as other data around image quality. A screen shot example is displayed below Fig 4.28.



Field Name	Tag	Content
▼DICOMObject		
MetaElementGroupLength	0002,0000	200
FileMetaInformationVersion	0002,0001	0x0001
MediaStorageSOPClassUID	0002,0002	1.2.840.10008.5.1.4.1.1.1
MediaStorageSOPInstanceUID	0002,0003	1.2.392.200036.9125.4.0.319806861.4146272512.1603904381
TransferSyntaxUID	0002,0010	1.2.840.10008.1.2.4.91
ImplementationClassUID	0002,0012	1.2.276.0.7238010.5.0.3.5.4

Figure 4.28 Snapshot example of Meta-Data associated with a DICOM file

It is possible to modify the content of the displayed fields. This can be achieved by altering the parameter settings within General Preferences, see Chapter 2

To search the Meta-Data window, use the search field which can be found within the toolbar of the pop up window.

Modifications to the fields within the Meta-Data can be done at an image level, ensuring only the current image is modified, at a Series, Study or Patient level.

To make a modification, double click on the desired field value, input the new value and then press return to validate the change.

To enable the DICOM header edition, click on the ‘edit’ button. To disable the DICOM header edition, click on the ‘disable’ button, see Chapter 2.

Sorting Images

This additional feature is available if the Meta-Data tool is loaded whilst viewing images using the 2D viewer tool. By selecting this tool from the Meta-Data toolbar it is possible to change the order of images within a case series (4.29).

The default order of image display is determined by the *Instance Number* field within the Meta-Data. If you choose to alter the *Instance Number* to change the order in which images are displayed, the images will only be temporarily re-ordered. Neither the DICOM files themselves, nor the structure of the Horos database is affected by this change. Consequently, the next time you open the series, you can choose to restore the default order in which the images are displayed.

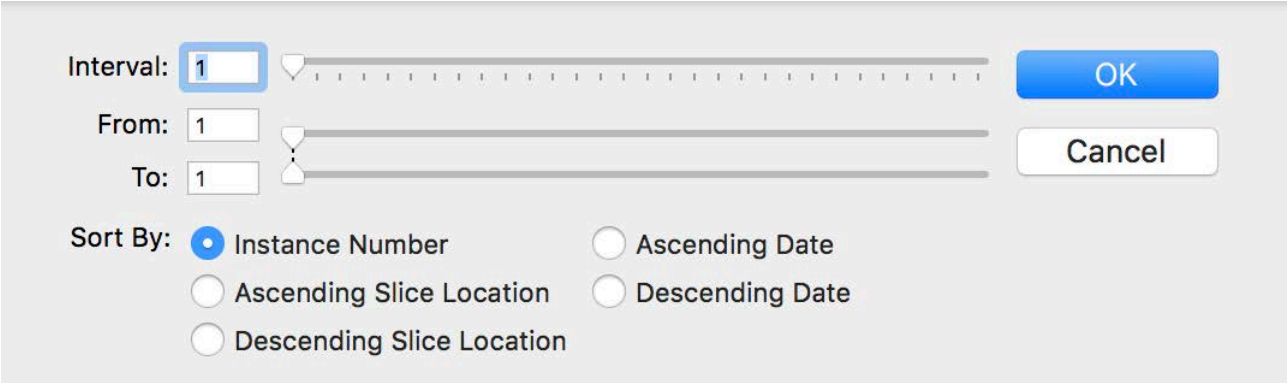


Figure 4.29 Dialogue window for sorting images

DICOM Validator Tool

In order to verify whether an image is DICOM standard [10] and consequently correctly formed, a validator tool is available within the Meta-Data window. Once the validator tool is selected, a text output window, displaying the validation, is displayed. The validator tool within Horos is based upon the DICOM validator, *dciodvfy* [3].

Importing images

DICOM files can be imported into Horos. In order to reduce compatibility issues, three DICOM reader toolkits are incorporated into the Horos software to import and read DICOM files. This is because DICOM files themselves are based upon a complex protocol.

The available toolkits for important and reading DICOM files within Horos are:

DCM Framework
DCMTK from Offis
Papyrus

These toolkits can be modified within the 'settings' feature in General preferences. See Chapter 2 for more information.

DICOM files can be imported into Horos in one of several ways:

Using the File Menu. Select 'import' from the drop down menu.

Using the 'Finder' function on the study list. Files can be dragged and dropped to or from this location.

CD/DVD. Insert a CD or DVD containing DICOM images into your computer to browse its content. Files can be copied into your database by selecting the 'copy' option from the pop-up window.

DICOM Communications. It is possible to receive DICOM images through network sharing protocols. More information can be found on this in Chapter 9.

Database Sharing. Images can be downloaded from a distant Horos workstation, see Chapter 9

ZIP Files. If a ZIP file is received either via email or through an external storage device, Horos will automatically decompress and import the content.

INCOMING Folder. Horos regular checks the content of the INCOMING Folder, and will automatically index and archive files found, including sub-directories. The interval for content checking can be specified. See Chapter 2 for more details.

Chapter 5

Displaying Images

Occasionally, users will want to change the layout of the 2D views on the screen. For example, you may prefer to display brain CT series differently than those for abdominal or 4D series. Fortunately, Horos allows you to set the 2D views in ways that correspond with your study modality. You can define a set of multiple layouts for one Study Description (database field studyName, DICOM field StudyDescription (0008, 1030), and a different one for another Study Description. Once you have set the layout for a given modality, when you open it again Horos will display it according to the layout you specified.

To create a specific layout for a modality (brain CT studies, for example), open the Horos Preferences and click on Protocols icon (Figure 5.1). This opens a window like that shown in Figure 5.2. You can specify the modality using the drop-down list at the top and set the layout using the Window Tiling and Image Tiling options. If you want to apply a layout to all studies of a given modality, use Default as the study description. Otherwise, you must set the StudyDescription for the study to the exact string you plan to use in the Protocols Preferences. The layout refers to the number of rows and columns for the Viewers (Series Rows, Series Columns) and for image tiling (Image Rows, Image Columns)

Figure 5.1. The Protocols icon from the Horos Preferences panel.

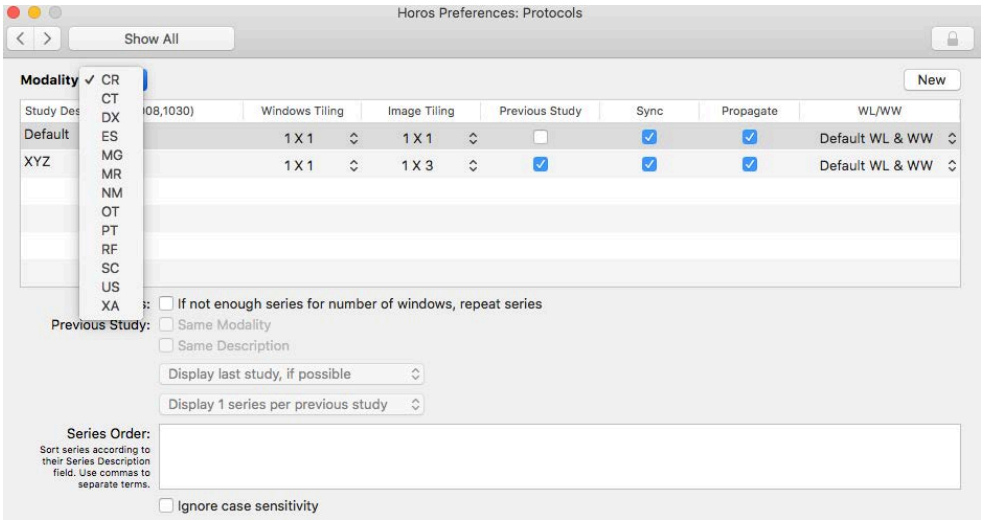


Figure 5.2. The Protocols preferences window options showing the modality drop-down list.

For example, suppose you wanted to add a new protocol for an abdominal CT study with six series. You might set the layout to Window Tiling 2x3 and Image tiling to 1x2. Doing so would result in a layout similar to that shown in Figure 5.3.

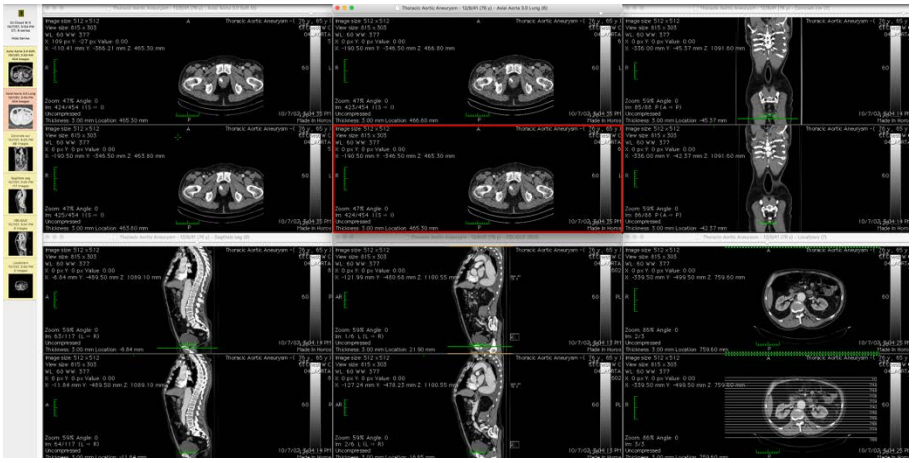


Figure 5.3. Multiple views layout for a study with six series.

Viewers

The Viewers preferences (Figure 5.4) allows you to customize a wide range of behaviors for the 2D Viewers (Figure 5.5). These settings modify the display parameters of the 2D views, including mouse behavior, ROIs display, etc. You can also modify the behavior of multiple 2D Viewers using settings for magnetic windows, widow tiling, etc.

Figure 5.4. The Viewers icon in the Horos Preferences panel.

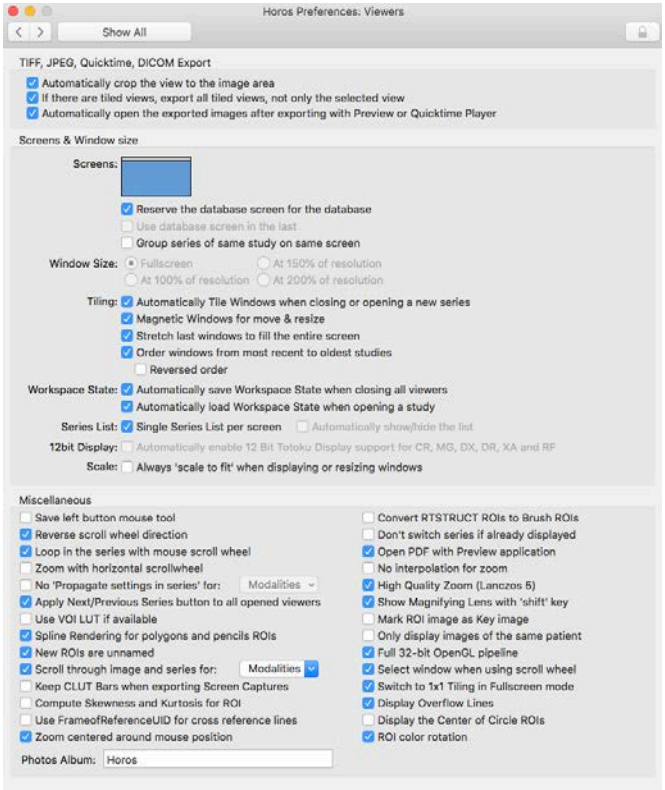


Figure 5.5.

The Viewers Preferences options from the Horos Preferences panel.

At the top are settings for exporting **TIFF, JPEG, QuickTime,** and **DICOM** images from any Viewer. You can automatically crop images to remove black regions surrounding images. You can choose to export an image that consists of all tiled views (if multiple tiled views are open). Finally, you can automatically open and preview images exported as TIFF, JPEG, or QuickTime sequences.

The middle section allows you to set parameters for **Screens and Window size**. For example, if you have multiple computer screens, you can open 2D Viewers on all available screens or a subset of available screens. The Screens parameters are activated by clicking on the screens icon to bring up a list of available screens.

The top checkbox is an option to always reserve a screen for the database window. When checked, no 2D Viewers windows are displayed on the database screen. Unchecking the top checkbox allows you to use the database window in the last screen (if all others screens are

already used). Finally, you have the option to keep Series from the same Study on the same screen.

The Window Size options allows you to open series at 100%, 150% or 200% of their resolution in a window of the same size, or in a window that fills the whole screen (Fullscreen). By default, these options may be grayed out because the Automatic Tiling option is turned on (see below). To change Window sizes, simply uncheck the Automatic Tiling options. With Automatic Tiling option on, windows are automatically resized and rearranged so that all windows fill the available screen space. Turning on the Magnetic Windows option causes windows to automatically stick to the screen edges and to each other. Tiling and Magnetic Windows features are also described in Chapter 6.

The Workspace State allows you to automatically save the state of the workspace displayed on the screen. Parameters that will be saved include WL/WW, pan, zoom, rotation and other settings. You can also choose to automatically load the workspace state if one have been saved. The 12bit Display will only be available if a 12bit Totoku display is available. When turned on, the scale to fit option will ensure that the whole image is always visible when resizing the window.

The remaining options are found under the Miscellaneous parameters options at the bottom. These options are described in Chapter 2.

Chapter 6

2-D Viewer

In this chapter we describe how 2D images are displayed and manipulated in Horos. Typically, the 2D Viewer window is the first place to start. Open a study and click on the 2D Viewer button on the top Horos menu bar. This dispalys the DICOM stack in the 2D Viewer window (Figure 6.1). There are three parts to the Viewer window; the Toolbar across the top, the Series List on the left side, and the Image View displaying one slice from the DICOM stack.

Figure 6.1. The 2D Viewer window

Across the top is the 2D Viewer Toolbar containing buttons for the most commonly used functions in the 2D Viewer. The Toobar can be customized by clicking on Formal > Customized Toolbar from the main Horos menu bar (Figure 6.2)

Figure 6.2. The options for customizing the 2D Viewer toolbar.

The Series List along the left margin displays the open series or studies. The largest window is the Image View which displays a single slice from the DICOM stack. You can move through the stack by moving the small triangular marker at the top of the image view to the right or left.

The Toolbar

The 2D Viewer Toolbar provides a subset of the tools and functions for working with patient DICOM images. Recall that you can add additional tools or remove unwanted tools from the toolbar using the Format > Customize Toolbar command. The default toolbar (Figure 6.3) is described below in order from left to right.

Figure 6.3. The 2D Viewer Window Toolbar

Cloud Report

This button allows registered users to access the Horos Cloud and create detailed reports and manage signatures using simple templates.

Database

Clicking on the Database button closes the 2D Viewer windows and takes you back to the main database window.

Windows

The Windows button displays a dropdown list of options for tilling multiple windows on the screen. You can choose how many windows to display and their orientation on the screen (Figure 6.4).

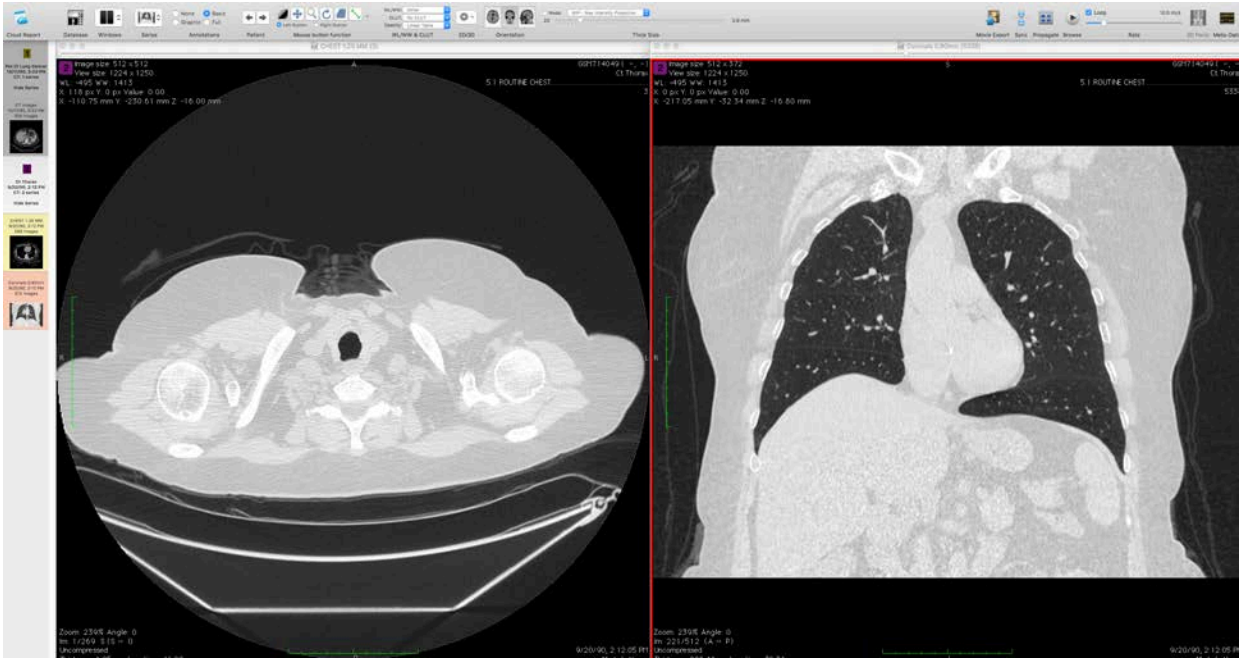


Figure 6.4. The 2D Viewer window with the Windows button set to 2 vertical images

Series

Clicking the Series button brings up a list of series. Clicking on a new series bring up that series in the Image Window. You can also access these options from the main Horos menu by clicking 2D Viewer.

Annotations

The Annotations button gives you four choices for how annotations are displayed on the Image Window. Clicking the None option removes all text annotations. The Basic option is the default and displays information about the image size, slice thickness, and other attributes about that series, except the patient name. The Graphics option removes text from the image and the Full options displays all annotations including the patient's name (if available).

Patient

You can display the next or previous patient by clicking on the forward or back arrows.

Mouse button function

There are twenty-one function buttons (only a subset maybe visible) that can be assigned to you mouse's right or left button (Figure 6.5)

Figure 6.5. The visible list of mouse buttons for image manipulation.

These five buttons manipulate the image, while the remaining buttons (Length through Selector) are used with regions of interest (ROIs). From left to right are:

- *Window Level & Width Tool* – Click on this tool and then click and dragging anywhere on the image and the Window Level changes (level refers to contrast/brightness).
- *Pan* – You can reposition the image within the Image Window by clicking and dragging on the Pan button
- *Zoom* – The Zoom tool (magnifying glass) changes the magnification of the image. Clicking on the Zoom button and click and drag up on the image increases the magnification. Dragging down decreases the zoom level.
- *Rotate* – You can rotate the image within the Image Window by holding down the mouse button and moving the mouse
- *Scroll* – The scroll button looks like a stack of cards. Clicking on it and then clicking and dragging up or down anywhere in the Image Window allows you to scroll through the DICOM stack in ascending or descending order.

In addition to the first five buttons described above, there are 16 additional mouse buttons that are used to manipulate ROIs (Figure 6.6). These are described briefly below and discussed in more detail in the Quantification Tools section.

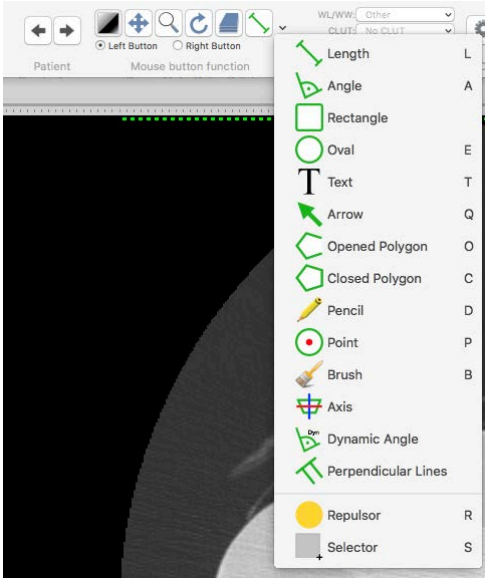


Figure 6.6. The dropdown list of additional mouse buttons for use with ROIs.

ROI tools include:

• *Length* – Click on the Length tool and click and drag on the image to create a straight line with it's distance units displayed.
• *Angle* – Click on the Angle tool and then click three places with the image to display angle lines with both inside and outside angles given in degrees.
• *Rectangle* – This tool allows you place a rectangle on the image. It also displays the rectangle's area, width, height, and the mean, max and min pixel values within the rectangle.
• *Oval* – The Oval tool allows you to place an ellipse on the image. It displays the ellipse's area, width, height, and the mean, max and min pixel values within the ellipse.
• *Text* - Clicking on the Text tool allows you to enter comments or other text at the location you clicked on in the Image Window.
• *Arrow* – You can add an arrow anywhere on the image by choosing the Arrow tool and clicking at the location on the image where you want the tip of the arrow to begin.
• *Closed Polygon* – You can create a polygon with as many corners as needed by clicking at various places on the image and closing the polygon by double-clicking. Double-clicking connects the first and last corners of the polygon. The polygon's area and other attributes are displayed when the polygon is closed.
• *Opened Polygon* – Open polygons are similar to closed polygons except that the first and last corners are not connected.
• *Pencil* – The pencil tool creates a closed polygon by clicking and dragging the mouse around the object of interest.
• *Point* – Click on the image with the Point tool and you will see information displayed about that point including pixel value and its 2D and 3D position.
• *Brush* – Click on the image with the Brush tool and you will see a pop-up screen with brush attributes. Select brush and begin painting on the image to create a region of interest (ROI). Choosing erase from the brush attributes allows you to erase parts of the previous brush ROI.
• *Axis* – Creating four points on the image with the Axis tool displays the mean axis based on those four points.
• *Dynamic Angle* – This tool displays the angle between two lines (between the first two points and the last two points). The sum of these two angles is equal to 360 degrees.
• *Repulsor* - The Repulsor is used to modify existing ROI shapes created with the Length, Opened Polygon, Closed Polygon and Pencil tools. Select the repuslor tool, click and drag toward an existing ROI line, and the repulsor's yellow ball with push the contour of that ROI line to reshape the line (Figure 6.7).
• *Selector* - The Selector tool allows you to select ROIs currently displayed in the Image Window.

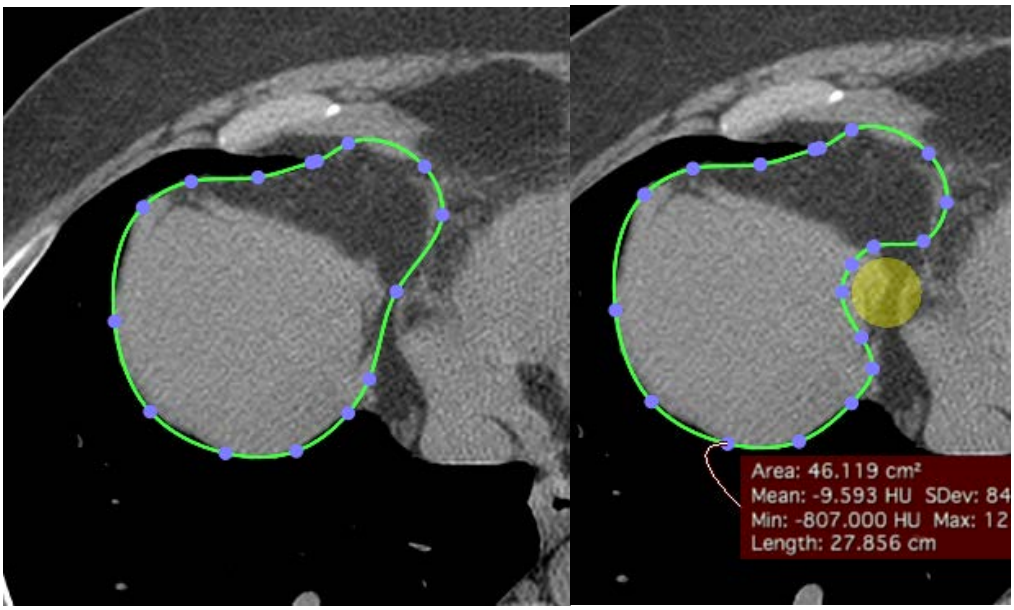


Figure 6.7. The Closed Polygon tool was used to create the ROI on the left. The Repulsor tool (yellow circle) is pushed into the ROI to create an adjusted boundary

WL/WW & CLUT Tools

The next set of tools are a set of three dropdown menu items; WL/WW, CLUT, and Opacity. The top item is the WL/WW, which translates to window level and window width. Clicking on the dropdown gives you several choices (Figure 6.8).

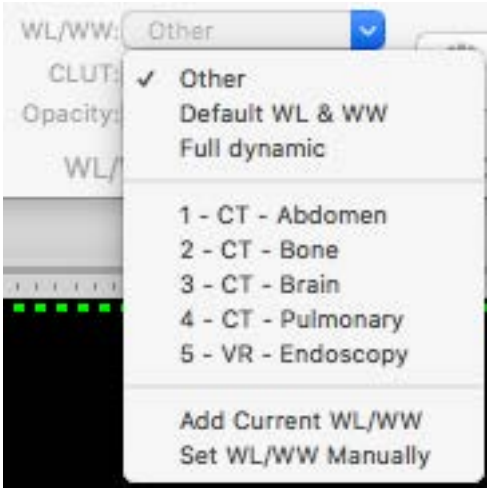


Figure 6.8. The dropdown menu for WL/WW options

Recall from the above description that WL and WW refer to brightness and contrast. In Figure 6.8 you can see the default option and the full dynamic option. Below those options are a set of predefined options that allow you to quickly move from one option to another. For example, Figure 6.9 shows three of the predefined options.

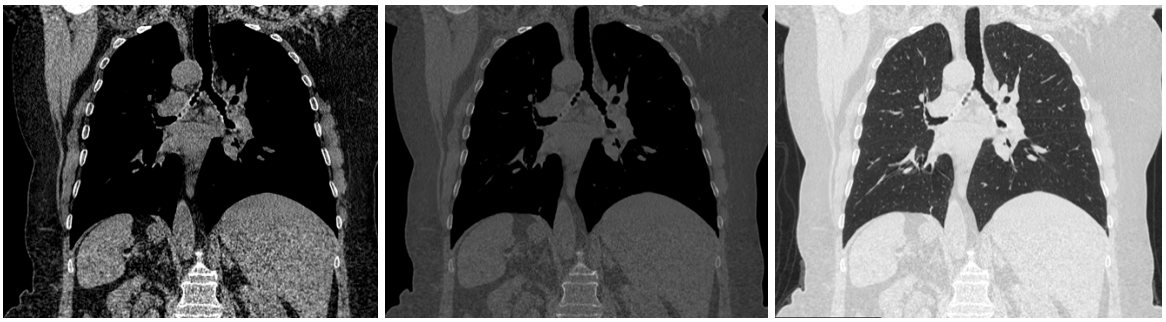


Figure 6.9. The left image shows the Abdomen pre-set, the middle images shows the Bone pre-set option, and the right images uses the Pulmonary pre-set option. You can use Add Current WL/WW to create a new pre-set using the current image settings.

The second dropdown list is the ***Color Look Up Table (CLUT)***. It provides a large series of options. The default is not to add a CLUT and just allow each pixel to retain a gray-scale value from 0 to 255, but if you want to visualize the image in a different way, you can use a predefine CLUT. For example, selecting the CLUT called VR Muscles-Bones displays an image with 0 pixel values as black, intermediate pixels as red, and pixel values of 255 as bright yellow to white (Figure 6.10). Try selecting a few CLUT choice to see how they display the image data.

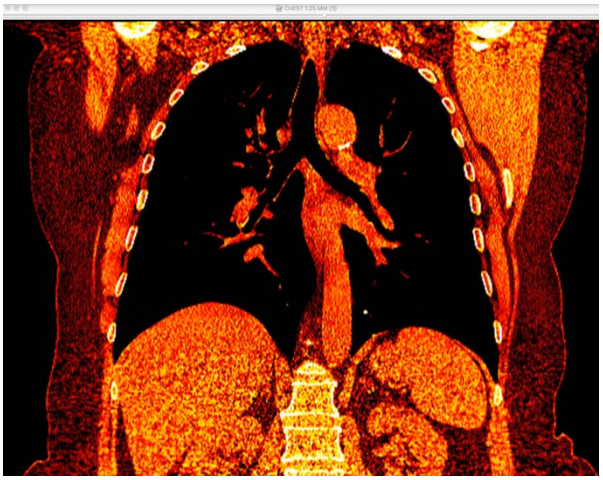


Figure 6.10. The VR Muscle-Bones CLUT

The bottom dropdown in the WL/WW & CLUT list is Opacity. Opacity options work like CLUT options in assigning each pixel an opacity value. The default opacity is linear. That is to say the input assigned opacity is the same as the output assigned opacity.

2D/3D Button

Clicking on this button displays a list of different 2 and 3 dimensional rendering options (Figure 6.11).

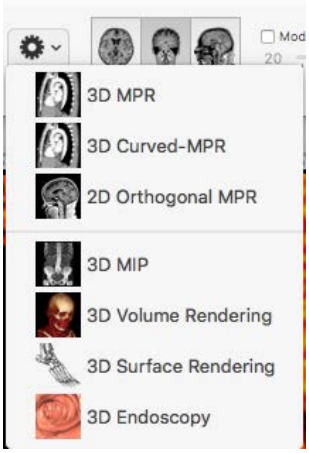


Figure 6.11. The dropdown list for the 2D/3D button.

3D MPR

You can use the 3D Multi-Planar Reconstruction to adjust the image volume in three oblique planes. Each plane can be tilted individually using the vertical and horizontal lines in each Image Window (Figure 6.12). For example, hovering the mouse cursor over one of these lines reveals two curved arrows indicating that you can rotate this line. As you rotate one line in one image view the other two images will adjust accordingly. Alternatively, if you use the cursor to gram the intersection of the two lines, the cursor becomes hand and you can move it right or left and up and down. As before, the other windows adjust accordingly (Figure 6.13).

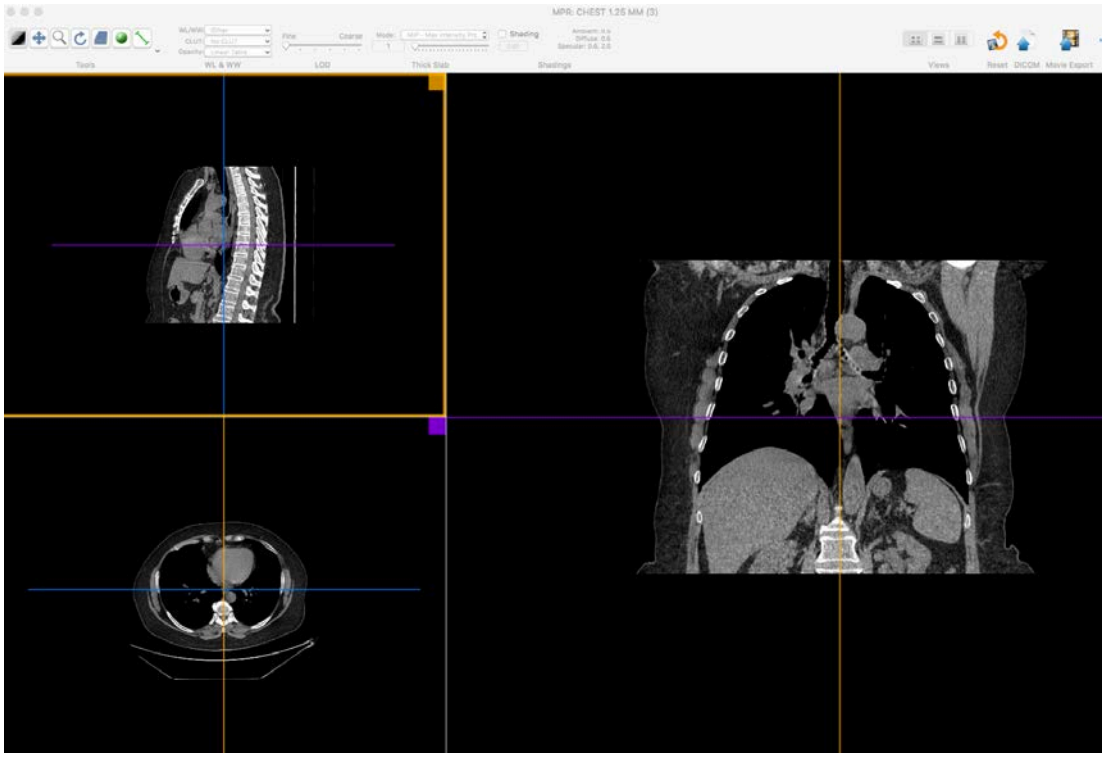


Figure 6.12. The MPR view showing three image windows (Axial, Coronal and Sagittal) and the horizontal and vertical position lines in each image.

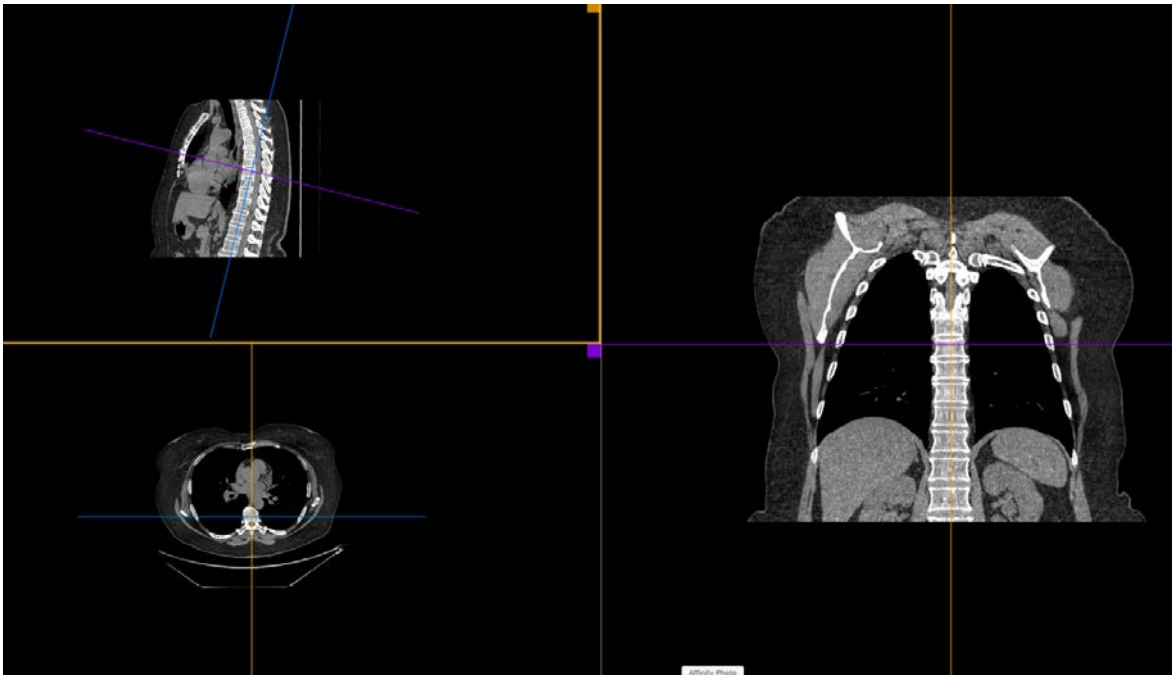


Figure 6.13. Here the image in the upper left has been tilted along the spinal cord. Notice That the two other images are repositioned accordingly.

3D Curved-MPR

You can use the 3D Curved MPR to display a curved section across the body or along an anatomical structure.

2D Orthogonal MPR

You can reformat and display the image volume along the 3 orthogonal planes (Axial, Coronal and Sagittal) as shown in Figure 6.14.

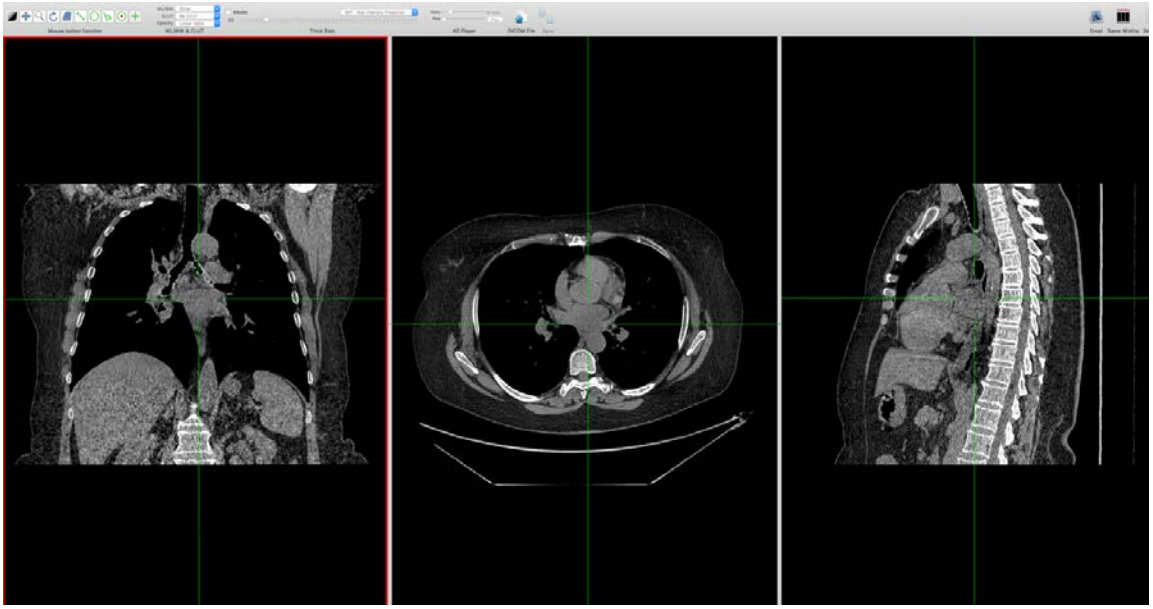


Figure 6.14. Three orthogonal planes as depicted in the 2D Orthogonal MPR.

The 3D tools listed below are described in greater detail in Chapter 7.

3D MIP

MIP stands for ***Maximum Intensity Projection***. It is a volume rendering technique that analyzes several consecutive sections (slices of a CT, for example) of a volume and projects the voxel (three dimensional pixel) with the maximum intensity. Imagine a cube with 10 voxels per side. See Chapter 7 for additional detail.

3D Volume Rendering

Volume Rendering technique creates as RGBA volume from the data and projects it as a 2D view. The RGB are the traditional red, green, blue colors and the A represents opacity. Here an opacity of 1 is totally opaque and an opacity of 0 is totally transparent. The volume is then projected on a opaque background (typically black). See Chapter 7.

3D Surface Rendering

Surface rendering is a 3D technique uses only part of the 3D data to reconstruct an image. Typically, the data used to reconstruct the image is defined by a threshold. Voxels with a value below the threshold are discarded, and voxels with a threshold value equal to or greater than the threshold will be rendered (Figure 6.15).

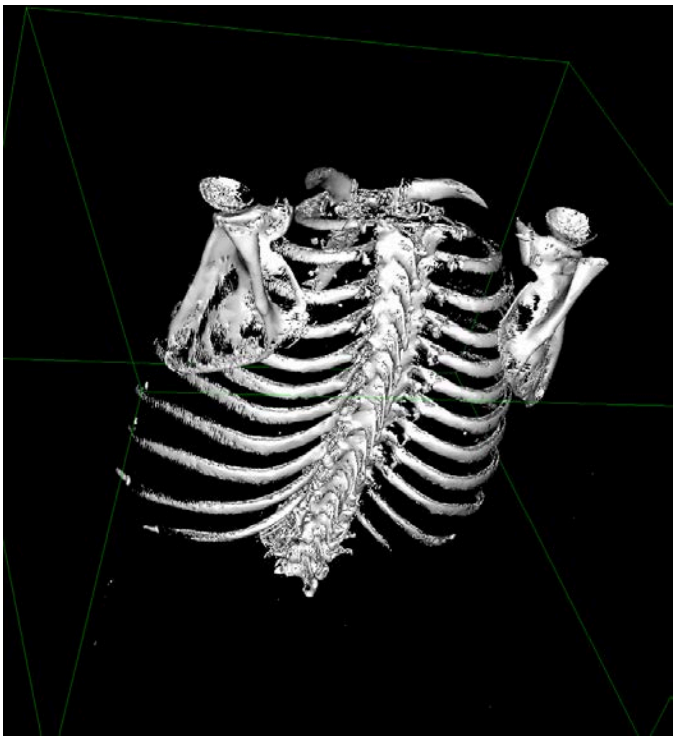


Figure 6.15. A 3D surface render of the image in Figure 6.14 using a threshold value greater than 200.

3D Endoscopy

This advanced rendering technique is used for interactive navigation of hollow organs, including colon, blood vessels and airways in the lungs.

Orientation

You can quickly move between axial, coronal, and sagittal image stacks using the orientation buttons (Figure 6.16). An example of each is shown in Figure 6.17.

Figure 6.16. The orientation buttons in the 2D Viewer Menu.

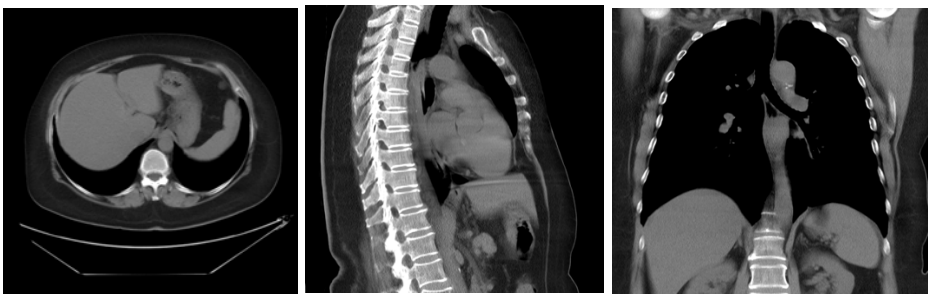


Figure 6.17. Left – axial image. Middle – Sagittal image. Right – Coronal image.

Thick Slab

Horos uses stacks of images to present 3D data. Typically, a single image represents one image in the stack and its thickness is determined at the time the patient was scanned. For example the images in Figure 6.17 are each 1.25mm thick. However, Horos also allows you to manually adjust the thickness (using different algorithms) using the Thick Slab slider in the tool bar (Figure 6.18). You can set the size of the slab (i.e. the number of images) and the algorithm to use when creating the new image.

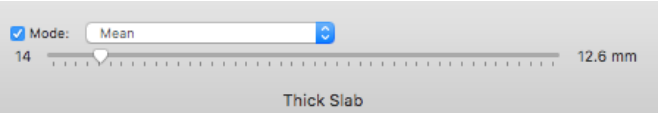


Figure 6.18. The Thick Slab slider in the Horos menu bar.

There are five rendering modes in the Mode dropdown menu. They are Mean, MIP, MinIP and Volume Rendering (two modes). For example, the Mean mode uses an algorithm that computes the average of each pixel at the same location and displays the mean pixel in the resulting image. The MIP mode stands for Maximum Intensity Projection. It displays the pixel in the thick slab stack with the maximum intensity. Conversely, the MinIP displays the pixel with the minimum intensity at that location in the slab.

The Volume Rendering algorithm will display a 3D representation of the thick slab images. Examples of each display are shown in Figure 6.19.

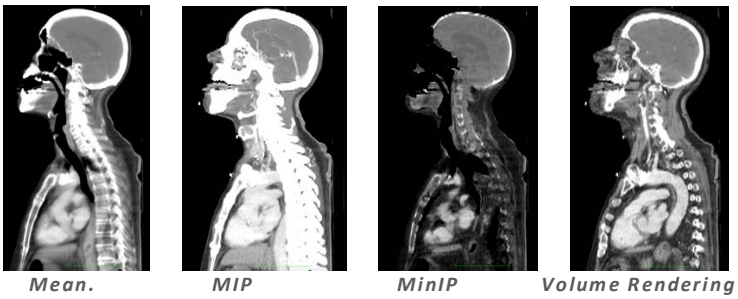


Figure 6.19: The 4 Thick Slab Algorithms with thick slab set at 35.

The final group of tools on the default tool bar is shown in Figure 6.20.

Figure 6.20. The right most panel of tools in the default display.

Movie Export

You can export a movie clip of the DICOM series by clicking on the Movie Export button. A popup screen is displayed that allows you to set such parameters as number of frames, starting frame, interval, and so on. If you are in sagittal view the movie will run through the sagittal series stack. This function is also available in the File > Export menu by selecting Export to Movie.

Sync

You can turn stack synchronization on and off using the Sync button.

Propagate

You can turn the settings propagation on and off using the Propagate button. This feature is also found in the Horos menu by clicking 2D Viewer > Propagate Settings Between Series.

Browse

The Browse button starts displaying the stack as if you were scrolling through the stack. The rate at which images are displayed is et with the Rate slider. If you click the Loop box the scrolling will continue to loop from beginning to end and back again.

Rate

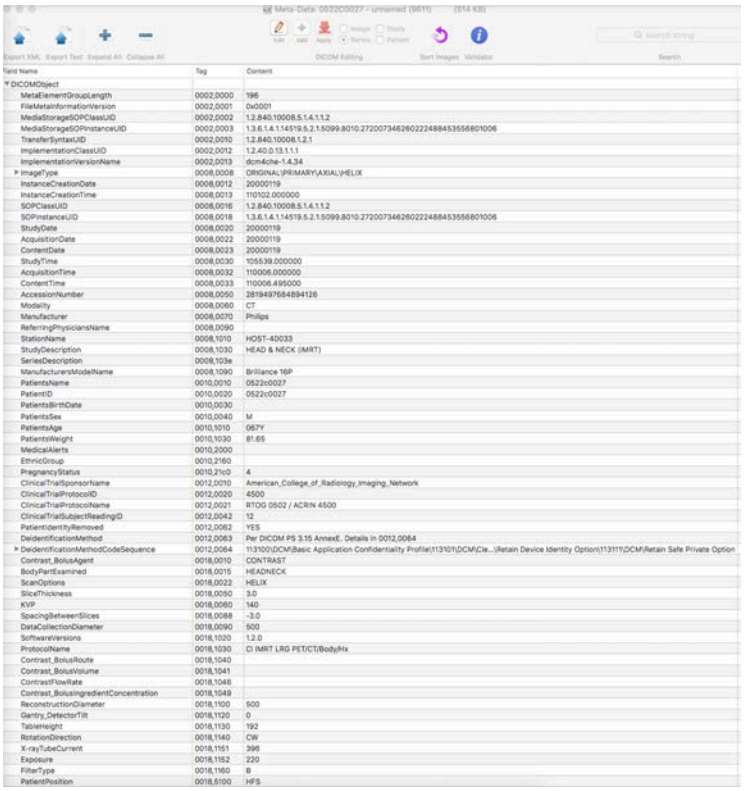
As described above in the Browse tool, the Rate slider allows you to change the speed at which images are displayed.

3D Panel

By clicking on the 3D Panel button you create a small floating window that displays a 3D MIP of the currently series.

Meta-Data

You can display the Meta-Data associated with this DICOM image next to the image by clicking the Meta-Data button as shown in Figure 6.21.



Field Name	Tag	Content
DICOMObject		
MetaElementGroupLength	0002,0000	196
FileMetaInformationVersion	0002,0001	0x0001
MediaStorageSOPClassUID	0002,0002	1.2.840.10008.5.1.4.1.1.2
MediaStorageSOPInstanceUID	0002,0003	1.3.6.1.4.1.14519.5.2.1.5099.8010.272007346260222488453556801006
TransferSyntaxUID	0002,0010	1.2.840.10008.1.2.1
ImplementationClassUID	0002,0012	1.2.40.0.13.1.1.1
ImplementationVersionName	0002,0013	dcm4che-1.4.34
ImageType	0008,0008	ORIGINAL\PRIMARY\AXIAL\HELIX
InstanceCreationDate	0008,0012	20000119
InstanceCreationTime	0008,0013	110102.000000
SOPClassUID	0008,0016	1.2.840.10008.5.1.4.1.1.2
SOPInstanceUID	0008,0018	1.3.6.1.4.1.14519.5.2.1.5099.8010.272007346260222488453556801006
StudyDate	0008,0020	20000119
AcquisitionDate	0008,0022	20000119
ContentDate	0008,0023	20000119
StudyTime	0008,0030	105539.000000
AcquisitionTime	0008,0032	110006.000000
ContentTime	0008,0033	110006.495000
AccessionNumber	0008,0050	2819497684894126
Modality	0008,0060	CT
Manufacturer	0008,0070	Philips
ReferringPhysiciansName	0008,0090	
StationName	0008,1010	HOST-40033
StudyDescription	0008,1030	HEAD & NECK (IMRT)
SeriesDescription	0008,103e	
ManufacturersModelName	0008,1090	Brilliance 16P
PatientsName	0010,0010	0522c0027
PatientID	0010,0020	0522c0027
PatientsBirthDate	0010,0030	
PatientsSex	0010,0040	M
PatientsAge	0010,1010	067Y
PatientsWeight	0010,1030	81.65
MedicalAlerts	0010,2000	
EthnicGroup	0010,2160	
PregnancyStatus	0010,21c0	4
ClinicalTrialSponsorName	0012,0010	American_College_of_Radiology_Imaging_Network
ClinicalTrialProtocolID	0012,0020	4500
ClinicalTrialProtocolName	0012,0021	RTOG 0502 / ACRIN 4500
ClinicalTrialSubjectReadingID	0012,0042	12
PatientIdentityRemoved	0012,0062	YES
DeidentificationMethod	0012,0063	Per DICOM PS 3.15 AnnexE. Details in 0012,0064
DeidentificationMethodCodeSequence	0012,0064	113100\DCM\Basic Application Confidentiality Profile\113101\DCM\Cle...\Retain Device Identity Option\113111\DCM\Retain Safe Private Option
Contrast_BolusAgent	0018,0010	CONTRAST
BodyPartExamined	0018,0015	HEADNECK
ScanOptions	0018,0022	HELIX
SliceThickness	0018,0050	3.0
KVP	0018,0060	140
SpacingBetweenSlices	0018,0088	-3.0
DataCollectionDiameter	0018,0090	500
SoftwareVersions	0018,1020	1.2.0
ProtocolName	0018,1030	CI IMRT LRG PET/CT/Body/Hx
Contrast_BolusRoute	0018,1040	
Contrast_BolusVolume	0018,1041	
ContrastFlowRate	0018,1046	
Contrast_BolusIngredientConcentration	0018,1049	
ReconstructionDiameter	0018,1100	500
Gantry_DetectorTilt	0018,1120	0
TableHeight	0018,1130	192
RotationDirection	0018,1140	CW
X-rayTubeCurrent	0018,1151	396
Exposure	0018,1152	220
FilterType	0018,1160	B
PatientPosition	0018,5100	HFS

Figure 6.21. The Meta-Data display widow.

Additional Tools

In addition to the default tool bar displayed by Horos users can customize the tool bar by adding and removing tools. The additional tools are available from the Format > Customize Toobar in the top menu. This brings up a window with all available tools listed. The non-default tools are described below in alphabetical order.

3D Position

When viewing two datasets simultaneously, you may notice the two image stacks are not well aligned. You can manually adjust the image registration between two modalities (PET–CT for example) using the 3D Position tool (Figure 6.22). This tool displaces the overlaid images in the up, down, left and right directions and in the axial, coronal and sagittal planes. You can move the image, by clicking on the arrows or clicking and holding the thumbnail icon in the middle. This item is also available as an icon in the 2D Viewer and the 2D Orthogonal MPR toolbar.

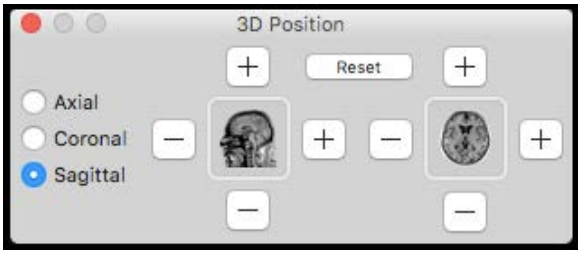


Figure 6.22. The 3D Position tool popup window.

4D Player

A 4D series contains multiple series with the same dimensions (matrix size) and the same number of images. For example, a 4D MRI of the heart might have 20 series of 512 × 512 images, with movement as the 4th dimension. Such a 4D dataset allows you to visualize blood flow to assess symptoms of aneurysm or valve disease. If you are using a 4D dataset, the 4D Player tool allows you to scroll through the 4th dimension. You can adjust the rate slider to set the number of images/sec and the Position slider to set the start point and then click Play.

Cobb's Angle

You can use this button computer the angle of Cobb. The Cobb angle is the angle formed between a line drawn parallel to the superior surface of a vertebra above a fracture or spine deformity and a second line drawn parallel to the inferior surface of a vertebra below the fracture (Figure 6.23). Using the Cobb's Angle tool you can select one line (it will be highlighted in yellow) and display the angle in the second line's info box (Figure 6.24). This tool can also be found in the ROI tab on the main Horos menu.

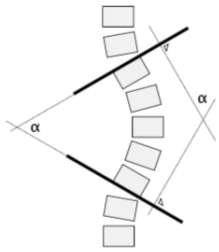


Figure 6.23: The angle of Cobb (represented by α).

Figure 6.24. An example of Cobb's Angle displayed on a sagittal section of the human spine.

Convolution Filters

You can apply various convolution filters in real-time, using the Convolution Filters dropdown list (Figure 6.25). These filters are also available in the 2D Viewer menu. The details for each filter are described later in this chapter.

Figure 6.25. The drop down list of available convolution filters.

Email

You can export the current image or all the images in the series as an email message (Figure 6.26). You can also export the current image to your Photos library ans set the image format as JPEG or TIFF.

Figure 6.26. The Email tool popup window.

Export as DICOM File

You can export the current image or the entire series as DICOM files by using this tool. Tool displays a pop up window (Figure 6.27) with several options. You can choose an image format (8 bit RGB, 16 bit BW or stored in memory in 16 bit BW. Clicking on the All images of the series button activates the interval slides in the middle of the pop up window. Changing the interval and the range reduces the number of images to be exported. At the bottom of the window, you can enter a name for the series you want to export.

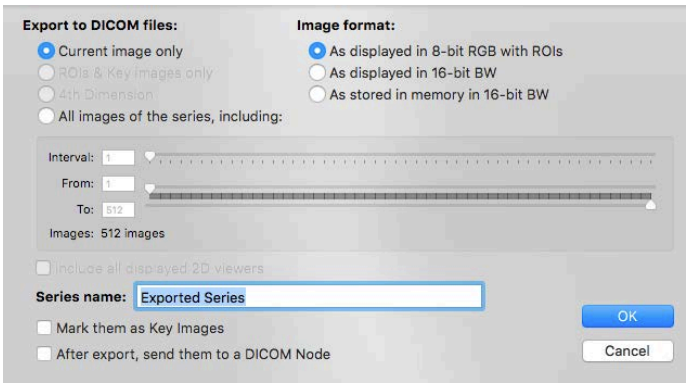


Figure 6.27. The Export as DICOM File popup window.

Flip

You can invert the order of images in a series using the Flip tool. The first image becomes the last image and vice versa. This function is also available in the 2D Viewer Menu: Flip Series.

Flip Horizontal

You can flip the image horizontally using this tool. For example, an image with the patient facing right is flipped so that the patient is now facing left on the screen. The orientation annotations displayed on the image are also correctly modified: right and left annotations will be flipped. This function is also available in the 2D Viewer Menu under Orientation.

Flip Vertical

This tool flips the image vertically. For example, an image with the patient's head at the top is flipped so that the patient's head is now facing down on the screen. The annotations displayed on

the image will be correctly modified:. This function is also available in the 2D Viewer Menu under Orientation.

Fusion

When two datasets are fused together (i.e. PET-CT studies), you can change fusion parameters such as fusion mode (linear, log, inverse, etc.) and the fusion percentage from 0% to 100%.

Growing

The Growing tool displays the Region Growing panel (Figure 6.28). Details of Region Growing algorithems and use of the Region Growing Panel are described below. This function is also available in the ROI menu: Growing Region (2D/3D Segmentation).

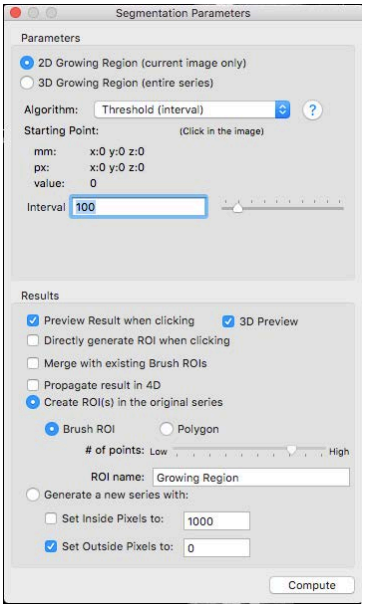


Figure 6.28. The Region Growing Panel.

Key Images

If you are working with a lot of images or want to create an illustrated report, you may want to tag important images (key images). Clicking the box next to Key Image selects the current image as a key image. You can switch from viewing only key images to viewing all images. This tool is also available from the 2D Viewer menu.

Navigator

You can display the Navigator Panel (figure 6.29) below the current image by clicking the Navigator tool. The Navigator panel displays all the images in the current series, in a row of thumbnail images. This panel allows you to quickly and easily see the entire series. This function is also available in the 2D Viewer menu under Navigator Panel.

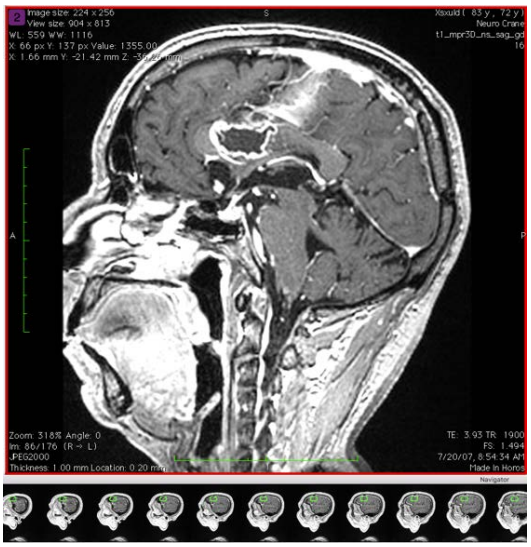


Figure 6.29. A sagittal section through the head with the Navigator Panel displayed at the bottom of the screen.

Photo

You can create a screen capture of the current image and add it to your Photos library by clicking the Photo tool. This will bring up the popup window shown in Figure 6.27 except the Photos icon will be highlighted.

Print

You can print the entire series or a subset of the series to a DICOM Printer if that printer has been defined in Preferences. This function is also available in the File menu: DICOM Print.

Report

You can begin writing a report for the current study by launching the report software via the Report tool. Horos supports several file formats including Pages, LibreOffice, Rich Text, and MS Word. The default format is set in the Database Preferences. This function is also found in the File menu > Report > Open Report.

Reset

If you have moved or changes the current image's settings, you can reset all display settings, including the image position in the window, the image size, the rotation, and the default window level and width. This function is also available from the 2D Viewer menu > Reset Image View.

Revert

If you have applied a convolution filter or other effect to the image, you can use the Revert tool to reload the pixel data from the files. This function is also available from the 2D Viewer menu > Revert Series.

RGB Factors

You can modify the balance of each RGB channel for both color and black and white images using the sliders provided with the RGB Factors tool. The raw data is not modified.

ROI Manager

The ROI Manager tool bring up a window that allows you to edit the list of existing ROIs and their areas and volumes (Fgiure 6.30). This function is also available from the ROI Menu > ROI Manager.

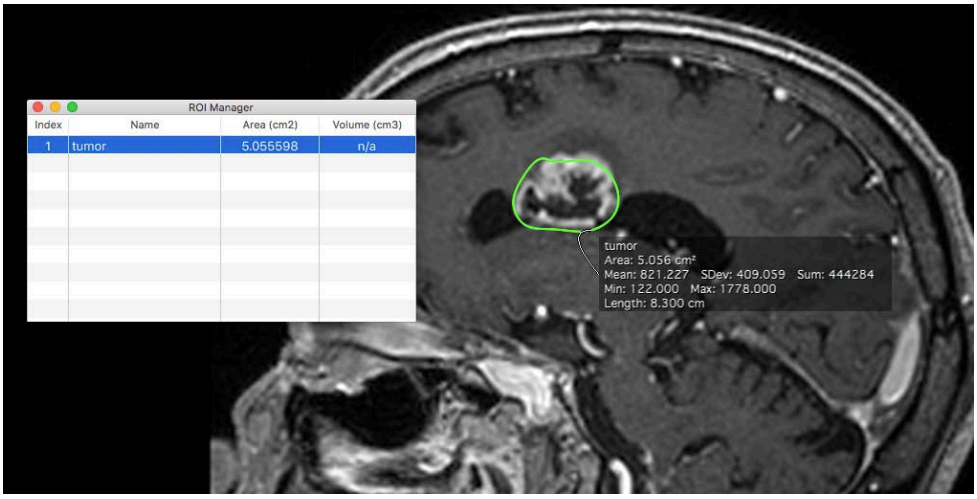


Figure 6.30. The ROI Manager dialog box for the tumor ROI shown on the image slice.

Send

You can send an entire series or a subset of the series to a DICOM node, with the DICOM C–STORE SCU protocol. This function is also available in the File menu > Export > Export to DICOM Network Node.

Set Pixels

You can modify the pixels values (intensity) by applying this algorithm to all pixels in the series, all pixels within ROIs with the same name as the selected ROI, or to all ROIs in the series (Figure 6.31). You can modify pixels that are contained in the ROIs or that are outside the ROIs. You can also set an lower and upper threshold value, to filter the pixels' intensity. This function is also available in the ROI menu > Set Pixel Values to.

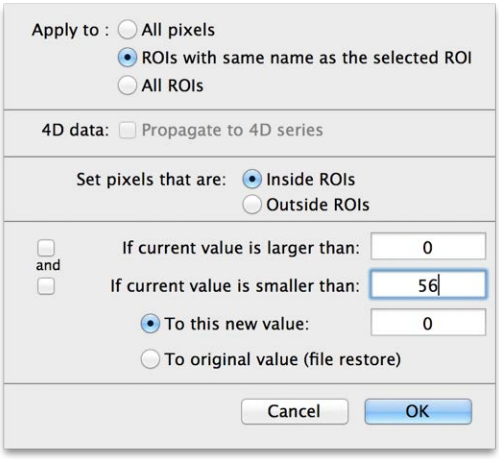


Figure 6.31. The Set Pixels popup panel

Shutter

If you have a rectangle ROI selected on an image, you can add or remove a mask to the entire series. This mask can be toggled on and off by clicking the shutter button.

Status & Comments

You can change the status of the series from empty to unread, reviewed, dictated, or validated. You can also add a comment for each series as described in the Database Chapter.

Subtraction

Sometimes you may need to remove parts of an image that are stationary over time to reveal those parts of the image that do change over time. This is commonly used in Digital Subtraction Angiography (DSA). The subtraction tool available in Horos allows you to adjust the subtraction function (Figure 6.32). The details of the Subtraction tool are described below. This function is also available in the 2D Viewer menu > Subtraction.

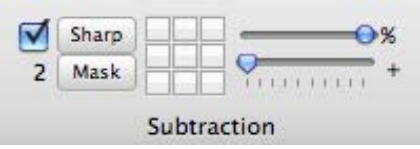


Figure 6.32. The Subtraction tool

SUV

The SUV, or Standardized Uptake Value (aka dose uptake ratio) is used with PET series. It is the ratio of activity per unit volume of a region of interest (ROI) to the activity per unit whole body volume. It is often used to distinguish between "normal" and "abnormal" levels of uptake. The SUV button displays the parameters used to compute the SUV values.

Tile

You can tile the opened windows by clicking on this button.

Displaying Images

Displaying a series

Horos provides several options for displaying a study or a series of DICOM images. The default display is a single series for one individual (a stack) presented in a single image view window (Figure 6.1). However, you can open multiple series (discussed below). To open a series, select the series in the database window and either double click on it or hit the return key. Simultaneously clicking on the option key on your keyboard and on the 2D Viewer icon (Figure 6.33) in the top menu of the database screen brings up a dialog box (Figure 6.34) that allows you to select a subset of images in the stack.

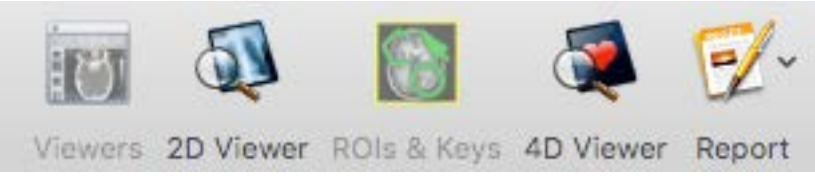


Figure 6.33. The 2D Viewer icon in the database toolbar.

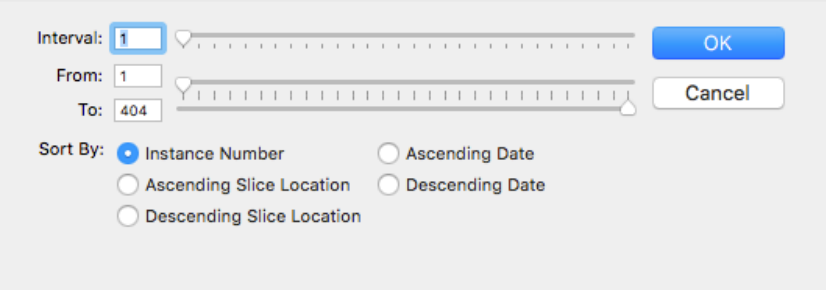


Figure 6.34. The dialog box for selecting a subset of images in a series.

Alternatively, you can open a study or series by selecting the study or series of interest and:

- *clicking on the 2D/3D viewer icon in the toolbar.*
- *Selecting the series in the lower left part of the window – the Series List – and double clicking or hitting the return key.*
- *Selecting the series in the lower left Series List and double clicking on the 2D/3D viewer icon in the toolbar.*
- *Selecting the series in the lower left Series List and double clicking on the preview pane.*

You can also open a merged selection by selecting the thumbnails in the lower part of the window and choosing Open Merged Selection from the contextual menu.

Displaying Multiple Series

Recall that a patient may undergo multiple MRIs or CT scans. Each generates a series of images, a DICOM stack. For example, a physician may require a patient to undergo MRIs before and after a treatment – generating a before and after series. Or a patient will have a CT and PET done. Sometimes it is useful to display several series from that patient simultaneously (Figure 6.35).

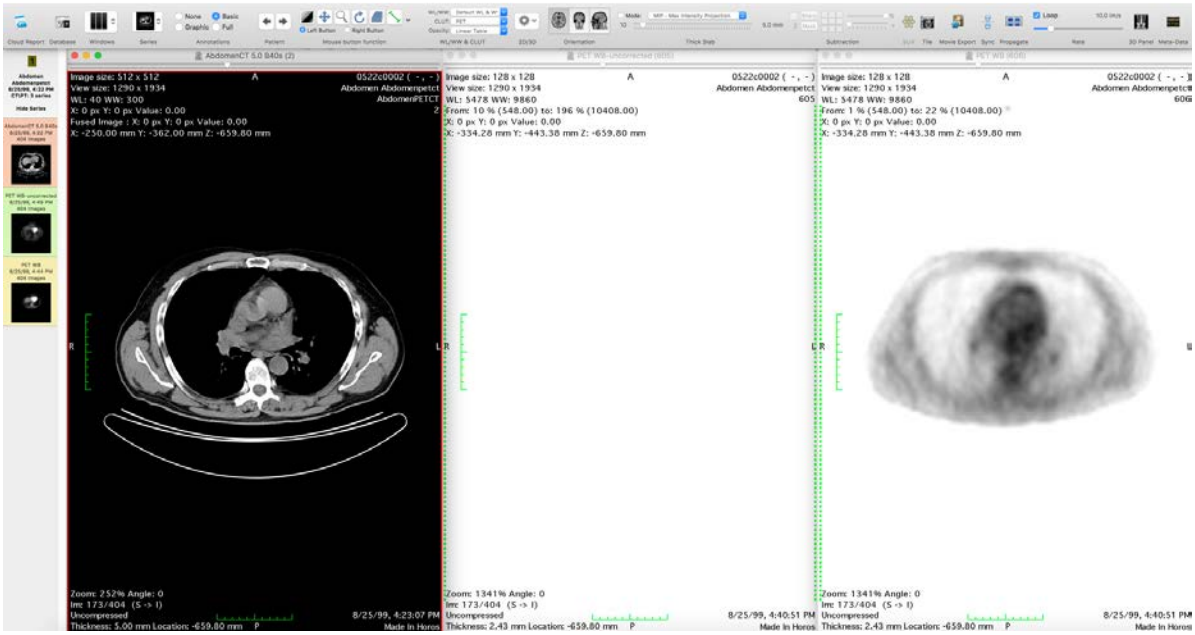


Figure 6.35. A view of an abdominal CT (left), uncorrected PET (center) and PET (right) for one patient.

For example, you can select all three series in a study by holding down the shift key (or command key) as you click on the thumbnail icon for each series. Once selected, click on the 2D Viewer icon in the database toolbar. This displays the three series simultaneously in side-by-side tiled windows as shown in Figure 6.36. Horos will adjust the window sizes to fit the screen but you can manually change each window size and reposition its location on the screen(s) at will. Once the series are displayed in the 2D Viewer, you can choose a different window tiling option from the 2D Viewer menu at the top by clicking on Image Tiling in the dropdown list and selecting the tiling arrangement form the list of choices.

Tiling & Magnetic Windows

As described above, tiling will reorganize the opened windows to fill the screen. The Magnetic windows feature allows you to quickly reorganize the open windows. Grab an open window along the top gray bar with your cursor and drag it to a new location on the screen. When the dragged window approaches a screen border or another window edge, the window being moved will stick to it. When you move a window onto another one, the second window is automatically moved to the window's previous position and both windows are resized to fit their new position. To correctly use this feature, you must drag the upper left-hand corner of your window on top of the corresponding corner of the second window. Holding down the option key while moving windows turns off the magnetic window feature. These features can also be modified in the Viewers Preferences panel.

Propagate Settings

You can synchronize the viewing settings (WL/WW, rotation, etc.) when multiple 2D Viewers are open using the Propagate Settings feature in Horos. When propagation is turned on, WL/WW, pan, zoom, and rotation are effected. That is, if you modify the WL/WW in one window viewer, it will be similarly applied to the other open window viewers. There are four exceptions:

1. WL/WW will be propagated only if the modality and acquisition parameters are identical. Thus, WL/WW will not be propagated between CT and CR images.

2. Setting will never be propagated between CR and NM modalities.

3. In PT modality, WL/WW will not be propagated between a SUV converted series and a non-SUV corrected series.

4. Pan, rotation and zoom settings are not propagated if the viewers have different planes. For example, a sagittal series will never propagate pan and zoom settings to a coronal series.

Often you will make changes to the CLUT or WW/WL settings on one image in a series. In the 2D Viewer you can propagate those settings to all the images in the series by selecting the Propagate Settings in Current Series from the dropdown list in the 2D Viewer menu (Figure 6.36).

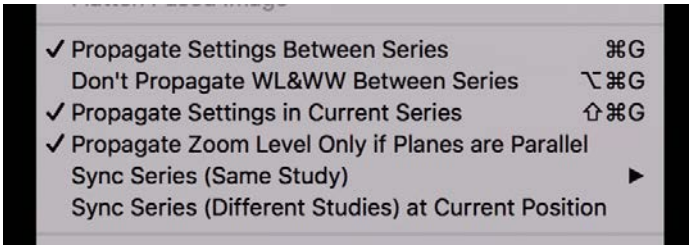


Figure 6.36. The choices for settings propagation from the 2D Viewer menu.

You can also choose to propagate those settings between series in a study or not to propagate the WL&WW settings between series. For CR, DX and DR modes, you can block this function by selecting No Propagate settings in series for CR, DX, DR, in the Viewers Preferences.

Synchronization

Horos allows you to synchronize the slice position across several open 2D Viewers (figure 6.37). When Synchronization is turned on, all open viewers display the same stack z level. Synchonization works automatically if the open series belong to the same study. For example, the three abdominal acquisitions of the same CT/PET study shown in Figure 6.37. This is accomplished using the Image Position Patient DICOM field (0x0020,0x0032) to locate the nearest corresponding slice. Note, that if this DICOM field is not available, no synchronization is

possible. Additionally, synchronization works only if the open 2D Viewers display series with the same orientation plane.

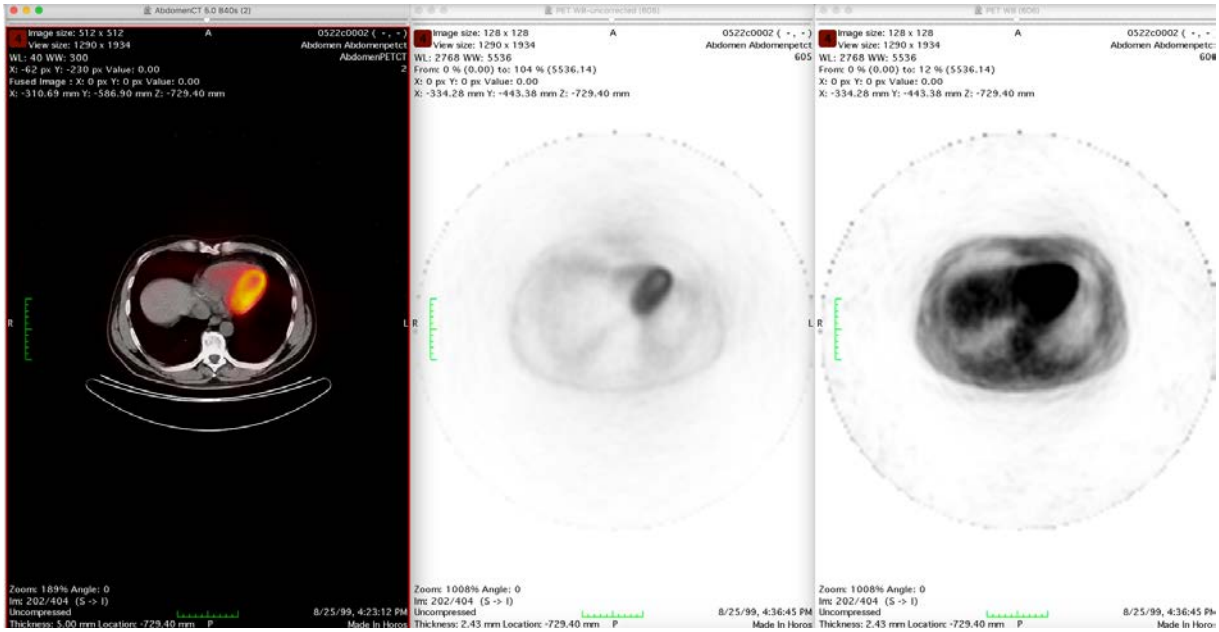


Figure 6.37. The Synchronization feature illustrated in three viewer windows for abdominal transverse sections.

The Synchronization function can be activated manually from the 2D Viewer dropdown list (Figure 6.36). Alternatively, if you have placed the Sync button in your toolbar, you can just click on that button. Thus, you can compare a CT study acquired in June and another CT study acquired in September. Horos notes the current position in the stack of the viewers and attempts to keep them synchronized even if acquisition parameters such as slice interval or slice thickness are not identical.

Reference Lines

If you display several series of the same study showing different orientation planes, Horos adds reference lines on the non-active viewers (Figure 6.38) allowing you to easily locate the current slice on the other series. A central thicker green line shows the location of the current slice, while the two thin green lines depict the slice thickness. Orange lines reveal the bounds of the selected volume on the other viewers.

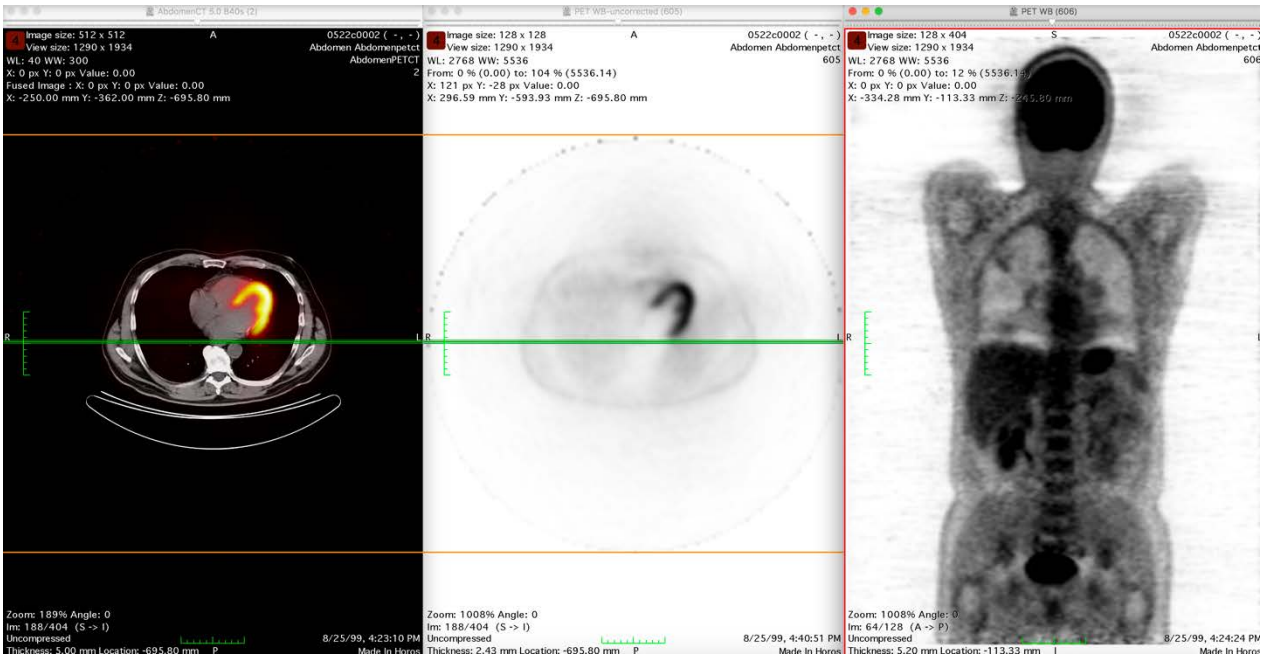


Figure 6.38. Reference lines on the middle and left viewers show the location of the slice shown on the right viewer window.

Scrolling across the active stack causes the green line to move as Horos locates the same position on the other planes/windows. Reference lines can be hidden/shown by clicking on the Annotations > Display Cross Reference Lines item from the 2D Viewer menu.

Navigating Between Studies And Series

Suppose you have CT data from three patients in your database and you want to rapidly switch back and forth from one patient to another. One option is to simultaneously display the three patients in three side-by-side window viewers (as described section 6.3). However, you can also rapidly navigate from one patient to another or from one series to another from the same patient. Horo uses a very fast dynamic mode to let you view one set of images, then load and display a new set of images with almost no delay even for large sets of images. There are several ways to quickly switch series, studies, or patients.

Switching image series

In the 2D Viewer menu's dropdown list, you can use Next Series and Previous Series to replace the current image series with either the next or previous series in the same study. The keyboard shortcuts (⌘→ and ⌘←) preform the same functions. Alternatively, you can use the Series list on the left-hand side of the viewer. Clicking on a thumbnail in this list will load the corresponding series, replacing the current one. Finally, if you have added the Series icon to your toolbar, you can simply click on the icon's up and down arrows to display the full list of open series (Figure 6.39).

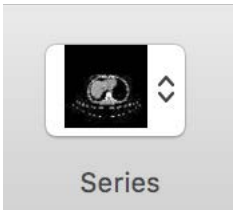


Figure 6.39. The Series list icon from the custom toolbar menu.

Switching patients

If more than one series is available from the database, the Patient icon in the 2D Viewer toolbar (Figure 6.40) allows you to switch to the next and previous patients. Alternatively, you can choose Next Patient or Previous Patient from the dropdown list under the 2D Viewer tab in the top menu. Finally you can use the keyboard shortcut shift + command + arrow (⇧ ⌘ ←) to move between patients.

Figure 6.40. The Patient icon from the 2D Viewer toolbar.

Switching back to database browser

You can return to the database window, using Show Database Window from the File menu. This leaves the 2D Viewer window open but brings the Database window to the front. Alternatively, you can shift click on the Database icon in the 2D Viewer toolbar to perform the same action. If you click on the Database icon without holding down the shift key, all open windows will close except the Database window.

The Series list

2D Viewers have a vertical bar on the left of the window displaying thumbnails of the current series list (Figure 6.41). Clicking on a thumbnail will load that series in the viewer exchanging the current one. The thumbnails can be color coded with green, yellow, red, or white frames (Figure 6.41). A green frame means that this series is loaded and fused in the 2D Viewer window. A yellow frame denotes a series that is loaded but not in the current 2D Viewer window. A red frame means the series is currently loaded and displayed in the 2D Viewer window and a white frame means this series is currently not loaded in any 2D Viewer window.

Figure 6.41: Thumbnails for the Series list in the 2D Viewer window showing the four different colors.

You can hide the Series list by dragging the vertical gray bar separating the thumbnails list from the open viewer to the left. You can also remove the series thumbnails by selecting Series List from the 2D Viewer menu. This action collapses the list and expands the viewer window to cover that area. Be aware that Horos will record that preference and the next time you open a viewer the Series List will not appear. You can make the thumbnail list appear again by reselecting Series List from the 2D Viewer menu. A second method for hiding the Series List is to activate Series List auto-hiding from Viewer Preferences. With auto-hiding set in Preferences, you can make the list visible any time you move your mouse over to the far left of the viewer window.

Holding down the command key (⌘) while clicking on a thumbnail from the Series List allows you to open that new series in a new tiled viewer window. If you have a study with many series, you can easily lose track of the currently loaded series in the Series List. You can automatically re-center the Series List thumbnail on the current series by double-clicking anywhere on the current image.

Workflow

Workspace State

In Horos you can save the “state” of the currently displayed series in the 2D Viewer windows. This is called a workspace state and each study can store one workspace state. It saves the settings for the following parameters:

- *the position of each 2D Viewer window on the screen*
- *pan*
- *zoom*
- *WL/WW*
- *image index*
- *rotation*
- *orientation*

In the 2D Viewer dropdown list you can select Save Workspace State, Load Workspace State, or Reset Workspace State.

When you open a study, Horos checks to see if a workspace state is attached to that study. If so, the workspace state is loaded and the series is displayed as previously saved. Alternatively, you can click the Database button icon in the 2D Viewer toolbar which will close all viewer windows and save the workspace state for that study. You can turn off automatic workspace saving/loading in Viewer Preferences.

Key Images

For many studies, you will want to include certain images in reports or have as easy way to find those images among the many images in a series. Horos allows you to tag key images using the Key Image function of the 2D Viewer Menu or by using the equivalent keyboard shortcut (⌘K). If you have the Key Images icon in your toolbar, clicking on it will also mark the current image as a key image. If you have created a series of ROIs (regions of interest) you can use Mark All ROI Images as Key Images entry in the 2D Viewer menu or by choosing the Mark ROI Images as Key Images in Viewers Preferences.

With one or more key images marked, you can quickly open only those key images from the Database window by clicking the Keys & ROIs button of the database toolbar. Clicking on the right and left arrow keys scrolls you through the key images. You can display only Key Images without ROIs by holding down the option key while clicking on Keys & ROIs button in the Database toolbar. Holding down the shift key and the Keys & ROIs button opens only those key images with ROIs. Once opened, all the key images can be exported as a new DICOM series or printed.

Printing

You can print to standard printers and DICOM printers in Horos. Standard printers are configured using the Print & Fax Preferences of Mac OS X (located in System Preferences). DICOM printers must be added to the DICOM Print list using the Horos Print Preferences (see Chapter 2). Once you have set up the image in Horos, use the zoom and pan features to fill the entire window with the image. You can print the image by selecting the Print icon from the 2D Viewer toolbar or selecting Print or DICOM Print from the File menu. Selecting Print brings up the window shown in Figure 6.42 below. Here you can adjust the Layout from 1x1 with 1 image per page (default) select other options from the dropdown list. Header information can also be

changed. You can add a custom string as the first line at the top of the page, turn on or off the white background on the page behind the image, and turn on or off the printing of the patient and study information.

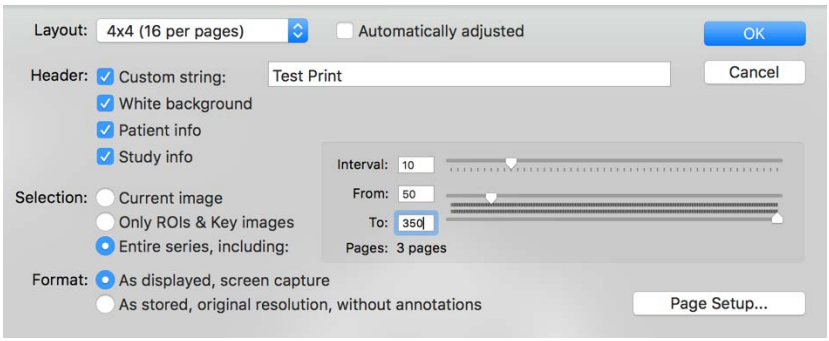


Figure 6.42: Page Set Up options, before printing

In the Selection section, you can choose to print only the current image, a group of Key images or images with ROIs, or the entire series. If you choose the entire series option, you can print every image in the series or adjust the interval to print every 10th image and you can use the From/To sliders to trim the stack. For example, the settings in Figure 6.42 show that 16 images will be printed on each page beginning with image number 50 and ending with image number 350. This will produce a printed page similar to that shown in Figure 6.43. Finally, you can choose to print the images from screen captures (including zoom, rotations, ROIs and pan settings) or the raw image data.

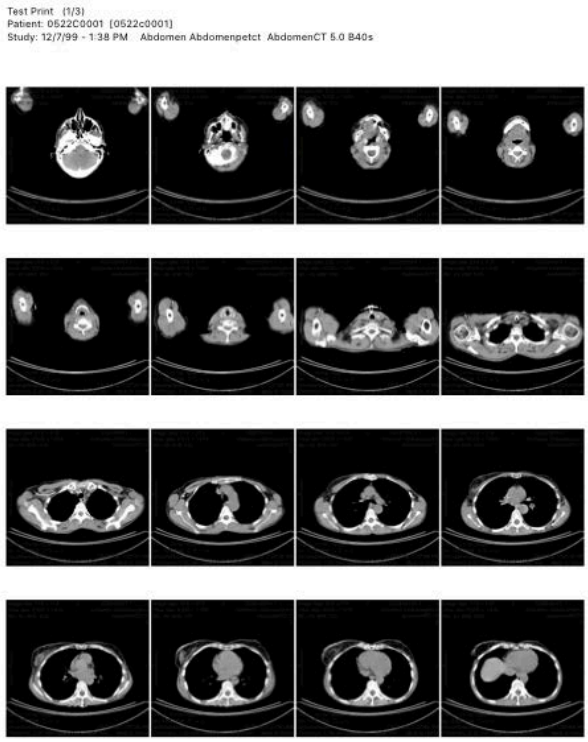


Figure 6.43. A sample page printed from the settings in Figure 6.42.

Selecting Ok sends you to the Print page where you can see a preview of the page and choose to print it or save it as a PDF or PostScript file.

Selecting the DICOM Print option opens a different dialog window (Figure 6.44) with similar options to those described above.

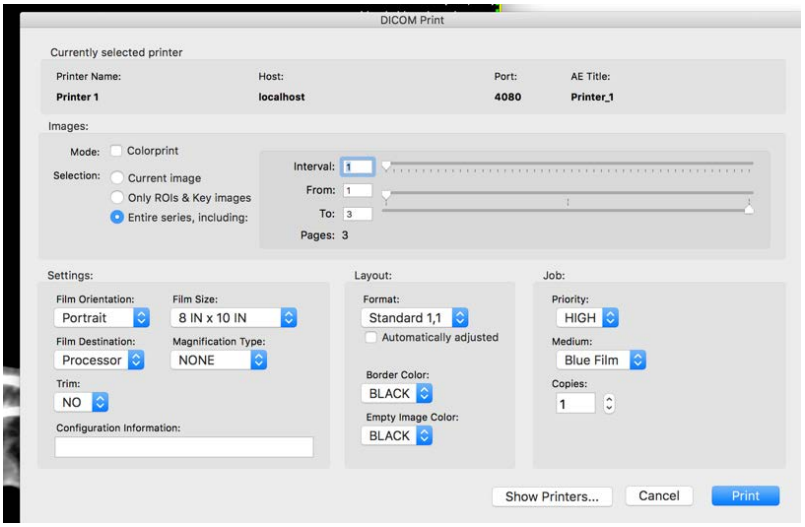


Figure 6.44. The DICOM Print dialog window.

Email

Selecting the Email button from the 2D Viewer toolbar (assuming it has been added to the toolbar) allows you to quickly share the current image from the 2D Viewer via email. The currently displayed image with all of its settings (CLUT, zoom, etc.) will be captured as a JPEG and added as an attachment to your email using the Mail app that comes with the Mac OS (Figure 6.45). You can also access the Email function via the File menus by selecting Export > Export to Email.

Figure 6.45. A sample email with the JPEG image attached.

If you wish to send the entire DICOM file, you must use the Email function available from the Database toolbar.

Magnifying Lens

Occasionally you may want to draw attention to one area of the current image. To do this you can use the Magnifying Lens tool in the 2D Viewer. Pressing the shift key brings up the magnifying lens (Figure 6.46). The magnifying lens uses the image's raw data to magnify the image by 4 times the current zoom level. The diameter of the magnifying lens can be adjusted using the up and down arrows and the zoom level within the lens can be changed with the plus and minus keys on the keyboard. The magnifying lens feature can be turned off in Viewers preferences (See Chapter 2).

Figure 6.46. The Magnifying Lens feature.

Image Export

You can export a screen capture image from a 2D Viewer in standard TIFF or JPEG formats for use in presentation software such as PowerPoint or Keynote. In the File menu select File > Export to TIFF or File > Export to JPEG. You can also copy the image to the clipboard using Edit > Copy and paste it into another software program using Edit > Paste. Finally, you can also drag and drop the image (Figure 6.47) onto the desktop by clicking and holding the mouse button down until a thumbnail of the image appears and then dragging the thumbnail onto the desktop (or onto another open software program). You can hide the annotations on the image (patient information) by using the tab key or by selecting None from the Annotations options in the toolbar. Drag and drop is also available from the database window. Image exports can also be modified in preferences settings (See Chapter 2).

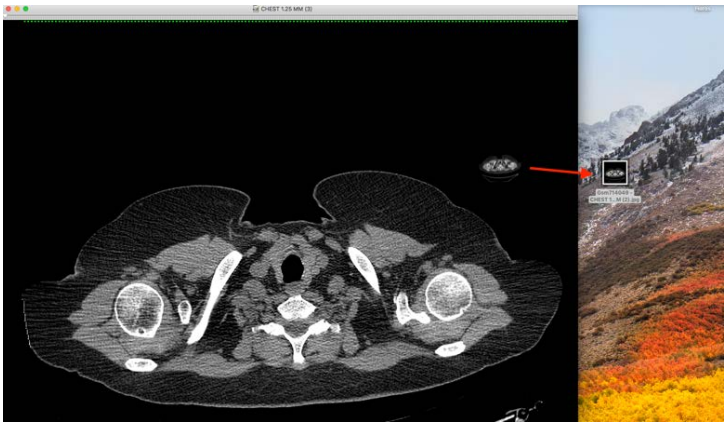


Figure 6.47. The Drag & Drop technique to export an image

Movie Export

You can export a movie of the series by selecting File > Export > Export to Movie or by clicking on the Movie Export icon in the toolbar (Figure 6.48). In either case, Horos brings up the dialog box shown in Figure 6.49, which lets you choose from 2D series, 4D series, Fused series (i.e. a PET-CT), or just Key images in a 2D series. You can also modify the interval and range of the series you wish to include in the movie.

Figure 6.48. The Movie Export icon from the toolbar.

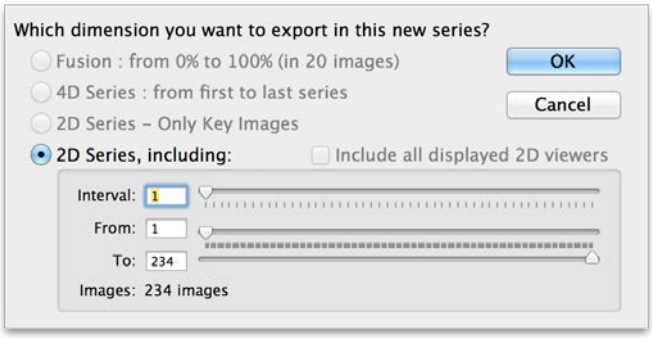


Figure 6.49. The Movie Export dialog box.

If you have several 2D Viewer windows open, clicking on the Include all displayed 2D viewers checkbox in the Movie Export dialog box will create a single movie of the contents of all open windows. In effect, this creates several sub-movies running within a single movie. This type of movie can be very useful for simultaneously viewing the same organ from several planes of view (Figure 6.50). You can hide patient information and other annotations by pressing the tab key during export or by selecting None from Annotations in the toolbar prior to export.

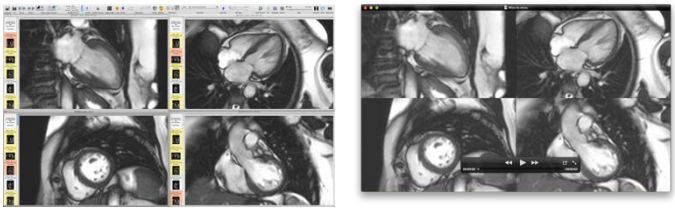


Figure 6.50. The image on the left shows 4 open viewer windows.
The right image shows the exported movie file.

Horos exports QuickTime format (.mov) movies by default. QuickTime movies can then be converted to other formats (MPEG4, WMV) using third party conversion software such the Open Source software Any video Converter or HandBrake. Converting to WMV format produces high quality and compressed movie compatible with Windows.

DICOM Secondary Captures

You can create a secondary capture image in DICOM format that are added to the database. Horos creates a DICOM header for these new images containing the information linked to the corresponding patient and study. A new SeriesInstanceUID (0020, 000e) and SOPInstanceUID (0008, 0018) is created to uniquely identify the files for archiving on a PACS or on another DICOM compatible software.

To generate a secondary DICOM capture, select File > Export > Export to DICOM File(s) or click on the DICOM file icon in the toolbar. As with the Movie Export and Print functions described above, you can choose several options from the DICOM Export options dialog box.

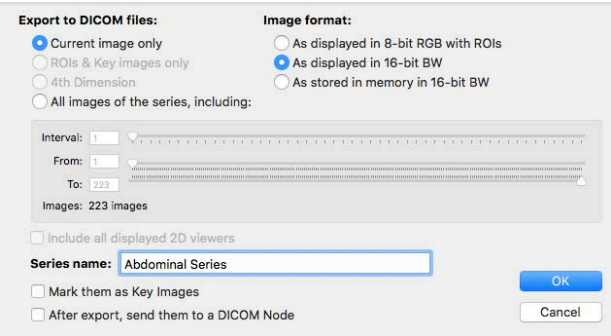


Figure 6.51. The DICOM Export options dialog box.

You can also choose to export only the current image or the entire series as well as ROIs or 4th dimension images if they are available. You can also choose from three image formats:

- As displayed in 8-bit RGB with ROIs - this is a screen capture of the currently displayed image(s), including zoom, pan, ROIs, CLUT, etc. The new image will be encoded in three 8-bit (RGB) channels. In this format, you lose the full 16-bit dynamic.
- As displayed in 16-bit BW - this is a screen capture of the displayed image(s), including zoom, pan, etc. but without the ROIs or CLUT. The image is encoded in a single 16-bit channel, retaining the full 16-bit dynamic: in the case of a CT image you will be able to view a lung window from a screen capture with a mediastinal window.
- As stored in memory in 16-bit BW - this saves the original raw data, without zoom, pan, ROIs, CLUT. The image is encoded in a single 16-bit channel, retaining the full 16-bit dynamic: in the case of a CT image you will be able to view a lung window from a screen capture with a mediastinal window.

As with the Print and Movie export functions, you can truncate the number of images to export in the series using the Interval, From, and To sliders. Finally, there are two additional options that can optimize your workflow. You can choose to mark the newly generated images as Key Images, and you can automatically send them to a DICOM node (See Chapter 9).

Viewing Tools Details

The viewing tools are described in section 6.1. However, this section describes additional details for some of the tools and options in the 2D Viewer.

Window Level & Width Tool

This is a mouse tool that allows you to modify the settings for window level and window width (WL/WW). Click anywhere in the image while holding down the mouse button and move the mouse:

- right to increase the Window Width

- left to decrease the Window Width
- up to increase the Window Level
- down to decrease the Window Level

Window level and window width are also known as brightness and contrast. They are indispensable for viewing large-dynamic DICOM series in black and white. In addition to using the mouse, Horos has a set of predefined settings available through the WL/WW toolbar pop-up menu (Figure 6.52). These presets allow you to quickly move between parameter sets and return to the default WL/WW settings. The presets numbered 1-5 can be triggered using the corresponding number keys on the computer's keyboard. For example, the Abdomen, Bone, and Pulmonary presets are shown in Figure 6.53.

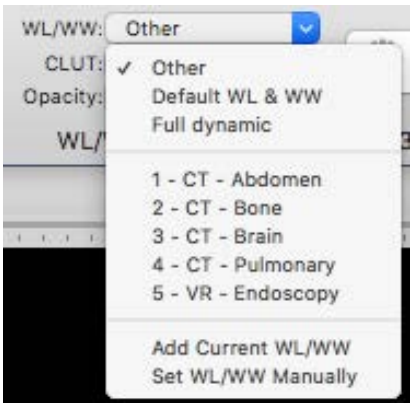
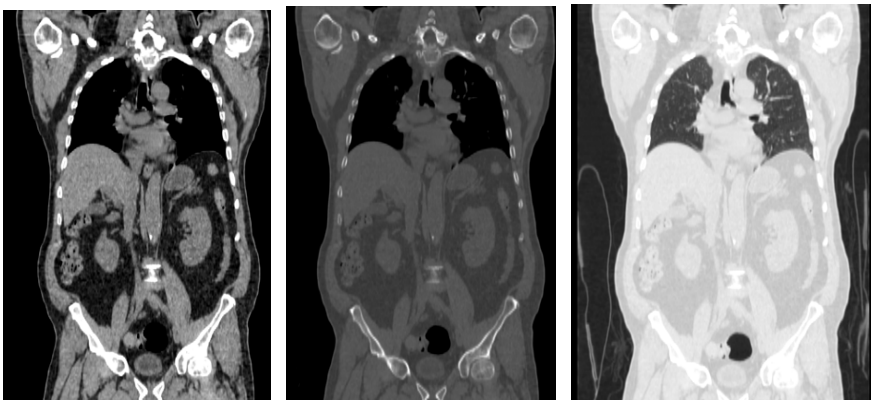


Figure 6.52. The WL/WW popup menu from the toolbar.



(a) Abdomen window *(b) Bone window* *(c) Pulmonary window*

Figure 6.53 Example of different WL/WW presets for the same image.

The two options at the bottom of the dropdown menu allow you to create your own WL/WW presets by using the Add Current WL/WW option. By default, the current WL/WW values are displayed as annotations on the image. You can also remove an item from this menu by holding down the shift key and simultaneously selecting it from the pop-up menu. As a precaution, you will be asked for confirmation before the selected preset is removed.

Color Look Up Table

When you display a series in the 2D Viewer, a CLUT to the pixel data. A CLUT is short for Color Look Up Table. The default CLUT is Black & White (also referred to as No CLUT), which will match black to low intensity pixels, white to high intensity pixels and different levels of grays for the pixel intensities in between. A CLUT table is coded on 8-bit values from 0 to 255. It is applied on the 8-bit image, after the WL/WW are applied. You can also display a color bar on the right of the image to show the colors assigned to each pixel intensity (Fig. 6.54). You can show or hide this bar selecting or deselecting 2D Viewer >Color Look Up Table Bar.

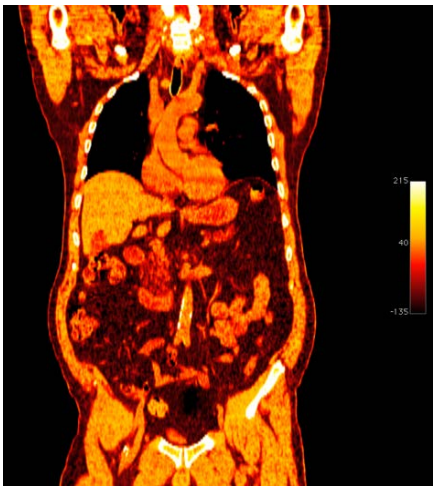


Figure 6.54. The CLUT Bar on the right displays pixel intensities for the Muscles and Bones CLUT.

You can choose from a variety of preset CLUTs (Figure 6.55) by clicking on the CLUT dropdown list in the WL/WW & CLUT tool in the toolbar. Alternatively, you can access the CLUT list by 2D Viewer > Color Look Up Table. Because CLUTs simply assign a new color value to the pixel intensity there is rule for which CLUT to use other than user preference. However, PET series are displayed by default with the B/WW Inverse CLUT or when fused with the PET CLUT. You can change these settings in the PET Preferences (See Chapter 2).

Figure 6.55. The options for preset CLUTS from the WW/WL &CLUT dropdown list in the toolbar.

The following CLUTs are available:

CLUT Name	*0* *255*
No CLUT	
BW Inverse	
BlackBody	
Endoscopy	
Flow	
GEColor	
GrayRainbow	
HotGreen	
HotIron	
HotMetal	
Hue1	
Hue2	
Ired	
Jet	
NIH	
PET	
Rainbow	
Rainbow2	
Rainbow3	
Ratio	
Spectrum	
Stern	
UCLA	
VR Bones	
VR Muscles-Bones	
VR Red Vessels	

Figure 6.56

Navigator

Clicking on the Navigator button (assuming you have added it to your toolbar) displays the Navigator Panel, under the 2D Viewer window. The Navigator panel shows all the images in a series as thumbnails in a single row. If the current 2D Viewer window contains a 4D series, the 4th dimension series will each be displayed in a separate row (Figure 6.57). This panel allows you to quickly review the entire series. You can apply the same shortcut keys and functions to each thumbnail image, for pan, zoom, window levels, and the like.

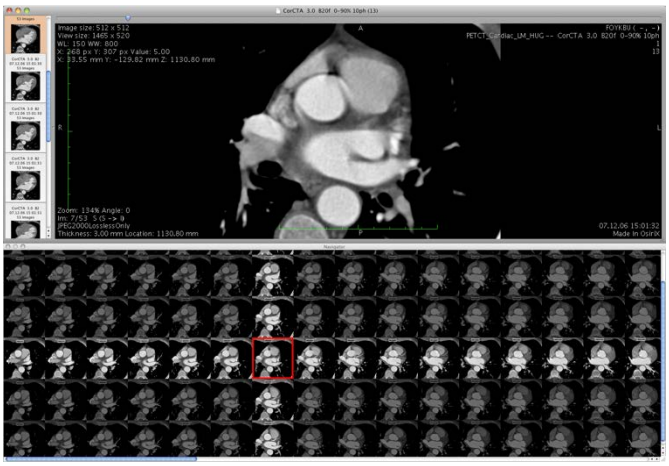


Figure 6.57. The Navigator Panel displayed for a 4D dataset.

Image Subtraction

Digital angiography and some other imaging modes benefit from subtracting a mask image that removes those parts of the image that do not change over time (DSA or Digital Subtraction Angiography). In digital subtraction angiography, for example, the mask is an image taken prior to the injection of a contrast agent administered via a catheter. If the mask is chosen to reflect a loss of contrast material, the subtracted images may appear white, whereas if the mask was chosen to reflected an increase in contrast agent, then the subtracted images will appear dark. Unchanged areas in the images will remain gray.

The dynamic subtraction tool is available from the Format > Custom Toolbar in the Horos menu (Figure 6.58) or from the Horos 2D Viewer menu. This technique takes the numeric value of pixels from one image (the mask) and subtracts them from the remaining images.

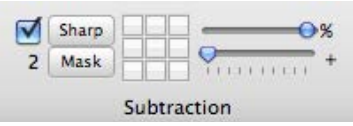


Figure 6.58. The Subtraction tool options.

You can use the subtraction tool to adjust the parameters of the subtraction function. Once you are at the image slice you wish to use as the mask image, go to 2D viewer in the Horos menu and select Subtraction > New Mask from the dropdown list (Figure 6.59). If the Subtraction tool is in your toolbar click on the mask button. This image will then be dynamically subtracted from the remaining images in the series. Pressing the spacebar will display the images in a looped movie with the mask subtracted. To turn on and off the subtraction feature simply click on the on/off checkbox. You can also adjust the percent of subtraction using the small slider at the top of the Subtraction tool. The lower slider bar changes the number of frames to add to the mask. The 3 x 3 boxes shift pixels north, east, south ,or west. These pixel shift options are also available from the 2D Viewer dropdown list (Figure 6.59). An example of a digital subtraction angiogram is shown in Figure 6.60.

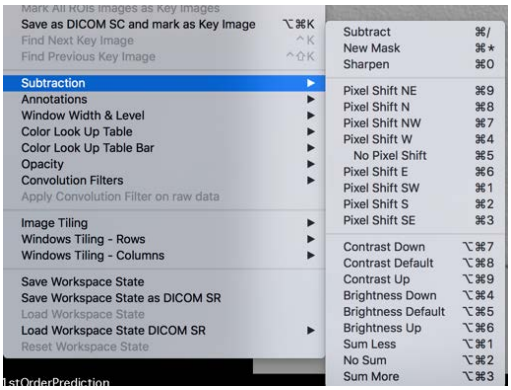


Figure 6.59. The Subtraction options from the 2D Viewer menu list.

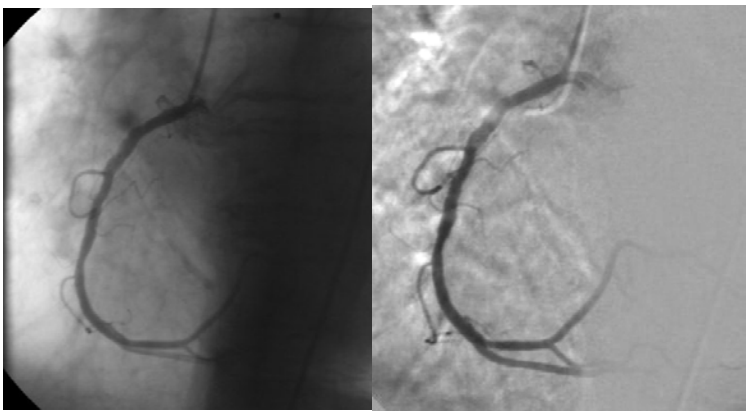


Figure 6.60 An image before (left) and after (right) subtraction.

Image Fusion

Positron emission tomography (PET) generates images of metabolic processes that are clinically useful in detecting cancer and other pathological processes. However, PET images are relatively noisy making small tumors difficult to detect. By fusing a metabolic PET series with a higher resolution CT series, you can precisely register regions of high metabolic activity (Figure 6.61).

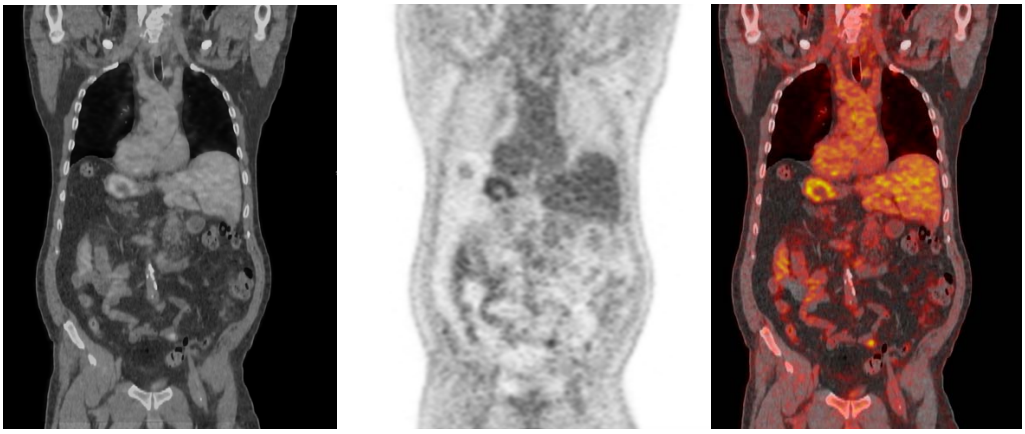

(a) CT *(b) PET* *(c) PET–CT*

Figure 6.61 Fusion of the PET on the CT

You can fuse any series with another so long as both share the same dimensions. For example, you can fuse two 2D series or two 3D series, but not a 2D series with a 3D series. Likewise, a CR cannot be fused on a CT.

Open two series from the same patient, one a CT and the other a PET. Click and hold down the mouse on the title of one of the series (PET in this example) until a small icon with the series tile appears. Drag and drop this icon onto the other series (Figure 6.62). A popup window appears (Fig.6.63) giving you the choice to resample, reorient, or register the two image series.

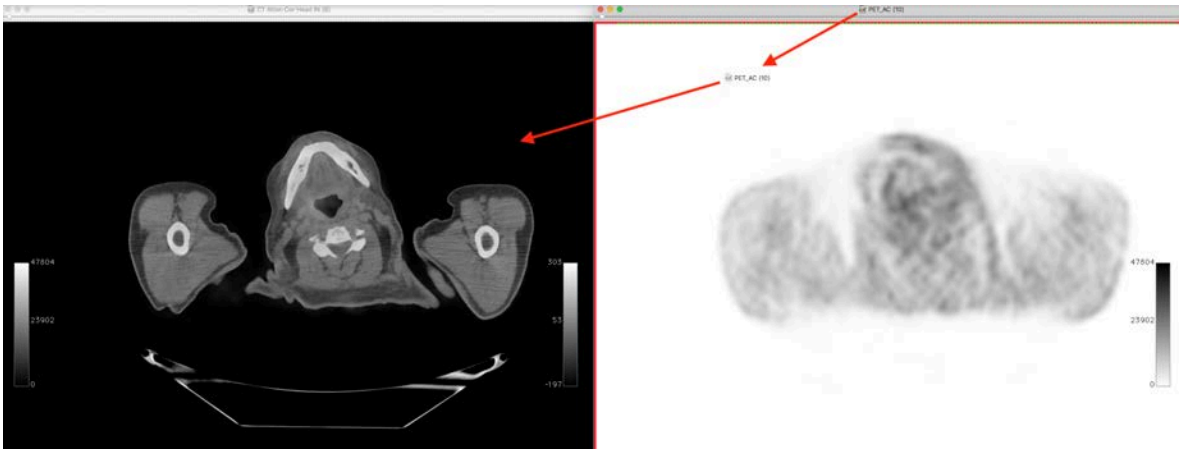


Figure 6.62. Drag and drop the icon from one window to another.

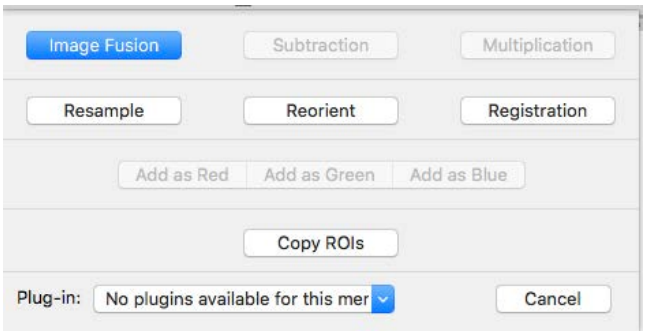


Figure 6.63. The image fusion popup window.

Horos will automatically fuse the PET-CT or SPECT-CT studies when both are open as long as both series are part of the same study. Automatic fusing can be turned on or off in the PET Preferences or using the Fuse/De–Fuse PET/SPECT – CT option from the 2D Viewer menu (⇧ ⌘ F shortcut).

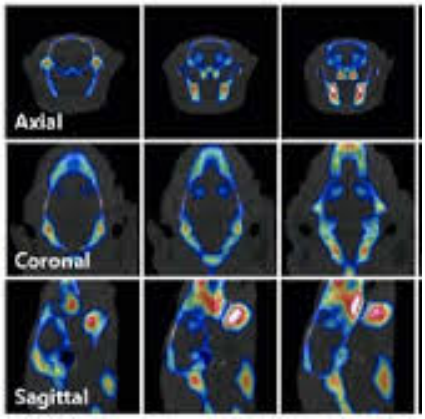


Figure 6.64. A PET–CT study in three planes.

3D Position

Occasionally, the fused images are misaligned. You can manually correct the alignment using the 3D Position tool found in the 2D Viewer menu (Figure 6.65). The 3D Position tool allows you to nudge the two image stacks up, down, left and right by clicking on the arrows or by clicking and holding the thumbnail icon in the middle. These adjustments can be made in the axial, coronal and sagittal planes by selecting the plane from the list on the left.

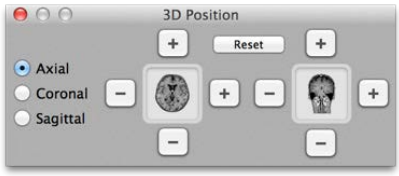


Figure 6.65. The 3D Position Panel

Series Registration

You use the 3D Position Panel (Figure 6.65) to register two 3D datasets along the orthogonal axis. However, sometimes you may need to scale and rotate images to properly register two 3D datasets (i.e., when registering a coronal MR series with an axial CT series).

Horos allows you to use a point-based registration algorithm, based on Horn registration algorithm [6]. You can do this by selecting the Point ROI tool from the Mouse button function too in the toolbar. Then click on matched pairs of points in each of the series. Be careful to ensure that the label of the point in one series matches the same point in the other image series. Each pair of points will be assigned sequential numbers as they are added.

Three pairs of points are needed to realign one image set over another. This technique uses a rigid registration method; it that applies scaling, rotation and translation transforms, but not warping or local image deformations to match the selected points. The point-based registration uses a transformation matrix computed via the Horn registration algorithm [6].

To complete the point-based registration, drag and drop one series over the other (as described above, grab the small icon located on top of its window and drop it onto the target series window). When the image fusion dialog box appears (Figure 6.66), press the Point-Based Registration button to realign the series using the 3D point ROIs you selected.

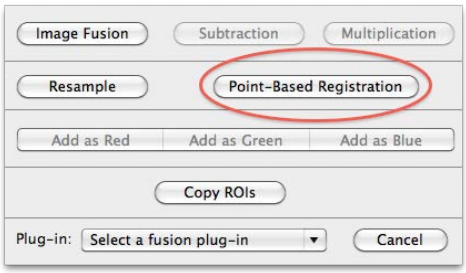


Figure 6.66 The Point-Based Registration function.

Image Stitching

Studies often come with different image series covering different parts of the body (i.e. a thoracic series and an abdominal series. In Horos, you can use the image fusion tool to stitch multiple series into a single larger image (Figure 6.67). Image stitching is particularly useful for viewing merged series in coronal or sagittal views.

To merge a thoracic MR with an abdominal MR drag and drop the thoracic MR series onto the abdominal series as described above for image fusion. Then select Flatten Fused Images from the 2D Viewer Menu. The raw data for the thoracic MR and the abdominal MR are now merged and can be processed as any other 3D dataset. For example, you can apply MPR or save it as a new 3D series in the database. Planar CT images can also be merged.

You may need to crop the original images using the shutter too if the image intensities of the two series are very different. This avoids edges caused by intensity differences.

Figure 6.67. Image Stitching.

Annotations

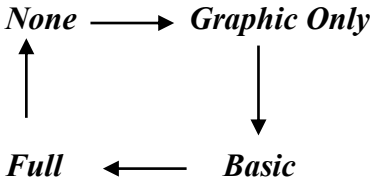
The 2D Viewer displays several annotations on the image, including:

- *Textual labels (WL/WW, zoom, patient name...)*
- *ROIs*
- *CLUT bar*
- *Cross Reference Lines*
- *Scale bars*

You can hide some or all of the annotations by selecting Annotations from the 2D Viewer menu. The options are:

- ***None*** — only the image is displayed
- ***Graphics Only*** — no textual label is displayed
- ***Basic*** — all textual labels are displayed, except the patient name.
- ***Full*** — all textual labels are displayed
- ***Plugin Only*** — some plugins can display information on the image.

You can also activate these annotation options using the tab key on the keyboard. Pressing the tab key sequentially changes the option in a cyclical manner. For example, if the current state is None, pressing the tab key will switch the state to Graphics Only. Pressing tab again switches the state from Graphics only to Basic, pressing tab a third time switches the state from Basic to Full annotation, and pressing tab a fourth time cycles the annotation state back to None. The tab key does not activate the Plugin Only state.



The Annotations > Display Cross Reference Lines item in the 2D Viewer list also allows you to display or to hide the cross-reference lines. Selecting Color Look Up Table Bar from the 2D Viewer list toggles on or off the CLUT bars.

You can modify textual annotations to display any DICOM or database fields. For example, you can display mAs and KV for a CT study or the MR sequence for a MR study. You can also modify font size and typeface for textual annotations using Format > Font.

Shutter Tool

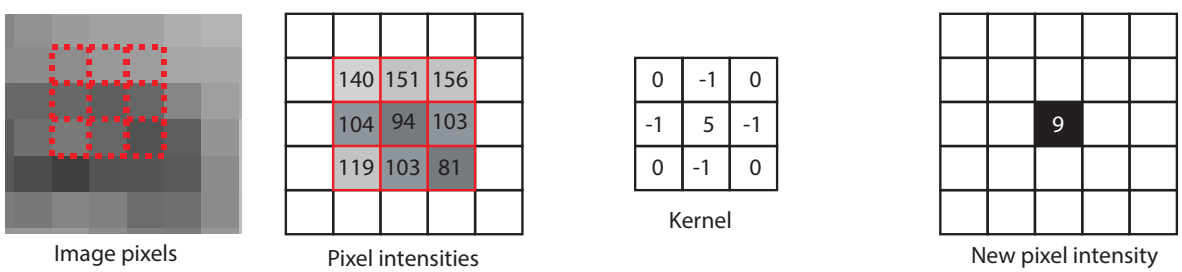
You can reduce the size of the displayed area (without deleting any original data) using the shutter tool (Figure 6.68). The shutter tool is available from the custom tools using Format > Custom tools in the 2D Viewer menu. To use the shutter tool, first choose the Rectangle ROI

tool from the mouse button items and draw a rectangle enclosing the area you want to keep. Clicking on the shutter tool icon makes everything outside the rectangle black.

Figure 6.68. The shutter tool icon from the custom tools.

Convolution Filters

Images can be enhanced by image processing using pre-configured filters to smooth, blur, sharpen, etc. These filters operate in the same way as filters in Photoshop or Gimp. Each filter uses a 3 x 3 or 5 x 5 matrix of pixels. The filter takes the original value of each pixel in the matrix and multiplies it by the corresponding value in the kernel (an array of numeric values). For example, suppose you have an image with the intensity values (from 0 -255 in gray scale) shown on the left in Figure 6.69. The central pixel has an initial value of 94. The filter will multiply the initial pixel value of 94 and its 8 surrounding neighbors by the values in the 3 x 3 kernel (shown in the center of Figure 6.69. The filter will begin in the upper left corner with pixel 140, work across the top row, then jump back to the left side of the middle row and continue until it reaches pixel 81 in the lower right. Thus, the central pixel with an initial value of 94 will become a pixel with a filtered value of 9 because (140 x 0) + (151 x $^{-}$1) + (156 x 0) + (104 x $^{-}$1) + (94 x 5) + (103 x $^{-}$1) + (119 x 0) + (103 x $^{-}$1) + (81 x 0) = 9. The filter actually works on a copy of the image so the original data is preserved. The kernel of the filter, is an array of numeric values, which in this case is the sharpen kernel.



9 = (140 x 0) +(151 x -1) + (156 x 0) +(104 x -1) + (95 x 5) + (103 x -1) + (119 x 0) + (103 x -1) + (81 x 0)

Figure 6.69. Convolution filers using the sharpen kernel.

In general terms, let A(m,n) be the pixels matrix of an image of size m × n:

$$\mathbf{A}_{(m,n)} = \begin{bmatrix} a_{(1,1)} & a_{(1,2)} & \cdots & a_{(1,n)} \\ a_{(2,1)} & a_{(2,2)} & \cdots & a_{(2,n)} \\ \vdots & \vdots & \ddots & \vdots \\ a_{(m,1)} & a_{(m,2)} & \cdots & a_{(m,n)} \end{bmatrix}$$

This matrix might represent a 512 x 512 pixel image, where m = 512 and n = 512.
and K the kernel of a convolution filter of size 3 × 3:

$$K = \begin{bmatrix} k_{(1,1)} & k_{(1,2)} & k_{(1,3)} \\ k_{(2,1)} & k_{(2,2)} & k_{(2,3)} \\ k_{(3,1)} & k_{(3,2)} & k_{(3,3)} \end{bmatrix}$$

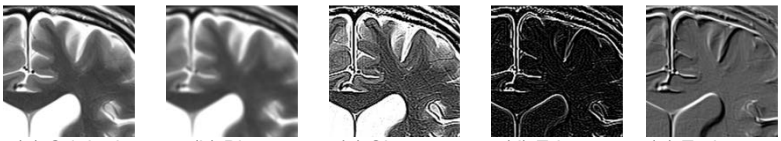
The resulting image is also of size m × n and the pixel at position i, j is computed as follows:

$$B_{(i,j)} = k_{(1,1)} \bullet a_{(i-1,j-1)} + k_{(1,2)} \bullet a_{(i-1,j)} + k_{(1,3)} \bullet a_{(i-1,j+1)} + k_{(2,1)} \bullet a_{(i,j-1)} + k_{(2,2)} \bullet a_{(i,j)} + k_{(2,3)} \bullet a_{(i,j+1)} + k_{(3,1)} \bullet a_{(i+1,j-1)} + k_{(3,2)} \bullet a_{(i+1,j)} + k_{(3,3)} \bullet a_{(i+1,j+1)}$$

There are four categories of filters in Horos: the blurring filters, the sharpening filters, the edges detection filters and the embossing filters (Table 5.2). Table 5.2. groups the filters according to their kernel size (3 × 3 or 5 × 5). The effects of these four groups of filters are illustrated in Figure 6.70. The details for each filter are described in the next section.

	Blur	***Sharpen***	***Edges***	***Emboss***
3 x 3:	***Blur 3x3*** ***Lowpass***	***Bone Filter*** ***Excessive Sharpen 3x3***	***Edges 3x3*** ***Laplacian 4*** ***Laplacian 8***	***Emboss*** ***Emboss*** ***Emboss heavy*** ***Emboss north*** ***Emboss west***
5 x 5:	***Basic Smooth*** ***Blur 5x5*** ***Gaussian blur*** ***Inverted blur*** ***Negative blur***	***Highpass 5x5*** ***Sharpen 5x5***	***Hat*** ***Laplacian***	

Table 5.2: The convolution filters.



(a) Original (b) Blur (c) Sharpen (d) Edges (e) Emboss

Figure 6.70. Illustration of the different categories of filters available in Horos. The original image is shown in a.

New filters can be added by selecting the Add Filter item from the Convolution Filters drop-down list under the 2D Viewer menu (Figure 6.71). Alternatively, existing filters can be edited by selecting it from the list while holding down the option key (alt).

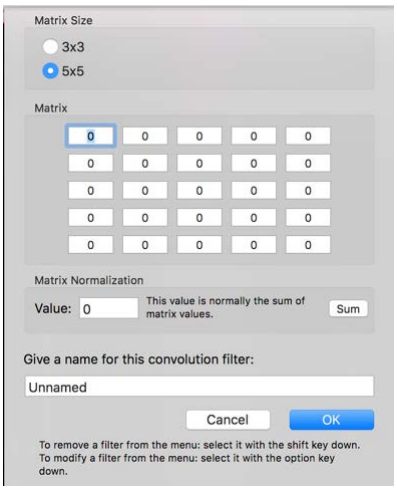


Figure 6.71. The convolution filter edit panel.

From the convolution filter edit panel you can choose the size of the kernel and set the values in the matrix. You can also set the matric normalization factor and give your filter a new name. Clicking OK adds your new filter to the filters list. You can remove a filter from the list by selecting it while also holding down the shift key on the keyboard.

Smoothing & Blurring Filters

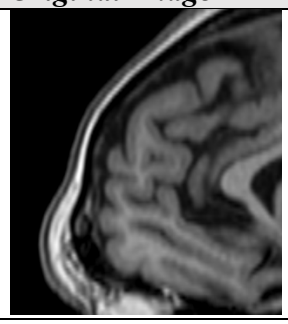
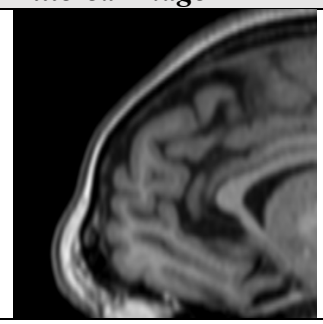
Kernel	***Original Image***	***Filtered Image***
$1/16 \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$		

Table 6.3. The Blur 3 x 3 filter.

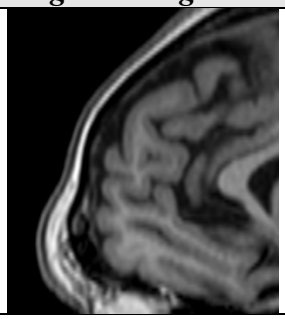
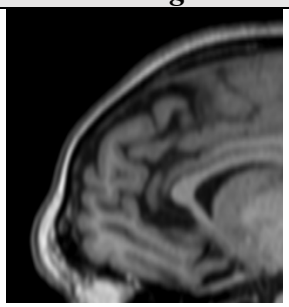
Kernel	*Original Image*	*Filtered Image*
$1/9 \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$		

Table 6.4. The Lowpass filter.

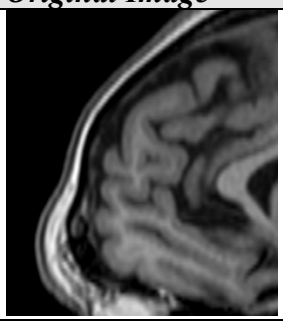
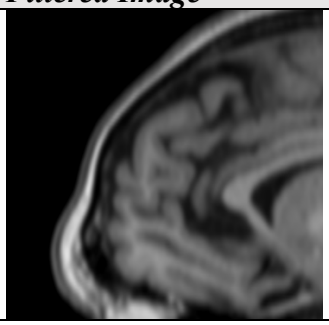
Kernel	*Original Image*	*Filtered Image*
$1/60 \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 4 & 4 & 4 & 1 \\ 1 & 4 & 12 & 4 & 1 \\ 1 & 4 & 4 & 4 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$		

Table 6.5. The Basic smooth 5 x 5 filter.

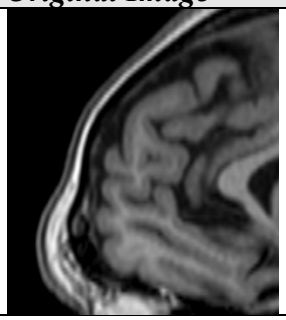
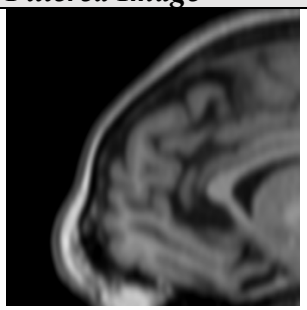
Kernel	*Original Image*	*Filtered Image*
$1/44 \begin{bmatrix} 1 & 1 & 2 & 1 & 1 \\ 1 & 2 & 3 & 2 & 1 \\ 2 & 3 & 4 & 3 & 2 \\ 1 & 2 & 3 & 2 & 1 \\ 1 & 1 & 2 & 1 & 1 \end{bmatrix}$		

Table 6.6. The Blur 5 x 5 filter.

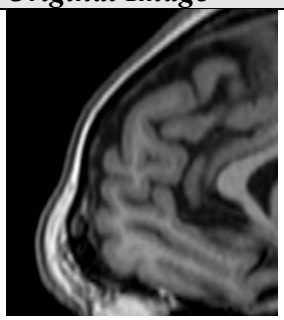
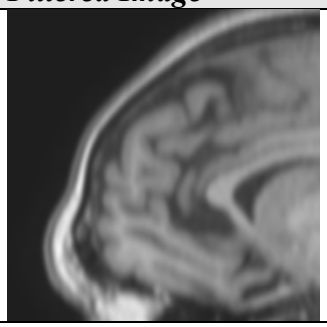
Kernel	*Original Image*	*Filtered Image*
$1/52 \begin{bmatrix} 1 & 1 & 2 & 1 & 1 \\ 1 & 2 & 4 & 2 & 1 \\ 2 & 4 & 8 & 4 & 2 \\ 1 & 2 & 4 & 2 & 1 \\ 1 & 1 & 2 & 1 & 1 \end{bmatrix}$		

Table 6.7. The Gaussian blur filter.

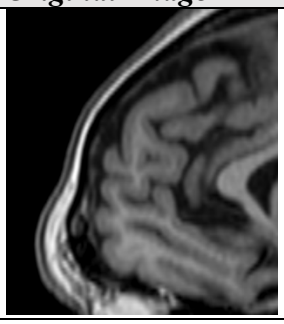
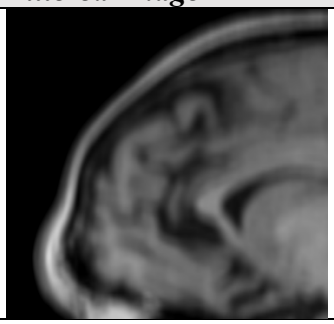
Kernel	*Original Image*	*Filtered Image*
$1/56 \begin{bmatrix} 3 & 3 & 2 & 3 & 3 \\ 3 & 2 & 1 & 2 & 3 \\ 2 & 1 & 0 & 1 & 2 \\ 3 & 2 & 1 & 2 & 3 \\ 3 & 3 & 2 & 3 & 3 \end{bmatrix}$		

Table 6.8. The Inverted blur filter.

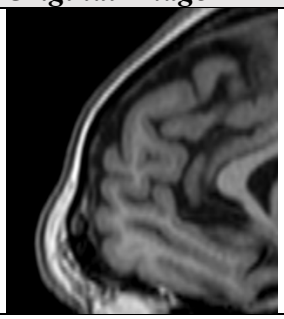
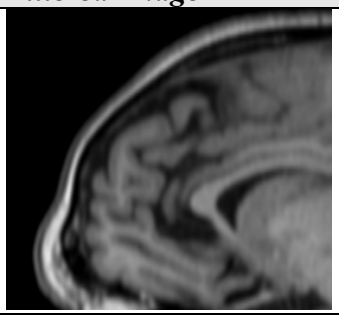
Kernel	*Original Image*	*Filtered Image*
$1/19 \begin{bmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 2 & 1 & 0 \\ 1 & 2 & 3 & 2 & 1 \\ 0 & 1 & 2 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix}$		

Table 6.9. The Negative blur filter.

Sharpening Filters

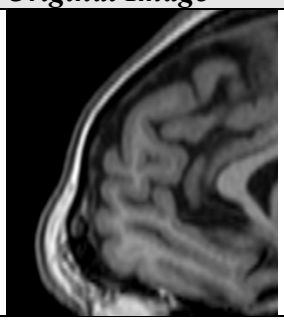
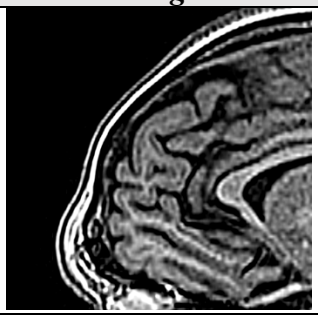
Kernel	*Original Image*	*Filtered Image*
$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{bmatrix}$		

Table 6.10. The Bone 3 x 3 filter.

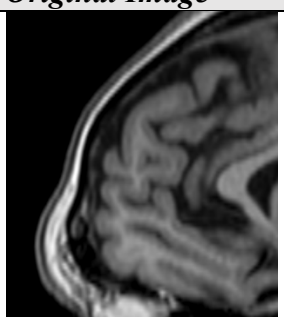
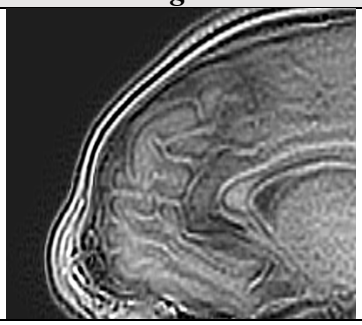
Kernel	*Original Image*	*Filtered Image*
$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 7 & 1 \\ 1 & 1 & 1 \end{bmatrix}$		

Table 6.11. The Excessive edges filter.

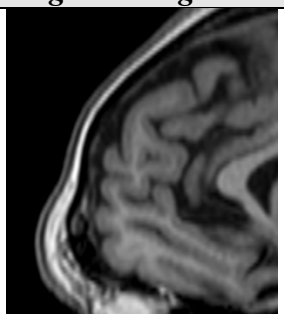
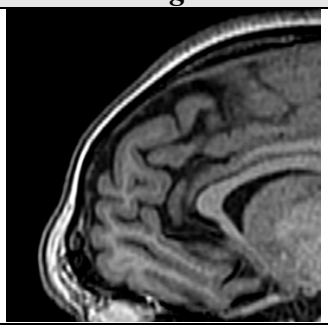
Kernel	*Original Image*	*Filtered Image*
$1/3 \begin{bmatrix} -1 & 0 & -1 \\ 0 & 7 & 0 \\ -1 & 0 & -1 \end{bmatrix}$		

Table 6.12. The Sharpen 3 x 3 filter.

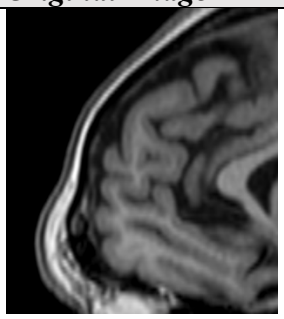
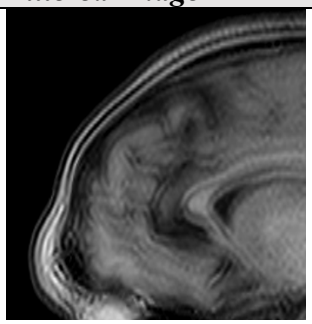
Kernel	*Original Image*	*Filtered Image*
$1/7 \begin{bmatrix} 0 & 1 & 1 & 1 & 0 \\ 1 & -2 & 4 & -2 & 1 \\ 1 & 4 & -13 & 4 & 1 \\ 1 & -2 & 4 & -2 & 1 \\ 0 & 1 & 1 & 1 & 0 \end{bmatrix}$		

Table 6.13. The Highpass 5 x 5 filter.

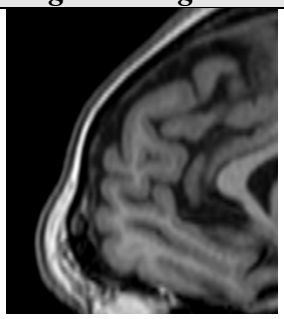
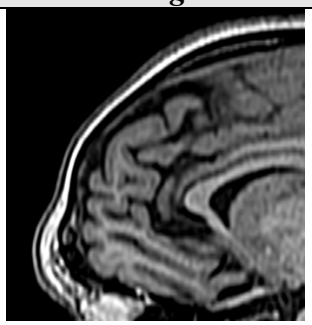
Kernel	*Original Image*	*Filtered Image*
$\frac{1}{8}\begin{bmatrix} -1 & -1 & -1 & -1 & -1 \\ -1 & 2 & 2 & 2 & -1 \\ -1 & 2 & 8 & 2 & -1 \\ -1 & 2 & 2 & 2 & -1 \\ -1 & -1 & -1 & -1 & -1 \end{bmatrix}$		

Table 6.14. The Sharpen 5 x 5 filter.

Edge Filters

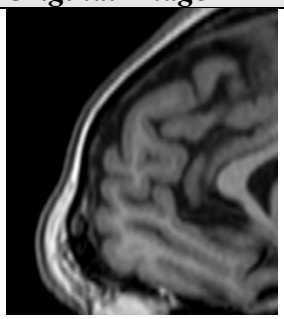
Kernel	*Original Image*	*Filtered Image*
$\begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix}$		

Table 6.15. The Edges 3 x 3 filter.

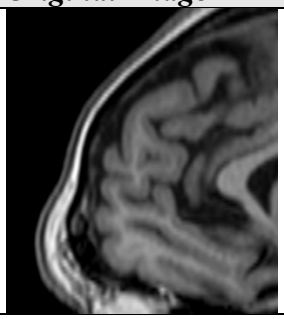
Kernel	*Original Image*	*Filtered Image*
$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$		

Table 6.16. The Laplacian 4 filter.

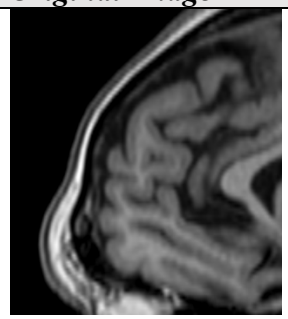
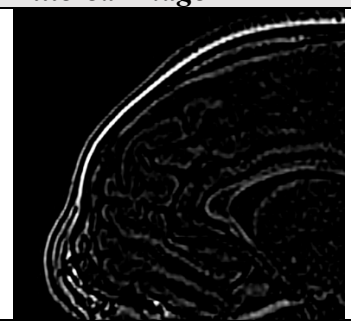
Kernel	***Original Image***	***Filtered Image***
$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$		

Table 6.17. The Laplacian 8 filter.

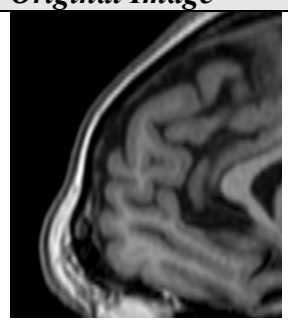
Kernel	***Original Image***	***Filtered Image***
$\begin{bmatrix} 0 & 0 & -1 & 0 & 0 \\ 0 & -1 & -2 & -1 & 0 \\ -1 & -2 & 16 & -2 & -1 \\ 0 & -1 & -2 & -1 & 10 \\ 0 & 0 & -1 & 0 & 0 \end{bmatrix}$		

Table 6.18. The Hat filter.

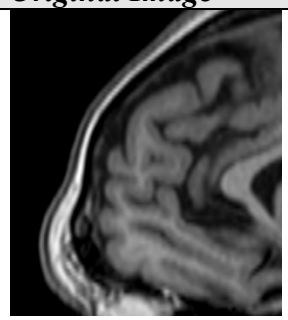
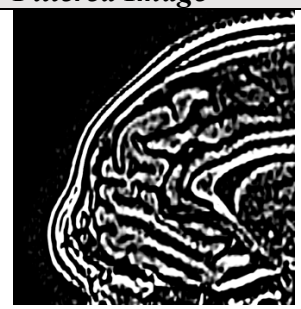
Kernel	***Original Image***	***Filtered Image***
$\begin{bmatrix} -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & 24 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \end{bmatrix}$		

Table 6.19. The Laplacian filter.

Emboss Filters

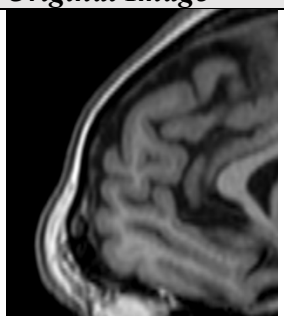
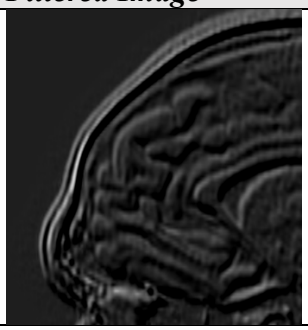
Kernel	***Original Image***	***Filtered Image***
$\begin{bmatrix} -1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$		

Table 6.20. The Emboss filter

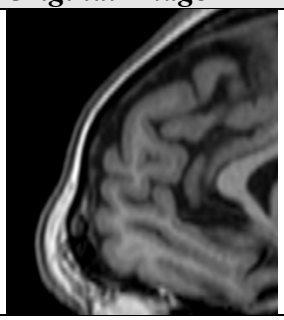
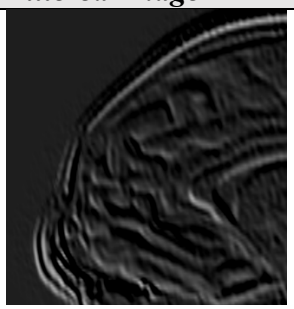
Kernel	***Original Image***	***Filtered Image***
$\begin{bmatrix} 0 & 1 & 0 \\ -1 & 0 & 1 \\ 0 & -1 & 0 \end{bmatrix}$		

Table 6.21. The Emboss diagonal filter.

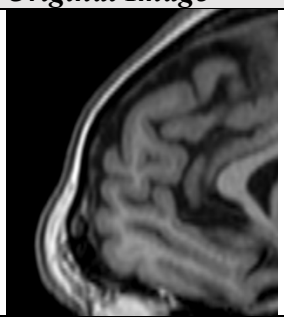
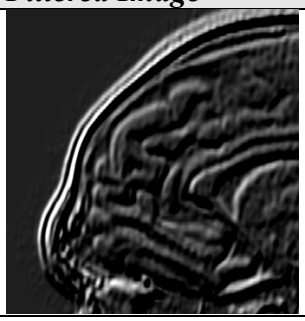
Kernel	***Original Image***	***Filtered Image***
$\begin{bmatrix} -1 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 1 \end{bmatrix}$		

Table 6.22. The Emboss heavy filter

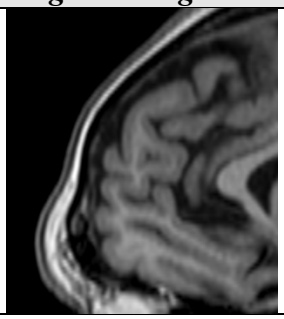
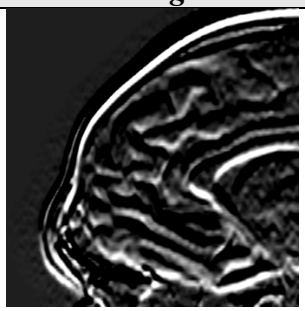
Kernel	*Original Image*	*Filtered Image*
$\begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$		

Table 6.23. The Emboss north filter.

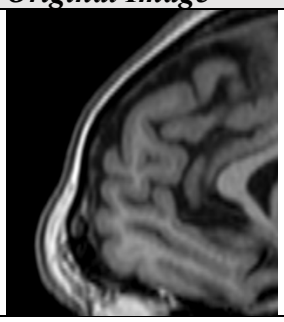
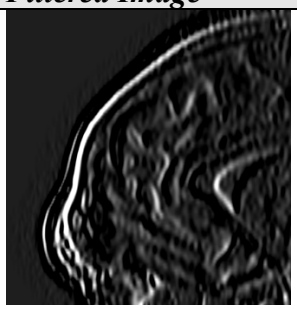
Kernel	*Original Image*	*Filtered Image*
$\begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}$		

Table 6.24. The Emboss west filter.

Using a 12-bit Totoku Monitor

You can use high-dynamic monitors, such as Totoku monitors with Horos. These monitor displays a higher BW dynamic than RGB screens. Thus, these monitors display approximately 12 bits to represent each pixel, for black and white this means 4096 levels of gray as opposed to only 256 levels of gray for 8 bits. However, this feature requires a Totoku screen, a modern GPU such as ATI Radeon or Nvidia FX, and a Totoku plugin (the plugin can be found in the Plugin Manager). With these installed, a new toolbar item called Display type will be available in the 2D viewer >Format >Custom toolbar. Placing the Display type tool in your toolbar, will allow you to switch from the standard 8 bit display to the high-dynamic 12 bit display. If you are using several monitors, make sure you move the 2D Viewer window to the Totoku screen.

ROI Quantification Tools

Recall that ROI stands for Region Of Interest and is used in Horos to describe a measurement, an area or an annotation. There are several different types of ROIs and ROI tools in Horos. An ROI is an object overlaid on top of the displayed image (but not added to the raw image data). Horos stores these ROIs as DICOM SR encapsulated files. This allows you to transport the ROIs are

DICOM compliant files over a DICOM network. However, note that the ROI description in the file may be unreadable by other software.

To draw an ROI on an image, you click on the small gray triangle on the right of the Mouse button function icon in the 2D Viewer toolbar (Figure 6.72). This displays the list of ROI tools (Figure 7.72)

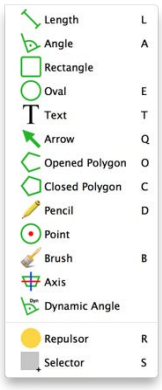
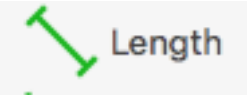


Figure 6.72. The ROI tool list.

You can also access the ROI tools using the 2D Viewer menu by right clicking on the viewer and choosing an appropriate ROI tool from the sub menu. Each ROI tool also has a keyboard shortcut (shown as a letter to the right in figure 6.72). Keyboard shortcuts can be modified through the Hot Keys Preferences (See Chapter 2). Each ROI tool is described in order from top to bottom below.



Length ROI

You can draw simple lines and compute its linear measurement using the Length ROI tool. Click on the point on the image where the line is to begin and, keeping the mouse button pressed, drag the mouse to the point where the line is to end. When you release the mouse button the lines length is displayed. Depending on the pixel information attached to the DICOM image, the length is displayed in cm, or in µm for values smaller than 1 mm, or in pixels (Figure 6.73)

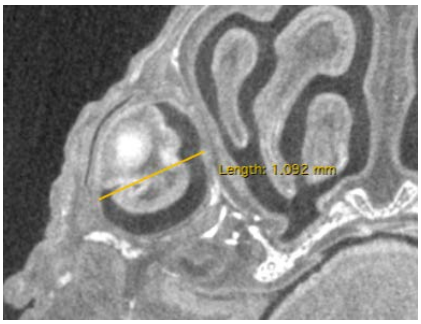
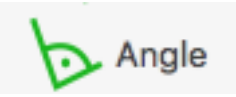


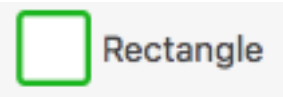
Figure 6.73. A microCT scan of a bat embryo with the eye width displayed in millimeters.



Angle ROI

You can draw and measure angles using the Angle ROI tool. Drawing angles requires three click on the image to define the 3 points of the angle (Figure 6.74).

Figure 6.74. The Angle ROI tool.

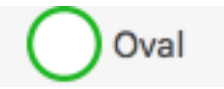


Rectangle ROI

You can use the rectangle ROI tool to draw rectangles or squares and to compute their area (figure 6.75). Click on one of its corners and keep the mouse button pressed while dragging to the opposite corner. When the mouse button is released, the area, width, height, mean, standard deviation, sum, minimum value, and maximum valure are displayed in a box to the side.

Figure 6.75. The Rectangle ROI tool.

If pixel dimensions are available from the DICOM file, area is given in cm^2 or in μm^2 (for values less than 1 mm^2). Otherwise, the values are given in square pixels and pixels respectively. The rest of the statistical values are in pixels.



Oval ROI

You can draw ellipse on an image and to compute its area. Click and hold on the image where you want the center point of the ellipse and drag the mouse away from the center to define the size and eccentricity of your ellipse. When you release the mouse button, the ROI is validated and information on its area, mean, standard deviation, sum, minimum value and maximum value are displayed (Figure 6.76). If pixel dimensions are available from the DICOM file, area is given in cm^2 or in μm^2 (for values less than 1 mm^2). Otherwise, the values are given in square pixels and pixels respectively. The rest of the statistical values are in pixels.

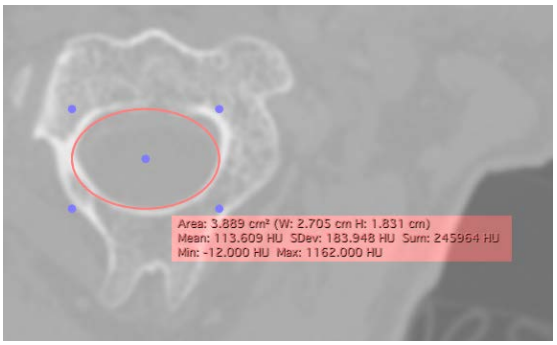


Figure 6.76. The Oval ROI tool.

Text ROI

You can add text annotations to an image by clicking anywhere on an image; the text label will be centered at this location. To edit the text, simply double click and enter the information in the popup window. The ROI Info Panel will also allow you to change the size (thickness), color, and opacity of the text.

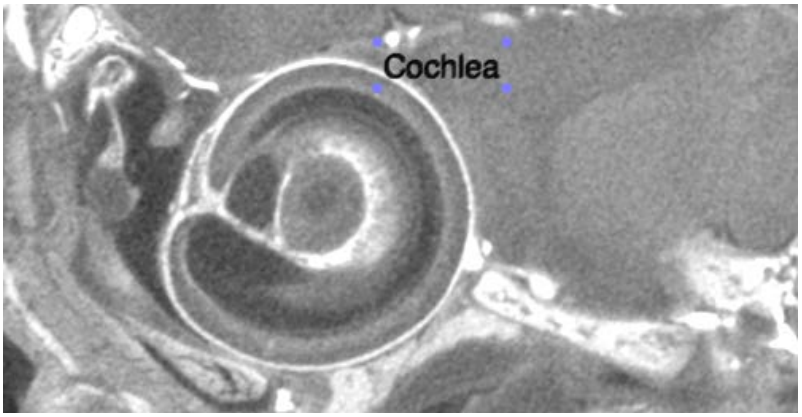
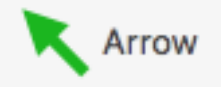
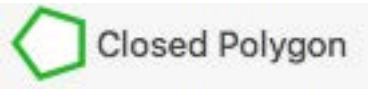


Figure 6.77. The Text tool.



Arrow ROI

You can add arrows to an image by clicking and dragging the mouse. Begin at the point where you want the arrowhead and drag away the desired length.



Closed Polygon ROI

You can create a closed polygon with as many corners as you desire. Begin by clicking on a point on the image you would like to enclose in a polygon. Continue to click to add corners to the polygon until you have nearly enclosed it. Finish by double clicking on the last point. This creates a closed polygon with information on area, perimeter (length), mean, standard deviation, sum, and maximum and minimum values for the polygon (Figure 6.78).

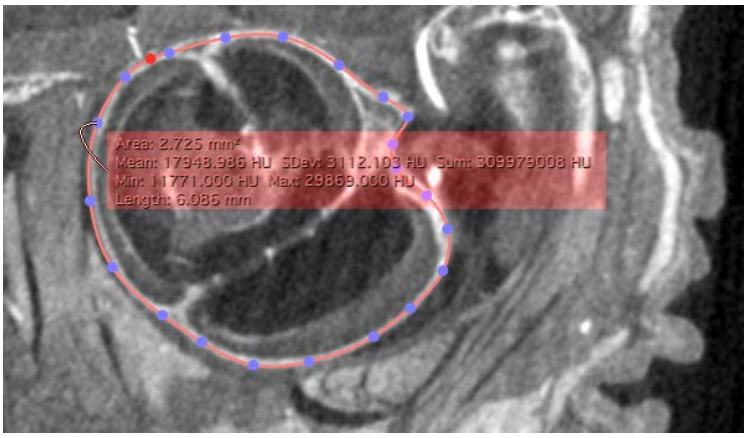
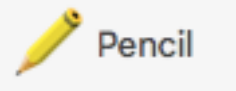


Figure 6.78. The Closed polygon tool with the statistical information displayed.

If pixel dimensions are available from the DICOM file, area is given in cm^2 or in μm^2 (for values less than 1 mm^2). Length is given in cm or µm. Otherwise, the values are given in square pixels and pixels respectively. The rest of the statistical values are in pixels.

Opened Polygon ROI

The Opened Polygon tool is similar to the Closed Polygon tool except that the first and last points are not connected. Double clicking on the last point displays the length of the line.



Pencil ROI

You can create a closed polygon with the Pencil ROI tool, however the pencil tool is used differently. With the pencil tool selected, click and hold the mouse button on the starting point and drag the mouse along a path to enclose the structure you wish to measure. Releasing the mouse button completes the ROI and brings up information such as area, perimeter length, etc. (Figure 6.79).

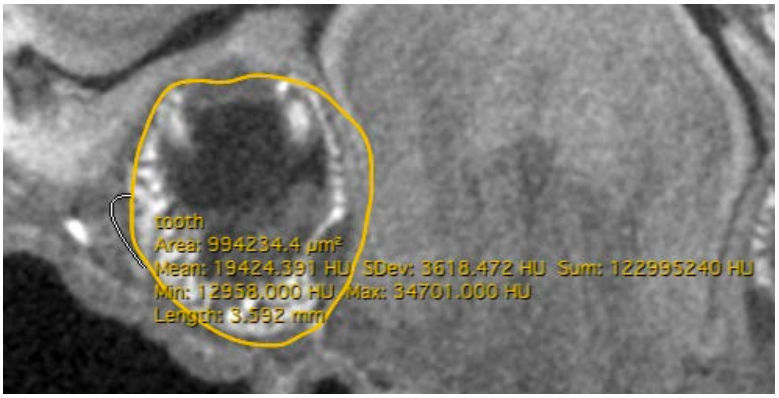
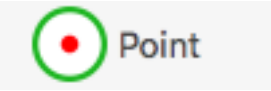


Figure 6.79. An area outlined using the pencil tool.



Point ROI

The Point ROI tool allows to get data on single pixels in an image. Clicking on a point in the image brings up a box that displays the pixel value, along with its 2D (x, y) and 3D (x, y, z) positions in pixels (Figure 6.80). 2D positions are given in pixels and 3D positions are given in mm. Note that Point ROIs will also be visible on the 3D Volume Rendering, 3D Surface Rendering tools (see the specific sections for more details).

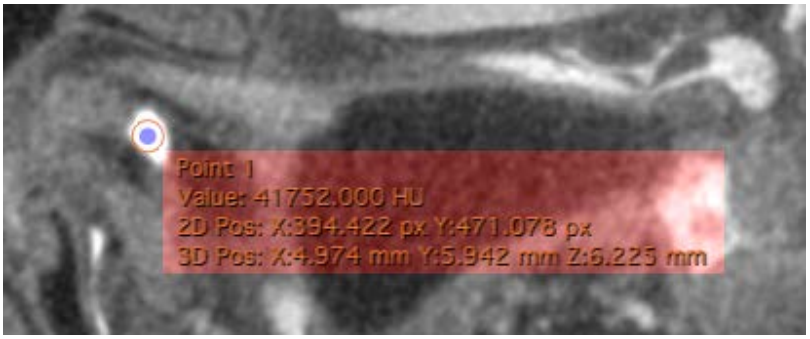
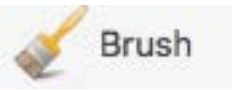


Figure 6.80. The point ROI tool.



Brush ROI

The brush ROI tool allows you to paint a region on the image by clicking and dragging the mouse with the button held down. When the region has been painted, simply release the mouse button. When you first select the brush tool a popup window appears (Figure 6.81) which allows you to adjust the size of the brush for more precision. Clicking on the erase button in the popup tool converts the brush to an eraser and allows you to remove regions you previously painted. Double clicking on the brushed region brings up the ROI info panel which allows you to name the region, change the brush color, modify the opacity among other options (Figure6.82).

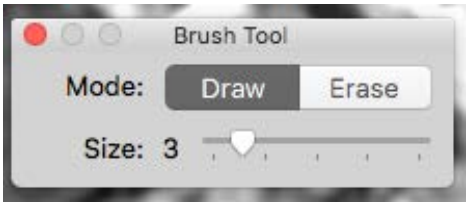


Figure 6.81. The Brush tool popup window.

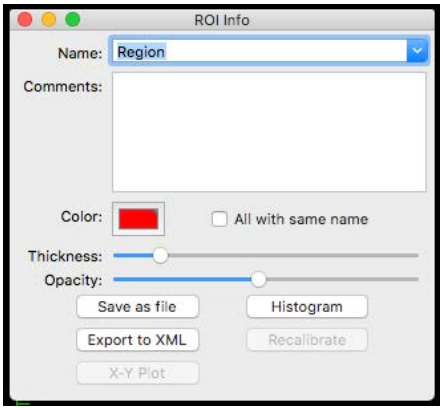


Figure 6.82. The ROI info panel.

Unlike other ROI tools, the brush ROI cannot be resized or rotated. It is attached to its underlying pixels. Completed brush ROIs also display information on area, mean, standard deviation, sum, and maximum and minimum pixel values. If pixel dimensions are available from the DICOM file, area is given in cm^2 or in μm^2 (for values less than 1 mm^2), or in square pixels. The rest of the statistical values are in pixels.

Axis ROI

The mean axis is calculated and displayed based on four points.

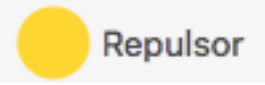
Dynamic Angle ROI

The Dynamic angle tool calculates the angle between two lines. Each line is defined by two points (the first two points define line 1 and the last two points define line 2). The angle between those lines is displayed in an info box along with its opposite angle. The sum of these two angles is equal to 360 degrees.

Perpendicular Lines ROI

The Perpendicular Lines ROI generates three lines, A, B, and C. Lines B and C are parallel to each other and orthogonal to line A (figure 6.83). Each line terminates in a small dot, which you can grab with the mouse and move. An info box provides information of the length of each line as well as the length between lines B and C in cm.

Figure 6.83. The perpendicular lines ROI.



Repulsor Tool

Although the Repulsor tool is found at the bottom of the ROI tools list, it does not create an ROI. Instead, it is used to modify the shape of existing ROIs on an image. The Repulsor only works with the Length, Opened Polygon, Closed Polygon and Pencil ROIs.

Assuming you have an appropriate ROI on an image, select the repulsor tool and click on the image while holding down the mouse button. The repulsor is a pulsing yellow circle. Note that when clicking close to the ROI, the radius of the Repulsor appears small and when clicking far from the ROI, the radius is large. With your mouse button still held down, drag your repulsor circle toward the ROI. The repulsor re-shapes the ROI border. Releasing the mouse button causes the repulsor circle to disappear, but clicking again on a new location brings the repulsor tool back. ROIs that are not currently selected will not be affected by the repulsor tool (use the

Selector tool to select ROIs). Note that you can also position the repulsor inside a closed polygon and push the border from within.

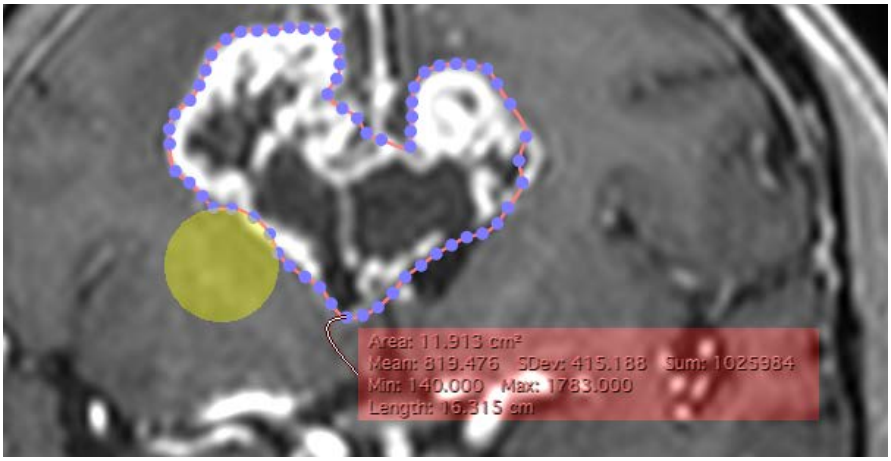


Figure 6.84 The Repulsor tool modifying a Polygon ROI created with the Pencil ROI tool. The ROI info box is shown in the lower right.

Selector Tool

The Selector tool is a special tool that does not create ROIs. As its name implies, the Selector allows you to select ROIs by clicking on an ROI, or by clicking and dragging the mouse to create a selection rectangle. All ROIs within, or partially within, the selection area will be selected.

ROI Info Box

Horos displays an info box next to each ROI containing several statistics, such as area, length, etc. The kind of statistics depends on the type of the ROI. For example, the closed polygon shown in Figure 6.84 has an info box displaying area, mean, sdev, sum, min, max, and length. Clicking on an info box will select its ROI.

If you have a large number of ROIs, each with an info box, it can sometimes obscure important parts of the image. You have two options (available from the ROI menu) to handle this problem in Horos:

> *Display Info Only when ROI Selected hides all info boxes except for the selected ROI.*
>
> *Display Name Only hides the statistics in the info boxes reducing their sizes.*

ROI Info Panel

You can modify certain parameters of a selected ROI using the ROI info panel (Figure 6.82). You can name the ROI, create associated comments, re-color the ROI using the standard Max OS color picker, change the thickness of the ROI border, and change the opacity from opaque to almost transparent.

The buttons on the bottom of the ROI info panel also allows you to:

- *Save as file - export the ROI in a proprietary .roi file for archiving, sharing, etc.*

- *Export to XML - export the ROI as an XML file for archiving, sharing, and statistical processing with third party software.*

- *X-Y Plot - display the plot of the pixels intensities along the line. This option is only available for length ROIs.*

- *Histogram - display the pixels intensities within the ROI as a histogram. You can adjust the bin width for the histogram bars in the popup window (Figure 6.85).*

- *Recalibrate - recalibrate the pixels size using a known length. This option is only available for length ROIs.*

You open the ROI info panel by either double clicking on the ROI, by selecting ROI Info from the ROI tab in the 2D Viewer menu, or by the keyboard shortcut ⌘ I.

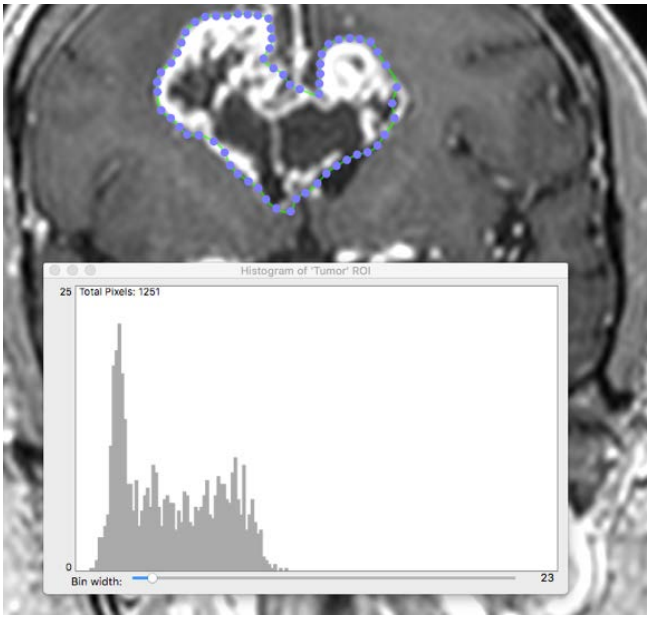


Figure 6.85. The histogram option within the ROI info panel. Note that you can adjust bin width using the slider at the bottom of the histogram window.

ROI naming

Each newly created ROI will be given a name in an incremental fashion. For example, length ROIs will be labelled measurement 1, measurement 2, etc. You can turn off automatic naming in the Viewer Preferences (sec. 2.2.1.3) by checking the New ROIs are unnamed box. In this case, Horos will not display their names in their ROI info boxes. Point, text and brush ROIs use different naming convention.

- New Point ROIs are always named Point 1, Point 2, Point 3, etc. with an incremental counter.
- New text ROIs are always named Double-Click to edit.
- New brush ROIs are always named Region.

The ROI menu at the top of the 2D Viewer offers two naming functions: ROI Rename and Set Default ROI Name. ROI Rename brings up a small popup window that allows you to assign a new name to all ROIs in the current image or all ROIs in the current series or all selected ROIs. The Set Default ROI Name also brings up a small popup window allowing you to set a new default name for all ROIs created subsequently (or to restore the default name).

ROI selection

There are several ways to select an ROI. You can select a single ROI by setting the mouse tool to any of the ROI tools (i.e. closed polygon, brush, pencil, etc.) and then clicking on the ROI. The ROI anchor points will change to blue dots, indicating that this ROI is selected. Alternatively, you can use the Selector tool to select ROIs.

With one ROI already selected you can select additional ROIs be holding down the shift key on the keyboard and clicking on a new ROI. You can also select all ROIs in the current series by using the Select All ROIs in this Series option from the ROI menu in the 2D Viewer. Click anywhere on the current image with an ROI tool selected to deselect ROIs on this image. To deselect all ROIs in the series, choose Deselect All ROIs in this Series from the ROI menu.

ROI deletion

You can delete a selected ROI by pressing the delete or backspace keys on the keyboard. Alternatively, you delete all ROIs in the series using the Delete All ROIs in this Series option from the ROI menu in the 2D Viewer.

ROI Spline Rendering

You can achieve a smoother border for an ROI using spline interpolation. This is available for the Opened Polygons, Closed Polygons and the Pencil ROIs only (Figure 6.86). You can turn on and off spline interpolation in Viewers Preferences.

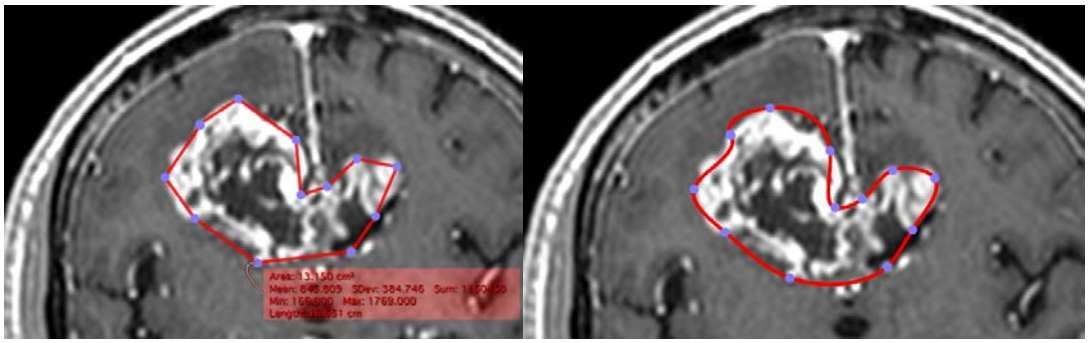


Figure 6.86. The ROI on the left is without spline interpolation and the image on the right uses spline interpolation for the same ROI.

3D ROIs and Volume

Horos can also create 3D ROIs from multiple 2D ROIs. For example, Figure 6.87 shows one of 18 ROIs outlining a brain tumor is a series. Clicking on the Compute Volume option in the ROI menu of the 2D Viewer reveals a popup window (Figure 6.88) showing the entire tumor rendered as a rotatable volume.

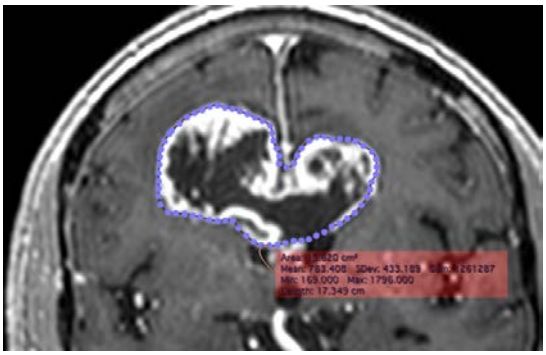


Figure 6.87. The ROI of a brain tumor.

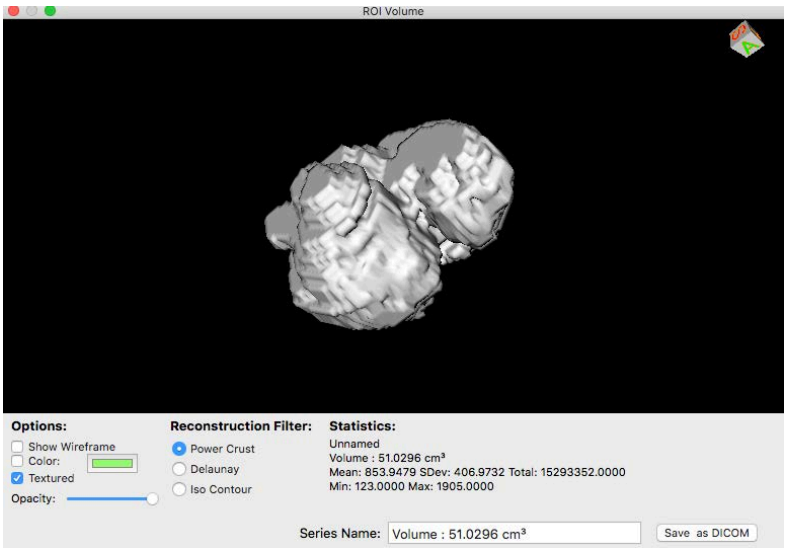


Figure 6.88. The Compute Volume popup window displaying a 3D volume for the tumor ROIs in Fig. 6.87.

The Compute volume tool uses the areas of all the selected ROIs of the same name along with the slice thickness of the series to estimate a volume. The Compute Volume option only works with polygon, brush, and pencil ROIs. Importantly, this tool only uses ROIs of the same name.

The ROI Volume popup window (Figure 6.88) displays the 3D volume along with several options. You can choose to display the 3D Volume as a wireframe, change its color, toggle texture on and off, and modify the volume's opacity. In addition, you can choose from three reconstruction filters, power crust (default), Delaunay, and iso contour. You will see the statistics associated with the 3D Volume on the right side of the ROI Volume window. These include the volume in cm^3. Finally, you can choose to save the 3D volume image as a DICOM file.

You can create ROIs for every slice in the series where a structure of interest appears (i.e. a tumor), or you can let Horos do some of the ROI creation for you. Suppose you creates an ROI for every third slice in the series. You can choose the ROI Volume > Generate Missing ROIs option from the ROI menu and Horos will automatically generate ROIs for the skipped slices. Horos uses a morphing algorithm based on the ROIs on either slide to fill in the missing ROIs. You should check them to see how accurate they are. If you need to modify one of the automatically generated ROIs you can do so using the repulsor ROI tool. The automatically generated ROIs contain the comment "morphing generated". You can delete only the automatically generated ROIs using the ROI Volume > Delete Generated ROIs option in the ROI menu.

Angle of Cobb

The Angle tool in the ROI dropdown list is useful for measuring simple angles between two lines. However, it may not be appropriate for measuring the angle of Cobb. The Cobb method is frequently used to measure the degree of scoliosis or other vertebral column abnormalities. The angle of Cobb is the angle formed between a line drawn parallel to the superior surface of a vertebra above a spine deformity and a second line drawn parallel to the inferior surface of a vertebra below the deformity (Figure 6.89).

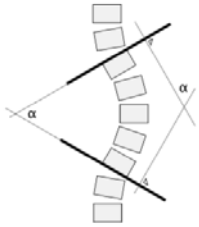


Figure 6.89. The angle of Cobb (represented by α).

To compute the Cobb angle, Select the Line ROI tool and draw two lines on the image. Horos displays the length of each line in cm or pixels, but not an angle. You can have Horos compute and display the Cobb angle by using the Cobb Angle tool in the Custom toolbar. Click on the

Cobb tool and then select one line. This line will be highlight it in yellow and angle of Cobb is displayed in the other line's info box (Figure 6.90). If more than two lines are drawn on the image, each line will display the Cobb angle relative to the selected line. When Cobb angle is activated it stays active until it is de-activated by clicking the Cobb tool in the toolbar a second time.

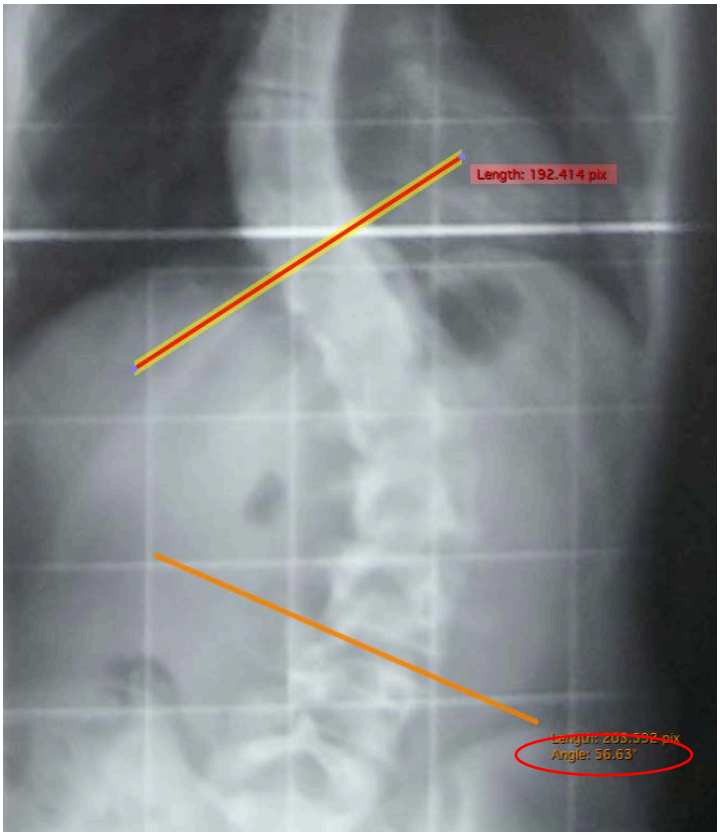


Figure 6.90. Cobb's Angle as displayed in Horos (circled).

Region Growing

Region growing algorithms begin from a seed region (typically one or more pixels) located inside the object to be segmented. The seed pixel's neighbors are then evaluated to determine if they should be considered part of the object. If they are considered part of the object, they are added to the region and the region grows. This process continues as long as there are new pixels to be added to the region. Because the process is iterative, the region grows according to a set of parameters set by the user. In medical imaging, image segmentation is often used to generate 3D reconstructions.

The Region Growing tool in Horos supports 2D and 3D black and white images (RGB images are not supported) and is based on the ITK toolkit.

You begin by clicking on the optional Growing tool from the 2D Viewer toolbar (Figure 6.91). This tool is found in Format > Custom Tools in the 2D Viewer menu. Alternatively, you can choose ROI > Grow Region (2D/3D Segmentation) from the 2d Viewer menu. This brings up the Segmentation Parameters popup window (Figure 6.92). Click on a point on the image that you wish to use as a seed point. A 2D preview is computed and displayed (based on the default parameters) with the segmented region in green (Figure 6.93).

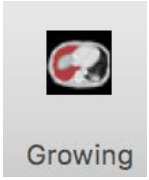


Figure 6.91. The Region Growing tool from the list of custom tools.

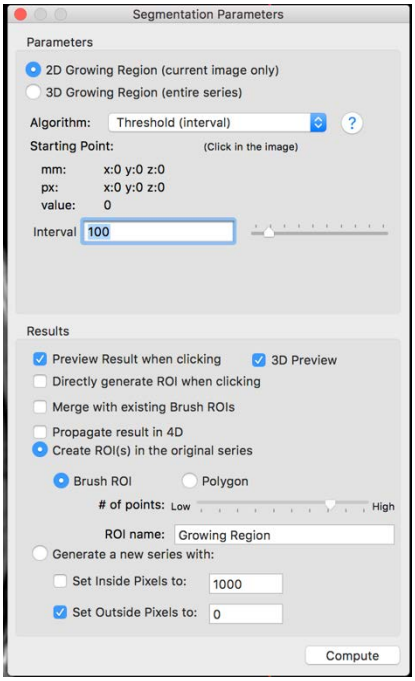


Figure 6.92. The Segmentation Parameters popup window.

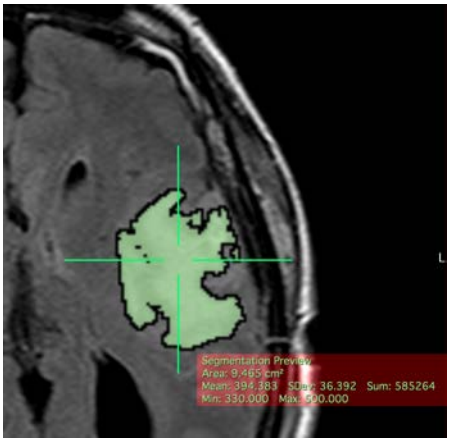


Figure 6.93. The segmentation preview of a brain tumor seeded by a single point (at the cross hairs).

You can adjust the green segmentation area on the 2D image using the interval slider in the segmentation parameters window. You can generate the final segmentation by clicking the Compute button at the bottom of the segmentation parameters popup window. Note that the preview segmentation is a 2D image only. The final segmentation is 3D and can look quite different if there are many connections among neighboring pixels in other images in the series. Remember that a 3D Region Growing that involves a large series of images may take some time to compute. The final region can be displayed as a brush ROI or a polygon ROI and can be edited in each slice using the ROI tools.

You can also create a mask series using the Generate a new series option at the bottom of the parameters window (figure 6.94). By also changing the pixel values in the Set Outside Pixel Values (or Set Inside Piexl Values if that box is checked), you can change the pixel intensity of the ROI.

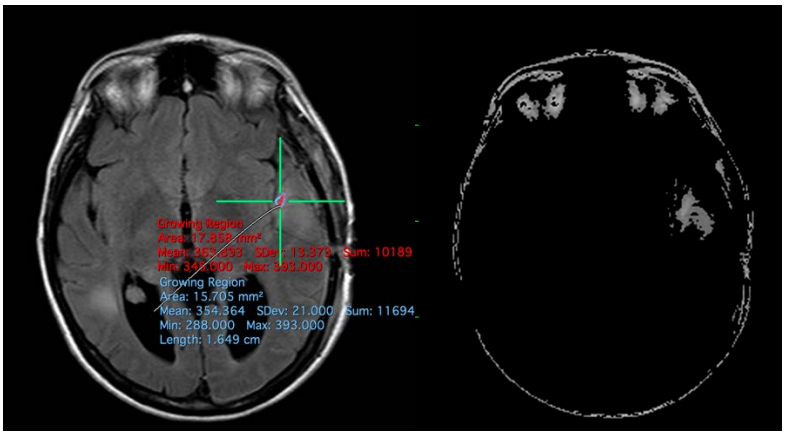


Figure 6.94. The image on the right is the mask generated from the 3D growing region on the left.

Horos implements four Region Growing algorithms. The two threshold algorithms consider only the value of the pixel itself. If the pixel's value is within the interval it is included in the region, otherwise it is omitted. In contrast, neighborhood algorithms consider a defined neighborhood surrounding the pixel and require each neighbor pixel intensity to within the interval for inclusion in the region. Neighborhood algorithms makes it less likely that small structures will be included in the region.

Threshold (interval) – Uses the seed point intensity to generate a connected set of pixels whose intensities are within the defined interval.

Threshold (lower/upper bounds) - Extracts a connected set of pixels whose intensities are within the defined upper and lower threshold values.

Neighborhood - Only accepts a pixel if all its neighbors have intensities that fit in the interval. Neighborhood size is defined by the integer radius provided by the user.

Confidence - Extracts a connected set of pixels whose pixel intensities are consistent with the pixel statistics of the seed point. The algorithm first calculates the mean and

standard deviation of intensity values for the seed point(s). It then uses a multiplier (set by the user) to generate a range and groups those pixels connected to the seed point that also fall with this range. The range is the mean plus or minus the multiplier times the standard deviation. The algorithm next re-calculates the mean and standard deviation for this new set of connected pixels and the iterative process repeats until no additional pixels can be added to the region, or the maximum number of iterations is reached.

Note that a multiplier of 2.5 would define a range wide enough to include 99% of the samples in the segment if the segment were Gaussian.

You can calculate the volume of a structure using the Region Growing tool. For example, you can use the region growing tool on a brain tumor by using a 3D ROI and then use ROI Volume > Compute Volume from the ROI menu.

Set Pixels Values

Pixel intensity can be changed using the Set Pixel Values popup window from the ROI menu in the 2D viewer (Figure 6.95). You can choose to modify pixel intensities for all pixels in the series, all pixels in ROIs with the same name, or all pixels in all ROIs. Furthermore, you can choose to modify pixels inside the ROIs or only the pixels outside the ROIs. Finally, you can set an upper and lower threshold to modify only those pixels within the threshold range. The original pixels are saved and can be reloaded simply by choosing the Revert Series

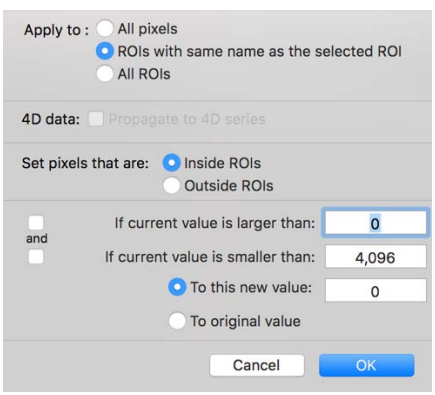


Figure 6.95. Set Pixels Values popup window.

You can reload the original pixels at any time by selecting Revert Series in 2D Viewer menu or by using its keyboard shortcut (⇧ ⌘ R).

SUV

The SUV function is frequently used with PET series where a radioactive tracer, such as 2-deoxy-2-[^{18}F]fluoro-D-glucose (FDG), is used to mark the position of cancers. There are several ways to measure the rate of accumulation (or the total amount) of radioactive tracer in a tumor.

Usually, it is the relative uptake of tracer that is measured because it somewhat compensates form variation in the amount of tracer injected and the patient's body size.

The basic equation is:

$$SUV = \frac{tissue\ radioactivity\ concentration}{decay - corrected\ \ injected\ activity/body\ weight}$$

Note that Horos does not support SUVs adjusted for body surface area (SUV_{bsa}) or adjusted for lean body mass (SUV_{bm})

SUV is calculated as:

$$SUV_{bw} = \frac{Pix \cdot P_w}{C}$$

Where Pix is the pixel intensities from the ROI in the PET scan, P_w is the patient's body weight (g), and C is the corrected activity. Corrected activity (C) is calculated as:

$$C = T \cdot 2^{-\frac{t_S - t_M}{t_{1/2}}}$$

Where T is tracer activity, t_S is the scan time, t_M is the measured time for the activity dose, and $t_{1/2}$ is the half-life of the tracer.
SUV values are calculated from DICOM metadata fields for:

- weight = patient weight = Study Patient Weight (0x0010, 0x1010)
- height = patient height = Study Patient Size (0x0010, 0x1020)
- sex = patient sex = Study Patient Sex (0x0010, 0x0040)
- tracer_activity = Total Dose (0x0018, 0x1074)
- measured_time = Radio Pharmaceutical Start Time (0x0018, 0x1072)
- half_life = Radio Nuclide Half Life (0x0018, 0x1075)
- scan_time = Image Acquisition date and time, as defined in PET Preferences window (see 2.2.3.6)
- decay_factor=DecayFactor(0x0054,0x1321), used on Siemens PET studies to correct the final pixel value (according to beds acquisition time)

At the time of writing these values are valid for Siemens and GE PET studies. Phillips PET studies store a proprietary field (0x7053, 0x1000) which allows you to multiply pixel values by this field to obtain SUV values.

In Horos, you can convert between original and SUV values by clicking on the SUV icon from the toolbar (found in the Custom Toolbar options). This opens the SUV parameters window (Figure 6.96).

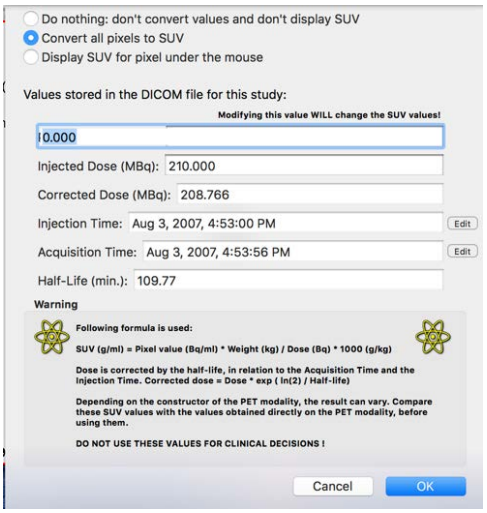


Figure 6.96. The SUV parameters popup window.

From the SUV parameters popup window you can choose to convert all pixel values to SUV, or convert only those pixels under the mouse to SUV (the SUV values displayed on the image change dynamically as you move the mouse).

The middle fields in the SUV parameters window allow you to check the values stored for:

- *Patient's weight (in [kg])*
- *Injected dose (in [MBq])*
- *Corrected dose (in [MBq])*
- *Injection time*
- *Acquisition time*
- *Half-life (in minutes)*

You can edit the following three values:

- *Patient's weight (in [kg])*
- *Injected dose (in [MBq])*
- *Injection time*

You can automatically convert pixel values to SUV when loading a PET or a NM series by editing the PET Preferences (Figure 6.97) from the Horos Preferences.

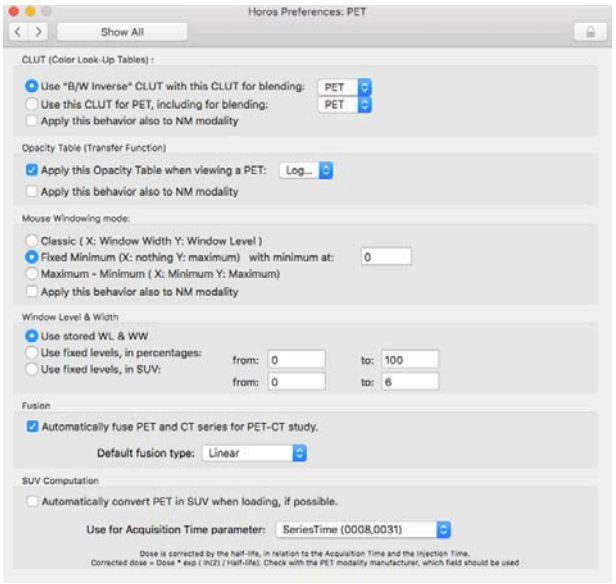


Figure 6.97. The PET Preferences window showing the automatic SUV conversion at the bottom.

Reconstruction Tools

There are eight possible reconstruction tools available for image stack loaded in the 2D Viewer (figure 6.98).

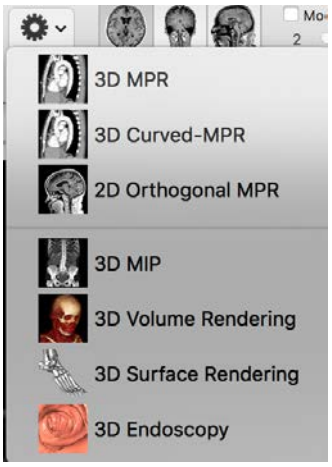


Figure 6.98. The 2D/3D reconstruction tools dropdown list from the 2D Viewer menu.

3DMPR

The 3D Multi-Planar Reconstruction is a technique used in 2D CT and MRI imaging to generate sagittal, coronal, and oblique views from axial sections (Figure 6.99). Multi-Planar images can be "thickened" into slabs and displayed as maximum intensity projections (MIP), minimum intensity projections (minIP), mean, and volume rendering projections (see Chapter 7).

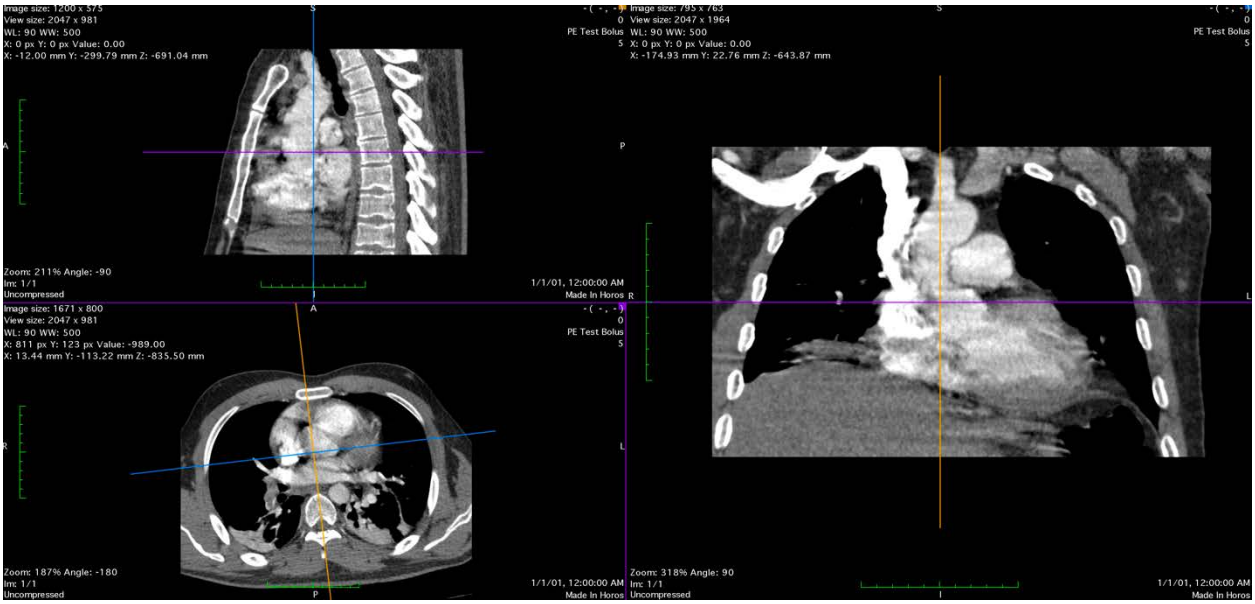


Figure 6.99. The 3D MPR windows.

2DCurved-MPR

The Curved MPR aligns the long axis of the image plane with a specific anatomic structure, such as a blood vessel or vertebral column, rather than with an arbitrary imaging plane (Figure 6.100).

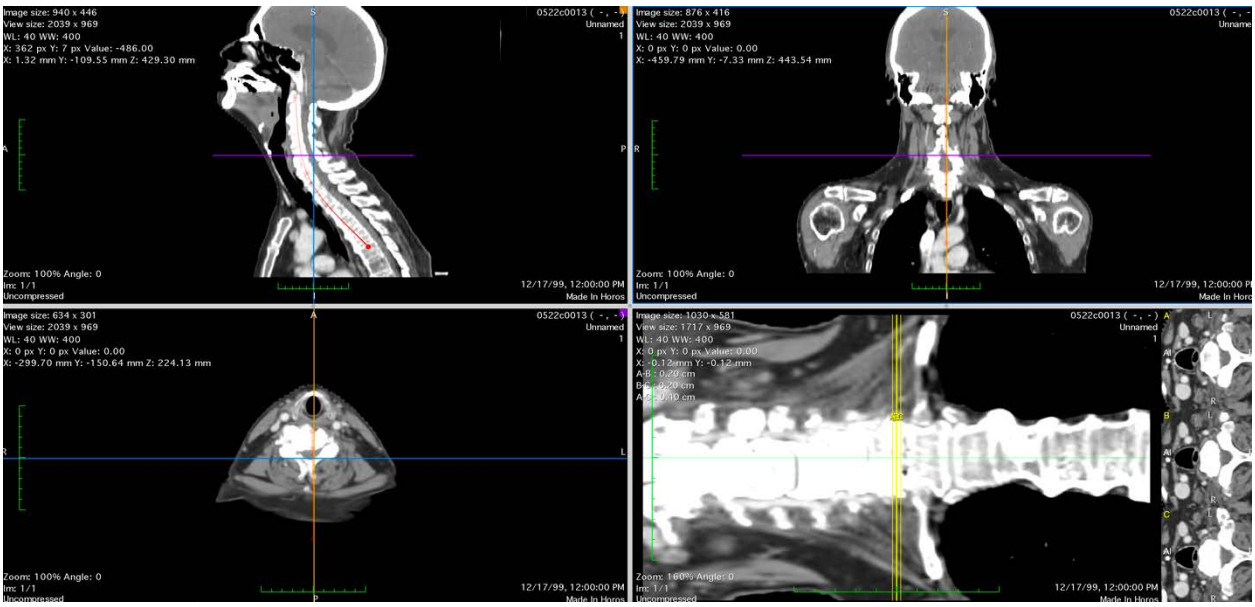
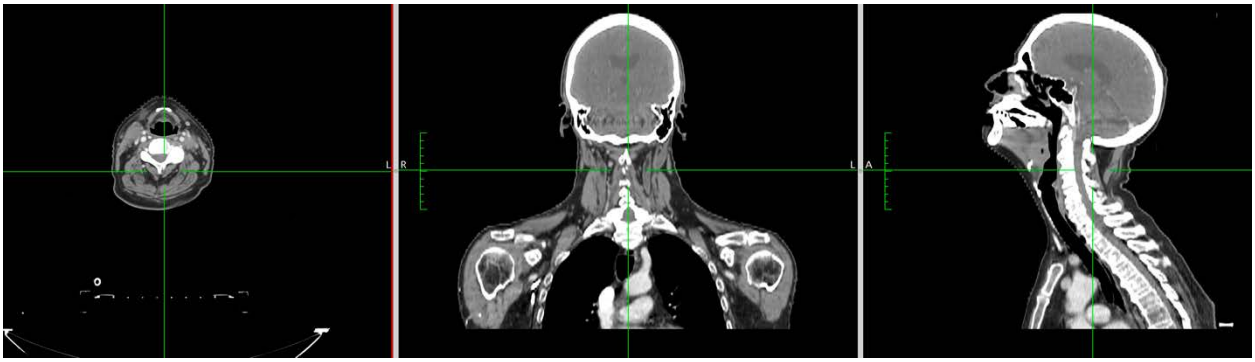


Figure 6.100. The 2D Curved MPR aligned along the vertebral column (red lines in upper left image).

2D Orthogonal MPR

You can reformat the image volume according to 3 orthogonal planes (Axial, Coronal and Sagittal) using the 2D Orthogonal MPR tool (Figure 6.101).



6.101. A 2D Orthogonal MPR.

3D MIP

This reconstruction creates a 3D Volume Rendering using maximum intensity projection (MIP, Figure 6.012).

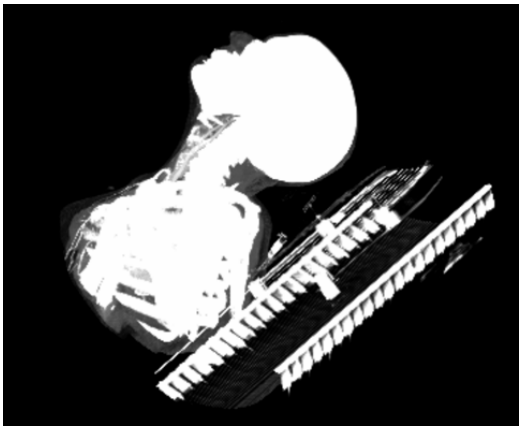


Figure 6.102. A 3D MIP of the same series used in Figure 6.101.

3D Volume Rendering

This tool renders the data using the 3D Volume Rendering (Figure 6.103) technique described in detail in Chapter 7.

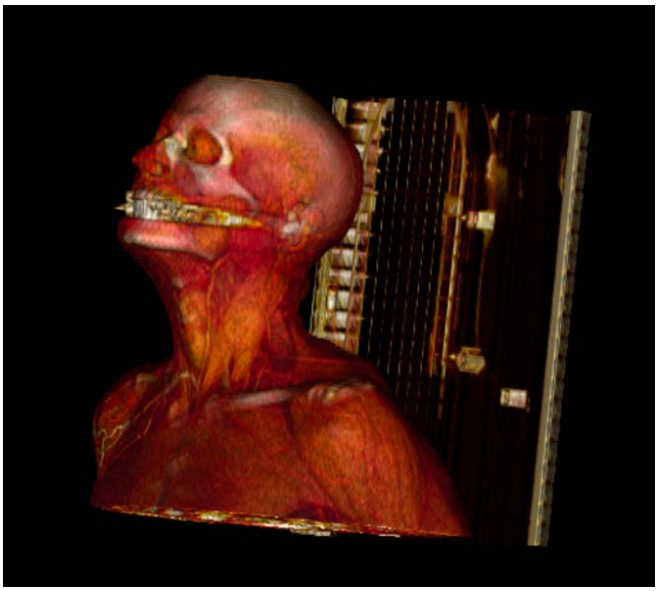


Figure 6.103. A 3D Volume rendering of the same series shown in Figure 6.102.

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.

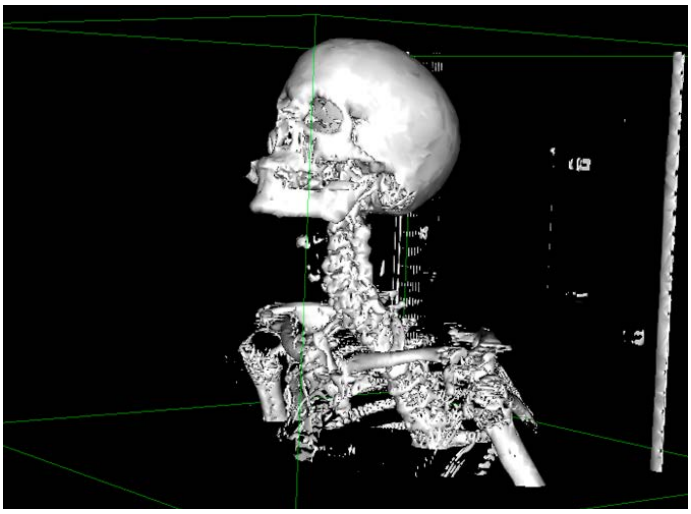


Figure 6.104. A 3D surface rendering of the series with surface settings set to a predefined threshold for bone.

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).

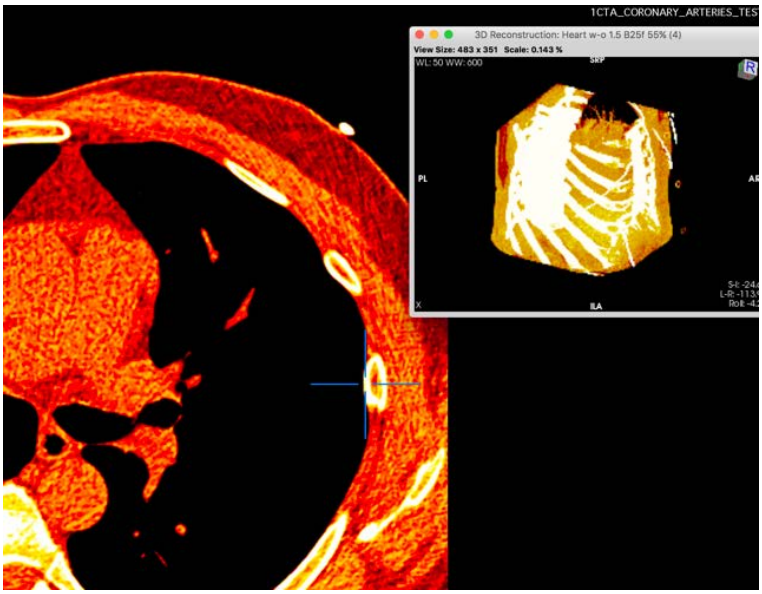


Figure 6.106. The floating 3D Panel, displaying a specific point on the 2D Viewer window (denoted by the cross hairs).

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:

$$Z = X \times Y$$

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.

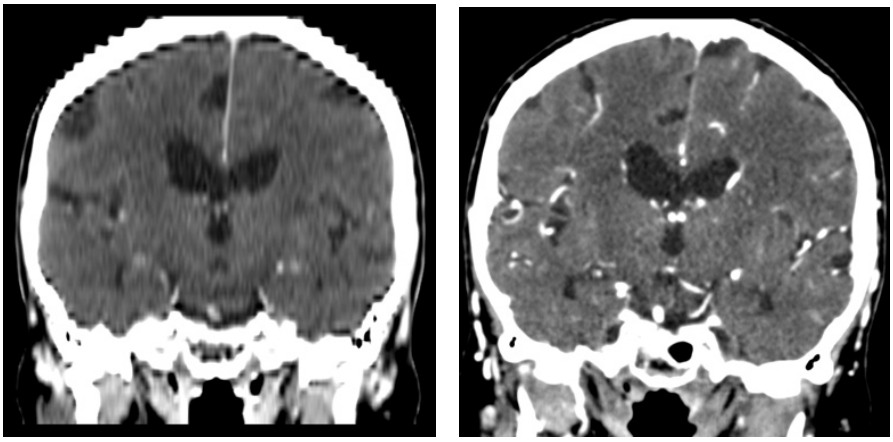


Figure 7.02. MPRs of two series. The left series has a large slice interval, while the series on the right has a small slice interval.

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

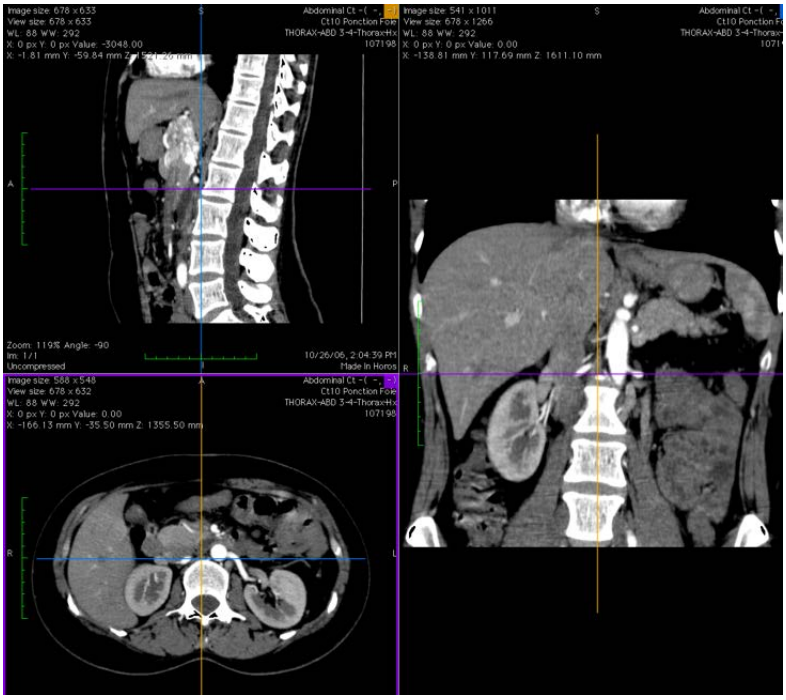


Figure 7.04. The 3D MPR window showing the three orthogonal views.

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.

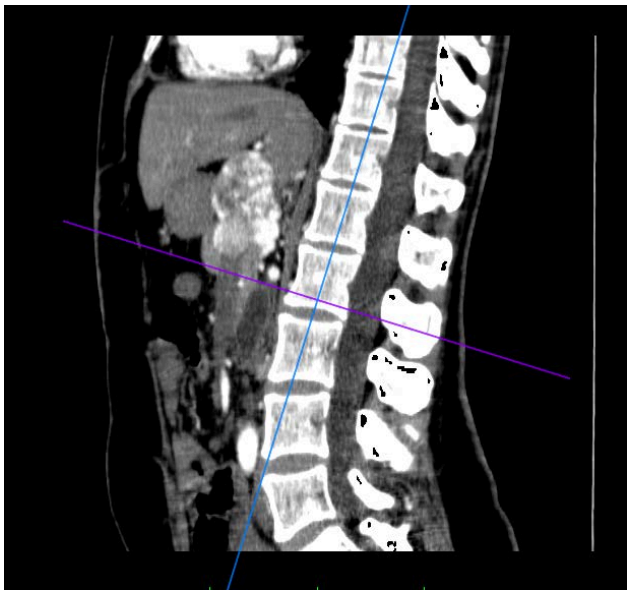


Figure 7.05. The axis lines have been moved to the center of the vertebral column and tilted along its length.

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.

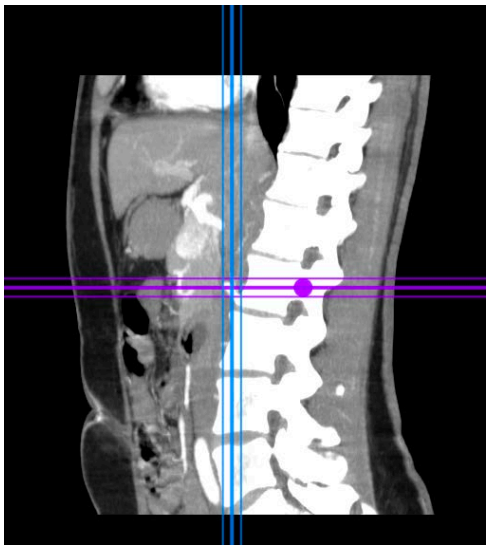


Figure 7.06. A Thick Slab rendering of an abdomen with thickness set to 10mm.

Shading

Shading is available when thick slab is in use and Volume Rendering mode is on. Click on the shading box and then click on the edit button to bring up a popup window. Here you can modify the shading settings for ambient coefficient, diffusion coefficient, specular coefficient, and spectral power.

Views

You can choose from three MPR Views. The default view is to have the screen divided such that there are two views on the left and one on the right. You can also choose to have all three planes displayed one on top of the other on the screen, or all three side by side (horizontally).

Reset

The Reset tool changes the Zoom, Rotation, Pan , and Re-sliced orientation back to the default settings.

Save as DICOM

You can save MPR views as DICOM images and have them added to the database window using this tool. You have the option to name the new series, set the image size (current size, 512x512, or 768x768), and the render quality (current or best). You can also choose to save the resulting images in 8-bit RGB or 16-bit black and white.

You can choose to save only the current image, an animated sequence if a 4th dimension is available, or as a new series (Figure 7.07).

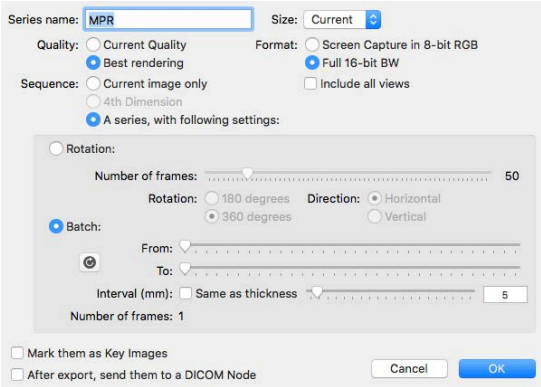


Figure 7.07. The Save as DICOM popup window.

If you select the new series option, you can modify the number of frames, rotation, and direction or choose the Batch mode. In Batch mode, you can re-slice a subset of the series by setting a start and end frame and an interval thickness from 1 to 200mm. Finally, you can mark the resulting images a key images and choose to send them to a DICOM node.

Movie Export

This tool creates a QuickTime movie of the selected series. The options are similar to those for Save as DICOM. You can choose the size of the movie, render quality, and sequence to be saved. The more frames you select, the smoother the movie sequence will appear (but file size will increase). Animated sequences can include 4th dimension data.

Axis

You can toggle on or off the axis lines on the MPR views using this tool.

Mouse Position

You can display or hide the position of the mouse on the two other MPR views when you move the mouse on the third view. The mouse position is denoted by a colored circle along each of the axis lines.

Sync Zoom

Choosing Sync Zoom allows you to have all three MPR views zoom at the same level simultaneously. This works with the Zoom tool from the Mouse tools.

Custom Tools

You can add or remove tools from the toolbar using Format > Custom from the main menu. Tools Custom tools for MPR views include the following:

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 3D MPR Viewer window and use the 4D Player tool in the toolbar to play the sequence or export the images in DICOM or QuickTime format.

Axis Colors

You can change the colors of the axis lines in each MPR view using this tool. You can choose from any color on the standard Mac OS X color picker.

Best Rendering

You can have the three MPR views rendered in highest quality by clicking on this tool.

Fusion

The 3D MPR Viewer supports image fusion. If you are working with a fused data set (i.e. PET-CT) you will see the fused series in the MPR views. These fused datasets are locked and move together. (You can computer the SUV value for a fused PET–CT study using the Oval ROI tool). When working with fused datasets, you can modify fusion parameters such as fusion mode (linear, log, etc.) and fusion percentage (0 to 100%).

THE 3D CURVED MPR VIEWER

A curved multi-planar reconstruction allows you to re-slice a dataset along a curved plane. This curved plane includes a user specified path (a series of points) and a set of corresponding orientation angles for each point on the path.

The Curved MPR rendering technique is most often used for complexly twisting structures, such as vessels. It essentially allows you to unroll the curved structures (e.g., blood vessels or colon) into a straitened tube. The whole length of the tubular structure is displayed as a single image making abnormalities such as stenoses, aneurysms, and plaques easier to measure and interpret. Curved MPR techniques help physicians make better diagnoses and treatment plans.

Your first step in Curved MPR is to define a curved path using sequential points on the three orthogonal views. For best image quality it is necessary to work with small slice intervals. Horos uses two mode for Curved MPR rendering: Straightened Rendering and Stretched Rendering.

Straightened Rendering

This type of curved MPR fully straightens a complexly folded, tubular structure. The newly straightened tube (i.e. a vessel) varies in diameter along the length of the tube. The advantage is that you can easily see changes in vessel diameter causes by abnormalities. A disadvantage is that you can only measure distances along the tube's length or tube diameters perpendicular to the long axis of the tube.

Stretched Rendering

Stretched rendering MPR preserves isometry (resolution along the X and Y axis are equals, so you can measure distances). If the goal is to preoperatively plan an endovascular stent treatment for an aortic aneurysm, a stretched rendering preserves the lengths of vascular segments allowing more accurate sizing of endovascular protheses.

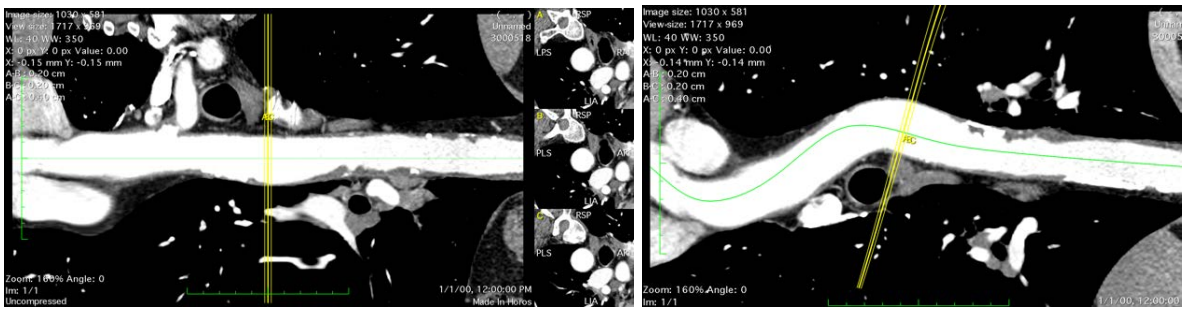


Figure 7.08. The Straightened (left) and Stretched (right) rendering of the aortic arch.

Curved MPR Engine

The 3D Curved MPR Viewer uses a different engine to display a curved plane. The algorithm used in the 3D Curved MPR Viewer is based on the method described by A. Kanitsar et al. 2002 [7]. It is computationally more intensive and so the engine is slower. Performance is linked to CPU processor speed and number of cores, not on GPU performance.

The 3D Curved MPR Viewer is divided into 3 parts: a toolbar, three orthogonal MPR views, and a curved MPR view rendered as straightened or stretched with 3 smaller view windows representing positions A, B, and C.

The toolbar (figure 7.09) contains buttons for the most useful functions. Tools can be added or removed from the toolbar using the Format > Custom Toolbar options from the main menu.

Figure 7.09. The Curved MPR Toolbar

The three orthogonal MPR views (Figure 7.10) are where you will draw your 3D Bezier path. In the lower right is the Curved MPR view where your 3D Bezier path is rendered as a curved plane image. The three smaller views on the right of the Curved MPR view depict three corresponding perpendicular views along the path at positions A, B, and C. Perpendicular views A, B, and C (Figure 7.11) are strictly perpendicular to the Bezier path, but if the path is not a straight line, they will not be parallel to each other.

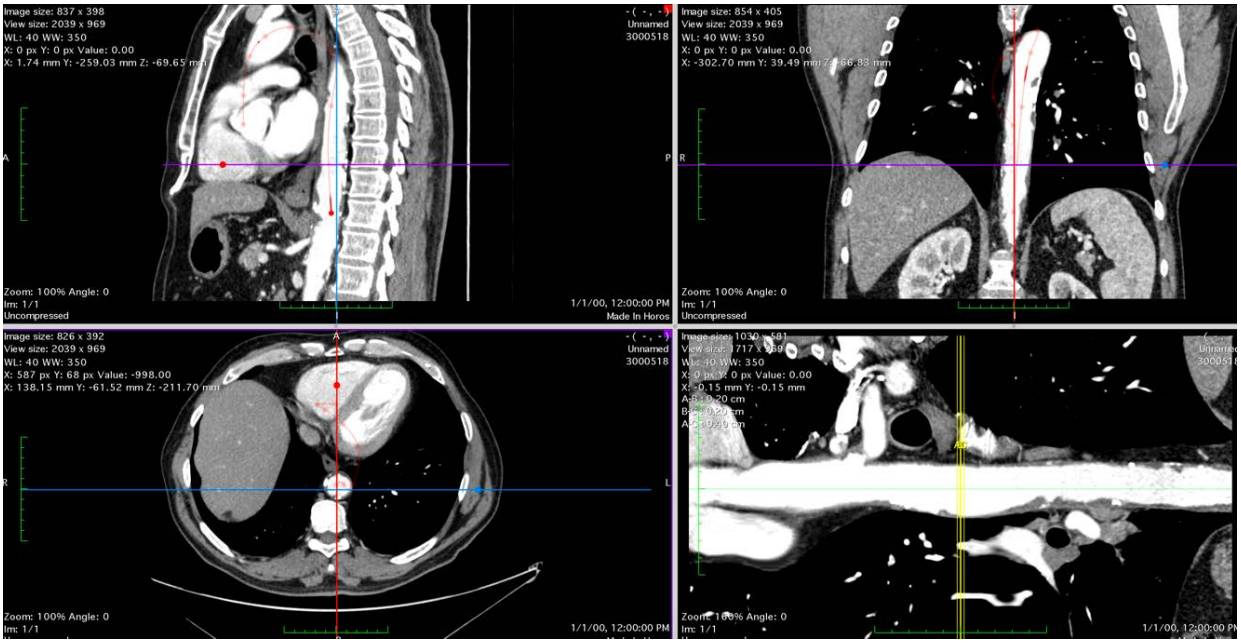


Figure 7.10. The three orthogonal MPR views with the curved MPR view in the lower right.

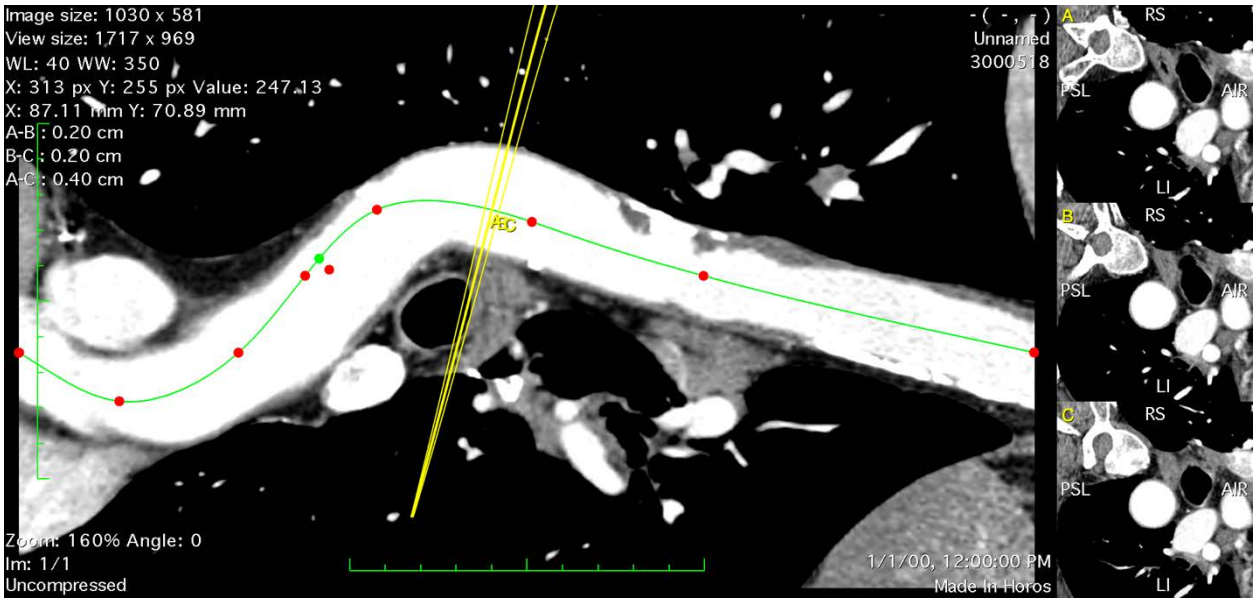


Figure 7.11. The curved MPR view with the three corresponding A, B, and C views. Note that they are not parallel to each other.

You can manipulate these views using the tools in the toolbar or via the mouse or keyboard. You can display a view full-screen by double-clicking on it (double click again to revert to normal size). You can adjust the size of each view using the separators between each view. Lastly, you can change the layout of the views using the View tool in the toolbar.

The Toolbar

This section describes each tool available in the default toolbar from left to right followed by the custom tools in alphabetical order.

Tools

These are mouse button tools accessed by selecting a tool and activating it with a mouse left-click.

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

The left mouse tool can also be one of the following ROI tools:

- *Length*
- *Angle*
- *Rectangle*
- *Oval*

- *Text*
- *Arrow*
- *Opened Polygon*
- *Closed Polygon*
- *Pencil*
- *Point*
- *Brush*

WL & WW

This allows the user to change the settings for WL/WW, CLUT, and opacity using presets.

LOD

You can change the Level of Detail for rendering from fine to coarse suing the slider in this tool.

Curved MPR Angle

You can change the current rendering angle for the Curved MPR plane by moving the slider from 0° to 360°. Alternatively, you can adjust the angle using the mouse scroll wheel if you are in the Curved MPR view.

Reformation Type

As described above, you can switch between a straightened or stretched curved MPR plane (Figure 7.08).

Resolution

You can choose from Standard or High-Res modes.

Path Assistant

The Path Assistant tool automatically finds a path between points. You can choose two to five points for use with the Path Assistant and select a level of path simplification using the slider. Moving the slider to the left reduces the number of interpolated points along the path.

Path Mode

You can select to create a new 3D Bezier path with the Creation Mode or edit an existing path with the Edit Mode buttons.

To create a new path, select the Creation Mode and then the Curved Path tool. Begin by dropping points onto any of the orthogonal MPR views. A new red point will be added to the path as you continue dropping points. The orthogonal views are automatically re-centered on the last point. To finish your path, simply double-click the last point to switch to the Edit Mode. The

points switch to green color in Edit Mode. You can delete the entire path and start over by pressing the escape or delete key on your keyboard. You may find it useful to hide the axis cross reference lines from time to time (use the spacebar) as you drop points. Note that you can restrict points to the same plane by pressing the control key. This prevents angular deformations.

To edit a path, select the Edit Mode, and click on the point you want to change and click and drag the point to move this point to a new position. In Edit Mode, the path and points are displayed in green. You can add new points to the path line, but you cannot extend the path. If you want to remove a point, click and hold the mouse button on a point while also pressing the delete key on the keyboard. To return to Creation Mode, double-click on the last point on the path or select Creation Mode from the toolbar.

It's important to remember that your path is always displayed on the MPR views, but the current MPR plane may not be positioned on the path. This means that your path (displayed in green) could be in front or behind the MPR plane. If the path is crossing the MPR view, the path is displayed in plain and bold green color, but if the path is positioned behind or in front of the MPR plane, it is displayed in darker and transparent green.

Views

You have three options for displaying the MPR views. You can choose three MPR views with a fourth horizontally rendered Curved MPR plane. You can choose a single MPR view with one horizontally rendered Curved MPR plane. Finally, you can choose two MPR views with a vertically rendered Curved MPR plane.

Thick Slab

The Thick Slab tool allows you to render thicker sections than a single slice. You can also select the MIP, MinIP, and Mean rendering algorithms from the Thick Slab dropdown list.

Reset

You can reset the 3MPR views to the default views. If will use default zoom, rotation, and pan setting. If you have a Curved Path visible, this tool will delete the Curved Path.

Save as DICOM

You can create snapshots of your 3D scene, save them to disk as DICOM files, and add them to the database. Clicking on the DICOM tool opens a popup window (Figure 7.12) where you can create a new series name for the exported snapshots. You can also modify the size of the images by choosing between current, 512x512, or 768x768. Depending on the volume rendering you are using, you can also choose between 8-bit RGB or 16-bit BW formats. You can choose to only export the current image, or a series of images. If you choose the animated series, you can change the number of frames to render (up to 360 frames), the direction of rotation for the animation, and the render quality. You can include Curved MPR views and transverse views.

Finally, you have the option to mark the images as key images and the option to send the exported images to a DICOM node.

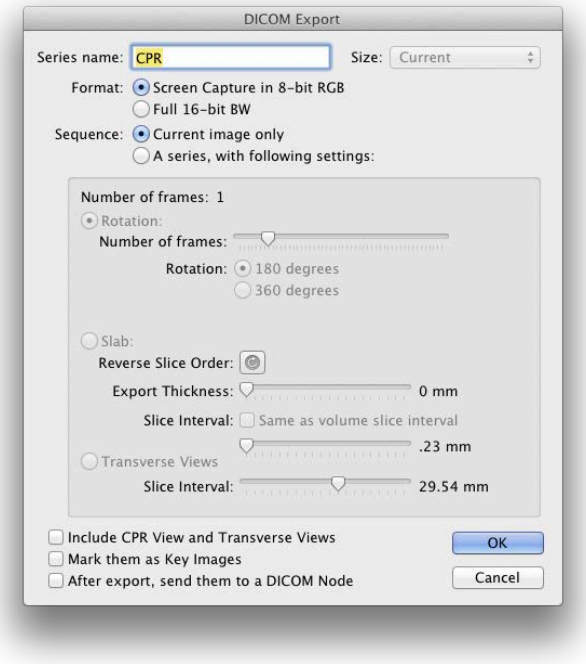


Figure 7.12. The DICOM Export options

Curved Path

If you have created a Curved Path, you can save the Curved Path in a file. This file contains the 3D points of the path, not the dataset itself. However, you can easily re-load the path by adding a Curved Path file to the 3D Curved MPR Viewer window.

Axis Colors

You can change the colors of the axis lines in each MPR view using this tool. You can choose from any color on the standard Mac OS X color picker.

Axis & CPR Axis

You can toggle on or off the axis lines for each of the three MPR views and the Curved MPR view.

Mouse Position

You can display or hide the position of the mouse on the three MPR views. The mouse position is denoted by a colored circle along each of the axis lines.

Sync Zoom

Choosing Sync Zoom allows you to have all three MPR views zoom at the same level simultaneously. This works with the Zoom tool from the Mouse tools.

Axis Colors

You can change the colors of the axis lines in each MPR view using this tool from the Custom Tools options. You can choose from any color on the standard Mac OS X color picker.

Interpolation Mode

You can choose from two interpolation modes, Nearest Neighbor or Cubic. This tool is available in the Custom Tools.

3D CURVED-MPR DETAILS

The three MPR views are reformatted DICOM images in orthogonal views. It is in these views that you will define the 3D Bezier path and the Curved MPR displays a view of the corresponding path.

The Curved-MPR image is calculated in real-time and automatically adjusts as new segments are added to the path. On the right of the Curved MPR view are three, small perpendicular (to the curved plane) views labelled A, B and C. These three views represent cross-sectional views at positions corresponding to locations A, B, and C (yellow perpendicular lines) on the Curved MPR image (Figure 7.13). On the MPR views, the positions of A, B, and C are displayed as yellow dots along the Bezier path.

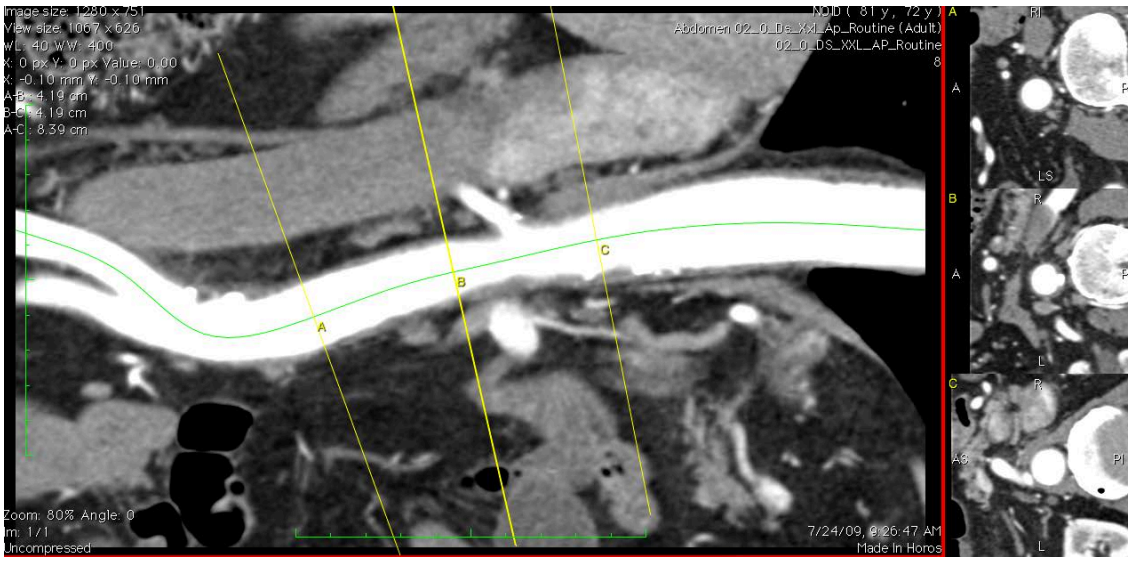


Figure 7.13. The Curved MPR view and the three small orthogonal views at positions A, B, and C.

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.

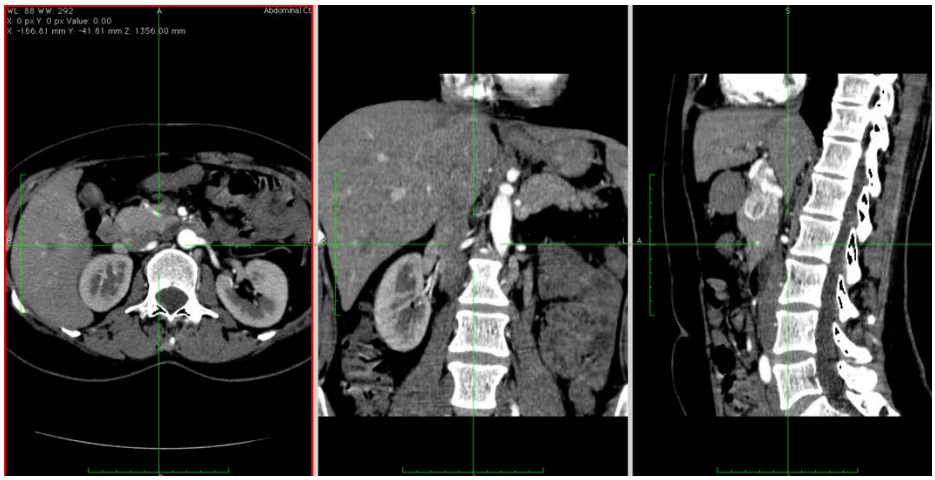


Figure 7.15. The default 2D Orthogonal MPR Viewer window.

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
- Pan
- Zoom
- Rotate
- Scroll
- ROI Tool Length
- ROI Tool Oval
- ROI Tool Angle
- ROI Tool Point
- 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).

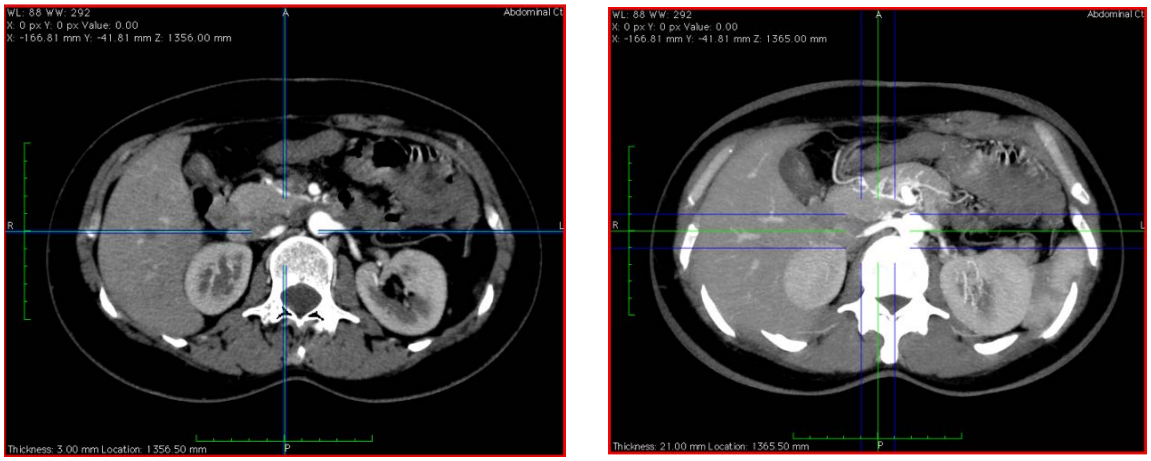


Figure 7.16. The axial plane showing the original slice on the left and the Thick Slab image on the right. Note the final image thickness in the lower left corner of the right image.

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.

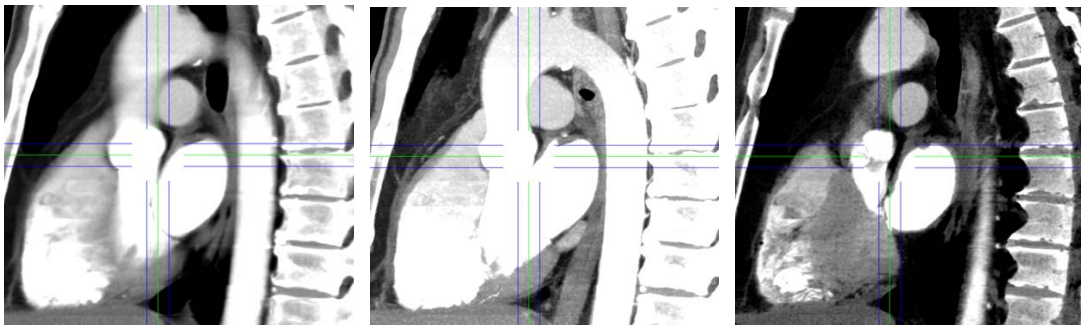


Figure 7.17. The three modes available in Thick Slab: Mean (left), MIP (middle), and MinIP (right).

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.

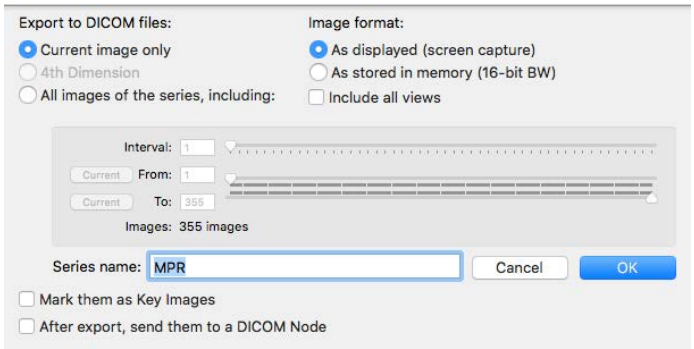


Figure 7.18. The Save as DICOM popup window in the 2D Orthogonal MPR Viewer.

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

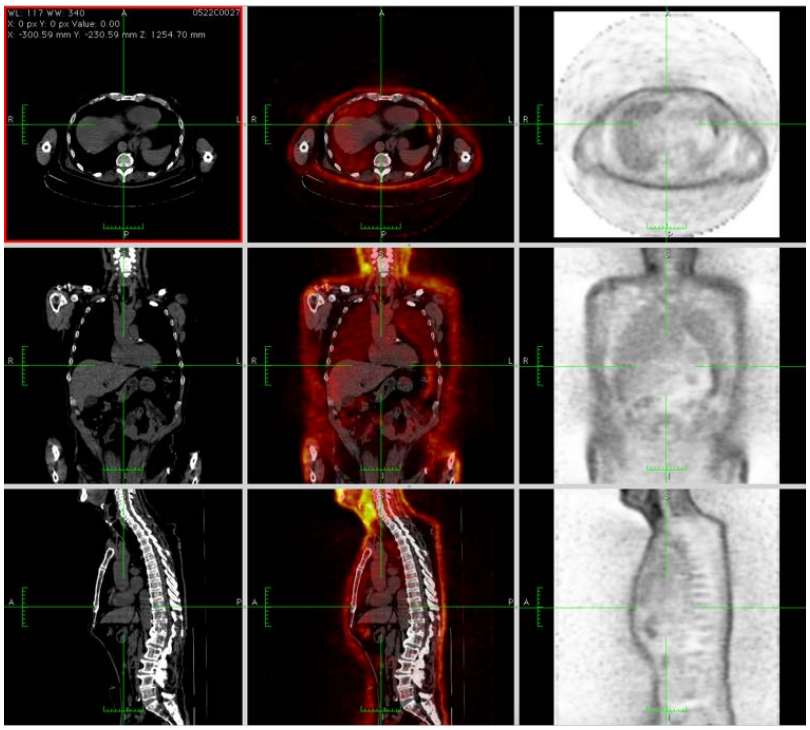


Figure 7.19. The nine views for a fused CT-PET series.

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.

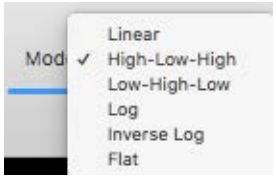


Figure 7.20. The mode options in the Fusion tool.

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).

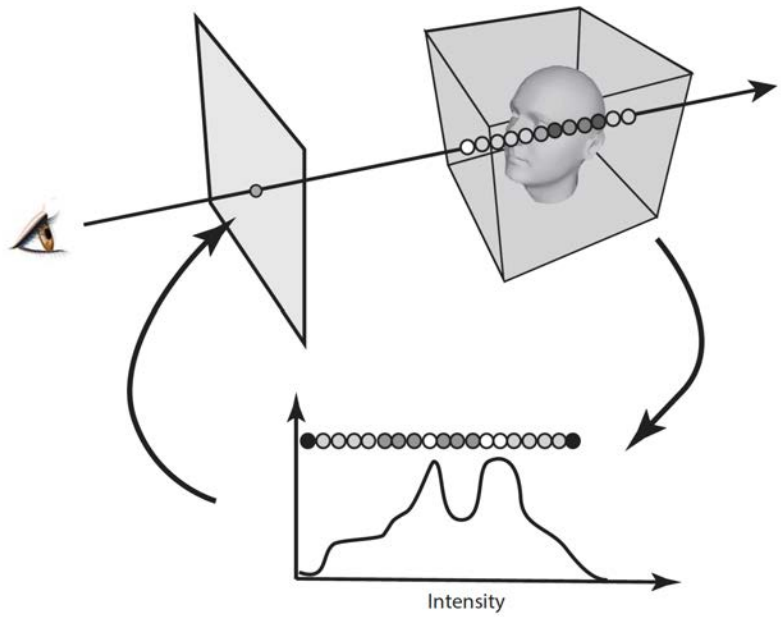


Figure 7.21. A ray cast from the viewer's eye through a 2D computer screen and then through the 3D volume where algorithms calculate RGBA values and deposit the final pixel on the computer screen.

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.

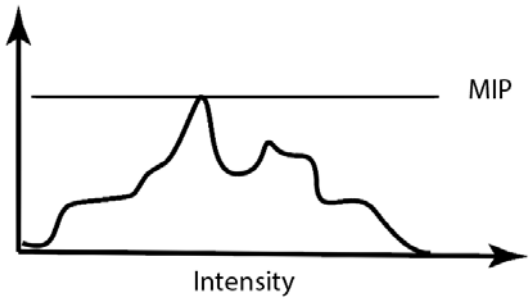


Figure 7.22. The MIP returns only the maximum intensity value.

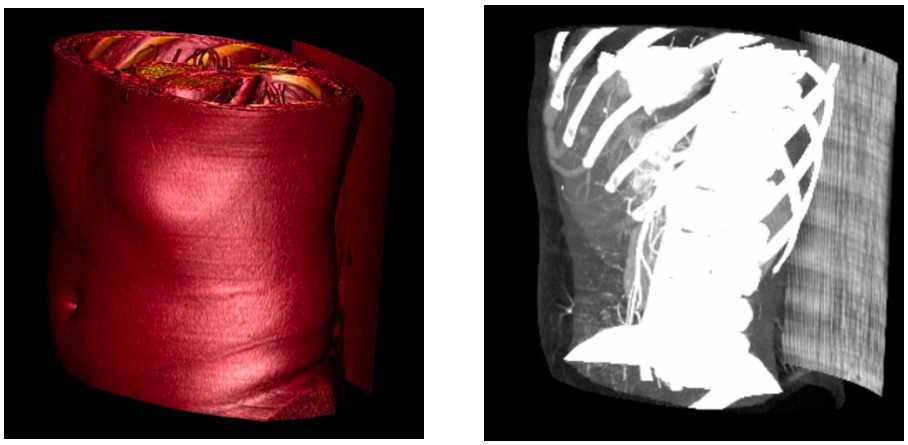


Figure 7.23. A volume rendering (VR) on the left and a MIP rendering on the right.

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.

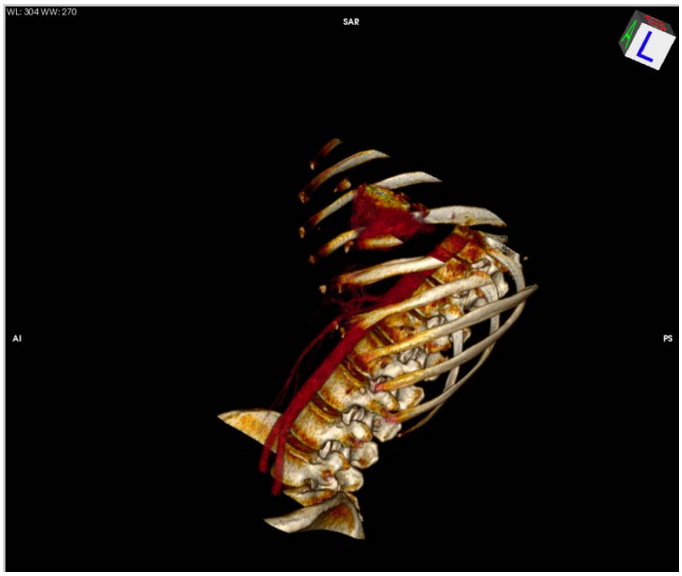


Figure 7.25. The Image window of the 3D MIP/VR Viewer showing a 3D rendered volume of the thoracic cavity.

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*

- *Volume rotate [default]*
- *Plane rotate*
- *Length*
- *3D Point*
- *Circle*
- *Scissors*
- *Bones removal*

All tools function as they did in the 2D viewer except the Volume rotate, Plane rotate, Circle, Scissors, and Bone removal tools. Volume rotate allows you to click and drag on the 3D image to move it in the x, y, z planes. The Plane rotate tools moved the entire 3D image in a single plane. The Circle tool allows you to draw a yellow circle on the 3D image. The Scissors tool allows you to create a polygon that can be removed from the 3D image. Selecting the Bone removal tool and then clicking on a bone (high density structure) in the 3D image, removes bones from the image.

WL/WW & CLUT & Opacity

These tools are organized as a group of three dropdown lists. All three operate as they did in the 2D Viewer. Briefly, the WL/WW allows you to change the settings for WL/WW using a series of presets. The CLUT allows you to modify the color lookup table using a series of presets or create a new CLUT using the 16-bit CLUT Editor. The Opacity tool allows you select from several preset opacity tables.

CLUT Editor

There are two CLUT editor options 8-bit and 16-bit. Clicking on the 8-bit button brings up a window that you can use to convert the image to 8-bit black and white (Figure 7.27). The 16-bit option is the default (Figure 7.28).

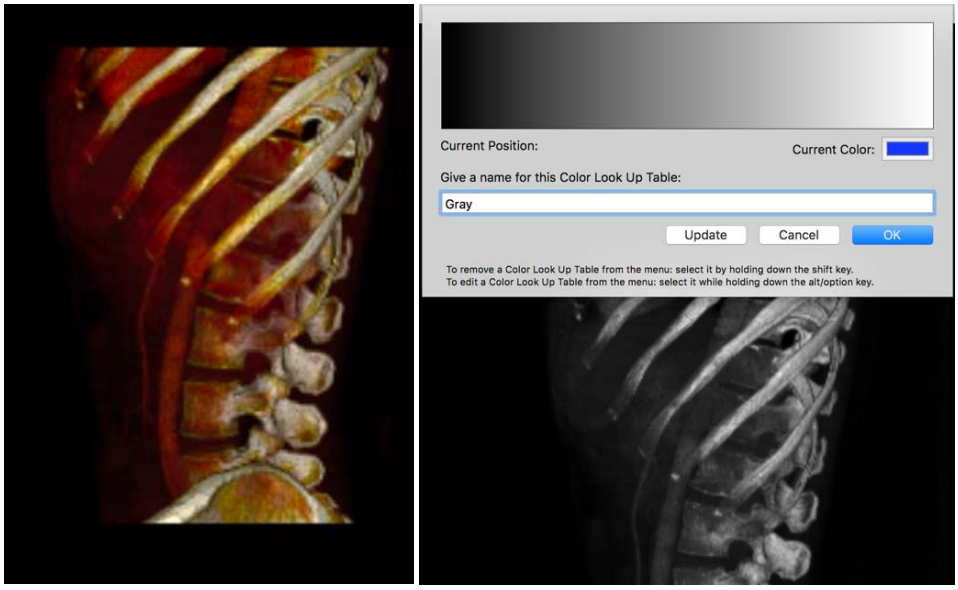


Figure 7.27. The default 16-bit CLUT is shown on the left and the 8-bit

CLUT editor popup window is on the right.

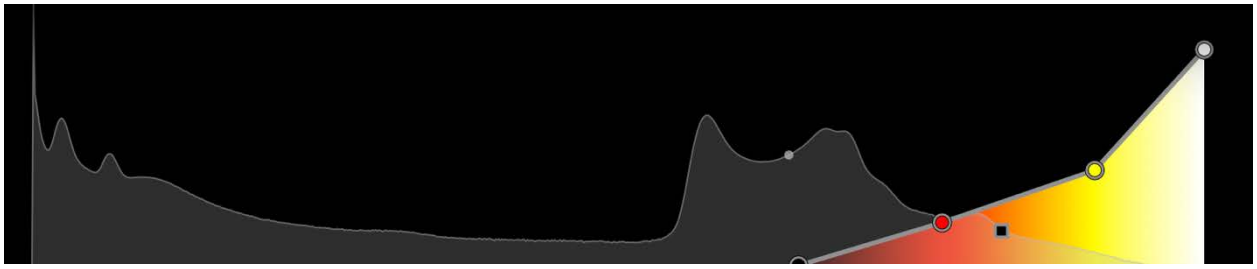


Figure 7.28. The window for the 16-bit CLUT editor.

Selecting the 16-bit editor brings up a second window at the bottom of the 3D image window (Figure 7.28).

3D Presets

You can select from a pre-defined set of rendering options by clicking on the 3D Presets button in the tool bar. This brings up a popup window (Figure 7.29) that show the presets available in three groups; Basic, Bone CT, and Soft tissue CT. For example, selecting the Bone + Skin II preset in the Bone CT group generates the 3D rendering shown in Figure 7.30 after you press the Apply button. Clicking on the Info button brings up an info box with details about the preset (Figure 7.8).

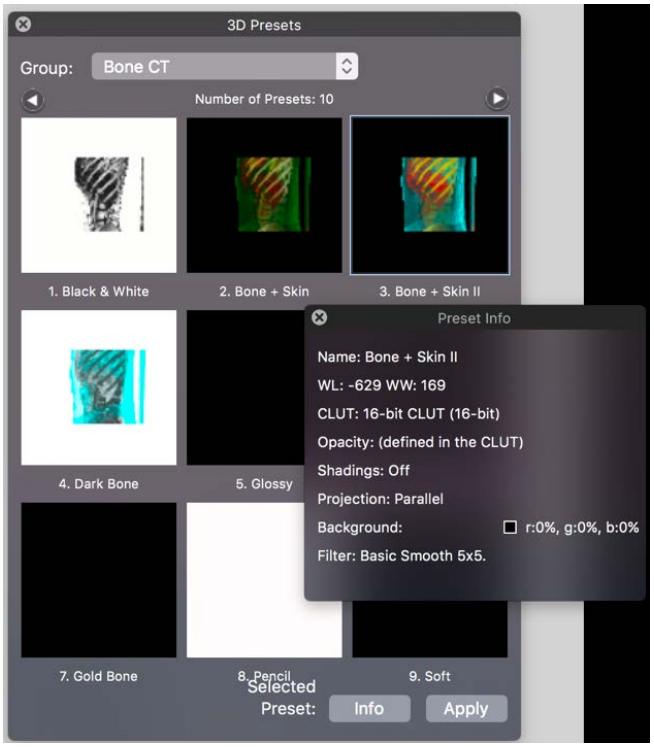


Figure 7.29. The 3D Presets popup window with the Bone CT group selected and the info box displayed for the Bone + Skin II preset.

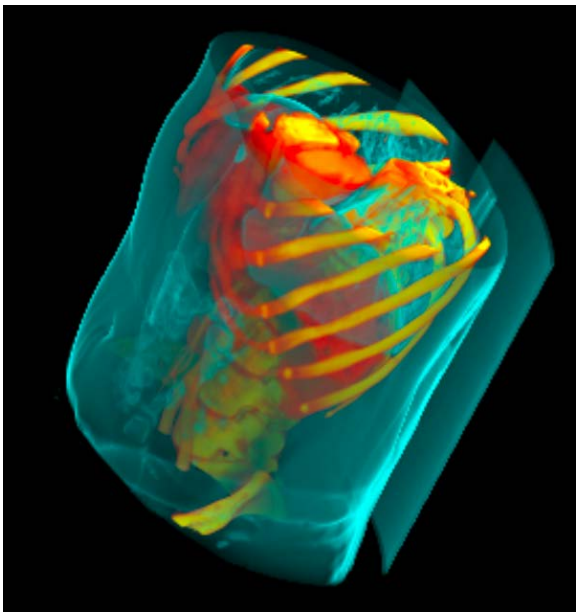


Figure 7.30. The Bone + Skin II preset displayed as a 3D volume rendering.

Level of Detail

You can select a finely rendered or a coarsely rendered image by moving the slider on the Level of Detail tool to the right or left.

Best Rendering

Clicking the Best Rendering tool forces Horos to render a high-quality image temporarily.

Engine

The Engine tool allows you to choose the computer's CPU (central processor) or GPU (graphics processor) engine to render images.

Cropping Cube

The Cropping Cube allows you to resize the area that will be rendered. The cube has 6 sides, each with a green ball in the middle of the plane. Clicking and dragging on one green ball moves that plane in or out. Data outside the bounds of the cropping cube will not be rendered (Figure 7.31).

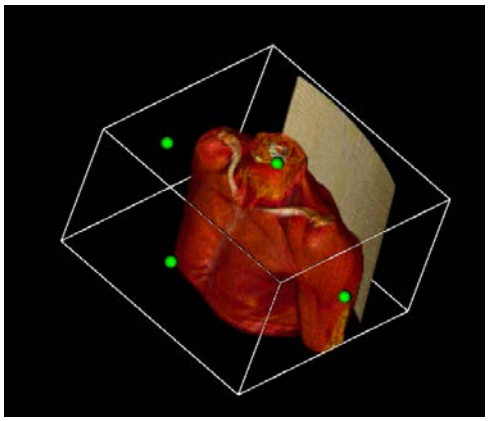


Figure 7.31. The Cropping Cube.

Orientation Cube

You can hide or display the orientation cube and labels using this tool. When displayed, there is a small orientation cube in the upper right corner and 4 small labels on each side of the image. The labels include left (L), right (R), posterior (P), anterior (A), superior (S), and inferior (I).

Shadings

You can modify the shading settings for a Volume Rendering (not an MIP) by clicking on the edit button in the Shading tool. This brings up a floating window (Figure 7.32) where you can adjust the levels of Ambient coefficient, Diffusion coefficient, Specular coefficient, and Spectral power. There are 4 predefined presets and you can create a new preset by clicking on the + to the right of the presets. Clicking on the edit button allows you to edit the four coefficients by using the slider to adjust the values. When you are satisfied, you can add this new preset by giving it a name and clicking the + to the right of the presets list

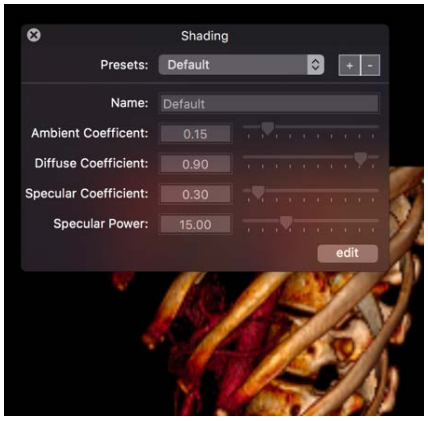


Figure 7.32. The Shading popup window.

You can turn shading on or off by clicking the check box.

Perspective

You can choose from three rendering perspectives; parallel, perspective, and endoscopy.

Filters

The Filters tool allows you apply convolution filters to the 3D image. There are 22 filters are available (Figure 7.33). Details for each filter are provided in Chapter 6.

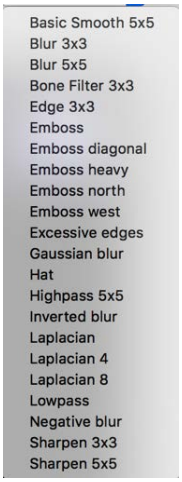


Figure 7.33. The convolution filters available from the Filters tool in the 3D Viewer.

Clipping

The Clipping tool allows you to create 2 clipping planes of defined thickness (using the slider). All image data outside the clipping planes will not be rendered. You can move the clipping planes by dragging the mouse over the image. You can also turn the clipping planes on or off by checking or unchecking the small checkbox.

Movie Export

You can create a movie of the 3D volume using the Movie Export tool. A popup window (Figure 7.34) allows you to choose the following options:

The number of frames to be generated – up to a maximum of 360 frames
The rotation amplitude (180º or 360º) and direction (horizontal or vertical)
The rendering quality (Current or Best)
The size of the movie (current, 512x512, 768x768)

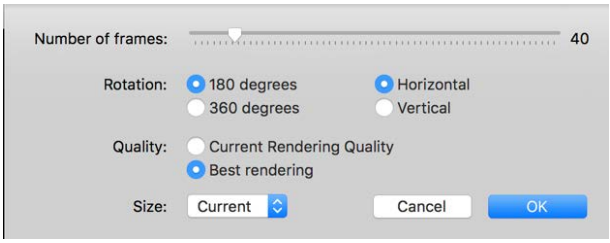


Figure 7.34. The Movie Export options window in the #D Viewer.

Orientations

Clicking on the four Orientations button in the Toolbar switches your view of the 3D volume beginning with axial (on the left), coronal, left sagittal, and right sagittal (on far right).

Reset

Choosing the Reset tool in 3D Volume Rendering changes the zoom, pan, rotation, WL/WW values, and camera position back to their default setting.

Revert

The Revert tool reloads and re-renders the image data from the original DICOM files. It cannot be undone.

Save as DICOM

You can create snapshots of your 3D scene, save them to disk as DICOM files, and add them to the database. Clicking on the DICOM tool opens a popup window (Figure 7.35) where you can create a new series name for the exported snapshots. You can also modify the size of the images by choosing between current, 512x512, or 768x768. Depending on the volume rendering you are using, you can also choose between 8-bit RGB or 16-bit BW formats. Note that 16-bit BW only works with MIP rendering. You can choose to only export the current image, an animated 4th dimension sequence (if available), or an animated series of images from the rotating volume. If you choose the animated series, you can change the number of frames to render (up to 360 frames), the direction of rotation for the animation, and the render quality. Finally, you have the option to mark the images as key images and the option to send the exported images to a DICOM node.

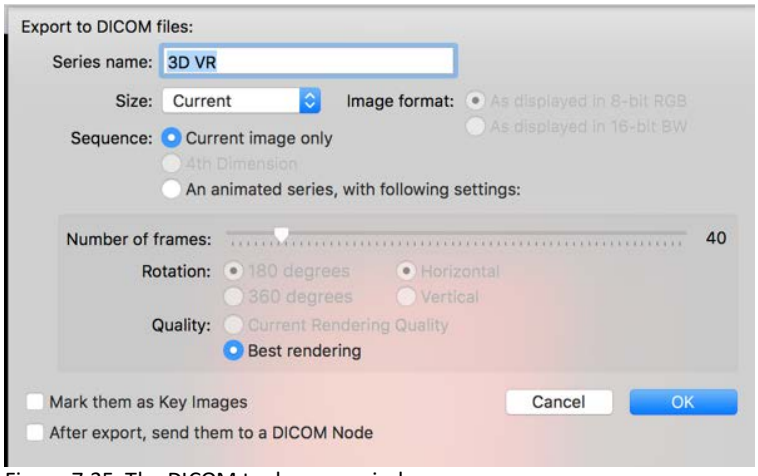
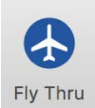


Figure 7.35. The DICOM tool popup window.



FLY THRU

You can create movies of 3D scenes in three 3D viewers; 3D MIP, 3D Volume Rendering, 3D Surface Rendering, and 3D endoscopy Viewer. To begin, open a patient series, double click on an image from that series in the bottom of the database window, and then choose 3D Volume render from the 2D/3D options button in the toolbar. With your 3D volume rendered, select the 3D Viewer menu from the top menu bar (Figure 7.36) and click on Add FlyThru Point option (or use the keyboard shortcut ⌘ **F1)**.

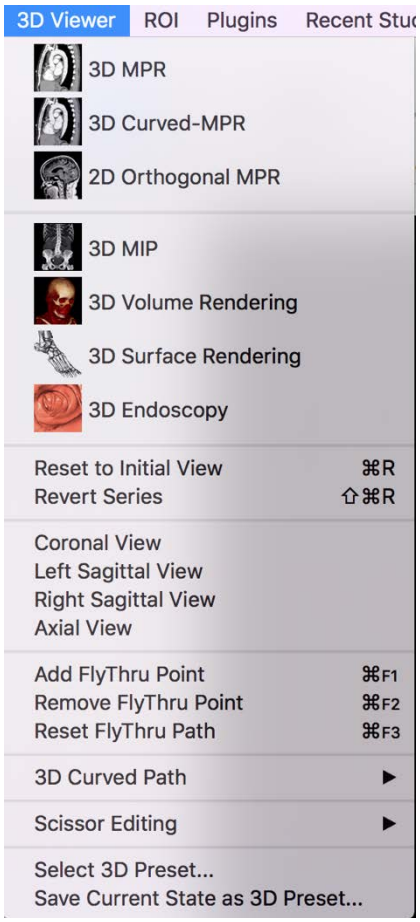


Figure 7.36. The options under the 3D Viewer menu bar.

The Fly Through popup window appears (Figure 7.37) with a thumbnail of the 3D volume rendered image in index 1. Move or rotate the 3D volume to a new position and click on the + symbol at the bottom left of the Fly Trough popup window. This adds a new index for that position. You can continue to add (plus sign) or delete (minus sign) index steps to the Fly Through window (Figure 7.37) or using the Remove FlyThru Point (⌘ **F2**) or Reset FlyThru Point (⌘ **F3**) options from the 3D Viewer menu. When you are finished, you will have a series of steps that comprise the movie (think of them as scenes). You can now create and export the movie using the Export button at the bottom of the Fly Through window. Horos will interpolate the missing frames between the steps (indexed frames) to generate a smooth sequence of frames

for your movie. If you choose the Movie button at the top right of the Fly Through window, you will see a new popup window that allows you to choose how many frames between indexed steps, the method for interpolation (spline or linear), and an option to loop the movie (Figure 7.37). The Spline method generates smoother transitions between steps. Clicking on the Compute button generates the interpolated movie.

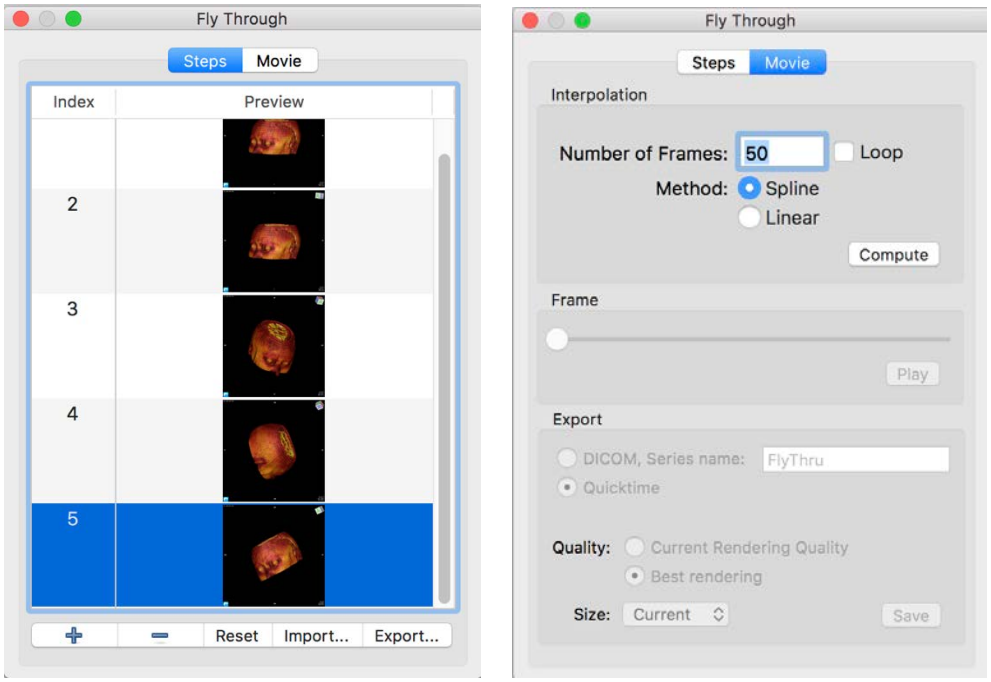


Figure 7.37. The Fly Through popup window. The left image is the Steps mode showing a series of 5 indexed steps. The right image is the Movie mode with 50 frames between each step.

You can play the newly created movie using the Play button in the middle of the Movie popup window. Finally, you can export the movie as a DICOM series or as a Quicktime (.mov) file in three size options (using the Size dropdown choices).

Note that in addition to rotating or moving the image between steps, you can also change image transparency, thresholding, color settings or other parameters between indexed images. Horos allows you to save a script file of the indexed images in XML format to disk for later retrieval.

Indexed steps are also called key steps and are d-dimensional vectors with d parameters. For example, if K is a key step, then:

$$\boldsymbol{K} = \boldsymbol{k_1}, \boldsymbol{k_2}, \cdots, \boldsymbol{k_d}$$

Where k_i is the ith parameter.

A linear path between two key steps K and L is a series of n points (P_i with i =1, …, n) where P_1 = K and P_n = L.

And where:

$$\|\boldsymbol{P_i} - \boldsymbol{P_{i+1}}\| = \|\boldsymbol{P_{i+1}} - \boldsymbol{P_{i+2}}\| \; \forall \boldsymbol{i} \in \{\mathbf{1}, \cdots, \boldsymbol{n} - \mathbf{2}\}$$

The difference between a linear path and a spline path is that a linear path contains points of a succession of paths going from K_i to K_{i+1} (i =1, …, m-1) and a spline path is a succession of equidistant points from a polynomial interpolation.

At each key step the camera position, camera focal point, camera view up, and camera view angle are recorded. If available, WL/WW, fusion percentage, and cropping box dimension and position are also recorded. A 3D state in generated for each point and a new frame is rendered along the interpolated path.

Custom Tools

Photos

You can export the current image to iPhoto using the Photos tool in the toolbar. It will open Apple's iPhoto application and adds the current 3D image as a JPEG.

Email

Selecting the Email tool opens Apple's Mail application, creates a new email message, and attaches the current image as a JPEG file.

Mode

The Mode tool allows you to switch back and forth between VR (volume rendering) and MIP (maximum intensity projection) modes.

Fusion

If you are viewing a fused series in 3D, you can use the Fusion tool to modify the fusion percentage.

4D Player

If you are viewing a 4D dataset, you can animate the time parameter of your 4D Series. The 4D Player tool allows you to play/pause the animation using the Paly button, choose the frame rate (images per second), and choose the time position using the sliders.

Stereo

You can create an anaglyph image of your 3D volume using the Stereo tool. An anaglyph is a 3D stereoscopic effect achieved by creating two colored images one for each eye. The 3D effect is achieved by wearing red/blue glasses.

3D Scissors State

The 3D Scissors State tool allows you to use the Scissors tool on 3D images. This tool is also available in the 3D Viewer menu.

ROI Manager

If you are working with a DICOM series that contains ROIs, the ROI Manager tool allows you to modify the appearance of the 3D ROIs (Figure 7.38). You can change the color of the ROI volume by changing the RGB values and the opacity of the ROI from transparent (0) to opaque (1). You can also turn the texture on or off.

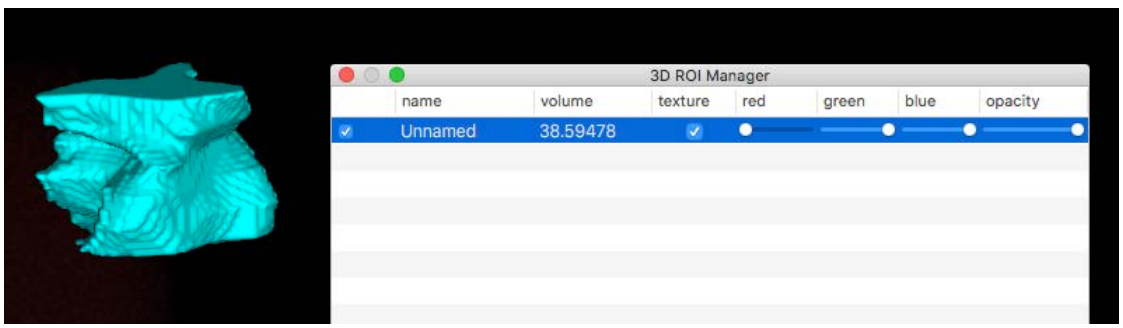


Figure 7.38. The ROI Manger popup window.

Background Color

You can change the background color of the 3D volume using any of the standard Mac OS X color pickers (Figure 7.39)

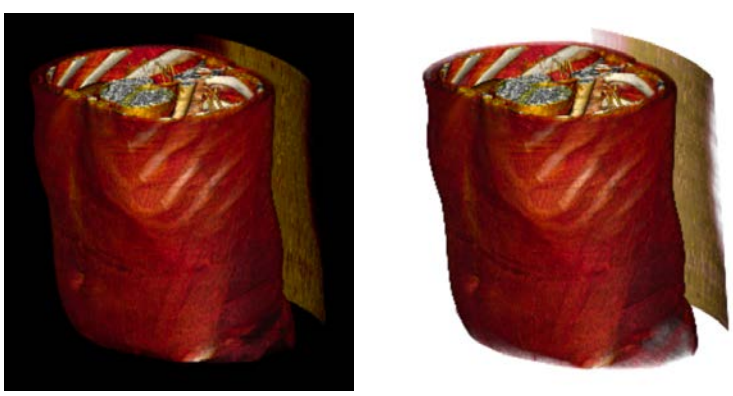


Figure 7.39. Two different choices of background color for a 3D volume rendering.

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.

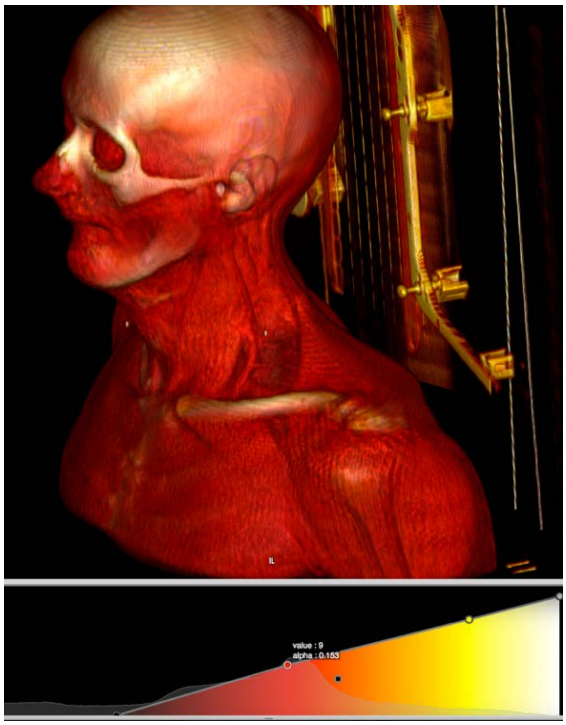


Figure 7.41. 16-bit CLUT Editor at the window bottom

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).

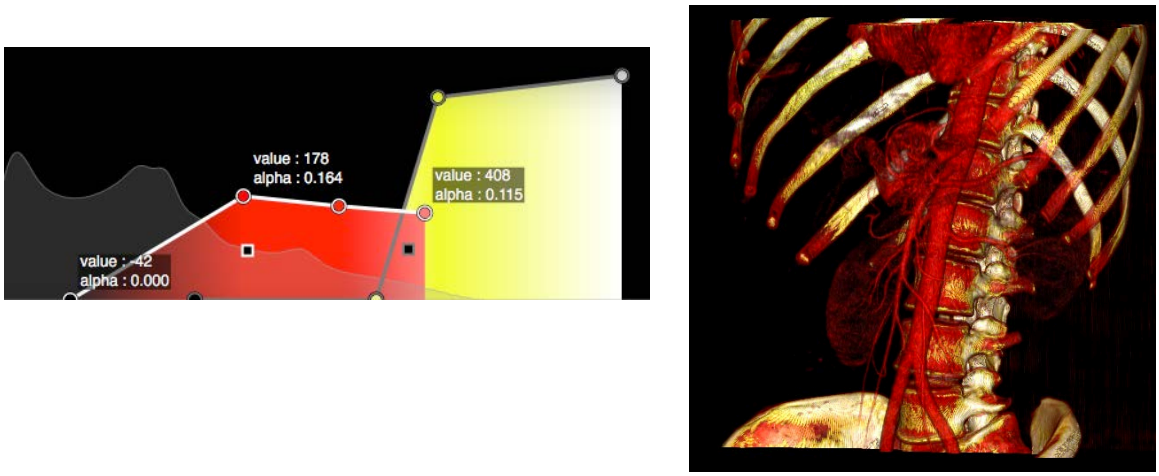


Figure 7.42. The CLUT Editor drawer (above) with two CLUT curves (one red and one yellow) and the resulting rendered image (left) showing the bones in yellow to white colors and the vessels in shades of red.

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.

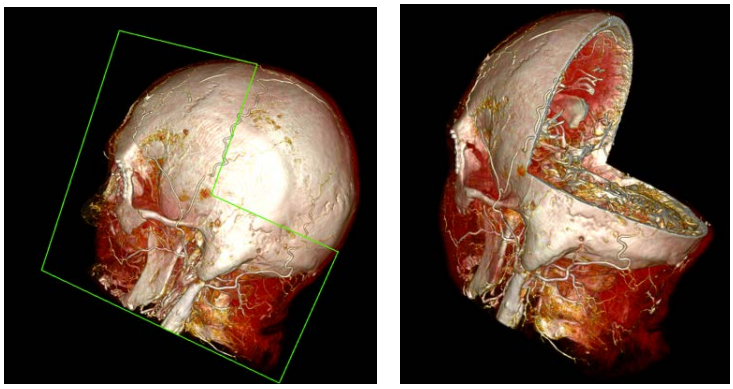


Figure 7.43. The scissors tool is used to create a polygon in green shown on the left. The image on the right is the image after the return key was pressed.

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.

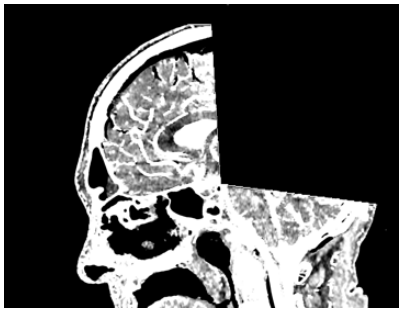


Figure 7.44. The 2D Viewer window showing the missing pixels for the sculpting shown in Figure 7.43.

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.

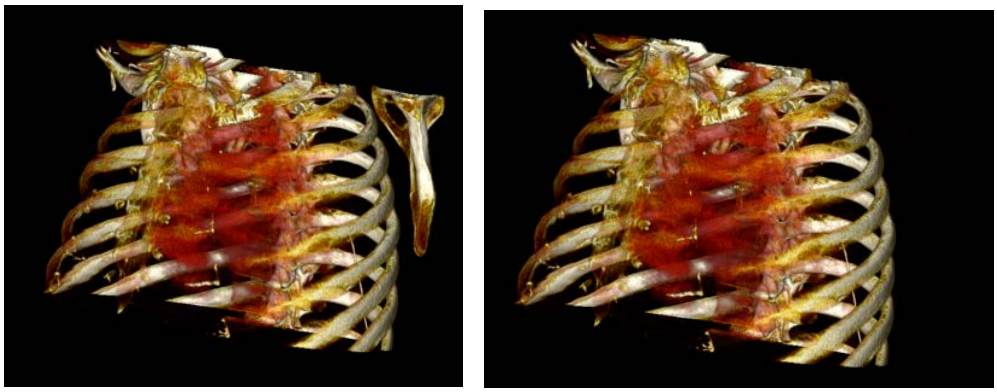


Figure 7.46. The Bone Removal tool. The image on the left is the original image. On the right image the left scapula has been removed.

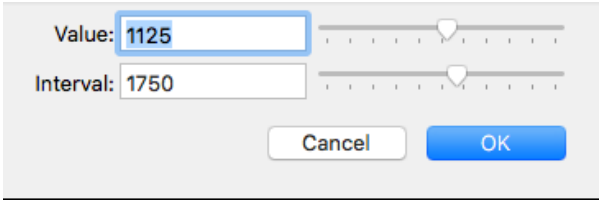


Figure 7.47. The Bone Removal popup window.

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.

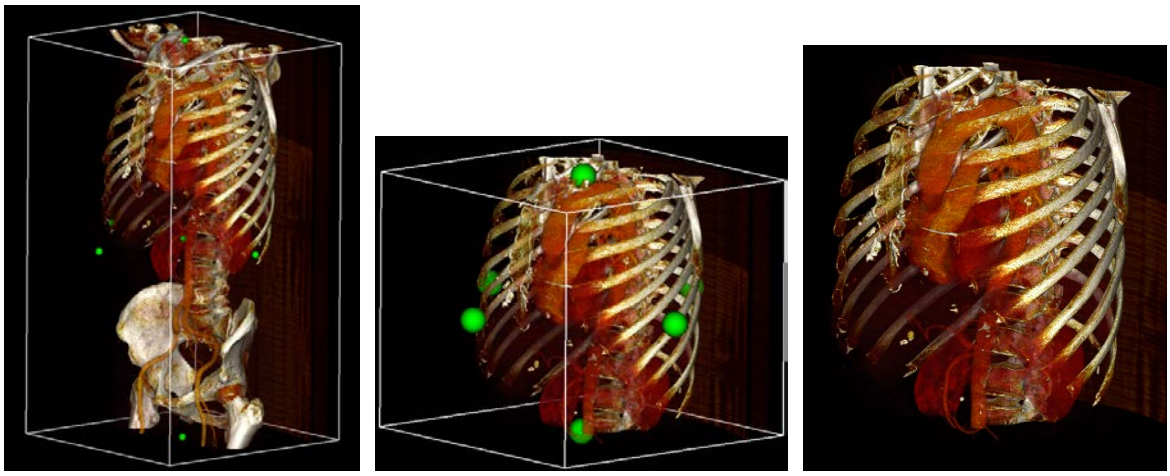


Figure 7.48. The Cropping tool. The left image shows the entire dataset. The middle image show the cropping tool bounding box restricted to just the thorax and abdomen. The right image is the final image with the cropping tool off.

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.

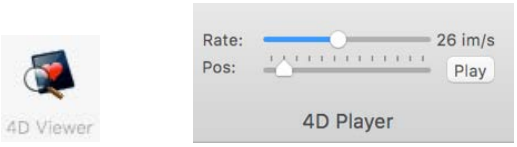


Figure 7.49. The 4D Viewer tool (left) from the database toolbar and the 4D Player tool (right) from the 3D Viewer toolbar.

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).

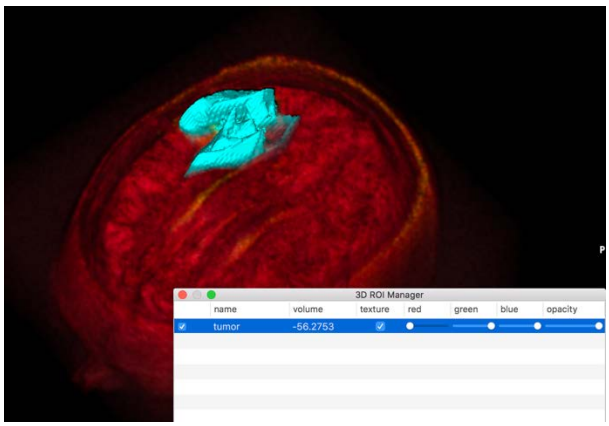


Figure 7.50. A 3D volume rendering of a brain tumor ROI.

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.

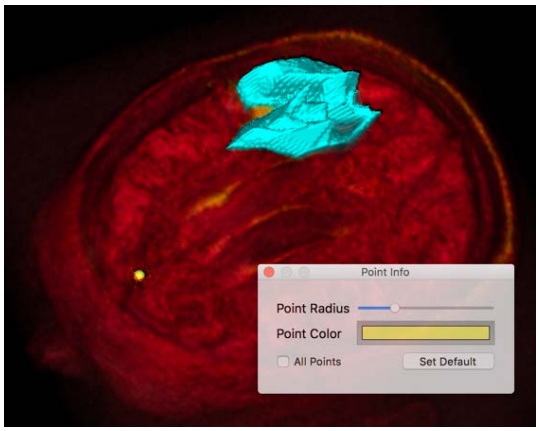


Figure 7.51. A Point ROI (yellow) added to the brain tumor rendering. The Point info dialog box can be used to change the appearance of 3D Points ROIs.

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.

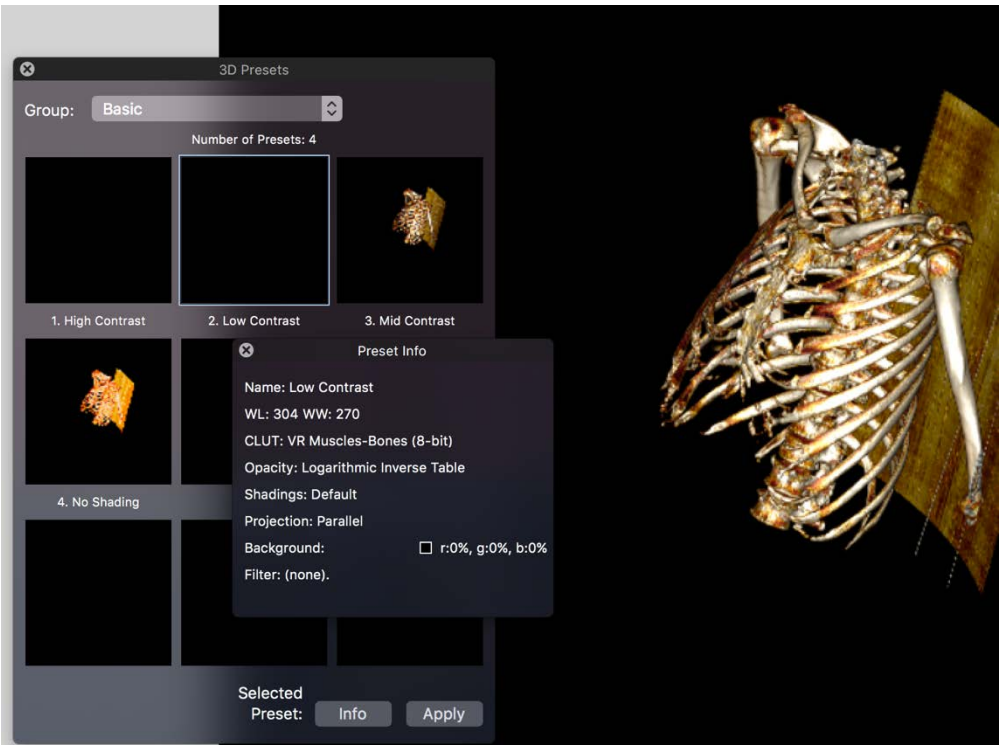


Figure 7.52. The 3D Presets tool with the info panel displayed.

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.

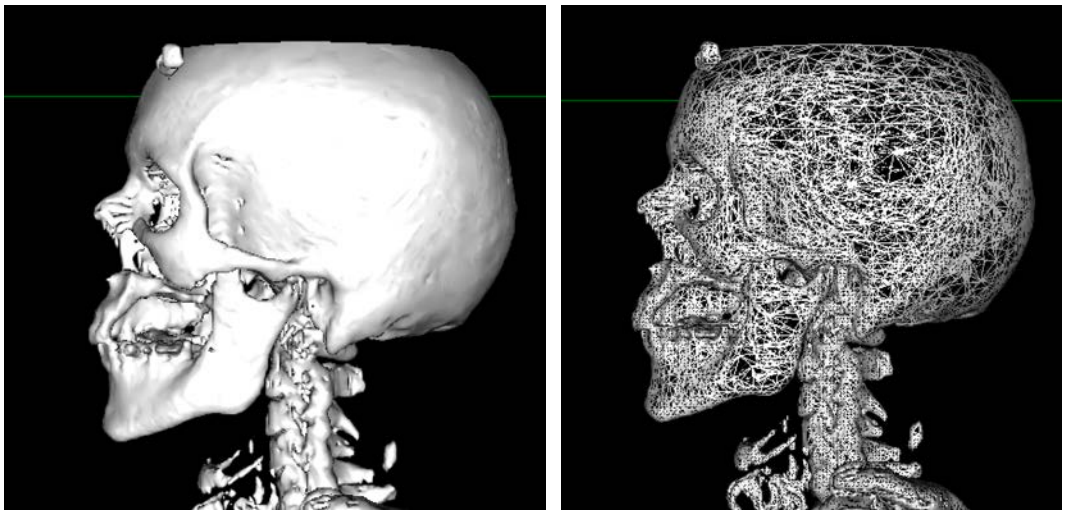


Figure 7.54. You can switch between (a) surface and (b) wireframe rendering.

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

second step is to render the polygon mesh using the computer's GPU. The algorithms used for this rendering technique are fast so the 3D image appears almost instantaneously, but only one or two surfaces are computed and rendered so you can see the entire volume (compared to volume rendering).

You can then choose a color and an opacity for the surface using the Surface Setting tool in the SR Viewer toolbar (Figure 7.55).

Finally, 3D surfaces can be exported as vectorial files that can be further manipulated in 3D modeling software such as Blender or Strata 3D.

The SR Viewer window is divided into a toolbar on top and an Image View on the bottom. The toolbar (Figure 7.55) contains buttons you use to access the most useful functions. The SR toolbar can be customized to fit your needs using Format > Custom Toolbar. The 3D rendered image is found in the image view window.

Toolbar

The SR Viewer toolbar (Figure 7.55) displays a variety of tools. Additional tools can be added, and other removed, using the Format > Custom Toolbar from the Format menu.

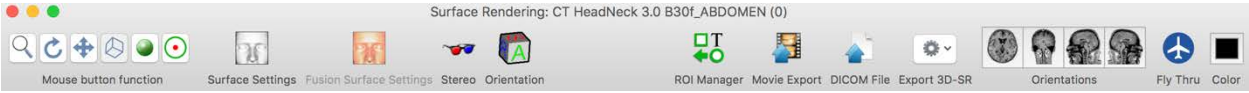


Figure 7.55. The SR Viewer Window Toolbar

Each tool is described below beginning with the default tools from left to right, followed by the additional custom tools in alphabetical order (Figure 7.56).

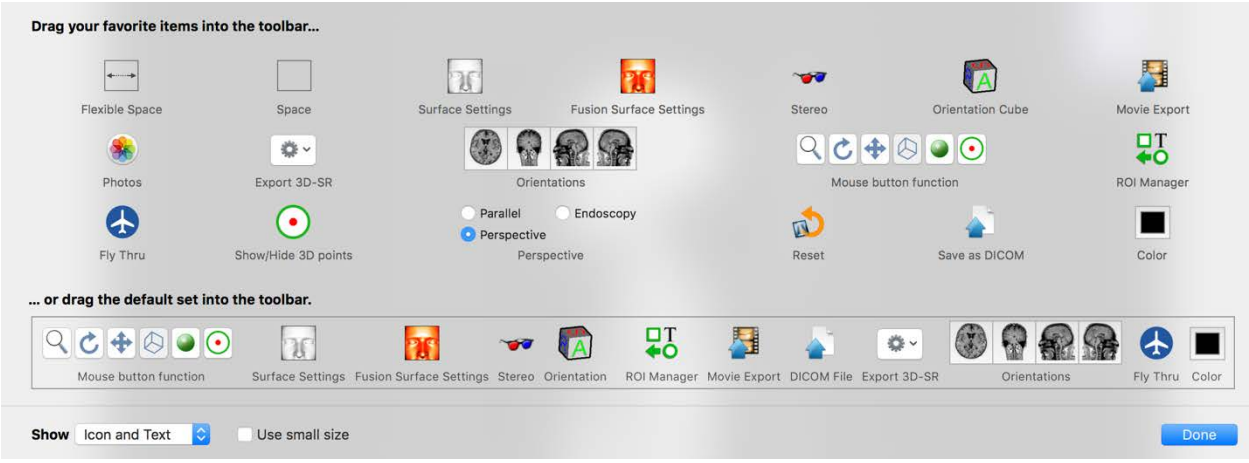


Figure 7.56. The custom tools available in the SR Viewer.

Mouse button function

The mouse button function tools allow you to choose a tool that activates when you click the left mouse button. You can choose Zoom, Rotate, Pan, Volume rotate [default], Plane rotate, and 3D Point tools. These tools have been described previously.

Surface Settings

The Surface Settings tool allows you to set rendering parameters for the primary 3D surface and an optional secondary (Figure 7.57). You can set the quality of the render using the slider to choose from low to high quality. The Decimate – Resolution can be set between 0.0 and 1.0. The decimate modifier is a way of reducing the polygon count in a mesh. The Smooth –Iteration function can be set between 1 and 100.

Two surfaces can be rendered. You can choose to enable or disable the primary and secondary surfaces using the checkbox to the left. For each surface, you can enter a pixel threshold value or choose from three pre-defined values for CT scans: Skin (−500), Bones (500), and Metal (2000). You can also set the transparency and color for the 3D surface rendering. Clicking on the Color square brings up the Mac OS X Color Picker.

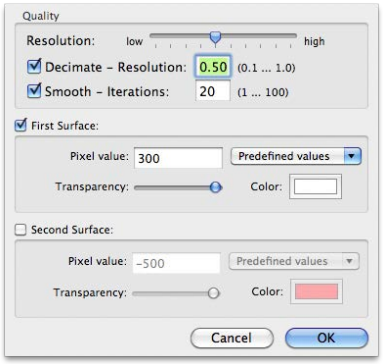


Figure 7.57. The Surface Settings used to compute the isosurface.

Fusion Surface Settings

If you are viewing a fused dataset, the Fusion Surface Settings icon will be active. It works like the Surface Setting tool, but with fused series.

Stereo

You can create an anaglyph image of your 3D volume using the Stereo tool. An anaglyph is a 3D stereoscopic effect achieved by creating two colored images one for each eye. The 3D effect is achieved by wearing red/blue glasses.

Orientation Cube

You can hide or display the orientation cube and labels using this tool. When displayed, there is a small orientation cube in the upper right corner and 4 small labels on each side of the image. The cube is displayed in the same orientation as the image. The labels include left (L), right (R), posterior (P), anterior (A), superior (S), and inferior (I).

ROI Manager

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

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 ROI Manager dialog box.

Point ROIs can be added directly onto the surface rendered image in the SR Viewer window. Select the Point tool from the Mouse Button list and click on the image where you want the point to go. 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. The color and size of the point can be edited using the Point Info dialog box.

Movie Export

You can create a movie of the 3D volume using the Movie Export tool. A popup window (Figure 7.34) allows you to choose the following options:

The number of frames to be generated – up to a maximum of 360 frames
The rotation amplitude (180° or 360°) and direction (horizontal or vertical)
The rendering quality (Current or Best)
The size of the movie (current, 512x512, 768x768)

DICOM File

This tool allows you to take DICOM snapshots of currently displayed 3D surface renders. The snapshots are added to the database. You can name the new series and set the size of the images (Current, 512x512, 768x768). You can also choose to save only the current image. However, if you choose to save a series of images from the rotating surface rendering, you have the option to set the number of frames (1-360), the amplitude of rotation (180° to 360°), and whether you want vertical or horizontal rotation. The new DICOM images can be marked as key images and sent to a DICOM node.

Export 3D-SR

This tool allows you to export the 3D Surface as vectorial data in five formats:

- *Renderman (.rib)*
- *VRML (.vrml)*
- *Inventor (.iv)*
- *Wavefront (.obj)*
- *STL (.stl)*

Orientations

The Orientations tool allows you to switch between axial, coronal, left sagittal, or right sagittal camera positions for viewing the volume.

Fly Through

You can create movies of 3D scenes by choosing several points along a camera path. To begin, open a 3D surface volume and click on the Fly Thru icon in the toolbar or select the 3D Viewer menu from the top menu bar and select Add FlyThru Point option (or use the keyboard shortcut **⌘ F1)**.

The Fly Through popup window appears (Figure 7.37) with a thumbnail of the 3D surface volume rendered image in index 1. Move or rotate the surface volume to a new position and click on the + symbol at the bottom left of the Fly Trough popup window. This adds a new index for that position. You can continue to add (plus sign) or delete (minus sign) index steps to the Fly Through window (Figure 7.37). When you are finished, you will have a series of steps that comprise the movie's path (think of them as scenes). You can now create and export the movie using the Export button at the bottom of the Fly Through window. Horos will interpolate the missing frames between the steps (indexed frames) to generate a smooth sequence of frames for your movie.

Choosing the Movie button at the top right of the Fly Through window will display a new popup window that allows you to choose how many frames between indexed steps, the method for interpolation (spline or linear), and an option to loop the movie. The Spline method generates smoother transitions between steps. Clicking on the Compute button generates the interpolated movie.

You can play the newly created movie using the Play button in the middle of the Movie popup window. Finally, you can export the movie as a DICOM series or as a Quicktime (.mov) file in three size options (using the Size dropdown choices).

Color

This tool allows you to change the background color of the 3D Surface view using the standard Mac OS X color picker.

Custom Tools

Perspective

You can choose the three perspective parameters for the rendering: Parallel, Perspective, or Endoscopy.

Photo

This tool opens Apple's iPhoto software and adds a JPEG image of the currently rendered image.

Reset

This resets the viewer to the default viewing settings.

Show/Hide 3D Points

This tool allows you to show or hide 3D points ROIs.

THE ENDOSCOPY VIEWER

The Endoscopy Viewer window is divided into three parts: a toolbar, three MPR views, and a 3D volume rendering. The toolbar (Figure 7.58) contains icons for useful tools. It can be customized from the Format > Custom Toolbar menu. The image view windows are divided into 3 orthogonal views and the 3D view (Figure 7.59).

Note that the Endoscopy Viewer is not compatible with image fusion or 4D data series.

Toolbar

This section describes each of these tools in the default Endoscopy toolbar from left to right. The tools on the left modify the MPR View and those on the right modify the 3D views.

Figure 7.58. The Endoscopy Window Toolbar

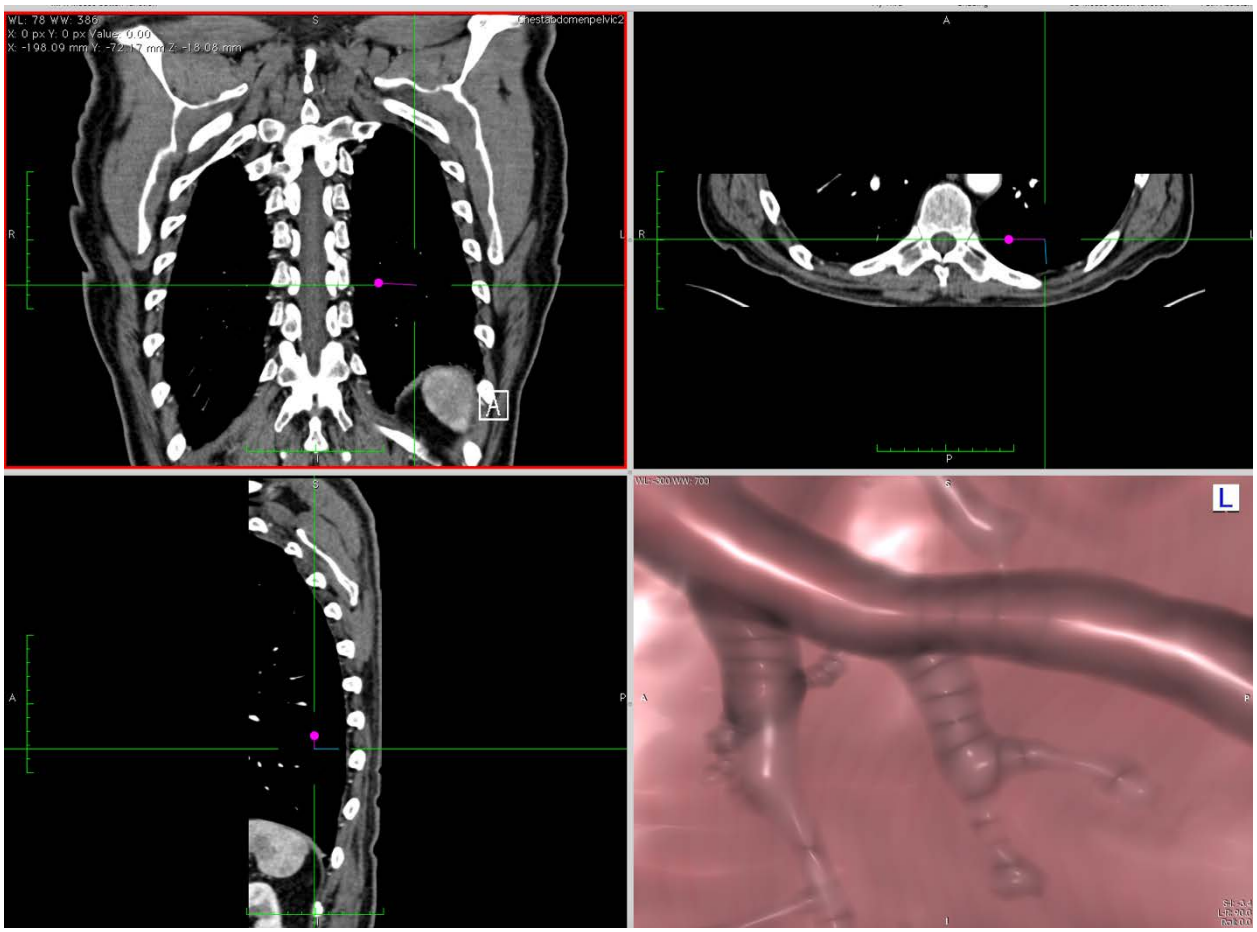


Figure 7.59. The three MPR views and the 3D endoscopy view (lower right).

MPR Mouse button function (MPR Views)

You can use these mouse button tools to manipulate the 3 MPR views. These tools has been described in the 2D Viewer chapter (Chapter 6), so only those tools that a new to the Endoscopy Viewer will be described in detail. The MPR mouse tools include:

- *WL/WW [default]*
- *Pan*
- *Zoom*
- *Rotate*
- *Scroll*
- *MPR plane move – This tool allows you to move through the series by clicking and dragging the mouse on one of the MPR windows. The other two MPR windows change to reflect the moves you made in your window.*
- *Length ROI*
- *Oval ROI*
- *Angle*

Fly Through (3D View)

You can create movies of 3D scenes by choosing several points along a camera path. To begin, open an Endoscopy volume and click on the Fly Thru icon in the toolbar or select the 3D Viewer menu from the top menu bar and click on Add FlyThru Point option (or use the keyboard shortcut ⌘ **F1)**.

The Fly Through popup window appears (Figure 7.37). Move or rotate the 3D volume to a new position and click on the + symbol at the bottom left of the Fly Trough popup window. This adds a new index for that position. You can continue to add (plus sign) or delete (minus sign) index steps to the Fly Through window (Figure 7.37). When you are finished, you will have a series of steps that comprise the movie's path (think of them as scenes). You can now create and export the movie using the Export button at the bottom of the Fly Through window. Horos will interpolate the missing frames between the steps (indexed frames) to generate a smooth sequence of frames for your movie.

Choosing the Movie button at the top right of the Fly Through window will display a new popup window that allows you to choose how many frames between indexed steps, the method for interpolation (spline or linear), and an option to loop the movie (Figure 7.37). The Spline method generates smoother transitions between steps. Clicking on the Compute button generates the interpolated movie.

You can play the newly created movie using the Play button in the middle of the Movie popup window. Finally, you can export the movie as a DICOM series or as a Quicktime (.mov) file in three size options (using the Size dropdown choices).

Note that in addition to rotating or moving the image between steps, you can also change image transparency, thresholding, color settings or other parameters between indexed images. Horos allows you to save a script file of the indexed images in XML format to disk for later retrieval.

Shadings (3D View)

You can modify the shading parameters of the 3D view by clicking on the Edit button in the toolbar. Shading parameters do not modify the three MPR views.

3D Mouse button function (3D View)

You also have access to seven mouse button functions for manipulating the 3D view. You can choose from:

- *WL/WW - This changes the WL/WW settings for the 3D view.*
- *Pan*
- *Zoom*
- *Rotate*
- *Volume rotate*

- *Plane rotate [default]*
- *3D Point*

Path Assistant (3D View / MPR Views)

The Path Assistant allows you to compute the centerline of an airway or vessel automatically. This can be helpful as a guide for moving the camera path in the 3D viewer. Clicking on the Path Assistant brings up a popup window (Figure 7.60) where you can choose from two modes and several settings parameters.

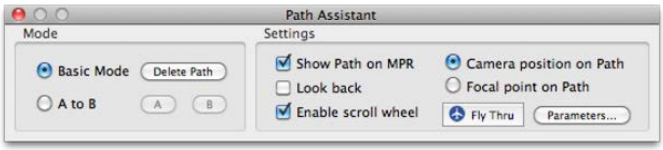


Figure 7.60. The Path Assistant panel

The **Basic** mode computes the centerline on the fly as you move the camera position. Click on the Lock path button next to Basic mode to activate it and then use the mouse scroll wheel to move the camera along the computed centerline (up and down arrow keys on the key board may also be used).

The **A to B** mode allows you to define a starting point (A) and an ending point (B). The Path Assistant then computes the centerline from A to B. Now you can use the scroll wheel on the mouse (or up and down arrow keys) to move along the computed centerline.

You can click on the Fly Thu button to create a movie sequence along the computed bath.

ENDOSCOPY VIEWER MPR FUNCTIONS

The Endoscopy MPR views use the same engine as the 2D Orthogonal MPR Viewer. The Endoscopy Volume Rendering view uses the same engine as the 3D Viewer. The basic tools and shortcuts in the three MPR views is similar to those of the 2D Viewer. If you double-click one of the views, it will display in full screen. A second double-click will switch it back to the 4-panel view.

Focal Point and Camera Position

In the Endoscopy Viewer, the orthogonal MRP views display the focal point and a camera position are denoted by a purple pin at the center of green cross reference lines (Figure 7.61). If the length of the focal point vector (pin length) is large, then the vector is parallel to the plane. However, if it is small, then the vector is perpendicular to the plane. Clicking on the focal point pin and dragging it changes the vector length.

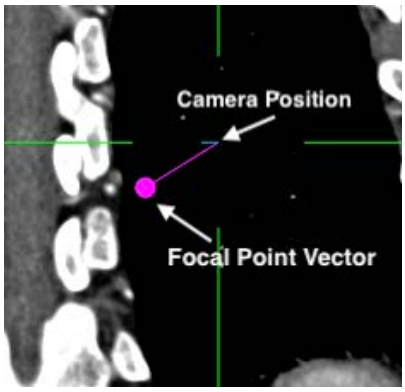


Figure 7.61. The Camera Position and Focal Point vector.

Cross reference lines

The green cross reference lines are displayed on all three orthogonal MPR views allowing you to see where a position is on each view. You can hide or show the green cross-reference lines by pressing the space bar.

ROIs

Temporary ROIs and point ROIs can be displayed on the MPR views in the Endoscopy Viewer. However, only point ROIs are displayed in the volume render view. The Endoscopy Viewer cannot display 3D ROIs. You can add Lines, Ovals, and Angle ROIs to the MPR views but they are temporary and will disappear when you move the position of the view.

To add a point ROI to the volume render view, select the Point ROI tool from the 3D Mouse button functions in the toolbar and click on the 3D render image where you want the point located. Horos uses the current WL/WW settings and computes a ray-casting to drop the point on a completely opaque structure. A point ROI added in the 3D volume will also be visible in the 2D Viewer window. Double-clicking on a point ROI allows you to change its size and color.

In the Endoscopy Viewer, you can export images of the MPR views and the Volume Rendering view in JPEG or DICOM format using the File > Export from the main menu. Exported images will be saved to the database and appear in the database window where they can be displayed or exported to a PACS workstation. Fly Thru sequences are exported via the Fly Thru export tool.

Chapter 8

Movies and Fly-Thrus

Movie Export

You can create and export a movie file for a series displayed in the Viewer by either selecting File > Export > Export to Movie from the main menu, or by clicking on the Export Movie icon in the toolbar (shown above). A pop-up window appears with options for exporting the movie file (Figure 8.1). Depending on the type of series displayed at the time, you can choose to export a movie of fused images (PET-CT), 4D data movies (i.e. including a time dimension), only key images from a 2D series, or a 2D series. You can choose the interval and a sub-section of frames by using the sliders or entering numbers in the text boxes to the left of the sliders.

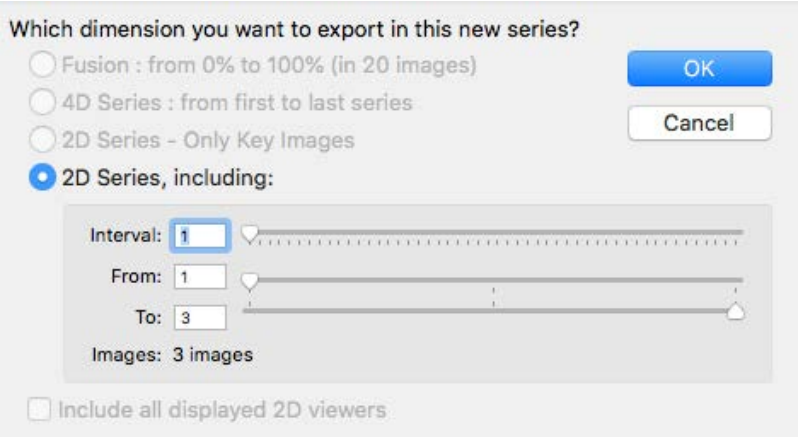


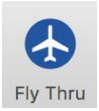
Figure 8.1. Movie Export options

If you have multiple 2D Viewers displayed on the screen (Figure 8.2), you can also select the Include all displayed 2D viewers option at the bottom. This will capture the images of all open viewers, combining them into a single movie image file. That is to say, you will have a single movie file displaying all viewers simultaneously. You can remove annotations from the exported movie using the tab key.

(a) As displayed in Horos (b) As exported

Figure 8.2. Exporting all displayed 2D Viewers in a single Movie Sequence file

The default movie export format in Horos is QuickTime format (.mov) or H264 (MPEG4) format. A number of third party applications are available to convert .mov or MPEG4 files to other formats.



FLY THRU

You can create movies of 3D scenes in three 3D viewers; 3D MIP, 3D Volume Rendering, 3D Surface Rendering, and 3D endoscopy Viewer. To begin, open a patient series, double click on an image from that series in the bottom of the database window, and then choose 3D Volume render from the 2D/3D options button in the toolbar. With your 3D volume rendered, select the 3D Viewer menu from the top menu bar (Figure 8.3) and click on Add FlyThru Point option (or use the keyboard shortcut ⌘ **F1)**.

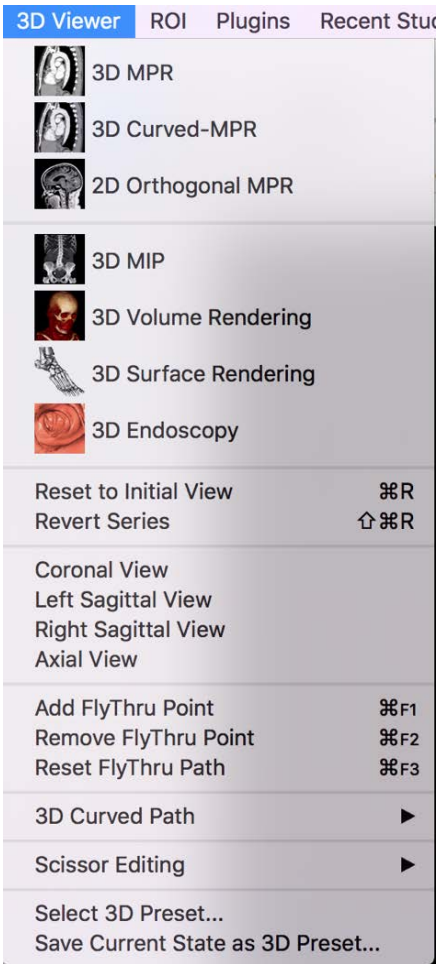


Figure 8.3. The options under the 3D Viewer menu bar.

The Fly Through popup window appears (Figure 8.4) with a thumbnail of the 3D volume rendered image in index 1. Move or rotate the 3D volume to a new position and click on the + symbol at the bottom left of the Fly Trough popup window. This adds a new index for that position. You can continue to add (plus sign) or delete (minus sign) index steps to the Fly Through window (Figure 8.4) or using the Remove FlyThru Point (⌘ **F2**) or Reset FlyThru Point (⌘ **F3**) options from the 3D Viewer menu. When you are finished, you will have a series of steps that comprise the movie (think of them as scenes). You can now create and export the movie using the Export button at the bottom of the Fly Through window. Horos will interpolate the missing frames between the steps (indexed frames) to generate a smooth sequence of frames for your movie. If you choose the Movie button at the top right of the Fly Through window, you will see a new popup window that allows you to choose how many frames between indexed steps, the method for interpolation (spline or linear), and an option to loop the movie (Figure 8.4). The Spline method generates smoother transitions between steps. Clicking on the Compute button generates the interpolated movie.

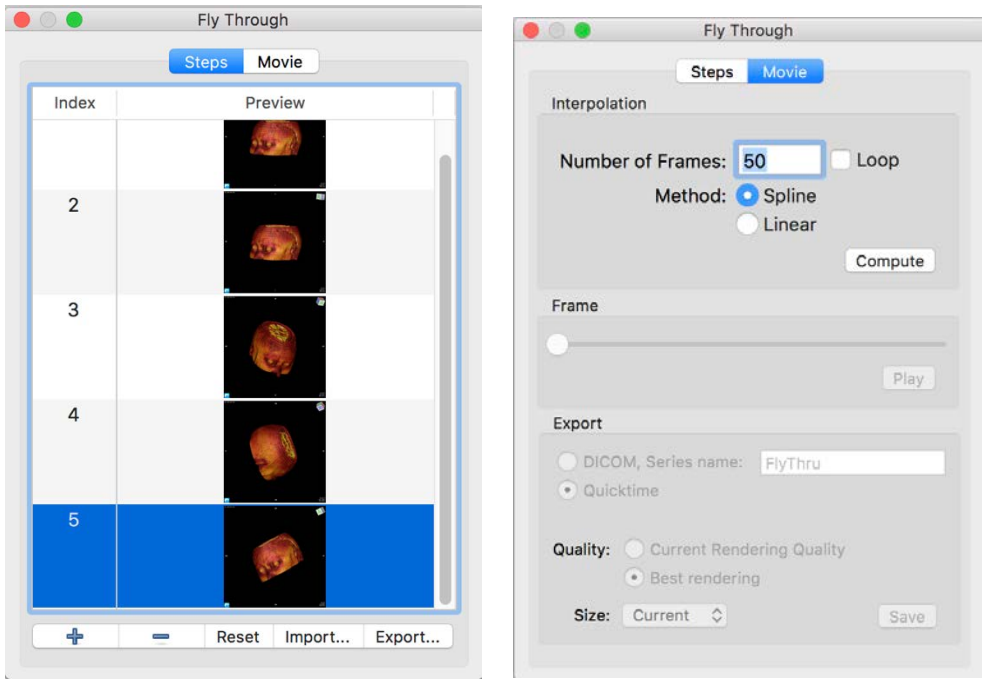


Figure 8.4. The Fly Through popup window. The left image is the Steps mode showing a series of 5 indexed steps. The right image is the Movie mode with 50 frames between each step.

You can play the newly created movie using the Play button in the middle of the Movie popup window. Finally, you can export the movie as a DICOM series or as a Quicktime (.mov) file in three size options (using the Size dropdown choices).

Note that in addition to rotating or moving the image between steps, you can also change image transparency, thresholding, color settings or other parameters between indexed images. Horos allows you to save a script file of the indexed images in XML format to disk for later retrieval.

Indexed steps are also called key steps and are d-dimensional vectors with d parameters. For example, if K is a key step, then:

$$\boldsymbol{K} = \boldsymbol{k_1}, \boldsymbol{k_2}, \cdots, \boldsymbol{k_d}$$

Where k_i is the ith parameter.

A linear path between two key steps K and L is a series of n points (P_i with i =1, …, n) where P_1 = K and P_n = L.

And where:

$$\|\boldsymbol{P_i} - \boldsymbol{P_{i+1}}\| = \|\boldsymbol{P_{i+1}} - \boldsymbol{P_{i+2}}\| \; \forall \boldsymbol{i} \in \{\boldsymbol{1}, \cdots, \boldsymbol{n} - \boldsymbol{2}\}$$

The difference between a linear path and a spline path is that a linear path contains points of a succession of paths going from K_i to K_{i+1} (i =1, …, m-1) and a spline path is a succession of equidistant points from a polynomial interpolation (as defined in 14).

At each key step the camera position, camera focal point, camera view up, and camera view angle are recorded. If available, WL/WW, fusion percentage, and cropping box dimension and position are also recorded. A 3D state in generated for each point and a new frame is rendered along the interpolated path.

Chapter 9

Using Horos in a Network and General Concepts

Introduction

This chapter covers some of the general concepts of functionality of Horos and how it interacts with a Picture and Archiving System (PACS) and other workstations. The concepts of the DICOM standard, DICOM nodes and DICOM protocols are also included in this chapter.

PACS Network

Within a Picture Archiving and System (PACS) there is typically a central server which stores the images on a database, in DICOM Standard format. Each imaging modality linked to the PACS, (MRI, CT, Ultrasound, CR, DDR etc) are set up to automatically send images to the PACS server using a protocol known as DICOM C-STORE. The data which includes the DICOM images and the DICOM-DIR files, the latter of which contains the field information such as imaging modality and patient information, are all communicated via a network.

The concept of a PACS is all based upon a client/server framework. Users wishing to access the DICOM images stored on the PACS are known as ‘clients’. To access DICOM images stored on a PACS the ‘client’ must first send a ‘Query & Retrieve’ request. This is done through a protocol known as DICOM C-STORE. This request is automatic if the client has networked access to the PACS.

For a ‘client’ to display the images on their own computer, medical imaging software such as Horos, is required. This software is known as a DICOM viewer. Images stored on a PACS will automatically appear in a ‘clients’ database.

Importing and Receiving Data

Images can be imported into a Horos database in one of two ways

- Directly from a CD/DVD or other external storage device. See Chapter 4 for more details
- Through the network via a PACS

To receive images through a PACS, Horos just has to be running. Files received in this way are automatically stored and indexed in the Horos Data folder. See Chapters 3 and 4 for more details.

The standard DICOM protocol used by Horos for receiving images and the associated data is **DICOM C-STORE SCP.**

Other more advanced or recent protocols supported are; WADO downloading, DICOM C-GET SCU and DICOM C-MOVE SCU. More information on DICOM protocols can be found later in this chapter.

Sending Data

Horos sends data to other workstations or comparable software using the DICOM C-STORE SCU protocol. For more information can be found on the C-STORE and other DICOM protocols later in this chapter.

Studies, series or images can be sent using this protocol in a number of ways:

- The contextual *File* menu
- Using the *Send* tool on the toolbar
- From the *Sources* section of the left hand side panel
- Auto-routing
- Automatic rules.

The first three are described in detail in Chapters 9 and 4. Auto-routing and automatic rules are described later in this chapter.

Sharing Data

Multiple protocols are available to share images with other Horos or DICOM compatible workstations. This provides the user with the option to use Horos as a PACS server, DICOM router or to share images or files created or manipulated in Horos for example reports, annotations and volume rendered images.

The built in protocols are:

- DICOM Query & Retrieve
- Database Sharing
- Auto-routing
- Synchronize and Archive
- HTTP Web Server
- PACS Server

DICOM Query & Retrieve

This feature, based on standard DICOM protocols, allows Horos to browse, search and download images from any distant DICOM-compatible software. This could include a PACS server or other Horos workstation and will allow any DICOM compatible software to use it. Further details on running a DICOM Query and Retrieve can be found later in this chapter and in Chapter 4.

DICOM communications

DICOM standard is most commonly understood as the format in which files store images. It also describes the standard protocols for sending, retrieving, printing and integration with a Radiology Information System (RIS) PACS, all performed on a network-based service.

As described earlier in the chapter under the *PACS* section, communications between DICOM applications and/or a PACS are based upon a client/server framework.

In order to exchange information, for example to access DICOM images stored on a PACS, a connection must be established and the following agreed between the two connected applications:

- Who is the server and who is the client.
- Which DICOM protocol its required to complete the requested task e.g. C-STORE
- Which format to transmit the image(s) in e.g. DICOM, JPEG2000, uncompressed

As these protocols are used within standard Transmission Control Protocol/Internet Protocol (TCP/IP), any TCP/IP interface can be used e.g. Wifi, Ethernet or 3G/4G. A TCP/IP is a group of standard protocols used to connect networked devices via the internet. The same protocols can also be used on a local intranet.

A DICOM node describes any networked DICOM software or hardware, which is used to manage, process or transfer DICOM images. This is essentially a workstation or PACS server. Each DICOM node is uniquely identified by the TCP/IP address of the computer e.g. 174.14.5.18 as well as the TCP/IP Port e.g. 4686 and its Application Entity (AE) title e.g. Horos.

If a software or hardware acts as a server it is described as ‘offering a service’ and is the ‘Service Class Provider’ (SCP).

If a software or hardware uses a service it is described as 'acting as a client' and is the Service Class User' (SCU).

Should you wish to search for images on a networked PACS, a series of DICOM services are engaged to perform this function. An example of the DICOM services engaged to search for and retrieve an image from a networked PACS, through the *Query and Retrieve* tool are shown below:

Action	**DICOM service**	**SCU**	**SCP**
Horos sends query to PACS	C-FIND	Horos	PACS
Horos retrieves study from PACS	C-MOVE, C-GET or WADO	Horos	PACS
PACS sends study to Horos	C-MOVE, C-STORE, C-GET or WADO	PACS	Horos

Adapted from Osirix user manual SCU, Service Class User. SCP, Service Class provider

DICOM protocols

In order to perform services on a DICOM network and communicate with other PACS and workstations, Horos employs and supports a number of recognized DICOM protocols. These protocols are described in the DICOM Standard [10].

In the case of a Service Class Provider (SCP), where the software or hardware acts as a server and is described as 'offering a service', these protocols are 'always-up' and ready to respond to a request.

In the case of a Service Class User (SCU), these protocols only run when a task or the tool is triggered by the user.

A list of the protocols supported by Horos is displayed below:

Protocol Name	**SCU/SCP**	**Description**
C-STORE	Both	Listener and Send Functions
C-FIND	Both	Image Queries*
C-MOVE	Both	Image retrieval*
C-GET	Both	Image retrieval*
C-ECHO	Both	DICOM Nodes test functions*
C-PRINT	SCU	DICOM printing
WADO	Both	HTTP Web protocol for image transfer

**These protocols are run through the Query and Retrieve Window*

Detailed descriptions of these protocols can be found at the end of this Chapter.

DICOM Listener

In order for your workstation to work as a PACS server, you will need to set up the DICOM Listener and configure your workstation as a DICOM-compliant *node.* A DICOM node describes any networked DICOM software or hardware, which is used to manage, process or transfer DICOM images. This is essentially a workstation or PACS server. Each DICOM node is uniquely identified by the TCP/IP address of the computer e.g. 174.14.5.18 as well as the TCP/IP Port e.g. 4686 and its Application Entity (AE) title e.g. Horos.

To setup the DICOM Listener, select the *Listener* tab from the *Preferences* (Fig 9.1). The dialogue window which is displayed requires you to enter:

- The Application entity (AE title) of your workstation e.g. Horos
- Your IP address e.g. 174.14.5.18
- The name and identity of the port used e.g. 4686

This information will be required both by your PACS server, and any other devices which you choose to send images to. More information on setting up the DICOM Listener can be found in Chapter 2.

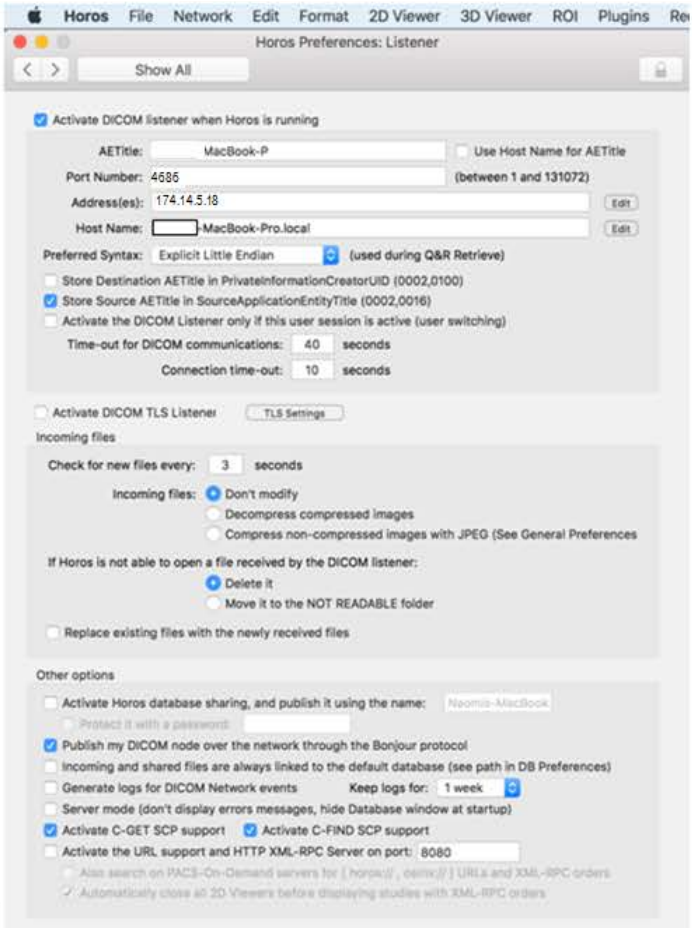


Figure 9.1 The DICOM Listener preferences window

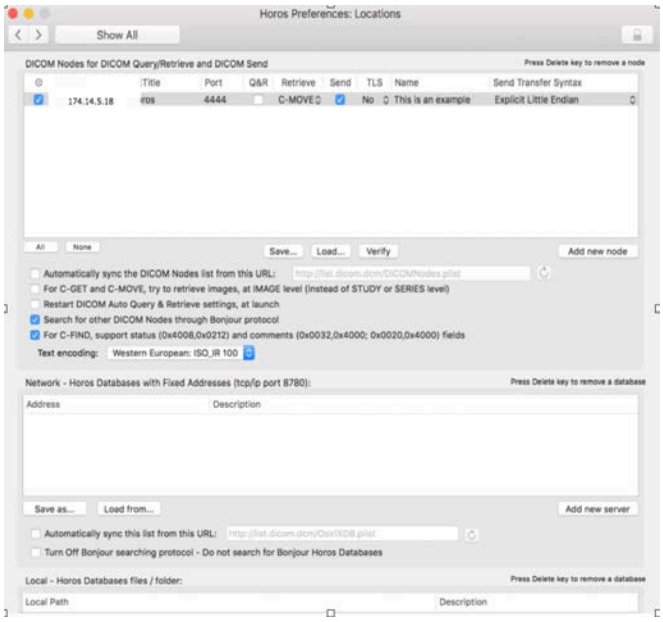
To configure your workstation as DICOM compliant, first select *Preferences* from the Horos contextual menu (Fig 9.2). Then you will require:

- A fixed IP address to allow your workstation to be configured as a DICOM receiver node
- A DICOM AE title. This is essentially a name you give your workstation software to identify it e.g. Horos

Figure 9.2 The Preferences window

DICOM Nodes - The DICOM node list

A DICOM node describes any networked DICOM software or hardware, which is used to manage, process or transfer DICOM images. This is essentially a workstation or PACS server. Each DICOM node is uniquely identified by the TCP/IP address of the computer e.g. 174.14.5.18 as well as the TCP/IP Port e.g. 4686 and its Application Entity (AE) title e.g. Horos.



In order to connect to a PACS server or another DICOM compatible workstation you will need to identify those devices/computers or software. Once this has been done you will be able to send a *Query* and then *Retrieve* images. This is done using their IP address and DICOM identifiers.

To do this, open the *Locations* tab within *Preferences*, in the Horos contextual menu (Fig 9.3), then check the box to the DICOM node you wish to identify. These are found at the top of the window.

Figure 9.3 The Locations Preferences window

It is possible to set up Horos to connect to multiple devices from which you can retrieve images and send images.

You will need to ensure your workstation is:

- Authorized to connect to these devices (nodes)
- That these devices are authorized to respond to the *Query* generated by your workstation
- The appropriate settings and privileges in your workstation have been setup

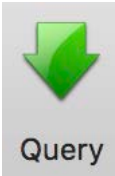
Contact your PACS administrator in the first instance for assistance with us. The Horos support team are also happy not help.

It is possible to use Horos as a PACS server whereby other workstations can retrieve images from your Horos database.

This function is performed through the C-MOVE SCP protocol. To enable this, the workstations must appear in the list of DICOM nodes in the *Locations Preferences* window.

If a distant workstation (DICOM node) sends a *Query (*C-MOVE SCU) to your workstation, it will fail unless that workstation is listed as a DICOM Node in your *Locations Preferences* window. To respond to the *Query*, Horos needs the TCP/IP address, port number and the AE title.

Query & Retrieve



The Query tool, available on the toolbar, allows you to search for, and retrieve, images from any source which is DICOM compliant. This includes PACS servers and other Horos workstations that you are authorized to access. You can then store, load and process these images in Horos. You can also access the Query tool via the Network contextual menu (Fig 9.4).

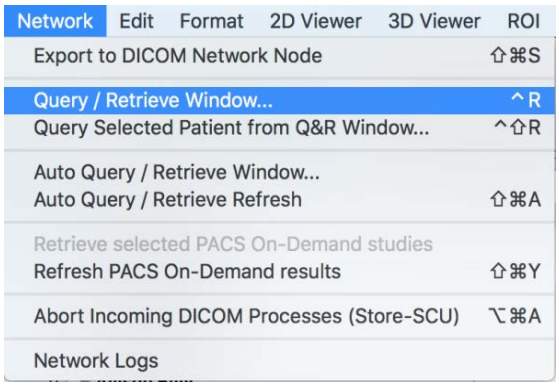


Figure 9.4 The Network contextual menu displaying the Query/Retrieve window function

Entering a Query

The default search criterion is patient name (fig 9.5(i)). When all or part off the name is entered, Horos searches all compliant sources for matching DICOM files. These may be local, external or on a networked server. It is possible to set limiting criteria to narrow the search results, such as acquisition time or study type. Matching files will be displayed in a list at the bottom of the search window. See Chapter 4 for more details.

When entering a query, a less restrictive or empty filter may take longer to return a result, particularly if the matching study is stored at a distant DICOM node.

Available DICOM Nodes (PACS and other workstations)

Available DICOM nodes, representing a PACS or workstation, are visible in the upper left box of the *Query/Retrieve* window (Fig 9.5(ii)). To select single or multiple nodes, simply check the box to the left of each named node.

The priority order of the nodes, i.e. the order in which they are listed, determines which node is used to retrieve a study. The node with the highest priority is always used and this is important if the study is stored at multiple nodes.

The priority order can be changed by selecting a line and dragging and dropping it. This is done by selecting the desired line and holding your finger on the mouse/mousepad whilst moving the cursor to the desired location.

To define your preferences for the DICOM nodes list, go to *Locations Preferences.* See Chapter 2 for more details.

Sending to an alternative workstation

To send the retrieved files to a workstation other than your own, select the desired DICOM node from the *Retrieve* list. This is found in the drop down menu box, immediately below the list of DICOM nodes (fig 9.5(iii)). It is important to note that this option only works if the selected DICOM Node has been setup to use the C-MOVE SCU protocol. See Chapter 2 for more details.

Retrieving the images

Once the list of matching studies, series or images are displayed in the box at the bottom of the window (fig 9.5(iv)). There are four main ways to retrieve and display the image (s):

- Double click on the desired line
- Select the desired line(s) and press *Retrieve*
- Select the desired line(s) and press *Return* on your keyboard
- Press the *Green Arrow* button in the first column of the list

Once the desired lines are selected, Horos will download and store the images in the *Horos Data* folder, whilst also indexing them in the database. This is performed as a background thread, which will appear in the activity box of the left hand side panel of the database window.

The added images will now appear on the study list and can be selected and processed as desired.

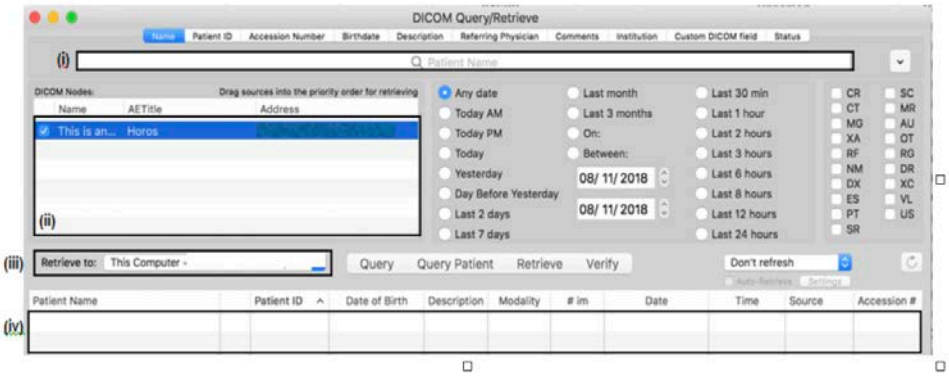


Figure 9.5 DICOM 'Query' window showing the *Query* box (i), available DICOM Nodes (ii), Retrieve box (iii) and the results box (iv)

The protocols used by Horos to perform and Query & Retrieve are:

- C-FIND SCU - to search for a study
- C-MOVE/C-GET SCU - C-STORE SCP - to retrieve the images

Note: WADO HTTP is an alternative protocol used by Horos to retrieve the images.

DICOM protocols continued

As described earlier in this chapter, in order to perform services on a DICOM network and communicate with other PACS and workstations, Horos employs and supports a number of recognized DICOM protocols. These protocols are described in the DICOM Standard [10].

In the case of a Service Class Provider (SCP), where the software or hardware acts as a server and is described as 'offering a service', these protocols are 'always-up' and ready to respond to a request.

In the case of a Service Class User (SCU), these protocols only run when a task or the tool is triggered by the user.

A list of the protocols supported by Horos is displayed below:

Protocol Name	**SCU/SCP**	**Description**
C-STORE	Both	Listener and Send Functions
C-FIND	Both	Image Queries*
C-MOVE	Both	Image retrieval*
C-GET	Both	Image retrieval*
C-ECHO	Both	DICOM Nodes test functions*
C-PRINT	SCU	DICOM printing
WADO	Both	HTTP Web protocol for image transfer

** These protocols are run through the Query and Retrieve Window*

Some or all of the protocols can be selected to run by you as the Horos user. Where this is the case a dialogue window, or graphic user interface (GUI), will be available to access for this purpose. The following table outlines how this can be done:

Protocol Name	**Graphic User Interface**	**Location of Setup**
C-STORE SCP	Always-up, No GUI	*Listener Preferences*
C-FIND SCP	Always-up, No GUI	No preferences
C-MOVE SCP	Always-up, No GUI	*Locations Preferences*
C-GET SCP	Always-up, No GUI	*Listener Preferences*
C-ECHO SCP	Always-up, No GUI	*Locations Preferences*
C-STORE SCU	SENDing, ROUTing	*Locations Preferences*
C-FIND SCU	Query/Retrieve Window	Q/R Window Settings
C-MOVE SCU	Query/Retrieve Window	Q/R Window Settings

C-GET SCU	Query/Retrieve Window	Q/R Window Settings
C-ECHO SCU	Query/Retrieve Window	*Locations Preferences*
C-PRINT SCU	Printing	Print Preferences
WADO	No GUI	*Locations Preferences*

The proceeding sections describe in greater detail each of the DICOM protocols.

Store Service Class Provider (C-Store SCP) - DICOM Listener

The DICOM Listener is the process of writing, or transferring, DICOM images and the associated files into the *INCOMING* folder of the *Horos Data* folder. From here the files are added to the database at regular intervals. The DICOM listener is able to download multiple images concurrently.

The DICOM Listener is a protocol which runs as a background thread when Horos is launched. It is known as the C-STORE Service Class Provider (C-STORE SCP). Upon launch of Horos, if the DICOM Listener has been activated, the C-STORE SCP is launched. See Chapter 2 for further details on activating and other options for the DICOM Listener.

Once the C-STORE SCP has identified incoming files, a separate 'forked' process commences. The outcome of this is that the C-STORE thread will continue to run in the background irrespective of other functions being undertaken within Horos and cannot be blocked by other actions of the Horos user.

Should the C-STORE SCP protocol crash, due to corrupted data for example, only this protocol will be affected and the Horos application will continue to function. No error message will be displayed. It is the Service Class User (SCU) which is responsible for generating the error message.

A number of options can be selected within the *Listener* found in *Preferences* (Fig 9.6a). Further details on these options can be found in Chapter 2. A number of options to be aware of are:

Activate DICOM Listener - Checking this option urns on the DICOM listener

Accept only one association at a time - It is recommended that you leave this option unchecked, otherwise the number of simultaneous image downloads is limited

Generate logs for DICOM Network events - This option logs each time a C-STORE SCP association occurs. The log is stored in the Network Logs file

Preferred Syntax - This option allows you to select which DICOM storage format will be accepted. The default setting for this is Explicit Little Endian (Fig 9.6b)

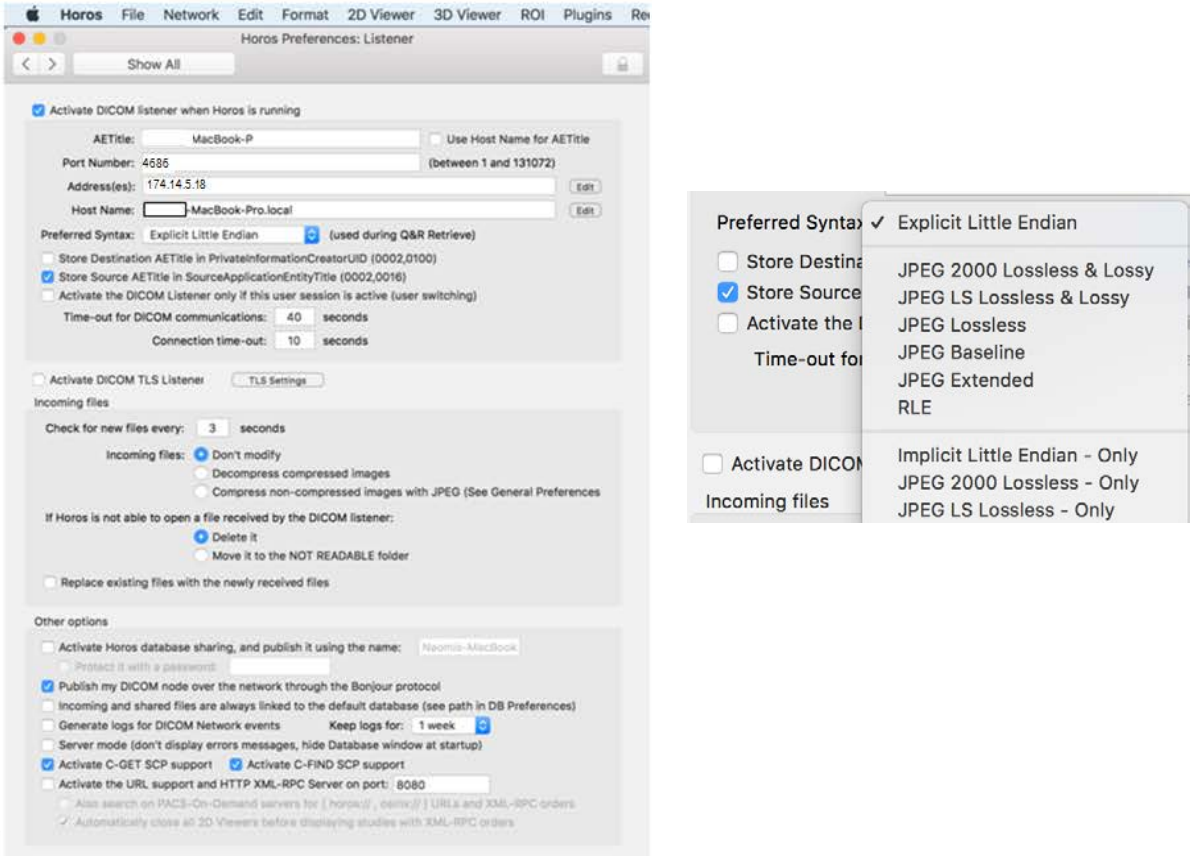


Figure 9.6 The Listener Preferences window (a) and the Preferred Syntax options (b)

Store Service Class User (C-STORE SCU) DICOM Send

DICOM Send (C-STORE SCU) is the protocol by which images can be sent from an imaging modality, from one user to another or to a PACS. Just like the S-STORE SCP it runs as a background thread, however it differs in that it is not 'forked' as a separate process. This means that the send protocol can be blocked or stalled if the user is concurrently undertaking actions, such as deleting files. Once the user has finished these actions and the database has essentially been restored, the DICOM send protocol will automatically resume.

Each DICOM Send order is queued, so only one C-STORE SCU association is created at a time. You will see these displayed in the *Activity* section of the left hand side panel. It is possible to alter this preference in the dialogue window which appears when the *SEND* tool is selected from the toolbar. A number of other options can be chosen from this dialogue window (Fig 9.8).

In contrast to the C-STORE SCP, an error message will appear if the *SEND* function fails.

If you wish to log each C-STORE SCU association, this can be selected in the *Preferences.* The log is stored in the *Network Logs* file. See Chapter 2 for more details.

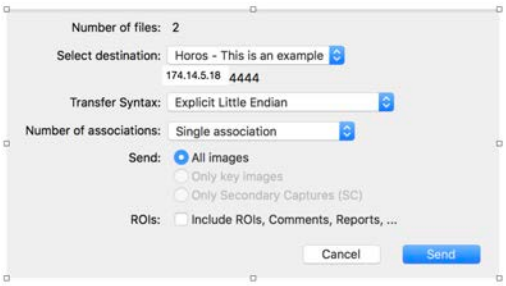
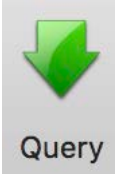


Fig 9.8 *SEND* Dialogue window with options

FIND Service Class Provider (C-FIND SCP)

Query



The query tool allows you to search for, and retrieve, images from any source which is DICOM compliant (Fig 9.9). The default search criterion is patient name. When all or part off the name is entered, Horos searches all compliant sources for matching DICOM files. These may be local, external or on a networked server. It is possible to set limiting criteria to narrow the search results, such as acquisition time or study type. Matching files will be displayed in a list at the bottom of the search window. See Chapter 4 for more details.

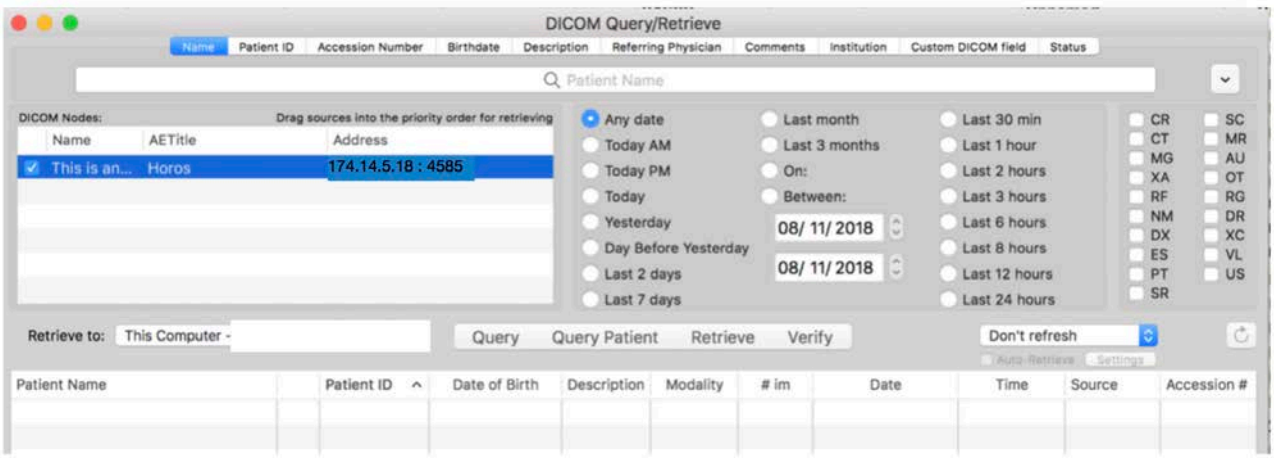


Figure 9.9 DICOM 'Query' window

When the *Query* tool is selected from the toolbar a database containing the query criteria is sent from the service class user (SCU) to the service class provider (SCP). The information contained within the query dataset has one of two attributes:

- Data to be matched, i.e. this with a value filled in such as patient ID
- Data to be returned, i.e. those left blank

The service class provider (SCP) responds by identifying matching datasets i.e. those studies or series which match the search criteria and sending them back to your Horos database. Queries are accepted at the study, series or image level, but not at the patient level.

Upon launch of Horos, if the DICOM Listener has been activated, the C-FIND SCP is launched. See Chapter 2 for further details on activating and other options for the DICOM Listener.

Once the C-FIND SCP is launched and an association is started, in a similar way to the C-STORE SCP, a separate 'forked' process commences. The outcome of this is that the C-FIND thread will continue to run in the background irrespective of other functions being undertaken within Horos and cannot be blocked by other actions of the Horos user.

Should the C-FIND SCP protocol crash, due to corrupted data for example, only this protocol will be affected and the Horos application will continue to function. No error message will be displayed. It is the Service Class User (SCU) which is responsible for generating the error message.

Once a C-FIND query is successfully generated, the query is applied in a SQL format, to either the current database for the default database. This can be altered in *Database Preferences*, see chapter 2.

Unlike the C-STORE SCP, C-FIND SCP events are not logged. The corresponding C-MOVE and C-GET events are logged however.

Three transfer syntaxes, or encoding rules, are utilised for this function. They are, in order of priority:

LittleEndianExplicitTransferSyntax	0
BigEndianExplicitTransferSyntax	1
LittleEndianImplicitTransferSyntax	2

Find Service Class User (C-FIND SCU)

The C-FIND SCU protocol is used by both the Query Tool, see chapter 4, and the auto-routing engine. The same transfer syntaxes, or encoding rules apply, as for the C-FIND SCP, described above.

In contrast to the C-FIND SCP, an error message IS generated if the C-FIND SCU fails.

In contrast to the C-FIND SCP, a query can be generated at the study or series level, but not at the patient level. Similarily, it is also not compatible at the image level.

When using the *Query* tool, Horos can generate a C-FIND protocol for the following DICOM fields (see fig 9.4 on the previous page):

- -Name
- -Patient ID
- -Accession number
- -Birthdate
- -Description
- -Referring physician
- -Comments
- -Institution
- -Custom DICOM field
- -Status

Similar to the C-FIND SCP, events are not logged. The corresponding C-MOVE and C-GET events are logged however.

Move Service Class Provider (C-MOVE SCP

Upon launch of Horos, if the DICOM Listener has been activated, the C-MOVE SCP launches. See Chapter 2 for further details on activating and other options for the DICOM Listener.

This allows the C-MOVE SCP to act as a C-STORE SCU and to copy composite instances to a requested AE Title which may or may not be the original C-MOVE SCU.

Once the C-MOVE SCP is launched and an association is started, in a similar way too the C-STORE SCP, a separate 'forked' process commences. The outcome of this is that the C-MOVE thread will continue to run in the background irrespective of other functions being undertaken within Horos and cannot be blocked by other actions of the Horos user.

Should the C-MOVE SCP protocol crash, due to corrupted data for example, only this protocol will be affected and the Horos application will continue to function. No error message will be displayed. It is the Service Class User (SCU) which is responsible for generating the error message.

In the same way as the C-FIND SCP, queries are accepted at the study, series or image level, but not at the patient level.

If the Networks logs function has been activated, see Chapters 2 and 9, each C-MOVE SCP is logged within the Network Log file.

The same transfer syntaxes, or encoding rules, are used as for the C-FIND SCP, described above.

Move Service Class User (C-MOVE SCU)

The C-MOVE SCU protocol is used to retrieve images from another DICOM node and is used when the Query tool is selected from the toolbar. A DICOM node describes any networked DICOM software or hardware, which is used to manage, process or transfer DICOM images. This is essentially a workstation or PACS server. Each DICOM node is uniquely identified by the TCP/IP address of the computer e.g. 174.14.5.18 as well as the TCP/IP Port e.g. 4686 and its Application Entity (AE) title e.g. Horos.

The C-MOVE SCU protocol requires that the server knows both the IP address, or DNS address, and the AE Title of the client, i.e the Horos application. If this information and the appropriate permissions have not been shared and agreed with the server then the association will fail and the image retrieve request will not be fulfilled.

However an alternative is to use the C-GET protocol. Provided the user (client) has selected the C-GET option for the requested DICOM node and that DICOM node supports the C-GET SCP protocol, this can be used instead. It should be noted that to use the C-GET protocol the distant node (server), must be running the current version of Horos.

In the same way as the C-FIND SCP, queries are accepted at the study, series or image level, but not at the patient level.

The C-MOVE SCU protocol uses the study, series or image unique identifiers (StudyInstance UID, SeriesInstranceUID and SOIPInstanceUID) for each *Query* sent.

It is possible for the images which are retrieved to be sent to an alternative DICOM node, as opposed to your current workstation. This is described in more detail in the Query and Retrieve section, earlier in this chapter.

If the Networks logs function has been activated, see Chapter 2, each C-MOVE SCP is logged within the Network Log file.

The same transfer syntaxes, or encoding rules, are used as for the C-FIND SCP, as described above.

In contrast to the C-MOVE SCP, an error message IS generated if the C-MOVE SCU fails.

Get Service Class Provider (C-GET SCP)

The C-GET protocol is very similar to the C-MOVE, however it has the advantage of avoiding problems relating to matching the AE title of your Horos application, intrinsic to C-MOVE. Upon launch of Horos, if the DICOM Listener has been activated, the C-GET SCP launches. See Chapter 2 for further details on activating and other options for the DICOM Listener.

Once the C-GET SCP is launched and an association is started, in a similar way to the C-STORE SCP, a separate 'forked' process commences. The outcome of this is that the C-GET SCP thread will continue to run in the background irrespective of other functions being undertaken within Horos and cannot be blocked by other actions of the Horos user.

Should the C-GET SCP protocol crash, due to corrupted data for example, only this protocol will be affected and the Horos application will continue to function. No error message will be displayed. It is the corresponding C-GET Service Class User (SCU) which is responsible for generating the error message.

In the same way as the C-FIND SCP, queries are accepted at the study, series or image level, but not at the patient level.

If the Networks logs function has been activated, see Chapter 2, each C-GET SCP is logged within the Network Log file.

The same transfer syntaxes, or encoding rules, are used as for the C-FIND SCP, described above.

Get Service Class User (C-GET SCU)

The C-GET SCU protocol is used to retrieve images from another DICOM node and is used when the *Query* tool is selected from the toolbar. A DICOM node describes any networked DICOM software or hardware, which is used to manage, process or transfer DICOM images. This is essentially a workstation or PACS server. Each DICOM node is uniquely identified by the TCP/IP address of the computer e.g. 174.14.5.18 as well as the TCP/IP Port e.g. 4686 and its Application Entity (AE) title e.g. Horos.

The C-GET SCU protocol will only be used if:

- The user (client) has selected the C-GET option for the requested DICOM node
- The DICOM node supports the C-GET SCP protocol

The C-GET SCU protocol therefore has the advantage, when compared to the C-MOVE SCU protocol, that the distant node (server) does not require the AE title or IP address of your Horos application. However the distant node (server) must be running the current version of Horos.

More information on selecting the C-GET option can be found in Chapter 2.

In the same way as the C-FIND SCP, queries are accepted at the study, series or image level, but not at the patient level.

Similarly to the C_MOVE SCU, The C-GET SCU protocol uses the study, series or image unique identifiers (StudyInstance UID, SeriesInstranceUID and SOIPInstanceUID) for each query sent.

If the Networks logs function has been activated, see Chapter 2, each C-GET SCP is logged within the Network Log file.

Print Service Class User (C-PRINT SCU)

Horos can be configured to print through the *Print* option in *Preferences* and DICOM printing is supported through the C-PRINT SCU.

Once the C-PRINT SCU is launched and an association is started, in a similar way too the C-STORE SCP, a separate 'forked' process commences. The outcome of this is that the C-PRINT SCP thread will continue to run in the background irrespective of other functions being undertaken within Horos and cannot be blocked by other actions of the Horos user.

Should the C-PRINT SCU protocol crash, due to corrupted data for example, only this protocol will be affected and the Horos application will continue to function. No error message will be displayed.

Similar to the C-FIND SCP, events are not logged.

Auto-Query & Retrieve

Auto-Query and Retrieve allows you to set up rules to automatically download studies using the same search criteria, from other DICOM nodes. This saves you having to repeatedly open, enter and submit searches through the Query window. For example, you may wish to set up Horos to automatically download all MR images produced throughout the day.

A DICOM node describes any networked DICOM software or hardware, which is used to manage, process or transfer DICOM images. This is essentially a workstation or PACS server. Each DICOM node is uniquely identified by the TCP/IP address of the computer e.g. 174.14.5.18 as well as the TCP/IP Port e.g. 4686 and its Application Entity (AE) title e.g. Horos.

To do this, first select *Auto Query/Retrieve Window* from the *Network* contextual menu (fig 9.10).

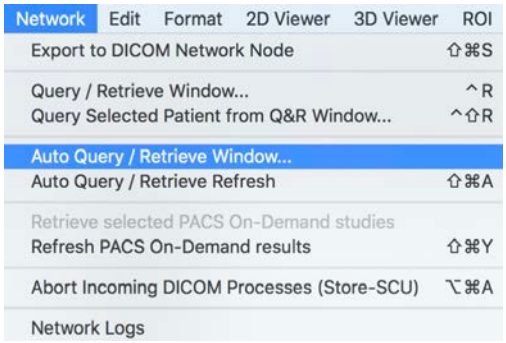


Figure 9.10 The *Network* contextual menu showing the Auto Query/Retrieve Window option

Within the *Auto-Query/Retrieve* dialogue box, enter your search criteria and select the required DICOM nodes, as described earlier on this chapter (Fig 9.11). To 'create' or delete instances, select the '+' or '-' buttons respectively from the Auto-Query window.

To view or modify a running instance, use the toggle button on the top toolbar on the Auto-Query window.

You can 'Lock' an instance by clicking on the padlock button in the top right hand corner of the window. This prohibits any modifications to the running instances.

NOTE: If a study has previously been downloaded into Horos, with the same number or more images, it will not be retrieved.

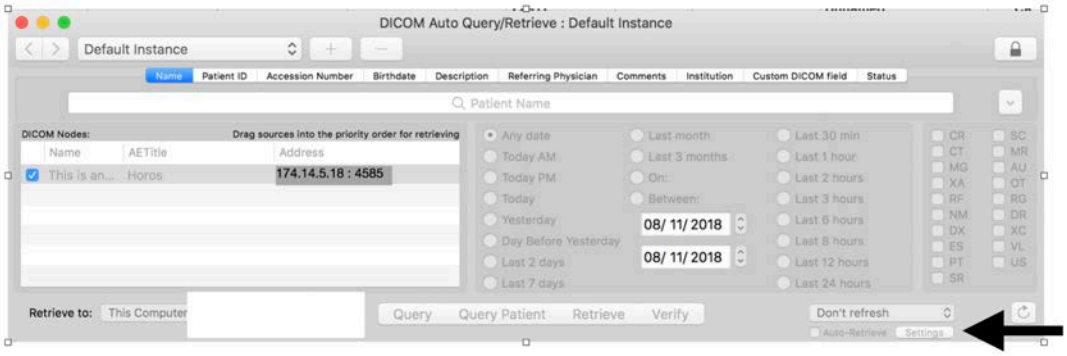


Figure 9.11 The *Auto Query/Retrieve* dialogue box, with the *Auto-Retrieve* option highlighted

It is possible to set up multiple rules, known as instances. For example you could have:

- An instance querying MR images from a specific DICOM node, acquired during the last hour
- Another instance querying all images acquired from another DICOM node over the last 24 hours

To automatically re-activate the last Auto-Query & retrieve upon launch of Horos open the Horos contextual menu and select *Preferences.* From the *Preferences* window select the *Locations* icon. Here you can select the option to *'Restart DICOM Auto-Query & Retrieve* settings, at launch' (Fig 9.12). See Chapter 2 for more details.

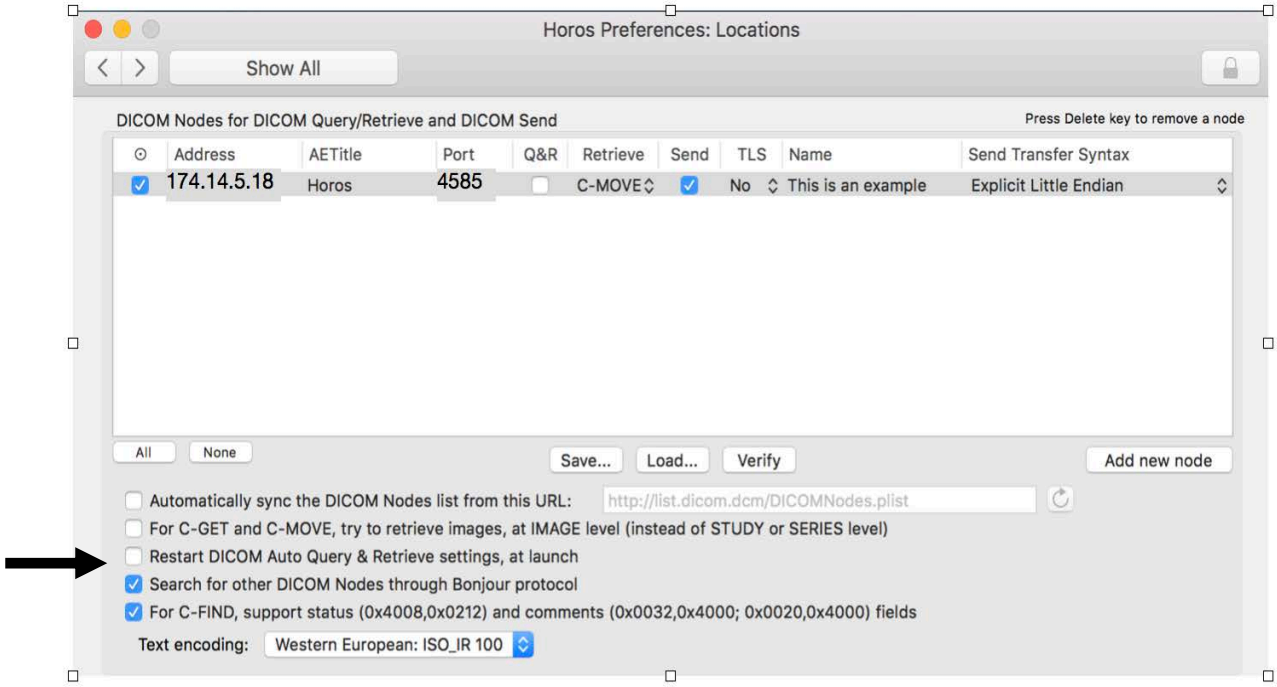


Figure 9.12 The Horos Preferences: Locations window, with the 'Restart DICOM Auto-Query & Retrieve settings, at launch' highlighted

Auto-routing

This is used to automatically forward images you have received or data you have produced, to other DICOM nodes. More details on this can be found in Chapter 4.

A DICOM node describes any networked DICOM software or hardware, which is used to manage, process or transfer DICOM images. This is essentially a workstation or PACS server. Each DICOM node is uniquely identified by the TCP/IP address of the computer e.g. 174.14.5.18 as well as the TCP/IP Port e.g. 4686 and its Application Entity (AE) title e.g. Horos.

Each rule you set up will be tested every 30 seconds. If there are images which match the rule, they will automatically be sent to your preferred DICOM node(s) using the DICOM C-STORE SCU protocol. The thread will appear in the *Activity* section of the left-hand side panel of the database window. See Chapter 4 for more details on the left hand side panel.

Rules will automatically be re-tried every 30 seconds if they fail, due to a network issue or the destination node is turned off. The number of re-tries is defined when setting the rule.

Setting up Horos as a PACS (Picture Archiving and Storage)

It is possible for Horos to be used as a PACS server, meaning that any workstation running DICOM compatible software can search and download studies stored in Horos. These workstations, local or distant, as well as the Horos workstation used as a PACS, are known as DICOM nodes.

A DICOM node describes any networked DICOM software or hardware, which is used to manage, process or transfer DICOM images. This is essentially a workstation or PACS server. Each DICOM node is uniquely identified by the TCP/IP address of the computer e.g. 174.14.5.18 as well as the TCP/IP Port e.g. 4686 and its Application Entity (AE) title e.g. Horos.

The number off images stored can be millions and is only really limited by the storage capacity of the server or workstation running Horos. RAID disks, for example, can be useful in maximizing storage capacity.

Multiple connections can be processed by Horos simultaneously, allowing multiple users to search, upload or download data to Horos without slowdowns.

To allow Horos to run efficiently as a server, it is recommended that you turn on *Server mode* within the *Listener Preferences* (Fig 9.13). In this mode, error messages are not displayed on screen. This allows Horos to continue working, even if an error occurs during communications with another DICOM node. Otherwise, should an error occur, Horos can be blocked from working until the user presses *OK* on the dialogue box which appears.

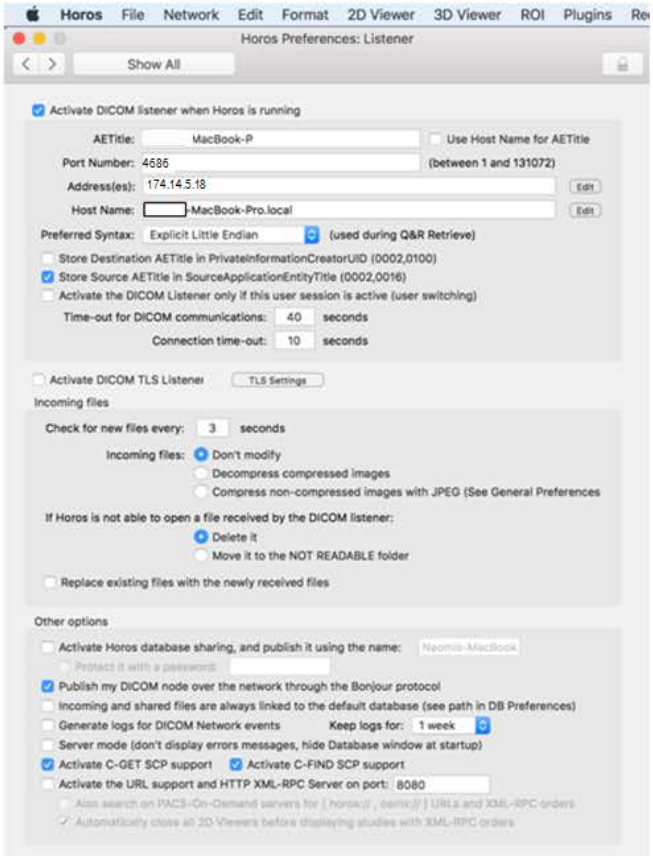


Figure 9.13 Listener Preferences with Server mode highlighted

Horos supports all the DICOM protocols required for it to be used as a PACS server (DICOM C-FIND, SCP, DICOM C-MOVE SCP, DICOM C-GET SCP and WADO). More information on these protocols can be found earlier in this chapter.

More information on setting preferences to run Horos as a PACS server can be found in Chapter 2.

The section on *Building a JPEG 2000 network* later in this chapter also provides more information on how to build and integrate Horos as an efficient PACS.

Synchronize and Archive

Horos can be used solely as a DICOM viewer for viewing images produced on different imaging modalities. Horos also generates data off its own such as Regions of Interest (ROIs) on images, comments, statuses, reports and secondary captures (SC). If using Horos in a PACS environment, or when multiple Horos workstations are used, automatically synchronization this data on all the Horos workstations, then archiving them on a PACS server, can be extremely useful. The Horos database then stores the data in DICOM SR format.

An auto-routing rule is required to automatically transfer DICOM SR files, once they have been generated. To do this first go to the *Horos* contextual menu and select *Preferences* (Fig 9.14a). This will bring up the *Preferences* menu window, here you select *Routing* (Fig 9.14b).

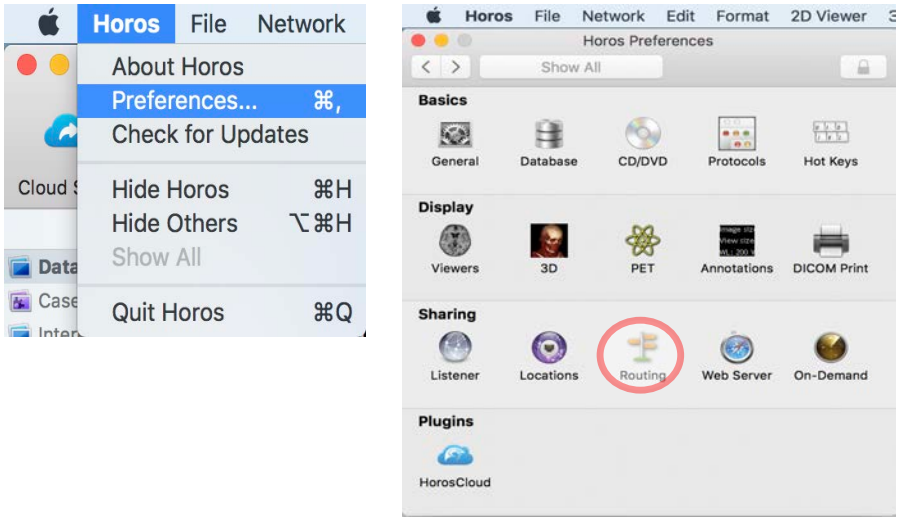


Figure 9.14 The *Horos* contextual menu with *Preferences* highlighted (a), and the Routing option in the *Preferences* window (b)

A dialogue box will appear. To create a new Auto-route, click on the option to do this in the bottom right hand corner of the window (Fig 9.15).

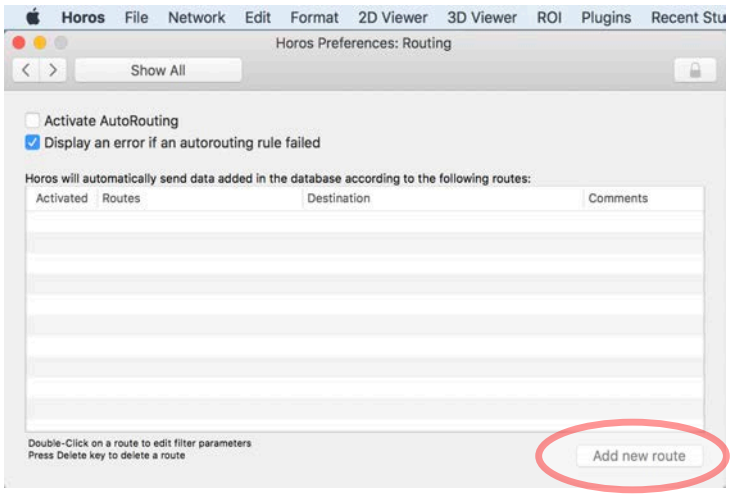


Figure 9.15 The Routing dialogue box with *Add new route* highlighted

In the next dialogue box which appears you will be able to set-up the Auto-route to allow you to automatically Synchronize and Archive files (Fig 9.16). You will need to set-up a new Auto-route rule for each workstation you wish to synchronize.

There are a number options you will need to select to set-up the new rule:

- Give the new route a name
- Select the destination of the data e.g. a PACS or another Horos workstation
- Select Data Generated (Status, Comments' Key Images, Secondary Captures, …)

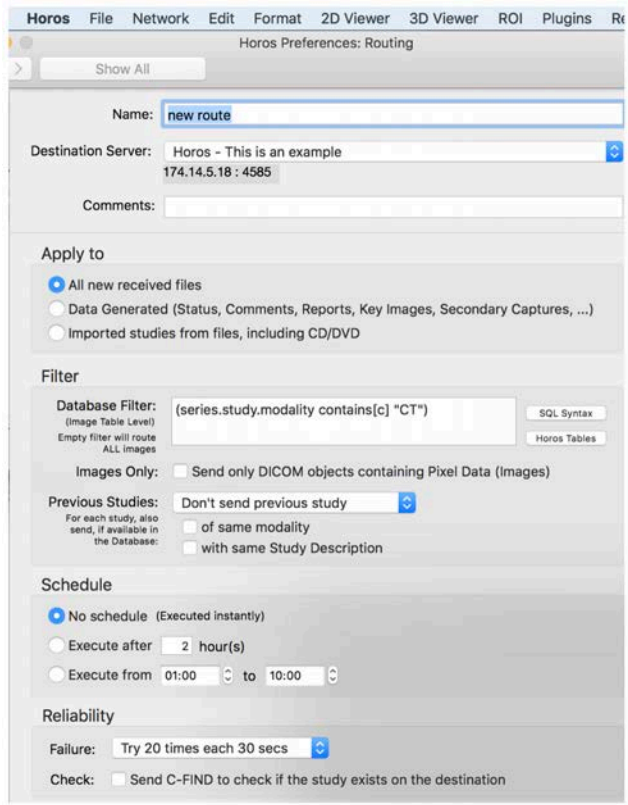


Fig 9.16 The *Routing* dialogue window

As the data is stored in DICOM SR format, the DICOM objects can be transferred and stored by any DICOM compatible software. This includes DICOM viewers and PACS, which are compatible with DICOM SR. They cannot however display and use these files. Only Horos can read, understand and manipulate these DICOM SR files.

It is possible to manually transfer data where this is more appropriate, for example if your Horos workstation is not connected to the network.

To do this select the desired studies from the database window. Right click on the study/studies and select *Apply this Auto-routing rule to selection* (Fig 9.17). You will be given the option to chose the rule you previously defined within *Routing Preferences,* or to set-up a new rule. The data is then transferred to the corresponding destination.

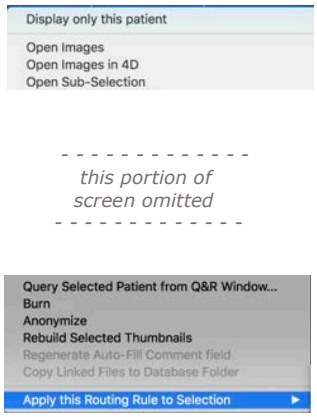


Figure 9.17 The Database Window contextual menu. *Apply this Auto-routing rule to selection* is found as the final option of the contextual menu.

WADO

The WADO protocol, supported by Horos, is used for retrieving DICOM files through standard HTTP protocols, and is defined in the DICOM standard. This has the consequence of reducing the complexity of DICOM transfers and provides the option of allowing the images to be displayed using any type of software, if they are sent as standard JPEGs.

The advantages of using WADO are:

- Multiple channels can be utilised when transferring studies utilizing full network bandwidth. This is useful on slow connections, e.g. a DSL (digital subscriber line)
- No fixed IP address is required, which is unlike Virtual Private Network (VPN) connections where this is often the case. This is similar to the DICOM C-GET SCU protocol

Horos can also act as a server using the WADO protocol and can retrieve images from compatible software e.g. Horos or dcm4chee. The Horos Web Server activates the WADO server protocol. The WADO client protocol can be activated using the DICOM Node list. See Chapter 2 for more information.

Database Sharing

Database sharing, supported by Horos using the Bonjour protocol to allow you to discover other workstations, allows the sharing of your database content with different Horos workstations on a network. Access can be password protected or unrestricted.

Sharing in this manner through the Bonjour protocol, should be restricted to firewall protected local area networks. Confidential patient data is at risk if databases are shared on the open internet where unauthorized users may capture the data. It is your responsibility as the user to ensure all transferred data is secure and within a controlled network with appropriate password protection and data access management.

To share your database go to the *Horos* contextual menu and select *Preferences* (Fig 9.18a). This will bring up the *Preferences* menu window, here you select *Listener* (Fig 9.18b).

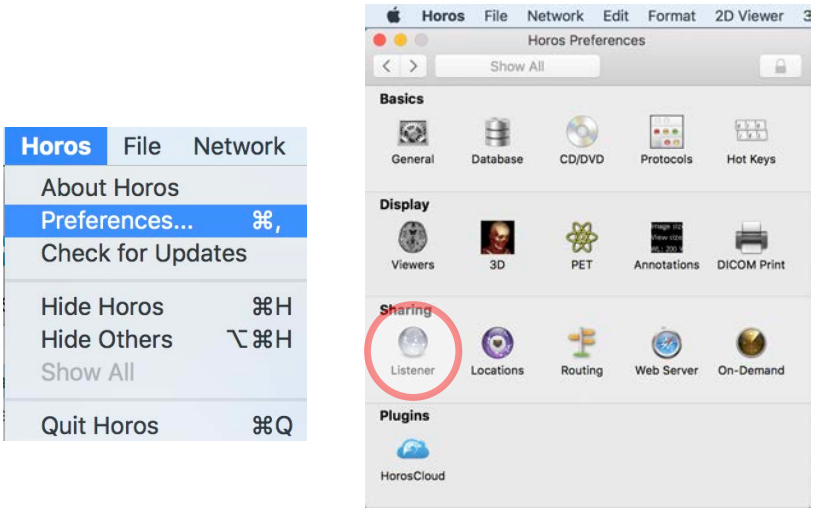


Figure 9.18 The *Horos* contextual menu with *Preferences* highlighted (a), and the *Listener* option in the *Preferences* window (b)

Within the *Horos Preferences:Listener* window, select 'Activate Horos database sharing, and publish it using the name: xxx'. This can be found within the *Other options* section at the bottom of the window (Fig 9.19). You can choose to password protect the database by entering your chosen password in a box which appears when you select the database sharing option.

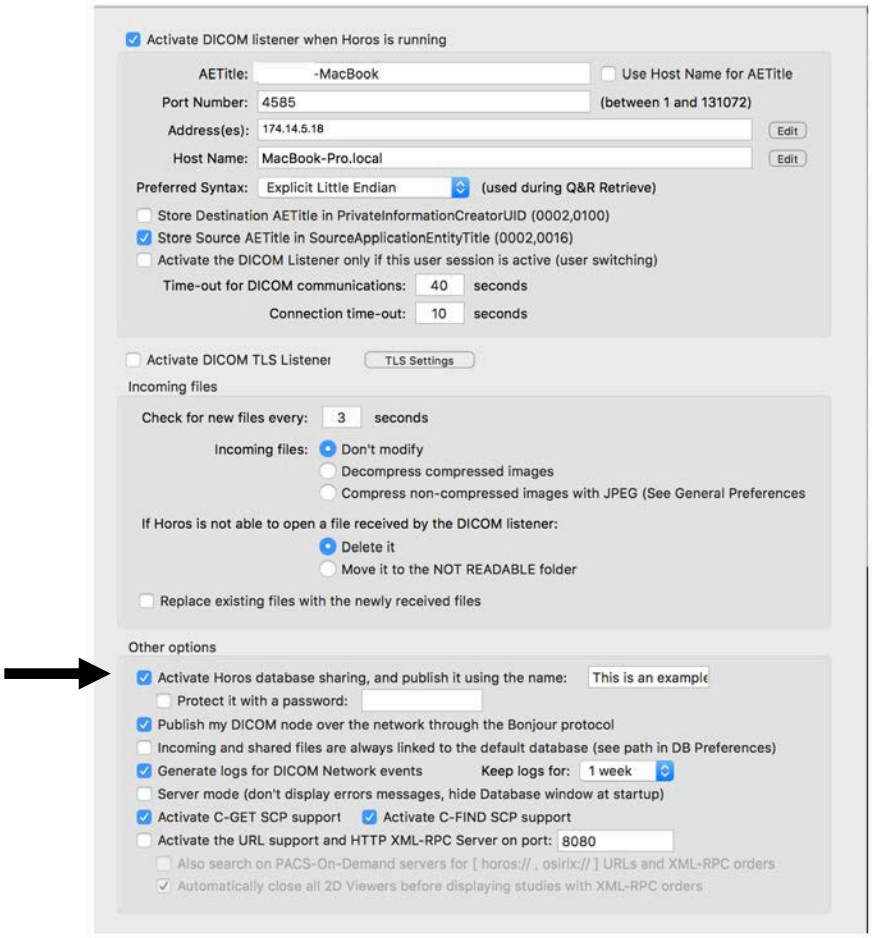


Figure 9.19 The *Horos Preferences: Listener window.* 'Activate Horos database sharing and publish it using the name xxx' is highlighted.

Once you have activated database sharing, it immediately becomes visible to local network users. Remote users can also access the database if they know your IP address. Your workstation name will appear on the list of shared resources, see Chapter 3 for more information.

When a database is shared, the user wishing to access the database first selects the desired database from the *Sources* list in the left hand side panel of the database window. Double clicking on the named database opens the study list allowing the user to browse and view images from the remote database, just as they would if were their local database. This provides much faster access than searching for and importing images from one workstation to another.

Network Logs

Communications between Horos and other workstations or a PACS can be logged. To do this go to the *Horos* contextual menu and select *Preferences* (Fig 9.20a). This will bring up the

Preferences menu window, here you select the *Listener* icon (Fig 9.20b). For more information on this see Chapter 2.

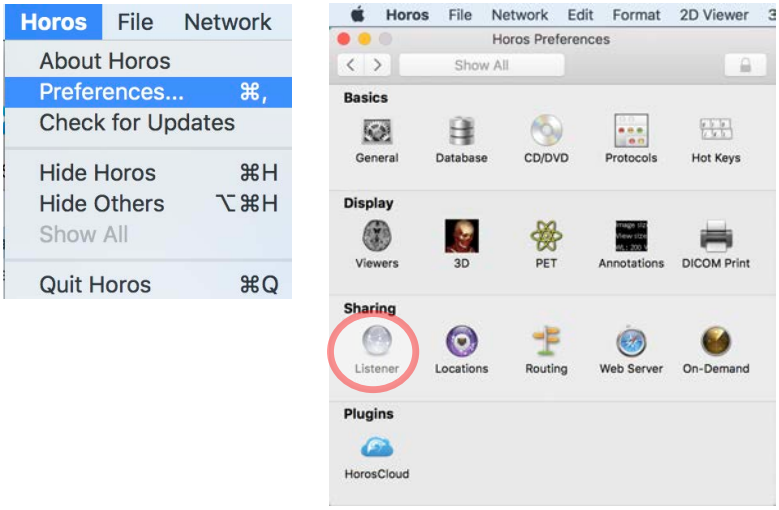


Figure 9.20 The *Horos* contextual menu with *Preferences* highlighted (a), and the *Listener* option in the *Preferences* window (b)

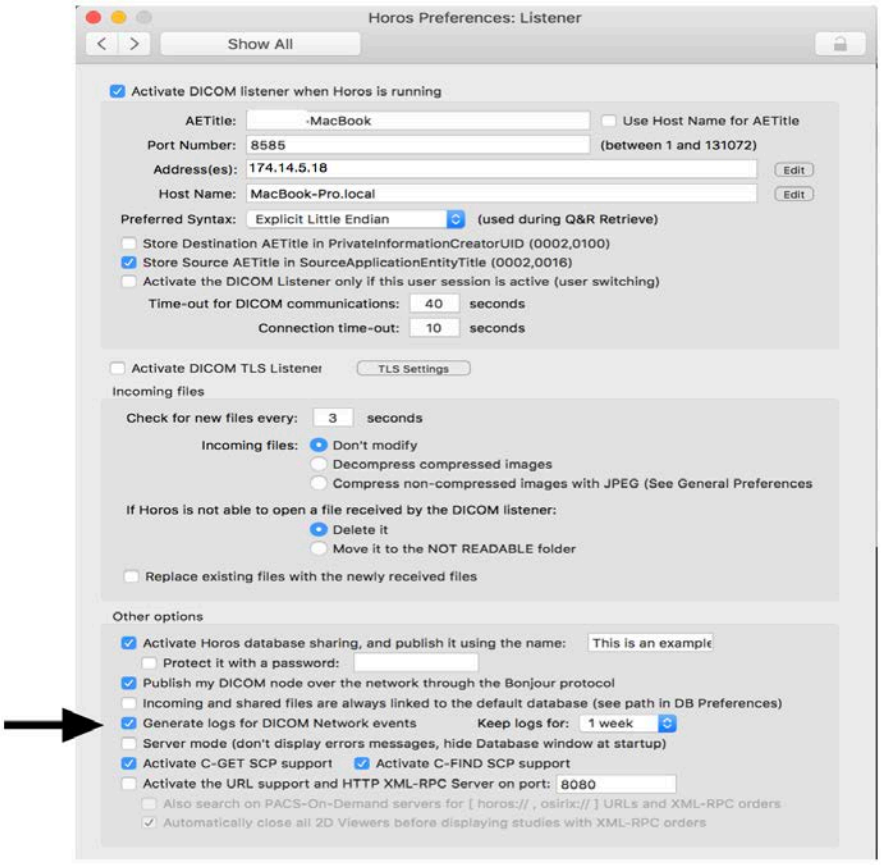
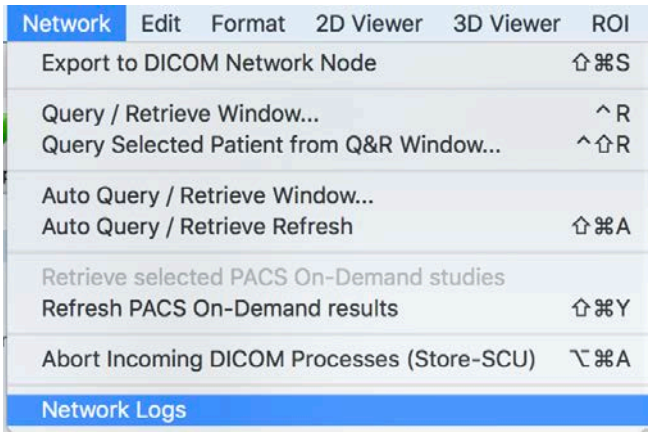


Figure 9.21 The Horos Preferences: Listener window. 'Generate logs for DICOM Network events' is highlighted.

Network logs are specific to each database and are stored ins the *database.sql* file. Logs are stored for a defined period of time, the default period being 1 week. This can be amended in *Horos Preferences:Listener.*



When you load the database, the logs are also loaded. A new set of logs will be started when a new database is created. Conversely, if the database is deleted the logs are also deleted.

To view the Network logs go to the *Network* contextual menu and select *Network Logs* (Fig 9.22).

Figure 9.22 The Network contextual menu, Network Logs is highlighted

The window is divided into 4 tabs: Retrieve, Send, Move and Web Server. Each of these tabs display the Network logs for their respective DICOM services.

HTTP Web Server

When activated, Horos can display the database contents on HTML pages allowing you to share data using a simple web browser. Horos contains a Web Server module which allows images to be easily shared with any user, even those with computers not running DICOM-compatible software. This feature can also be used to overcome firewall issues.

The contents of a Horos database can be accessed by an end-user via a simple web browser. To do this the user:

- Enters the web address of the Horos Web Server
- Completes the login screen (anonymous or authenticated), see Chapter 4 for more details
- Once redirected to the main screen, searches the database
- Receives a display list of matching studies
- Can display the contents of selected studies

To activate or deactivate this function go to the *Horos* contextual menu and select *Preferences* (Fig 9.23a). This will bring up the *Preferences* menu window, here you select the *WebServer* icon (Fig 9.23b). In the Horos Preferences: Web Server window, select '*Activate the built-in Web Server'* (Fig 9.24).

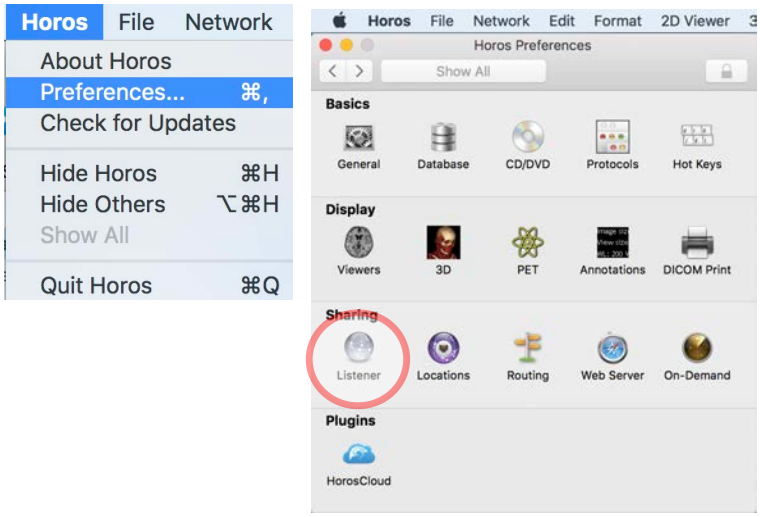


Figure 9.23 The *Horos* contextual menu with *Preferences* highlighted (a), and the *Listener* option in the *Preferences* window (b).

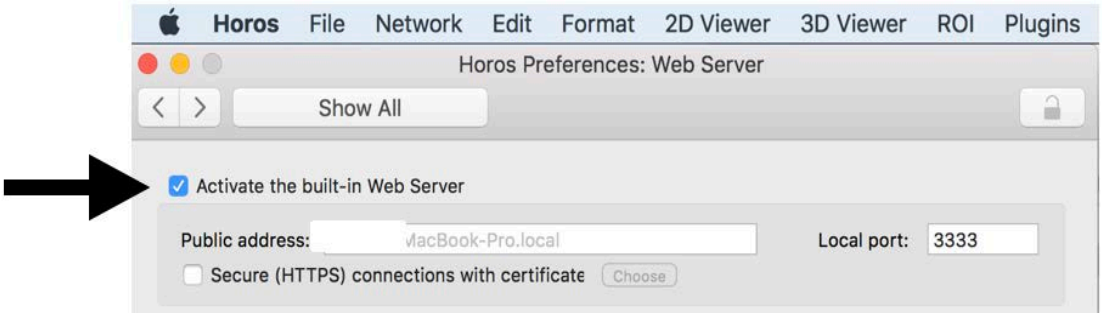


Figure 9.24 The Horos Preferences: Web Server window. 'Activate the built-in Web Server' is highlighted

Other parameters can also be accessed through the *Horos PreferencesWeb Server*, or directly through there Web pages if you have administrator preferences.

The original DICOM files can also be accessed through the Web Server by activating the WADO protocol. For more information on this see Chapter 4

Notifications

Users of the Web Server can choose, by activating the option within *Web Server Preferences,* to receive notifications when a new study is available. No images are sent in the email. Mac OS X Mail application is used, provided this has been correctly configured with a valid email address.

It is possible to manually send notifications to a user by selecting the *Notification* icon from the toolbar. A temporary user can also be created using the *Notifications* icon, allowing them to view selected studies.

More information is available on this in Chapter 2

Security

A number of security options within *Horos Web Server,* ensure data is safely transmitted without compromising patient data. When activating the Web Server on an internet connected computer, security layers should be appropriately activated.

HTTPS: When using HTTPS, all data shared between the Web Server and the browser (client) is encrypted. A combination of the HTTP and the SSL/TLS protocol is used for HTTPS. The server allows secure identification and encryption, using a valid certificate. The client will be informed that the data is encrypted and will know whether the server is trusted or not.

Authentification: The visibility of the server is limited to registered users only, via the authentication methods of the Web Server. See Chapter 4 for more details.

Image Access Restriction: Access to images can be restricted to certain images only, via the authentication system. See Chapter 4 for more details.

Transfer Limitations: Image downloads, uploads and sharing can be limited by the use of the authentication system. See Chapter 4 for more details.

DICOM TLS: DICOM TLS should be used by all DICOM nodes, if transfers are authorized on the Web Server, to ensure encryption of DICOM files. A DICOM node describes any networked DICOM software or hardware, which is used to manage, process or transfer DICOM images. This is essentially a workstation or PACS server. Each DICOM node is uniquely identified by the TCP/IP address of the computer e.g. 174.14.5.18 as well as the TCP/IP Port e.g. 4686 and its Application Entity (AE) title e.g. Horos. Appendix B provides more information.

Events Logging: Logged events are stored in the Network Logs table. This can be accessed from the *Network* contextual menu and selecting *Network Logs*. User logins, image downloads and study views are all logged including the event description, date, study and patient name and TCP/IP address of the user.

Users Management: A simple database can be utilised to manage user authentication, which manages user's identity e.g. name, address and passwords, as well as clearance levels for image transfers.

Users can be restricted to viewing only certain studies via the Web Server (Fig 9.25). Entry of a SQL filter is required to set this restriction e.g. Dr Marie Dole can be given access to view only her patients using the following SQL request:

(*referringPhysician* CONTAIN[cd] 'Marie Dole')

Alternatively the user can be given access to only a custom list of studies, manually managed from Horos. When other users share studies, this list will modify.

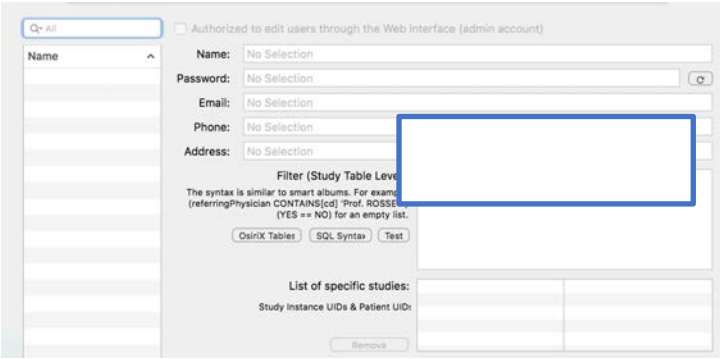


Figure 9.25 The study filter for the Web Server. Restrictions are entered into the highlighted box using a SQL request

A number of customizable options are available for each user. These are illustrated in Figure 9.26.

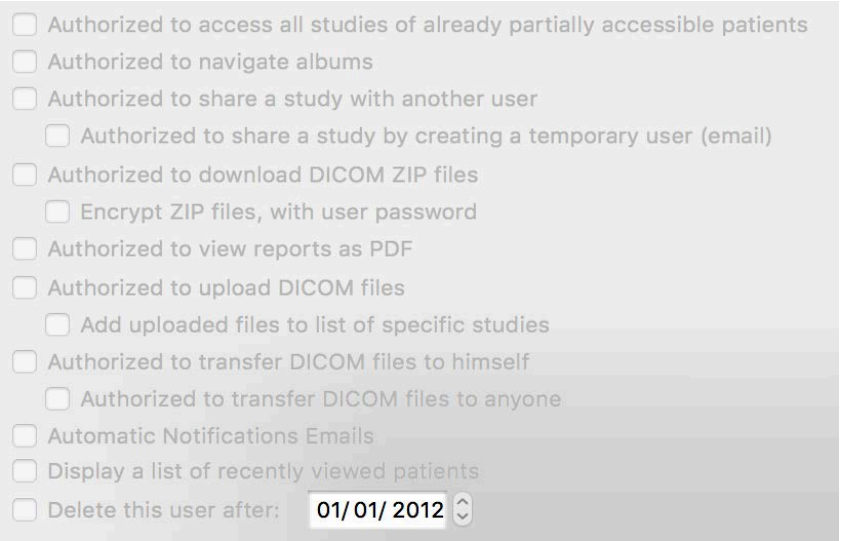


Fig 9.26 Customizable options for individual users of the Web Server

If a user its authorized to transfer DICOM files to himself/anyone, the user will require DICOM compatible software to receive the images. The DICOM C-STORE protocol is used and a DICOM C-STORE SCP will initiate by Horos to the TCP/IP address of the logged in user. For more information on transferring files to a DICOM node, see Chapter 2.

A DICOM node describes any networked DICOM software or hardware, which is used to manage, process or transfer DICOM images. This is essentially a workstation or PACS server. Each DICOM node is uniquely identified by the TCP/IP address of the computer e.g. 174.14.5.18 as well as the TCP/IP Port e.g. 4686 and its Application Entity (AE) title e.g. Horos.

When logged on, users can alter some of their account's settings and change their password, email address, address and phone number. If they wish they can also enable email Notifications. More information on email notifications can be found earlier in this chapter.

Web Pages Customization

The Horos default Web Server display can be customized with specific information or institutional logo. The HTML pages are built according to the user's choices. The HTML template is stored in the following folder: /Library/Application Support/Horos/WebServicesHTML. To use the English pages go to the 'English' folder.

To use a customized layout go to the *Horos* contextual menu and select *Preferences* (Fig 9.27a). This will bring up the *Preferences* menu window, here you select the *WebServer* icon (Fig 9.27b). In the Horos Preferences: Web Server window select 'use templates at…..' (Fig 9.28). The enter the folder name '/Library/Application Support/Horos/WebServicesHTML' into the dialogue box which appears (Fig 9.29).

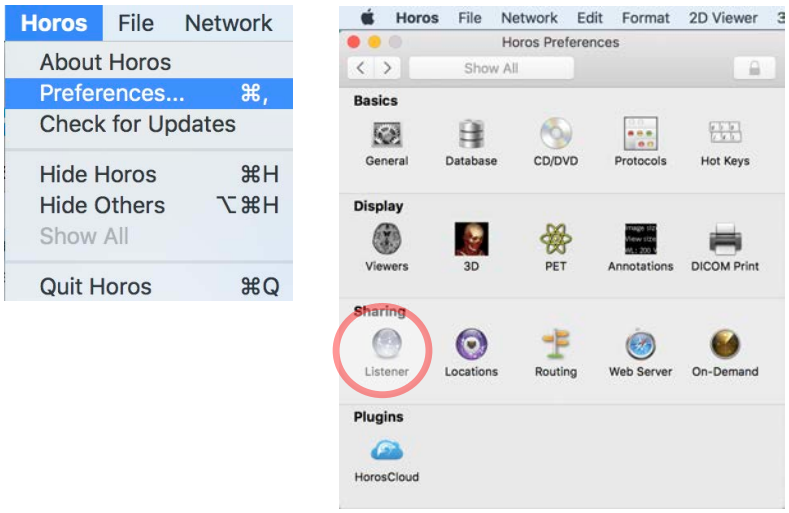


Figure 9.27 The *Horos* contextual menu with *Preferences* highlighted (a), and the *Listener* option in the *Preferences* window (b).

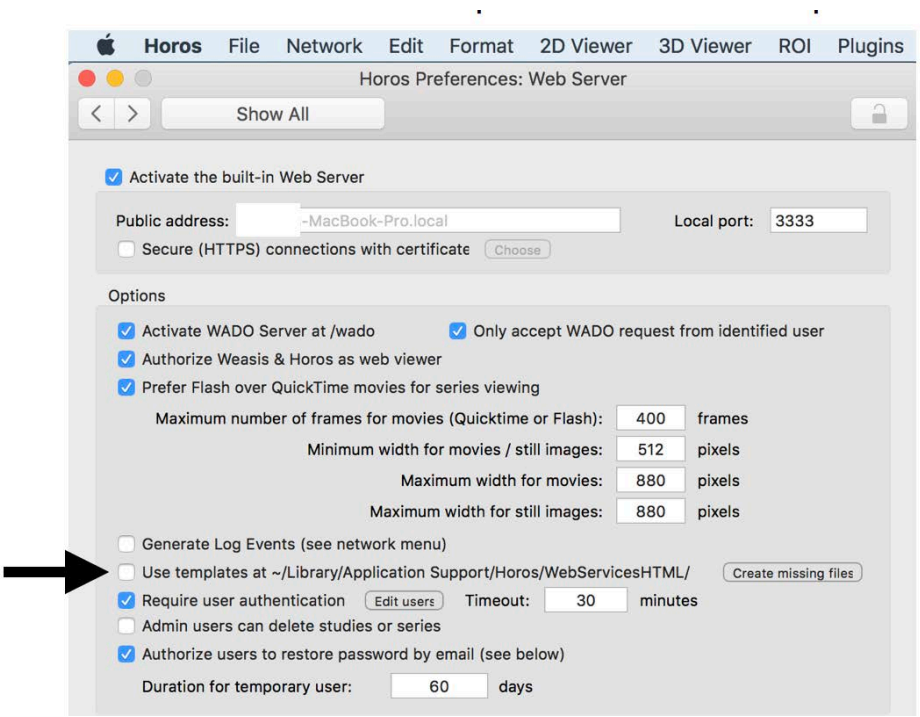


Figure 9.28 The Web Server Preferences window. 'Use templates at … ' is highlighte

The folder is, by default, hidden on MacOS. To locate and open this folder go to *Finder* and select *Go*, followed by *Go to Folder* (Fig 9.29). In the window that appears enter: Library/Application Support/Horos/WebServicesHTML (Fig 9.30). Your workstation will then take you to the hidden Horos folder.

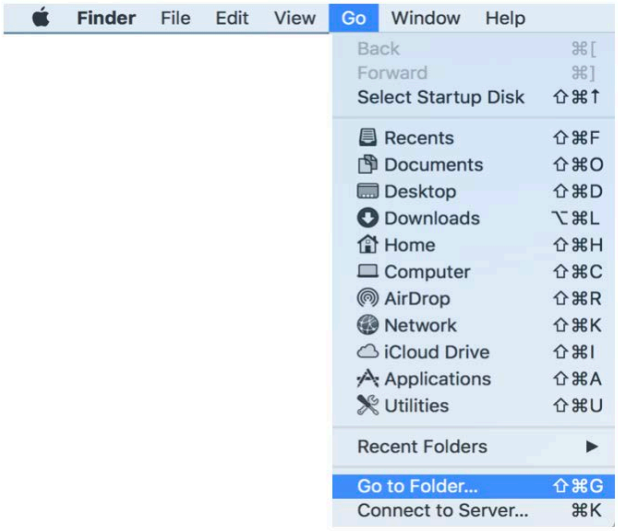


Figure 9.29 The *Finder* contextual menu. Select *Go* and followed by *Go to Folder*

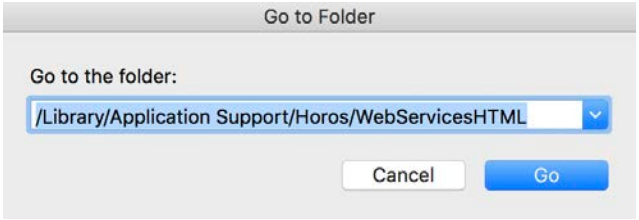


Figure 9.30 Enter the Web Services folder location into the window which appears

The essential components and structure of this folder are:

```
+WebServices HTML
    +English
        +account.html
        +emailTemplate.txt
        +index.html
        +main.html
        +password_forgotten.html
        +series.html
        +study.html
        +studyList.html
```

Other files, sub-directories, images, styles etc can be added and the required files can be modified. Certain folders and textual tokens should be treated with caution e.g. %name%, %AlbumNameURL%. These tokens will be parsed and used by the Web Server as structure markers our replaced by actual values.

It is important to note the these pages are written in script language interpreted by Horos, and nor real HTML.

XML-RPC

Horos is designed as a DICOM viewer, which can be used as a PACS server. It is not however a Radiology Information System (RIS) or Hospital Information System (HIS) which are designed to manage medical images, records and associated data. Horos integrates a HTML server with an XML-RPC protocol to be able to integrate with applications which can assist with data migrations.

If installed, RIS or HIS software can be useful to move information from or to another application such as an application running:

- On the same computer for example a Java or Web based software

- On the same computer but in a different, for example virtual, environment e.g. Windows OS on a virtual machine (VMware, Parallels)

- On a networked computer e.g. a web server application such as ASP software

For the application to be able to control Horos and consequently facilitate integration it needs to be able to perform all the routine functions around viewing a study on the Horos Database including, but not exclusive to:

- Checking for the presence of the study on the Horos database
- Opening and display images of a specific study
- Deleting a study

Any software/ computer with the network address of your Horos workstation can execute these methods, which can be built-in to Horos or added on as plugins.

To activate the XML-RPC server, which enables Horos to integrate with other information systems go to the *Horos* contextual menu and select *Preferences* (Fig 9.31a). This will bring up the *Preferences* menu window, here you select the *Listener* icon (Fig 9.31b).

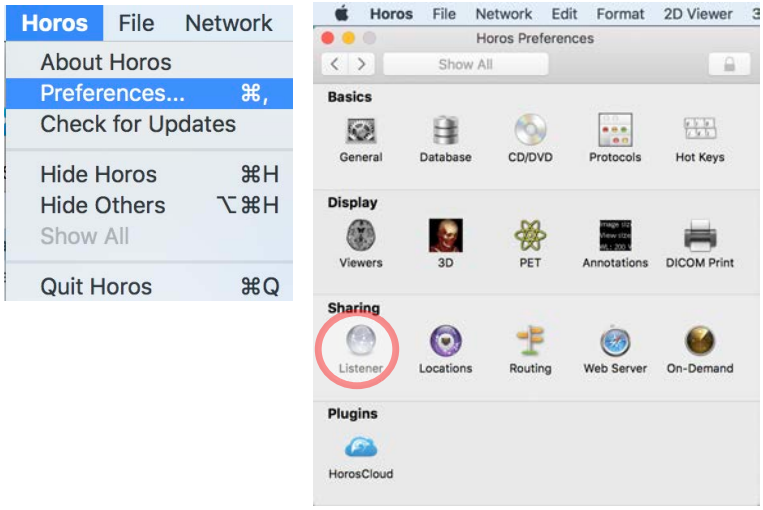


Fig 9.31 The Horos contextual menu with Preferences highlighted (a), and the Listener option in the Preferences window (b).

The XML-RPC server listens to XML_RPC messages using the 8080 default port. You can change this port to suit your requirements . If you change this port, you must remember to use a port not already in use by another service.

In the Horos Preferences: Listener window select: 'Activate the URL support and HTTP XML-RPC Server on port: xxxx' (Fig 9.32).

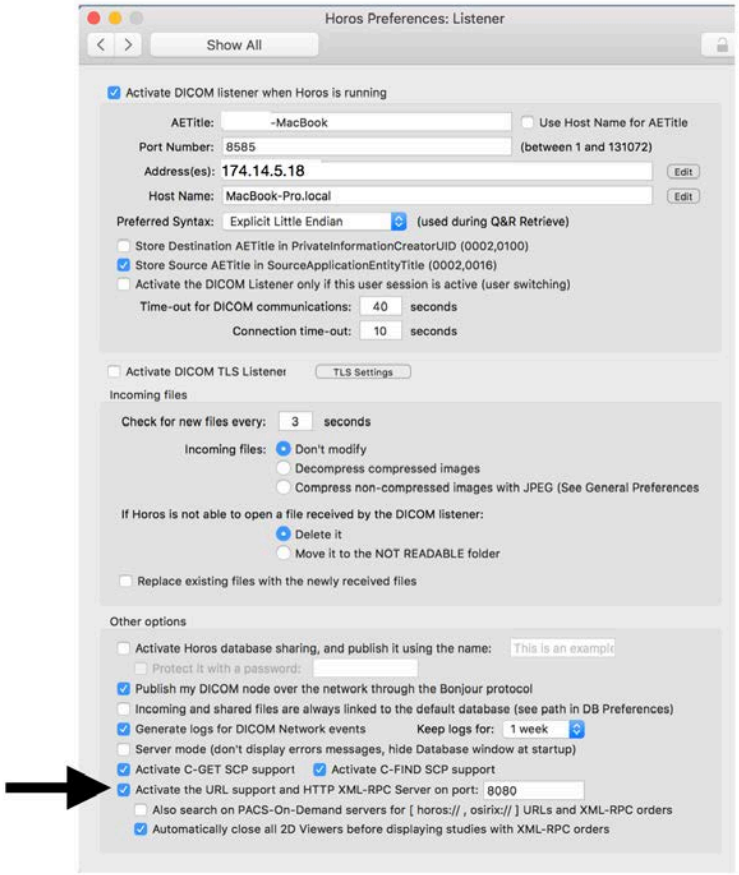


Figure 9.32 *Listener Preferences with* 'Activate URL support and HTTP XML-RPC Server on port: xxxx' highlighted

Supported XML–RPC Messages in Horos

Horos supports the following XML–RPC messages (built-in):

- The DBWindowFind method allows the user to execute an SQL query on the database of Horos and receive the matching elements in the response, see Table 4.1.

- The CloseAllWindows method allows the user to close all opened viewers, see Table 4.2.

- The OpenDB method allows the user to open a specific database, see Table 4.3.

- The SelectAlbum method allows the user to select a specific album and display its content in the database window, see Table 4.4.

- The GetDisplayed2DViewerSeries method allows the user to get the UID of the Series displayed in a 2D Viewer, see Table 4.5.

• The GetDisplayed2DViewerStudies method allows the user to get the UID of the Studies displayed in a 2D Viewer, see Table 4.6.

• The Close2DViewerWithSeriesUID method allows the user to close the 2D Viewer displaying the Series corresponding to the UID, see Table 4.7.

• The Close2DViewerWithStudyUID method allows the user to close the 2D Viewer displaying the Study corresponding to the UID, see Table 4.8.

• The CMove method allows the user to retrieve a Study from a DICOM server using the Study's accession Number, see Table 4.9.

Method Name DBWindowFind
Parameters request: a SQL request, see [2] for the syntax. table: an Horos Table, possible values are: Image, Series or Study. execute: Possible values are: Nothing, Select, Open or Delete. Execute is performed at the study level: you cannot delete a single series of a study.
Example request: name == 'Doe' table: Study execute: Select
Example request: name == "(name LIKE '*DOE*')" table: Study execute: Open
Response error: 0 elements: an array of elements corresponding to the request

Table 4.1: The DBWindowFind method for performing a search in the database.

Method Name CloseAllWindows
Parameters None
Response error: 0

Table 4.2: The CloseAllWindows method for closing all viewers.

Method Name OpenDB
Parameters path: path of the folder containing the Horos Data folder if path is valid, but if no database is found, Horos will create a new one.
Example path: /Users/johndoe/Documents/
Response error: 0

Table 4.3: The OpenDB method for opening a specific database.

Method Name SelectAlbum
Parameters name: name of the album
Example name: Today
Response error: 0

Table 4.4: The SelectAlbum method for selecting a specific album.

Method Name GetDisplayed2DViewerSeries
Parameters None
Response error: 0 elements: array of series corresponding to the displayed windows

Table 4.5: The GetDisplayed2DViewerSeries method, for getting the displayed Series.

Method Name GetDisplayed2DViewerStudies
Parameters None
Response error: 0 elements: array of series corresponding to the displayed windows

Table 4.6: The GetDisplayed2DViewerStudies method for getting the displayed Studies.

Method Name Close2DViewerWithSeriesUID
Parameters uid: series instance UID to close
Example uid: 1.3.12.1107.5.1.4.518.4.0.16429682...
Response error: 0

Table 4.7: The Close2DViewerWithSeriesUID method for closing a specific Series.

Method Name Close2DViewerWithStudyUID
Parameters uid: study instance UID to close
Example uid: 1.2.840.113745.10100.10800.37915.4331...
Response error: 0

Table 4.8: The Close2DViewerWithStudyUID method for closing a specific Study.

Method Name CMove
Parameters accessionNumber: accessionNumber of the study to retrieve server: server description where the images are located (See Locations preferences)
Example accessionNumber: UA876410 server: Main-PACS
Response error: 0 Possible values for error are: • 0: no error • -1: server not found • -2: server not responding • -3: no study found

Table 4.9: The CMove method for retrieving images from a DICOM server.

4.6.3 XML–RPC Messages format

The XML–RPC messages need to be sent in XML format. For example, Close2DViewerWithStudyUID, with the parameter uid: 1.2.840.113745.101000.1008000.37915.4331 corresponds in XML to:

```
<?xml version="1.0"?>
<methodCall>
<methodName>Close2DViewerWithStudyUID</methodName>
<params><param><value><struct>
<member>
<name>uid</name>\
<value>
<string>1.2.840.113745.101000.1008000.37915.4331</string>
</value>
</member>
</struct></value></param></params>
</methodCall>
```

For sending non-ASCII characters (like é, ç, ä, . . .), use UTF–8 encoding:

<?xml version="1.0" encoding="UTF-8"?>

XML–RPC Response format

The response to an XML–RPC call is also returned in XML format, for example:


```
<methodResponse><params><param><value><struct>
<member>
<name>error</name>
<value>0</value>
</member>
<member>
<name>elements</name>
<value><array><data><value><struct>
<member>
<name>dateAdded</name>
<value>2010-01-11 11:24:29 +0100</value>
</member>
<member>
<name>scale</name>
<value>0.002500711</value>
</member>
<member>
<name>dateOpened</name>
<value>2010-06-28 11:31:58 +0200</value>
</member>
<member>
<name>seriesSOPClassUID</name>
<value>1.2.840.10008.5.1.4.1.1.128</value>
</member>
<member>
<name>windowLevel</name>
<value>2444</value>
</member>
<member>
<name>modality</name>
<value>PT</value>
</member>
<member>
<name>name</name>
<value>PET FET Cerebral</value>
</member>
<member>
<name>date</name>
<value>2007-08-03 17:35:47 +0200</value>
</member>
<member>
<name>seriesDICOMUID</name>
<value>1.3.12.2.1107.5.1.4.48545.3</value>
</member>
<member>
<name>id</name>
<value>5</value>
```

```
</member>
<member>
<name>mountedVolume</name>
<value>0</value>
</member>
<member>
<name>numberOfImages</name>
<value>82</value>
</member>
<member>
<name>xOffset</name>
<value>0</value>
</member>
<member>
<name>xFlipped</name>
<value>0</value>
</member>
<member>
<name>displayStyle</name>
<value>3</value>
</member>
<member>
<name>seriesInstanceUID</name>
<value>0005 1.3.12.2.1107.5.1.4.48545.3</value>
</member>
<member>
<name>yFlipped</name>
<value>0</value>
</member>
<member>
<name>yOffset</name>
<value>0</value>
</member>
<member>
<name>windowWidth</name>
<value>3167</value>
</member>
</struct></value></data></array></value>
</member>
</struct></value></param></params></methodResponse>
```


Extending the XML–RPC capabilities of Horos

To add specific functions and behaviors to Horos for custom XML–RPC messages, you can write a plugin. Thanks to the XML support in Cocoa (NSXMLDocument), it is very easy to add a method in Horos. An example is available in the Horos Plugins source code repository: XML-RPC-Plugin. In this plugin, two new messages are added to Horos:

Method Name Parameters
exportSelectedToPath path: /Users/johndoe/Desktop/
openSelectedWithTiling rowsTiling: 2 columnsTiling: 2

As shown in the source code of this example, a unique plugin can support multiple messages and parameter decoding is easy:

```
if([[httpServerMessage valueForKey:@"MethodName"]
isEqualToString:@"exportSelectedToPath"])
{
NSXMLDocument *doc = [httpServerMessage valueForKey:@"NSXMLDocument"];
NSError *error = nil;
NSArray *keys = [doc nodesForXPath:@"methodCall/params//member/name"
error:&error];
NSArray *values = [doc nodesForXPath:@"methodCall/params//member/value"
error:&error];

if(1 == [keys count] || 1 == [values count])
{
int i;
NSMutableDictionary *paramDict = [NSMutableDictionary dictionary];
for(i = 0; i < [keys count]; i++)
{
[paramDict setValue:[[values objectAtIndex:i] objectValue] forKey:[[keys objectAtIndex:i] objectValue]];
}

// Ok, now, we have the parameters -> execute it !

NSMutableArray *dicomFiles2Export = [NSMutableArray array];
NSMutableArray *filesToExport;
filesToExport = [[BrowserController currentBrowser]
filesForDatabaseOutlineSelection:dicomFiles2Export
onlyImages:YES];
[[BrowserController currentBrowser]
exportDICOMFileInt:[paramDict valueForKey:@"path"]
files:filesToExport
objects:dicomFiles2Export];

// Done, we can send the response to the sender

NSString *xml = @"<?xml version=\"1.0\"?>
<methodResponse><params><param><value><struct><member><name>error</name><value>0</value>
</member> </struct></value></param></params></methodResponse>";

// Simple answer, no errors

NSError *error = nil;
NSXMLDocument *doc = [[[NSXMLDocument alloc] initWithXMLString:xml
options:NSXMLNodeOptionsNone
error:&error] autorelease];
}
}

// To tell to other XML-RPC that we processed this order

[httpServerMessage setValue:doc
forKey:@"NSXMLDocumentResponse"];
```

```
[httpServerMessage setValue:[NSNumber numberWithBool:YES]
forKey:@"Processed"];
```

Building a JPEG 2000 Network

This section describes how to build a JPEG 2000 Network, which allows the user to optimize storage and image communication. This can be highly beneficial in radiology to facilitate efficient workflow via fast exchange of DICOM images for reading and interpretation. Horos supports JPEG 2000 syntax but to maintain optimum performance:

- Network bandwidth between the PACS server and workstations should be optimal

A 100MB/s connection should be considered a minimum for efficient image transfer at a rate of 200 CT images/s. Compressed to JPEG 2000 in the JPEG LossLess algoirithm, image transfer speed is approximately 2.5 times at faster 500 CT images/s. This is based upon a typical 1000MB ethernet router. To test your network bandwidth go to the Activity Monitor application found in /Applications/Utilities folder.

- Disk speed

Servers need to load and transfer data quickly, for example when multiple workstations request large studies concurrently. Slow disk speeds, for example 5400 RPM, can cause problems in data transfer.

When selecting drives for workstations, a Solid-state drive (SSD) is recommended where possible. It is advisable to use either a RAID 0 or RAID 5 system for image storage on a server. A hardware-based RAID 5 system has the back-up security benefits and for this reason it is recommended for professional use. Eighteen million CT images, equivalent to approximately 9000 studies, each containing 200 images, can be stored on a 4TB system using JPEG2000 LossLess compression.

NAS Systems are not recommended for storing DICOM images due to slow reading and writing of images. The principal benefit of NAS is for multiple workstations to share the content. As only the server needs to load and send images, through the DICOM protocol, this feature is not beneficial.

JPEG2000 LossLess compression aids this process by reducing the data to load by almost three fold. This has the benefit of:

- Greater file storage potential

- Better and faster file reading potential
- Processor speed

JPEG2000 compression/decompression requires processing power. This should be borne in mind when setting up a JPEG2000 PACS system and at least dual core processors on the server side is advisable.

It is the server which compresses the images, before sending the compressed images to Horos workstations. It is the process of adding new images to the server which requires additional processing power, rather than the action of sending them to Horos client workstations.

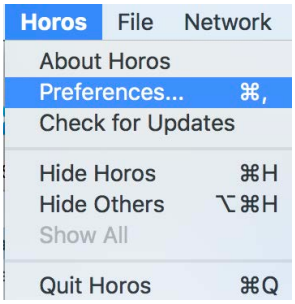
Horos user workstations will require at least a fast dual-core (3Ghz) or Quad-core system to receive and display images. Current MacBook start at 1.2GHz dual core.

Setting up and using Horos as a PACS Server

You can set up Horos as a small scale PACS, limiting usage to around 10 workstations. Horos will store and communicate files with other Horos workstations through standard DICOM protocols (C-FIND, C-MOVE and C-GET SCU/SCP). More information on these protocols can be found earlier in this chapter.

Activating Horos as a server

To activate Horos as a server first activate JPEG2000 compression. To do this go to the *Horos* contextual menu and select *Preferences* (Fig 9.33a). This will bring up the *Preferences* menu window, here you select the *Listener* icon (Fig 9.33b). In the Horos Preferences: Listener window go to the 'Preferred syntax' drop down menu and select 'JPEG2000 Loss less & Lossy' to activate JPEG2000 compression (Fig 9.34).



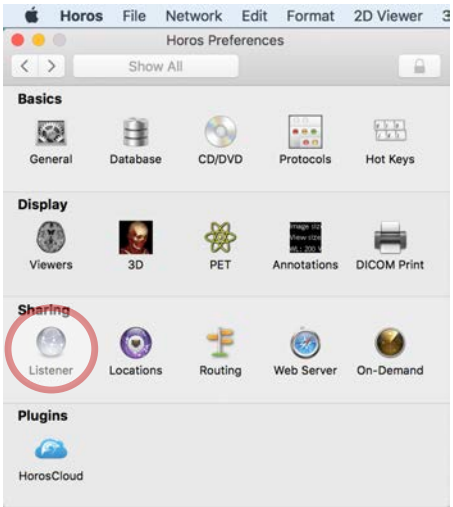


Fig 9.33 The *Horos* contextual menu with *Preferences* highlighted (a), and the *Listener* option in the *Preferences* window (b).

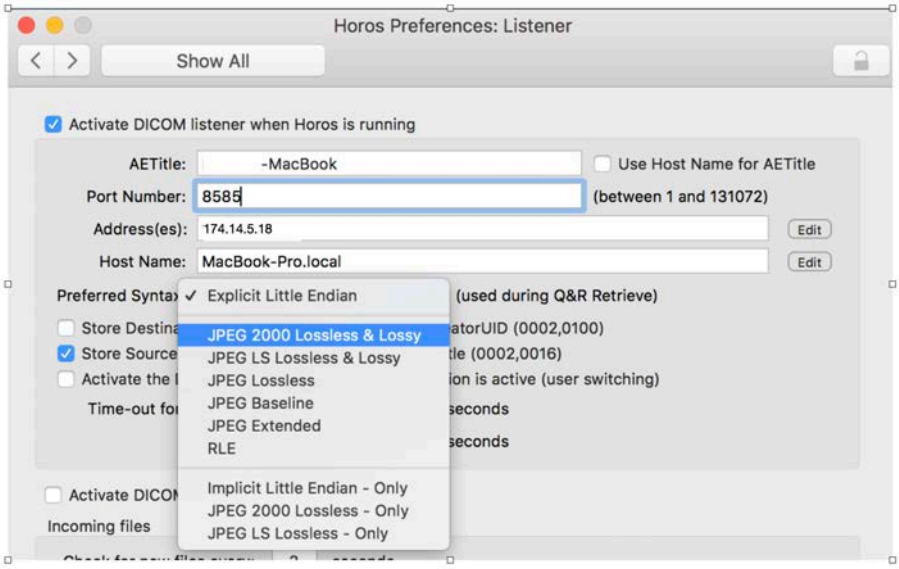


Figure 9.34 Listener Preferences showing the Preferred Syntax drop down menu

Next you need to activate JPEG2000 transfer syntax for each DICOM node. A DICOM node describes any networked DICOM software or hardware, which is used to manage, process or transfer DICOM images. This is essentially a workstation or PACS server. Each DICOM node is uniquely identified by the TCP/IP address of the computer e.g. 174.14.5.18 as well as the TCP/IP Port e.g. 4686 and its Application Entity (AE) title e.g. Horos.

To do this go to the *Horos* contextual menu and select *Preferences* (Fig 9.35a). This will bring up the *Preferences* menu window, here you select the *Locations* icon (Fig 9.35b). In the *Horos Preferences: Location* select JPEG2000 Lossless for each listed DICOM node (Fig 9.36).

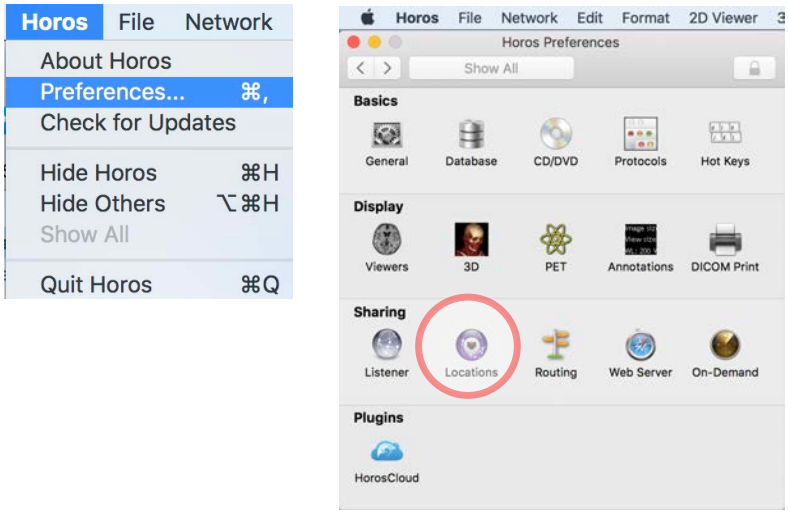


Fig 9.35 The *Horos* contextual menu with *Preferences* highlighted (a), and the *Locations* option in the *Preferences* window (b).

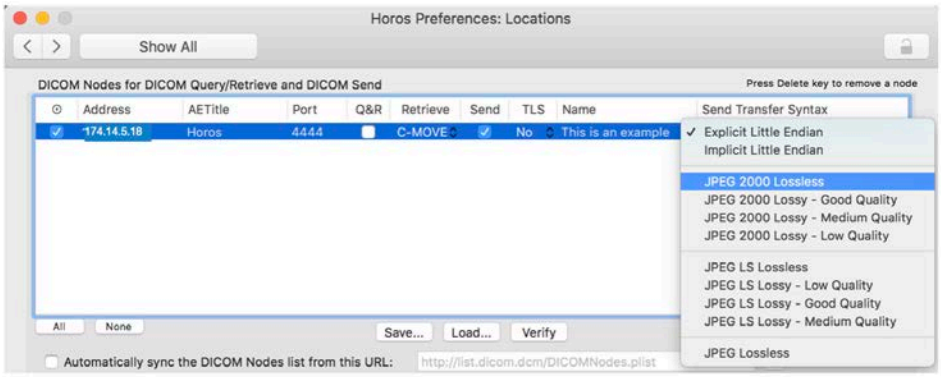


Figure 9.36 Locations Preferences showing the Send Transfer Syntax drop down menu

Horos workstations

To enable JPEG2000 transfer you will need to activate JPEG2000 syntax on each Horos workstation. To do this follow the same instructions as the previous paragraph.

More information on this can be found in Chapter 2.

Automatic image decompression

To activate automatic image decompression for incoming files go to the *Horos* contextual menu and select *Preferences* (Fig 9.37a). This will bring up the *Preferences* menu window, here you select the *Listener* icon (Fig 9.37b). In *Horos Preferences: Listener* select *Decompress*

compressed files in the *Incoming files* section (Fig 9.38). Activating this feature allows the best performance by only decompressing the images when they are displayed.

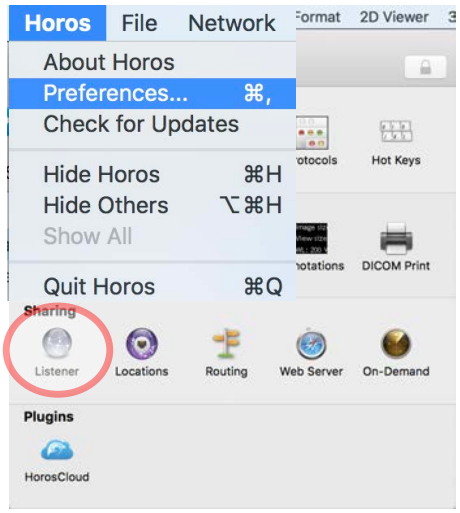


Fig 9.37 The Horos contextual menu with Preferences highlighted (a), and the Listener option in the Preferences window (b)

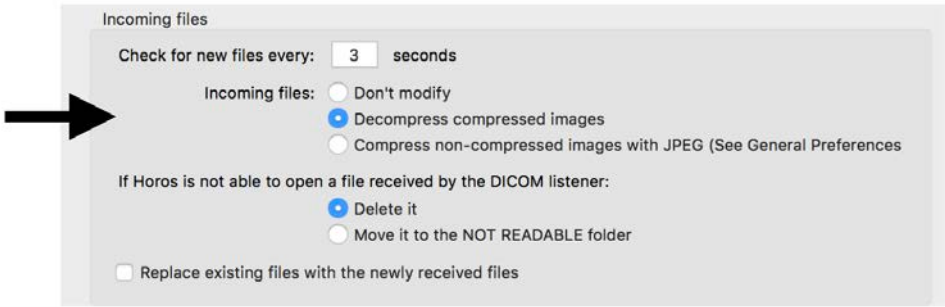


Fig 9.38 The *Horos Preferences: Listener* window. Decompress compressed files is found in the *Incoming Files* section

Conclusion

On demand image compression/decompression can be a slow process, particularly when viewing images on processors which are quad core or less. It is for this reason that Horos offers the option to build a JPEG2000 Network.

To configure JPEG2000 compression go to the *Horos* contextual menu and select *Preferences* (Fig 9.39a). This will bring up the *Preferences* menu window, here you select the *General* icon (Fig 9.39b). In the *General Preferences* window, JPEG2000 Image compression levels can adjusted by clicking on C*onfigure* (Fig 9.38). In the window which appears, image compression levels can be adjusted for each modality (Fig 9.40).

You need to ensure that your whole network, including the DICOM network protocol is 100% JPEG2000 configured, including your PACS server and workstations. If this is not the case you will suffer from slow network transfers. Images stored as JPEG2000 on the PACS will need to be decompressed for file transfers, all of which slows the process. The default position is Loss less/lossy.

It is important to store images in a consistent compression format across the whole PACS network. For example store all images as JPEG2000 rather than a mixture of JPEG and JPEG2000. If images are stored as a mixture off compression types this can cause issues with workstations trying find shared transfer syntax to exchange images and can result in blocked file exchanges.

For PET or small MR matrices which are small matrix images, only use lossless compression settings.

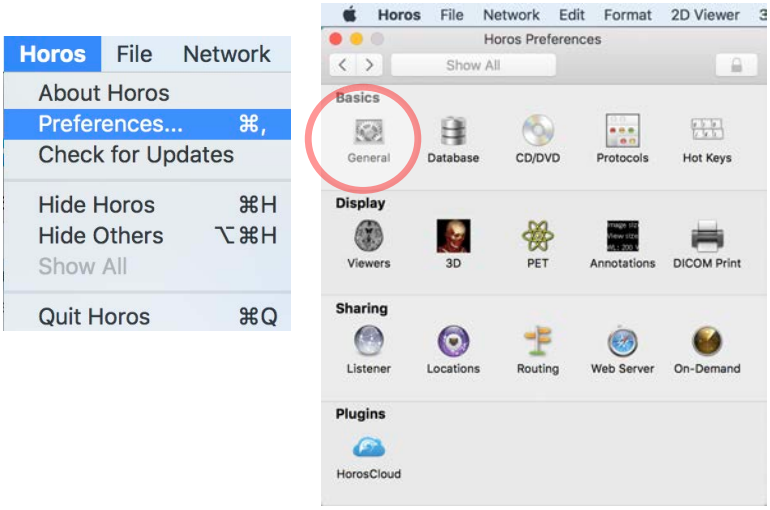


Fig 9.39 The *Horos* contextual menu with *Preferences* highlighted (a), and the *General* option in the *Preferences* window (b)

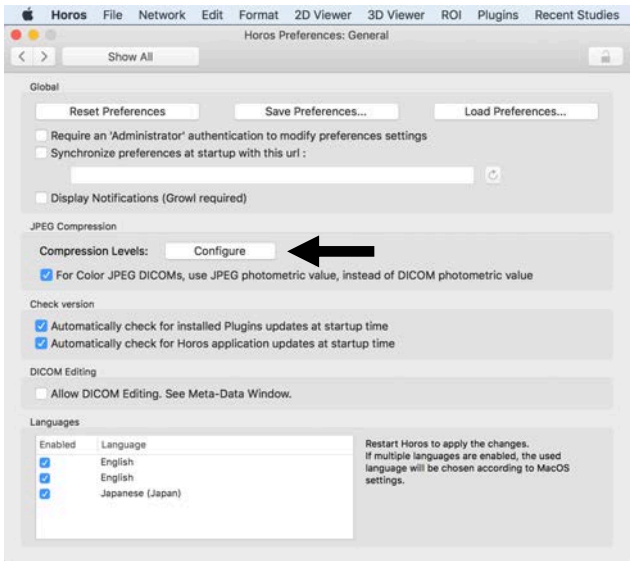


Figure 9.40 The *Horos Preferences: General* window. JPEG2000 Image compression levels can adjusted by clicking on C*onfigure* (arrow)

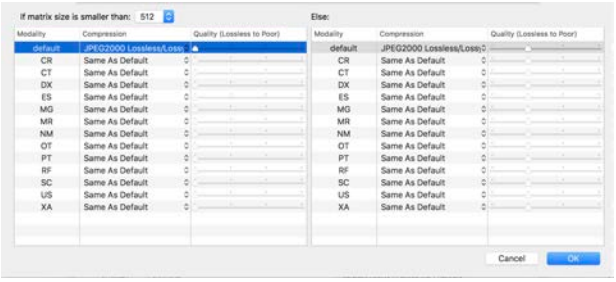


Figure 9.41 JPEG2000 Image compression levels can be adjusted here

If you encounter issues with image transfers or blocked file exchanges you can check your computer's settings to determine if you have *normal* performance. Go to /Applications/Utilities and select Console APP). If you are receiving error messages regarding compression/decompression, your transfer syntaxes are probably incorrect i.e. not all DICOM nodes are set to transfer/receive JPEG2000 files. It is important for the PACS server and Horos to be able to communicate without compressing/decompressing data.

In conclusion using a JPEG 2000 Network allows you to:

- Store 3 times more files on your server
- Have greater simultaneous client access to your server as files can be read three times faster
- Files can be transferred three times faster from the PACS server to the workstations.

Appendix A

•

Default Hot Keys

•

Tool/Function	*Default Key*
1st WL/WW preset	*1*
2nd WL/WW preset	*2*
3D Point Tool	*P*
3D Rotate Tool	*[*
3rd WL/WW preset	*3*
4th WL/WW preset	*4*
5th WL/WW preset	*5*
6th WL/WW preset	*6*
7th WL/WW preset	*7*
8th WL/WW preset	*8*
9th WL/WW preset	*9*
Arrow Tool	*Q*
Bone Removal Tool	*X*
Brush Tool	*B*
Camera Tool	*]*
Closed Polygon Tool	*C*
Default WL/WW	*~*
Flip Horizontal	*H*
Flip Vertical	*V*
Full Dynamic WL/WW	*0*
Mark Status as Dictated	\
Mark Status as Empty	*,*
Mark Status as Reviewed	*/*
Mark Status as Unread	*.*
Mark Status as Validated	*Y*
Measure Angle Tool	*A*
Measure Length Tool	*L*
Move Tool	*M*
Open Polygon Tool	*O*
Ortho MPR Cross Tool	*None*
Oval ROI Tool	*E*
Pencil Tool	*D*
Rectangle ROI Tool	*None*
Repulsor Tool	*R*
Rotate Tool	*I*
Scissors Tool	*None*
Scroll Tool	*None*
Selector Tool	*S*
Text Tool	*T*
WL/WW Tool	*W*
Zoom Tool	*Z*

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