$$\mathbf{A}_{(m,n)} = \begin{bmatrix} a_{(1,1)} & a_{(1,2)} & \cdots & a_{(1,n)} \\ a_{(2,1)} & a_{(2,2)} & \cdots & a_{(2,n)} \\ \vdots & \vdots & \ddots & \vdots \\ a_{(m,1)} & a_{(m,2)} & \cdots & a_{(m,n)} \end{bmatrix}$$

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:

$$K = \begin{bmatrix} k_{(1,1)} & k_{(1,2)} & k_{(1,3)} \\ k_{(2,1)} & k_{(2,2)} & k_{(2,3)} \\ k_{(3,1)} & k_{(3,2)} & k_{(3,3)} \end{bmatrix}$$

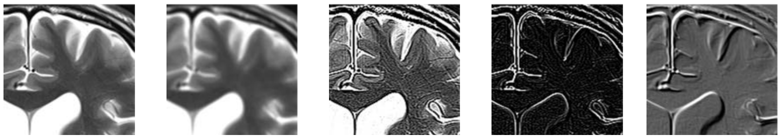
The resulting image is also of size m × n and the pixel at position i, j is computed as follows:

$$B_{(i,j)} = k_{(1,1)} \bullet a_{(i-1,j-1)} + k_{(1,2)} \bullet a_{(i-1,j)} + k_{(1,3)} \bullet a_{(i-1,j+1)} + k_{(2,1)} \bullet a_{(i,j-1)} + k_{(2,2)} \bullet a_{(i,j)} + k_{(2,3)} \bullet a_{(i,j+1)} + k_{(3,1)} \bullet a_{(i+1,j-1)} + k_{(3,2)} \bullet a_{(i+1,j)} + k_{(3,3)} \bullet a_{(i+1,j+1)}$$

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).

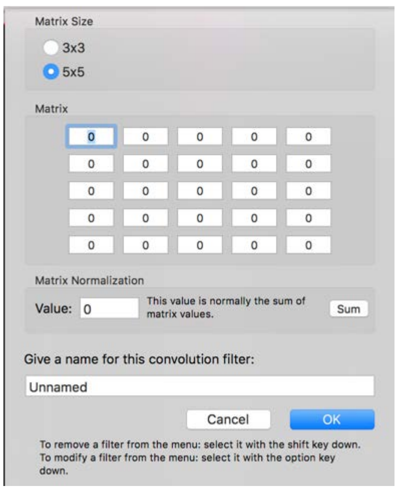


Figure 6.71. The convolution filter edit panel.

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

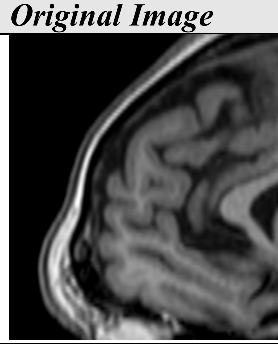
Kernel	***Original Image***	***Filtered Image***
$\mathbf{1/16}\begin{bmatrix}1 & 2 & 1\\ 2 & 4 & 2\\ 1 & 2 & 1\end{bmatrix}$		

Table 6.3. The Blur 3 x 3 filter.

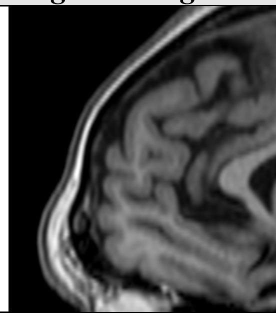
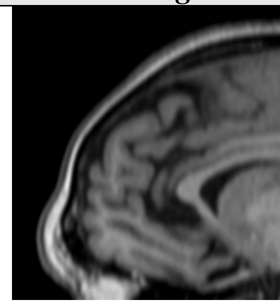
Kernel	*Original Image*	*Filtered Image*
$1/9 \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$		

Table 6.4. The Lowpass filter.

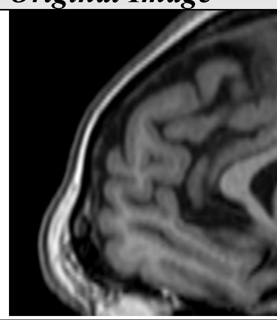
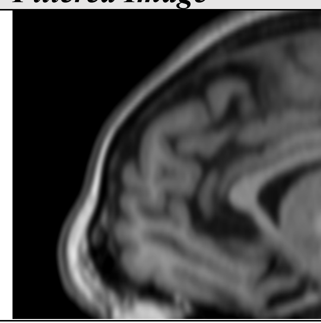
Kernel	*Original Image*	*Filtered Image*
$1/60 \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 4 & 4 & 4 & 1 \\ 1 & 4 & 12 & 4 & 1 \\ 1 & 4 & 4 & 4 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$		

Table 6.5. The Basic smooth 5 x 5 filter.

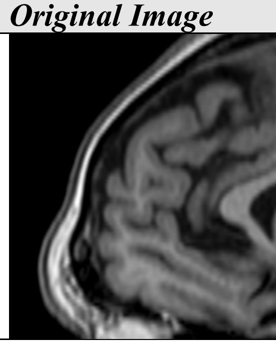
Kernel	*Original Image*	*Filtered Image*
$1/44 \begin{bmatrix} 1 & 1 & 2 & 1 & 1 \\ 1 & 2 & 3 & 2 & 1 \\ 2 & 3 & 4 & 3 & 2 \\ 1 & 2 & 3 & 2 & 1 \\ 1 & 1 & 2 & 1 & 1 \end{bmatrix}$		

Table 6.6. The Blur 5 x 5 filter.

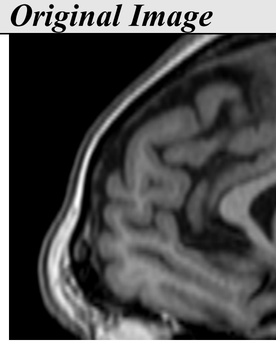
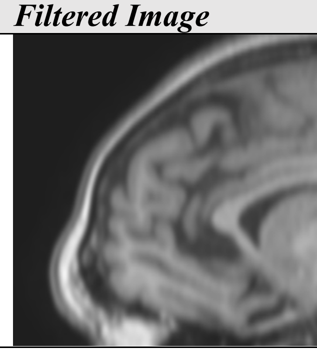
Kernel	*Original Image*	*Filtered Image*
$1/52 \begin{bmatrix} 1 & 1 & 2 & 1 & 1 \\ 1 & 2 & 4 & 2 & 1 \\ 2 & 4 & 8 & 4 & 2 \\ 1 & 2 & 4 & 2 & 1 \\ 1 & 1 & 2 & 1 & 1 \end{bmatrix}$		

Table 6.7. The Gaussian blur filter.

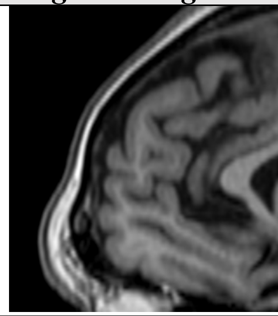
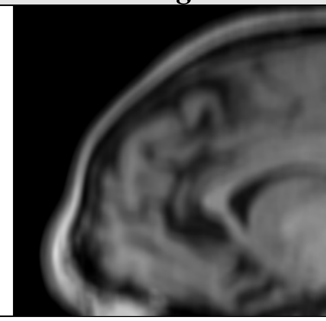
Kernel	***Original Image***	***Filtered Image***
$\frac{1}{56}\begin{bmatrix} 3 & 3 & 2 & 3 & 3 \\ 3 & 2 & 1 & 2 & 3 \\ 2 & 1 & 0 & 1 & 2 \\ 3 & 2 & 1 & 2 & 3 \\ 3 & 3 & 2 & 3 & 3 \end{bmatrix}$		

Table 6.8. The Inverted blur filter.

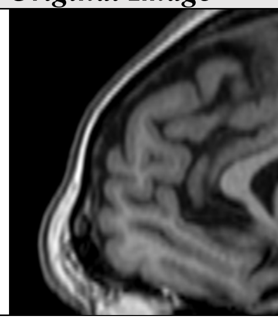
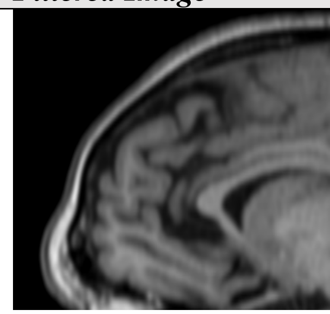
Kernel	***Original Image***	***Filtered Image***
$\frac{1}{19}\begin{bmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 2 & 1 & 0 \\ 1 & 2 & 3 & 2 & 1 \\ 0 & 1 & 2 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix}$		

Table 6.9. The Negative blur filter.

Sharpening Filters

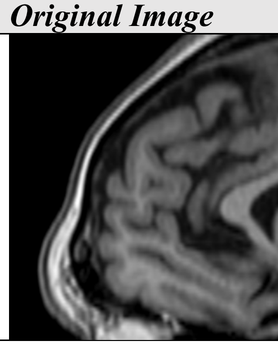
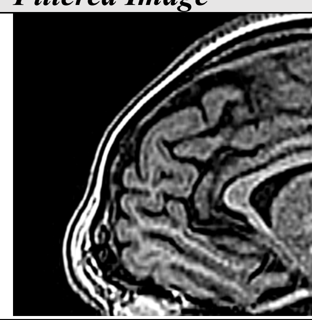
Kernel	***Original Image***	***Filtered Image***
$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{bmatrix}$		

Table 6.10. The Bone 3 x 3 filter.

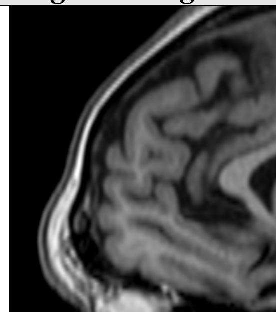
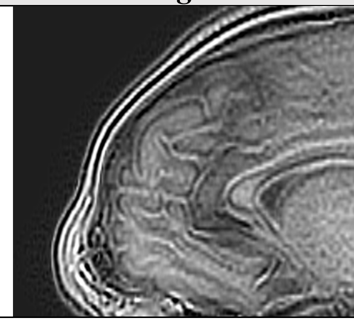
Kernel	***Original Image***	***Filtered Image***
$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 7 & 1 \\ 1 & 1 & 1 \end{bmatrix}$		

Table 6.11. The Excessive edges filter.

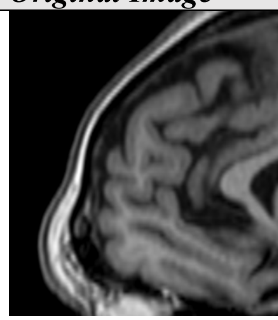
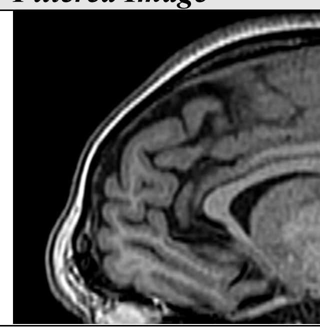
Kernel	***Original Image***	***Filtered Image***
$1/3 \begin{bmatrix} -1 & 0 & -1 \\ 0 & 7 & 0 \\ -1 & 0 & -1 \end{bmatrix}$		

Table 6.12. The Sharpen 3 x 3 filter.

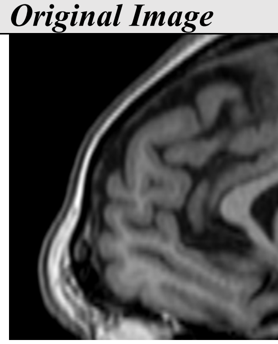
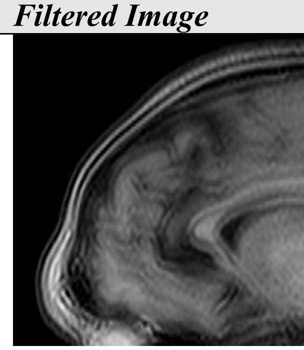
Kernel	***Original Image***	***Filtered Image***
$1/7 \begin{bmatrix} 0 & 1 & 1 & 1 & 0 \\ 1 & -2 & 4 & -2 & 1 \\ 1 & 4 & -13 & 4 & 1 \\ 1 & -2 & 4 & -2 & 1 \\ 0 & 1 & 1 & 1 & 0 \end{bmatrix}$		

Table 6.13. The Highpass 5 x 5 filter.

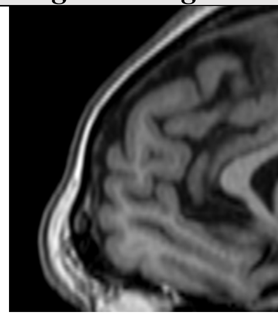
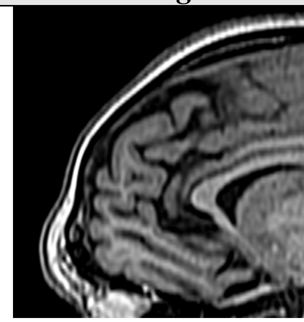
Kernel	***Original Image***	***Filtered Image***
1/8 $\begin{bmatrix} -1 & -1 & -1 & -1 & -1 \\ -1 & 2 & 2 & 2 & -1 \\ -1 & 2 & 8 & 2 & -1 \\ -1 & 2 & 2 & 2 & -1 \\ -1 & -1 & -1 & -1 & -1 \end{bmatrix}$		

Table 6.14. The Sharpen 5 x 5 filter.

Edge Filters

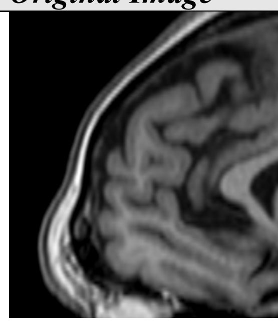
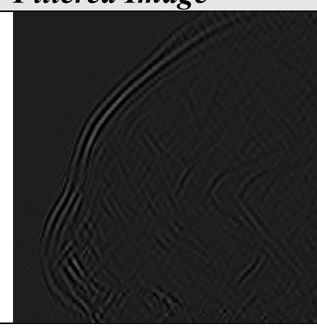
Kernel	***Original Image***	***Filtered Image***
$\begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix}$		

Table 6.15. The Edges 3 x 3 filter.

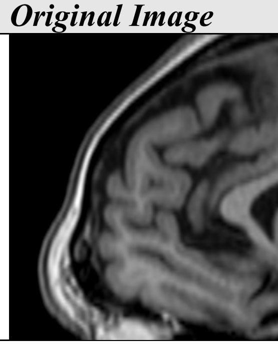
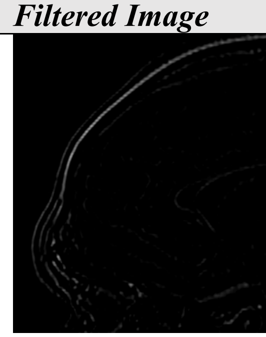
Kernel	***Original Image***	***Filtered Image***
$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$		

Table 6.16. The Laplacian 4 filter.

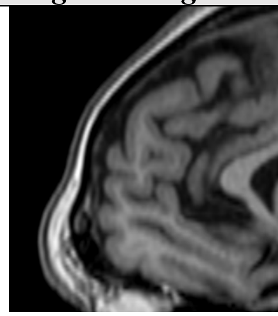
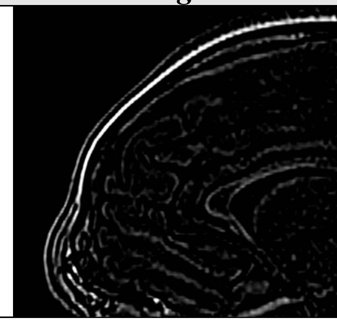
Kernel	***Original Image***	***Filtered Image***
$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$		

Table 6.17. The Laplacian 8 filter.

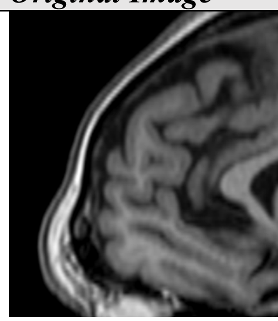
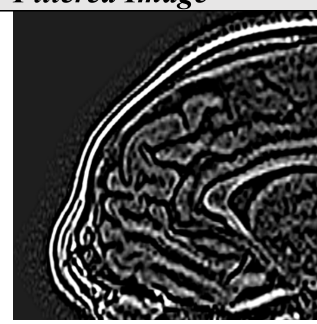
Kernel	***Original Image***	***Filtered Image***
$\begin{bmatrix} 0 & 0 & -1 & 0 & 0 \\ 0 & -1 & -2 & -1 & 0 \\ -1 & -2 & 16 & -2 & -1 \\ 0 & -1 & -2 & -1 & 10 \\ 0 & 0 & -1 & 0 & 0 \end{bmatrix}$		

Table 6.18. The Hat filter.

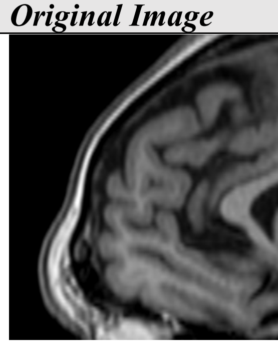
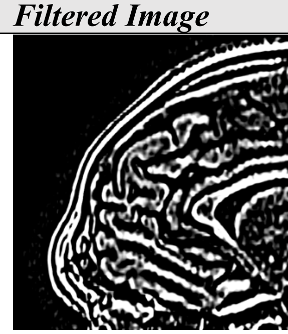
Kernel	***Original Image***	***Filtered Image***
$\begin{bmatrix} -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & 24 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \end{bmatrix}$		

Table 6.19. The Laplacian filter.

Emboss Filters

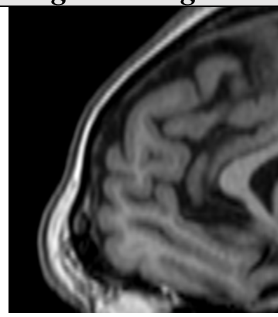
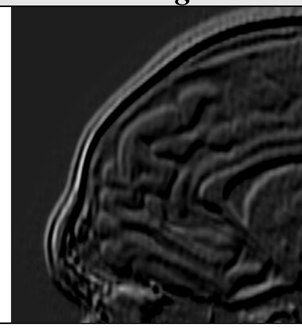
Kernel	***Original Image***	***Filtered Image***
$\begin{bmatrix} -1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$		

Table 6.20. The Emboss filter

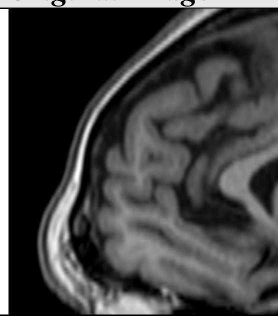
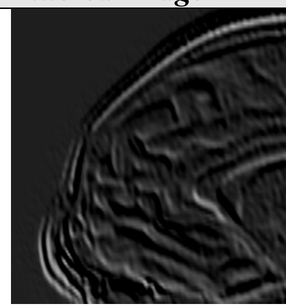
Kernel	***Original Image***	***Filtered Image***
$\begin{bmatrix} 0 & 1 & 0 \\ -1 & 0 & 1 \\ 0 & -1 & 0 \end{bmatrix}$		

Table 6.21. The Emboss diagonal filter.

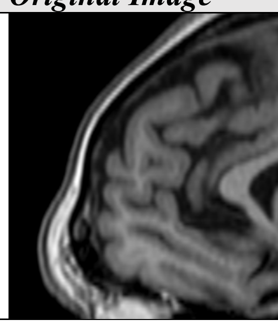
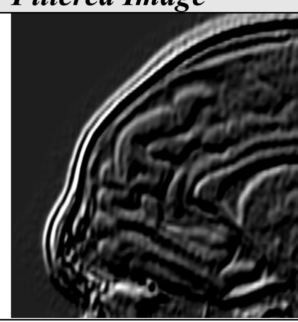
Kernel	***Original Image***	***Filtered Image***
$\begin{bmatrix} -1 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 1 \end{bmatrix}$		

Table 6.22. The Emboss heavy filter

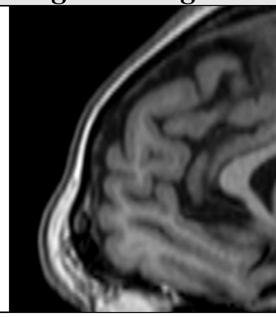
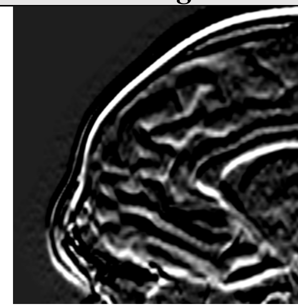
Kernel	***Original Image***	***Filtered Image***
$\begin{bmatrix} \mathbf{1} & \mathbf{2} & \mathbf{1} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{-1} & \mathbf{-2} & \mathbf{-1} \end{bmatrix}$		

Table 6.23. The Emboss north filter.

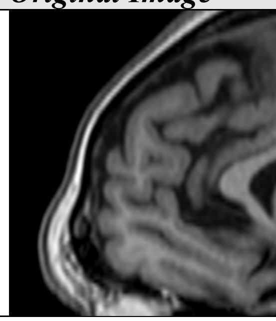
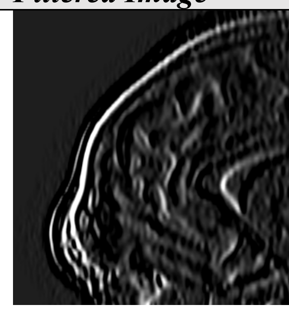
Kernel	***Original Image***	***Filtered Image***
$\begin{bmatrix} \mathbf{1} & \mathbf{0} & \mathbf{-1} \\ \mathbf{2} & \mathbf{0} & \mathbf{-2} \\ \mathbf{1} & \mathbf{0} & \mathbf{-1} \end{bmatrix}$		

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)

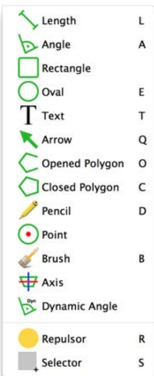
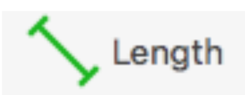


Figure 6.72. The ROI tool list.

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.