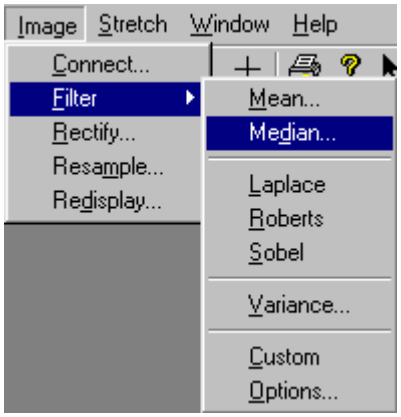
9. USING FILTERS TO ENHANCE IMAGES

Aim: To introduce you to how to use filters to enhance features of interest in images.

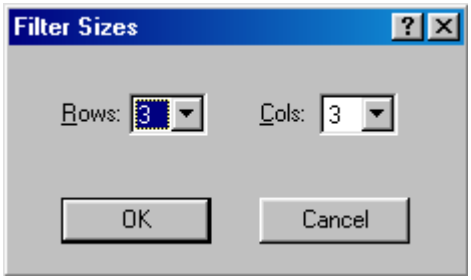
Objectives: By the end of this tutorial you will have learnt what the main types of filters are, what they do, how to apply them and how to construct customised filters.

This tutorial introduces you to the use of "filters" which act on your image (i) to enhance edges (like filters used to sharpen digital photographs), (ii) to smooth thematic or radar images (like filters use for dust and speckle removal or to blur digital photographs) or (iii) to enhance areas that are rough (with variable reflectance or backscatter). Filters perform calculations on the underlying image data and then create a new image transformed according to the type of filter applied.



The **Filter** submenu of the **Image** menu allows the user to apply filtering processes to an image. Six predefined filters (Mean, Median, Laplace, Roberts, Sobel and Variance) are provided and users are also allowed to create their own customised filters. The first two predefined filters act to **smooth** the image and are sometimes called 'low pass' filters. The middle three act to enhance edges or **gradients** (i.e. areas on the image where there are sudden changes in reflectance in a given waveband) and are sometimes called 'high pass' filters. The predefined **Variance** filter is a textural filter which makes areas of variable reflectance appear brighter than relatively uniform areas which appear darker the more uniform they are.

The three predefined high pass filters all act on 3 × 3 groups of pixels whilst the **Mean, Median** and **Variance** filters can have their sizes altered in a **Filter Sizes** dialog box (right). By default these filters act on 3 × 3 groups of pixels (3 rows × 3 columns) and this setting is initially displayed. The maximum size allowed is 15 × 15 pixels.



Activity: Open the image called ***AVHRR_Mulls_col#04.bmp***, a coloured thematic image showing sea surface temperatures in various colours with warmest water deep red and coldest cyan in colour. Before proceeding, check the filter options by selecting **Image, Filter, Options** to display the **Filter Options** dialog box. Make sure that all four checkboxes are checked and that the **Filtered Image Type:** is the Same as unfiltered. Then use **Edit, Select All** or press *<Ctrl>+A* to select the whole of this image for filtering.

The first filter you will experiment with is a simple 3 × 3 Median filter. This replaces the central pixel in each square of nine pixels by the median value of the nine pixels (i.e. the middle value after they have been ranked according to DN). This filter is a smoothing filter and will emphasise the major changes occurring in our thematic colour map of sea surface temperatures at the expense of localised differences. Often as the last cosmetic operation after creating a thematic map one smooths the final image to remove "noise" and emphasise the broad changes in features (in this case, sea surface temperature).

Activity: From the **Image** menu, select **Filter, Median** with the mouse. The **Filter Sizes** dialog box will appear (see above). Since we want a 3 × 3 filter, just click on OK. A Status box briefly appears as the filtering is carried out and then a window containing the filtered image appears. Compare the filtered and unfiltered image. Note that the broad changes in water temperature are more clearly displayed in

the smoothed image. You can see what you have done to the new smoothed image by clicking on the grey edge [indicated by arrow on picture to right] above the image but below the title bar (when you are in the correct position the mouse pointer changes into black upward and downward arrows emanating from a pair of parallel lines) and dragging this window pane downwards (it works a bit like a roller blind). Underneath the image you should see **3x3 Median Filter over AVHRR_Mulls_col#04.bmp : From (0, 0) To (511, 255)**

Note how the filter emphasises the broadscale distribution of water masses of different temperature. How ever, some detail is inevitably lost.

The larger the array used for filtering the harsher the smoothing will be. To see the effect of a large smoothing filter you should try a 7 × 7 Median filter, which replaces the central pixel in a 7 × 7 pixel array by the median of all 49 pixels in the array. As you can imagine, such a filter, although bringing out large-scale features, can cause considerable loss of detail.

Activity: Click on the ***AVHRR_Mulls_col#04.bmp*** unfiltered image. From the **Image** menu, select **Filter, Median**. In the **Filter Sizes** dialog box click on the down arrows by the **Rows:** and **Cols:** boxes and select 7 for each (or type 7 in each box), then click on OK. A **Status** box briefly appears as the filtering is carried out and then a window containing the filtered image appears. Compare this image both with your original unfiltered image and the image filtered with a 3 × 3 Median filter. Note how Malin Head and some small islands have almost disappeared and the rather cartoon like quality of the heavily smoothed image. This illustrates the care which one must take using such filters. Close the two filtered images (do not save changes).

The **Mean** filter acts in a similar fashion to the **Median** filter but replaces each pixel value by the **mean** (average) of the group of 3 × 3 pixels of which it is the centre. With the median filter all pixel values in the output filtered image will be represented in the image data but with a mean filter you may be creating pixels which have values which do not exist in the input image. Depending on the type of image you may wish to use one or the other filter.

We will now look at the effects of some custom 'high pass', edge-enhancing filters on a test image, which will demonstrate how directional filters work. The **Image, Filter, Custom** option allows you to create your own customised filters in which you define the weights (usually integers) for each cell in the filter array. We will experiment with constructing a few 3 × 3 filters to carry out specific modifications to an image. You will firstly try out a filter which is designed to enhance East–West running edges, then one designed to enhance North–South running edges, and finally one designed to pick up edges running in any direction. In each case after applying the filter you should perform an automatic linear stretch of the resulting image to display the result. Details of precisely how these *convolution* filters work are beyond the scope of this introduction but are covered in standard textbooks.

E-W edge enhancer

1	2	1
0	0	0
-1	-2	-1

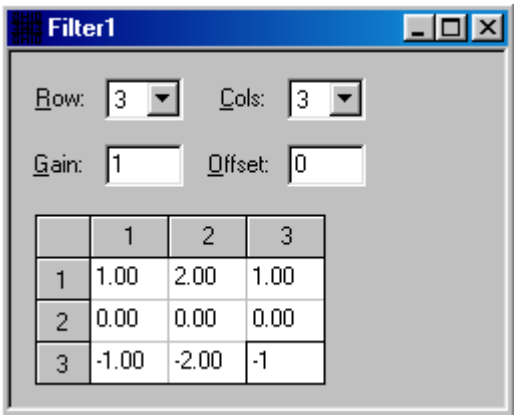
N-S edge enhancer

1	0	-1
2	0	-2
1	0	-1

Non-directional edge enhancer

-1	-1	-1
-1	8	-1
-1	-1	-1

Activity: Close the ***AVHRR_Mulls_col#04.bmp*** image and open the test image, which is called ***Filter_test.gif***. The test image looks remarkably boring with a patch of black in the north-west corner, a patch of white in the south-east corner and a big expanse of dull grey in between. Let's see what edge-enhancing filters can reveal.



Press *<Ctrl>+A* to select the whole of this image and select **Image, Filter, Custom.** Set up the custom filter as an E–W edge enhancer, typing the numbers into each cell of the array and using the *<Tab>* key to move between cells. When all the cells are correctly filled in, click on the Copy button, then click on the ***Filter_test.gif*** image and click on the Paste button to paste the filter to the image. You will see a faint but distinct pattern of horizontal lines in the grey area. Apply an automatic linear stretch (**Stretch, Auto Linear**) to see the results more clearly.

Note the series of lines running E–W that are now clearly revealed in the grey area.

Activity: Close the filtered image and the filter you created. Then open a new custom filter and set it up as a N–S edge enhancing filter as in the diagram above. When all the cells in the new filter are set up correctly, copy and paste the new filter to the ***Filter_test.gif*** test image. [*Note:* if you find you cannot paste the filter to the image then press *<Ctrl>+A* to select the whole image]. Apply an automatic linear stretch (**Stretch, Auto Linear**) to see the results more clearly.

Question 1: What do you see this time in the grey area?

Activity: Close the filtered image, save the filter you created as ***N-S_edge_enhancer*** (*Bilko* will automatically add the ***.flt*** extension) and then close it. Then select **File, Open**, make sure that the **Apply** checkbox is **not** checked, and open the filter called ***High_pass.flt***, which is the non-directional edge enhancing custom filter in the diagram above. Copy and paste the new filter to the ***Filter_test.gif*** test image. Note the pattern that now appears in the grey area. Apply an automatic linear stretch (**Stretch, Auto Linear**) to see the results more clearly.

Question 2: What do you see this time in the grey area?

Note: if the **Apply** checkbox of the **Open** dialog box had been checked and the ***Filter_test.gif*** image had been the active document, then the filter would have been applied directly to that image (without being opened). You may wish to experiment with this.

The exercises above show how selective filters can be. There is in fact some sort of faint grid within the grey area, which is not visible in the normal image but can be brought out by edge enhancing filters. The directional filters only reveal one part of the grid (e.g., *either* E–W *or* N–S running lines) whereas the non-directional filter reveals the whole grid.

The predefined edge-enhancing filters (**Laplace, Roberts,** and **Sobel**) all produce similar results to the non-directional custom filter. You can quickly check this by applying these three filters to the ***Filter_test.gif*** test image (see next activity). Details of these filters are available from *Bilko*'s **Help**.

Activity: Close the filtered image and the ***High_pass.flt*** filter. Make sure the entire ***Filter_test.gif*** test image is selected and then apply the three predefined edge-enhancing filters in succession, applying automatic linear stretches to see the results clearly.

If you select just part of the image [*Hint:* click on the block or box selection button and then click on the top-left of the area you want to filter and drag box to the bottom-right of the area], you can apply the filter to only the sub-area selected.

When you have finished experimenting, close all the filtered images (without saving them) and close the ***Filter_test.gif*** test image.

The remaining predefined filter, the **Variance** filter replaces each pixel value by the variance of the group of $n \times n$ pixels (default 3×3 pixels) of which it is the centre. Its use is demonstrated in specific lessons but will not be considered further here.

In this tutorial you have learnt how to smooth thematic or noisy images using mean and median filters, how to enhance edges using both custom filters and predefined ones and how to construct your own customised filters. You have also learnt how to save and open custom filters so that you could build up a set of your own specialist filters if required.

The final tutorial in this series of tutorials introduces you to *Bilko*'s powerful **formula documents** facility that allows you to carry out calculations on a single image or using combinations of connected images.