Getting Started

Filtering Images

with

TNTmips®

Before Getting Started

In working with digital forms of aerial photographs or satellite imagery, you will encounter many images that can be improved by the form of image enhancement known as filtering. This booklet introduces you to two of the filter processes in TNTmips®. The Spatial Filters process includes a variety of filters designed to reduce noise content, sharpen details, or highlight edges or other aspects of the image texture. The Locally Adaptive Contrast Enhancement (LACE) filter process can improve the appearance of high-contrast grayscale or color images.

Prerequisite Skills This booklet assumes that you have completed the exercises in *Getting Started: Displaying Geospatial Data* and *Getting Started: Navigating*. Those exercises introduce essential skills and basic techniques that are not covered again here. Please consult those booklets and the TNTmips reference manual for any review you need.

Sample Data The exercises presented in this booklet use sample data that is distributed with the TNT products. If you do not have access to a TNT products CD, you can download the data from MicroImages' web site. In particular, this booklet uses sample files in the FILTER, HAWAII, and CROPDATA data collections.

More Documentation This booklet is intended only as an introduction to filtering raster images. Consult the TNTmips reference manual, which contains more than 40 pages on the Spatial Filter and LACE Filter processes, for more information.

TNTmips and TNTlite® TNTmips comes in two versions: the professional version and the free TNTlite version. This booklet refers to both versions as "TNTmips." If you did not purchase the professional version (which requires a hardware key), TNTmips operates in TNTlite mode, which limits object size and does not allow export.

The Spatial Filter and LACE Filter processes are not available in TNTview or TNTatlas. All the exercises can be completed in TNTlite using the sample geodata provided.

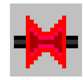
Randall B. Smith, Ph.D., 17 September 2001

It may be difficult to identify the important points in some illustrations without a color copy of this booklet. You can print or read this booklet in color from MicroImages' web site. The web site is also your source for the newest Getting Started booklets on other topics. You can download an installation guide, sample data, and the latest version of TNTlite.

http://www.microimages.com

Welcome to Filtering Images

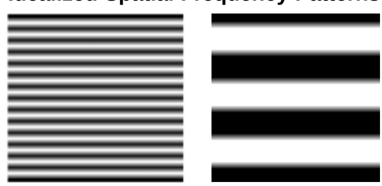
In conventional photography, filters of various types can be placed in front of the camera lens to alter and enhance the image that is recorded on film. Digital image processing can achieve an even wider range of image enhancements using numerical procedures that manipulate the brightness values stored in a raster object. The term **filter** is also commonly used to refer to these image processing operations. Filter operations can be used to sharpen or blur images, to selectively suppress image noise, to detect and enhance edges, or to alter the contrast of the image.



Pages 4-10 introduce you to key features of the Spatial Filters process interface and to filters in the General class. Noise Reduction filters are discussed on pages 11-14, Enhancement filters on pages 15-18, and Texture filters on page 19. The Locally Adaptive Contrast Enhancement (LACE) filter process is described on pages 20-22.

The variations in brightness at different spatial scales within a raster image can be thought of as a collection of spatial frequencies. Major changes in brightness over a short distance represent a **high-frequency** component of the image. Conversely, more widely-spaced shifts in brightness form a **low-frequency** component. Many filters act to suppress a particular set of spatial frequencies, while leaving others unaltered.

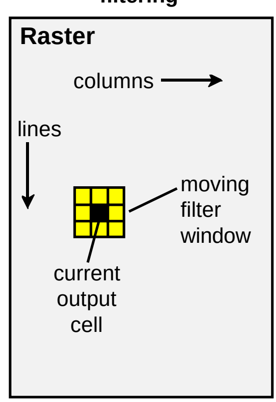
Idealized Spatial Frequency Patterns



High-frequency   Low-frequency

Most of the filter operations discussed in this booklet are included in the Spatial Filter process. The Spatial Filter operations calculate a new value for each raster cell using values in a surrounding group of cells. You specify the nature of this group by setting the shape and size of the **filter window**. (The default filter window is square and has an odd number of lines and columns). As the filter window is moved through the input raster cell by cell, the process reads the set of input cell values within the current window, applies a specific set of functions to calculate an output value for the central cell, and writes the new value to the corresponding cell in the output raster. This procedure is commonly referred to as **spatial convolution filtering**.

Spatial convolution filtering



General Filters

STEPS

☑ launch the Spatial Filter process (Process / Raster / Filter / Spatial Filter...)

☑ click [Rasters...] on the Raster Spatial Filtering window

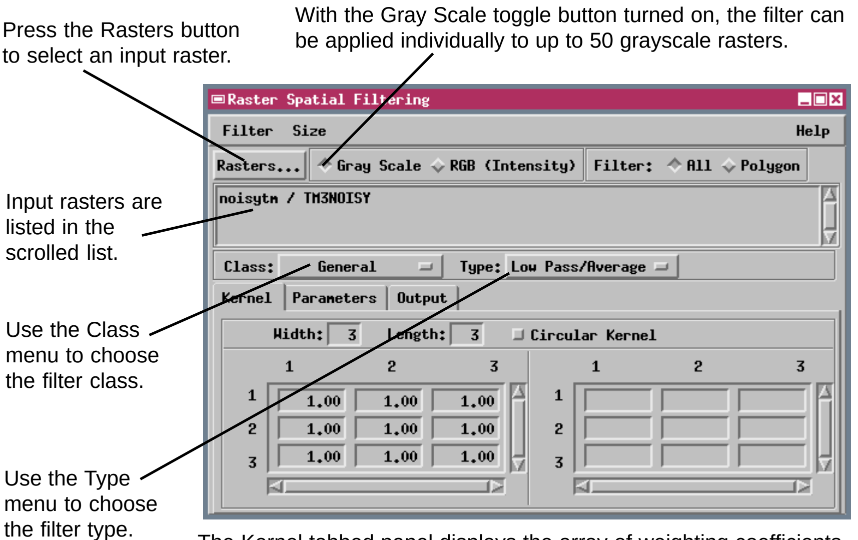
☑ use the standard File / Object Selection procedure to select raster object TM3NOISY from the NOISYTM Project File in the FILTER data collection

☑ accept the default selections on the Class and Type option menus

Use the standard display process (Display / Spatial Data) to view the input and output raster objects for each of the exercises.

When you launch the Spatial Filter process, the Raster Spatial Filtering window appears. The spatial filters are organized into six classes: General, Edge Detection, Enhancement, Noise Reduction, Radar, and Texture. To select a filter, first choose the appropriate filter class from the Class option menu, then the specific filter from the Type option menu.

The Class option menu defaults to General when you enter the Spatial Filter process. The filters in this class calculate a weighted average of the cells in the filter window. The set of weighting coefficients used in the calculations are called the **filter kernel**. The filter kernel always has the same dimensions as the current filter window; the default size is 3 lines by 3 columns. Each filter in the General class has its own set of filter kernels (for different kernel sizes) which produce characteristic results. The array table on the left side of the Kernel tabbed panel displays the coefficients for the currently selected filter.



The Kernel tabbed panel displays the array of weighting coefficients that make up the current filter kernel (for filters in the General class).

Low Pass / Average Filter

The default filter type in the General class is the Low Pass / Average filter. The output cell value calculated by this filter is the simple average (arithmetic mean) of the cells in the filter window. The averaging performed by the Low Pass filter removes some of the higher frequency features, while allowing the low-frequency features to "pass" through the filter unchanged (thus the term "low pass" filter). This has the effect of smoothing the raster image, emphasizing its larger-scale brightness trends.

Whether the smoothing produced by the low pass filter is beneficial or not depends on the characteristics of the input image. If the high-frequency features represent introduced "noise" that detracts from the overall image quality, the low-pass smoothing will improve the image. However, smoothing may also blurr edges, degrade useful image detail, and reduce contrast. In the example used in this exercise, the filter suppresses horizontal striping noise in the image, but also reduces image detail.

STEPS
- ☑ accept the default settings and select Run from the Filter menu
- ☑ use the File / Object Selection procedure to name a new Project File FILTOUT, and accept the default name for the output raster object
- ☑ click [OK] on the File / Object Selection window to close it and initiate the filter process

The weighting coefficients (filter weights) for the Low Pass / Average filter all have a default value of 1.00 (see illustration on previous page). The raw cell values are therefore used in the averaging process, and the resulting output value is the simple average (mean) of the cell values in the filter window.

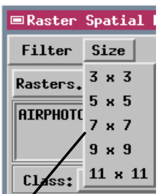
Upper right part of raster object TM3NOISY (input image), which shows horizontal striping.

Same part of image with 3 x 3 low pass filter applied (auto-normalized contrast). Striping is reduced, but small features are slightly blurred.

Change the Filter Window Size

STEPS

- ☑ select 7 x 7 from the Size menu of the Raster Spatial Filtering window
- ☑ select Run from the Filter menu and direct the output raster to the FILTOUT Project File



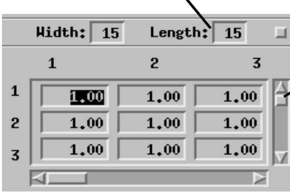
Select a predefined filter window size from the Size option menu.

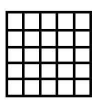
The spatial filter process provides several predefined filter window sizes up to 11 x 11 cells. You can create a larger filter window by typing new values in the Width and Length text boxes on the Kernel tabbed panel.

Increasing the filter window size extends the filter effects to lower spatial frequencies. For the Low Pass filter, this means that the degree of smoothing increases with increasing filter window size. The boundary between high frequency features removed and low frequency features retained moves toward the lower frequencies. The 7 x 7 Low Pass filter applied in this exercise removes more details, and larger-scale details, than the 3 x 3 filter applied in the previous exercise. For the small, low-resolution raster image we are using (28.5 meter cell size), the 7 x 7 filter produces excessive blurring. Larger filter window sizes are generally more appropriate for higher-resolution raster images.

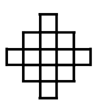
You can type new values in the Width and Length text boxes to create a filter window with a custom size.

When the filter window is larger than 3 x 3 cells, the scroll bars on the filter kernel array tables allow you to move the array to inspect the full set of weighting coefficient values.



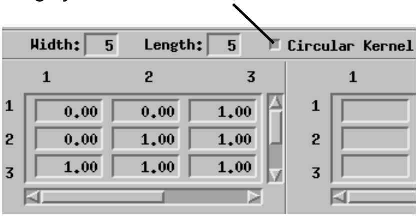


Square kernel



"Circular" kernel

The Circular Kernel option changes the weight values in the corners of the filter kernel to 0. This restricts the averaging process to a roughly circular window area.

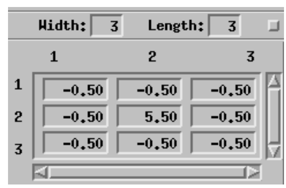


Upper right part of raster object TM3NOISY with 7 x 7 Low Pass filter applied (auto-normalized contrast). Spatial averaging has greatly reduced image detail.

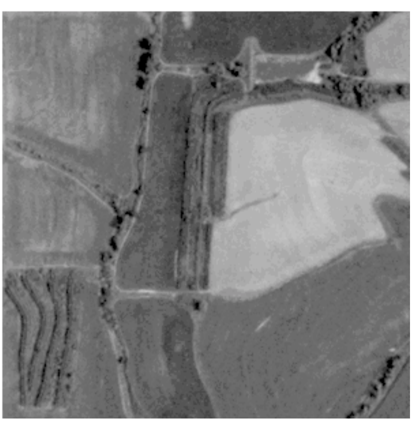
High Pass Filter

The High Pass filter selectively enhances the small-scale features of an image (high-frequency spatial components) while maintaining the larger-scale features (low-frequency components) that constitute most of the information in the image. The default filter kernel for the High Pass filter has filter weight values of -0.5 for all cells except the center cell, which has a positive weight (its value depends on the size of the filter window). The filter calculation essentially amplifies the value of the center cell, then subtracts from it half the average value of the surrounding cells. If the center cell differs greatly in brightness from its neighbors, this difference will be accentuated in the output image, while areas of uniform brightness are changed very little. The result is enhanced contrast for edges and other small-scale features in the image. The image appears sharper, and details obscured by atmospheric haze or poor focus in the imaging system become more obvious. Increasing the filter window size extends the enhancement to increasingly larger features, which at some point may make the output image appear too harsh.

STEPS
- ☑ click [Rasters...] on the Spatial Filtering window and select raster object RED from the RGBCROP Project File in the CROPDATA data collection
- ☑ select 5 x 5 from the Size option menu
- ☑ select High Pass from the Type option menu
- ☑ select Run from the Filter menu and direct the output raster to the FILTOUT Project File



Filter kernel for 3 x 3 High Pass filter.

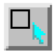


Upper left part of raster object RED (input image), which appears slightly blurred.

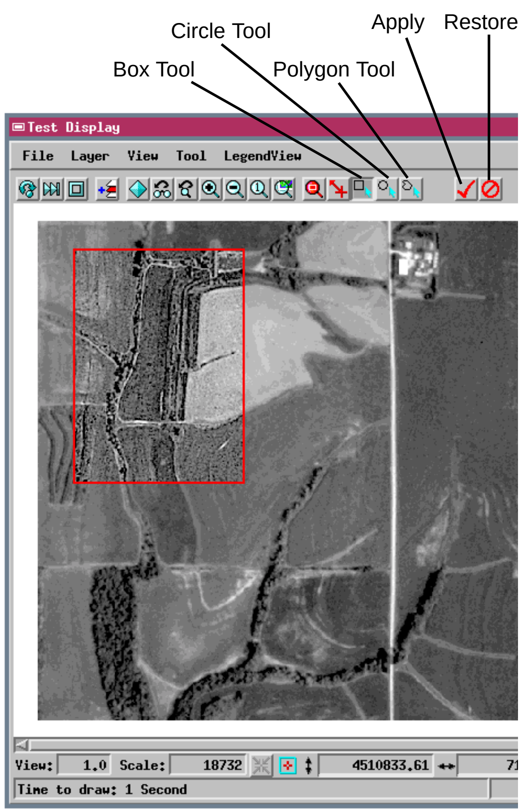
Same image with 5 x 5 High Pass filter applied (auto-normalized contrast). The image appears sharper, with clearer edges and enhanced details.

Test Filter Results

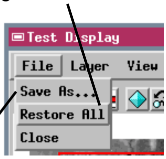
STEPS

- ☑ choose Test from the Filter menu
- ☑ click the Box icon button in the Test Display window 
- ☑ place the mouse pointer near the upper left corner of the image area
- ☑ click and hold the left mouse button as you drag the mouse pointer down and to the right to create a rectangle as illustrated
- ☑ drag an edge or corner of the box to resize it if necessary
- ☑ press the right mouse button to execute the test filtering
- ☑ choose Close from the File menu on the Test Display window when you are finished testing

The Test mode allows you to preview filter results for one or more selected parts of an image. Use the Box, Circle, or Polygon drawing tools on the Test Display window to outline a test area, which can be any size up to the dimensions of the input raster. Click the right mouse button or press the Apply icon button to apply the filter to the selected area and update the display. You can repeat the filter test on adjacent test areas or on the same test area to evaluate the effects of different filter settings. The test process is not cumulative; each filter operation is performed on the original input raster. You can restore the currently selected area of the display to its original appearance by pressing the Restore icon button.



When you test different areas, previous test results are retained in the display. Choose Restore All from the File menu to restore the entire display to the original unfiltered state.



The Save As option lets you save the temporary raster displayed in the Test Display window with whatever filter effects you have applied to part or all of the raster area.

When you use the Test operation with multiple grayscale or RGB input rasters, only a single selected raster is displayed for testing.

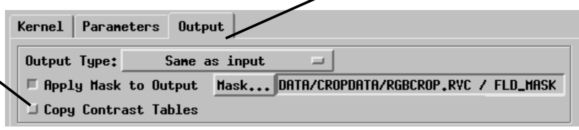
Apply a Mask

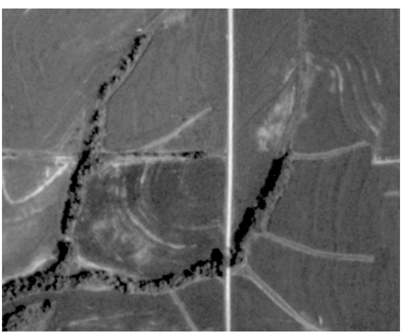
You can limit a filter to only a selected part of an image by applying a mask during the filter process. A **mask** is a binary raster used to control the display or processing of a corresponding image. The mask has a value of 1 for cells that will be processed, and a value of 0 for cells that will be excluded from processing. When you apply a mask in the Spatial Filter process, the masked portions of the image are copied without change to the output image. In this example wooded areas, fence rows, and roads are masked, so the high-pass filter accentuates detail only in the cultivated fields. (You can create a mask easily using the Region-of-Interest tool in the Feature Mapping process.)

STEPS
- ☑ turn on the Apply Mask to Output toggle button on the Output tabbed panel
- ☑ click [Mask...] and select the FLD_MASK raster object from the RGBCROP Project File
- ☑ select Run from the Filter menu and direct the output raster to the FILTOUT Project File

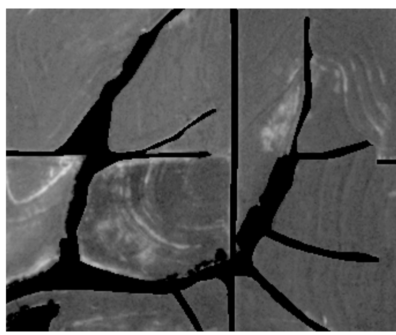
Mask controls are on the Output tabbed panel.

You can also choose to copy contrast tables from the input raster to the filtered image.

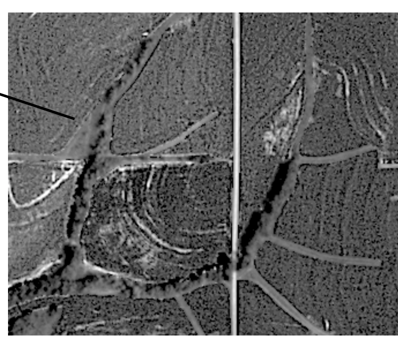




Lower right part of input image showing fields separated by strips of trees or grass.



Same image area displayed with mask.



Output image. Masked areas were not altered, but detail is increased in fields.

The Apply Mask to Output toggle button is turned off automatically when filter processing is complete, but the mask remains selected. To run additional filter operations with the mask, turn on the toggle button before running each filter.

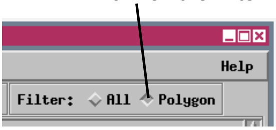
Filter Part of an Image

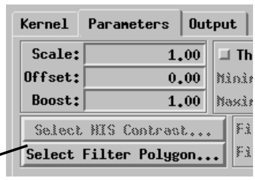
STEPS

- ☑ turn on the Filter: Polygon toggle button in the upper right part of the Raster Spatial Filtering window
- ☑ press the Select Filter Polygon button on the Parameters tabbed panel
- ☑ change the Mode setting of the Line / Polygon Edit Controls window to Stretch
- ☑ use the Add End operation to add vertices to build a polygon outlining the area for filtering as illustrated
- ☑ use the Drag Vertex operation to adjust the polygon shape as needed
- ☑ press the right mouse button to accept the area (or click [Apply] on the Line / Polygon Edit controls window)
- ☑ click [OK] on the Raster Area Selection window
- ☑ select Run from the Filter menu and direct the output raster to the FILTOUT Project File

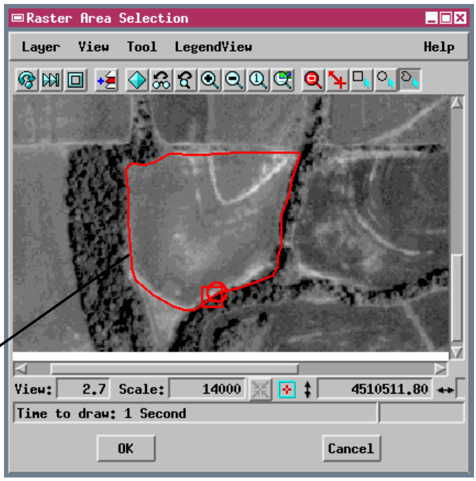
You can also restrict filtering to a portion of the image by using drawing tools to outline the selected area. For example, you might want to enhance a single field in a farm scene. The Raster Area Selection window provides Box, Circle, and Polygon drawing tools to let you select the area for filtering. Parts of the image outside the selected area are copied without alteration to the output image.

Turn on the Filter: Polygon toggle button...

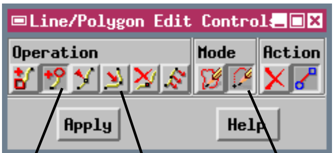




...then press the Select Filter Polygon button.

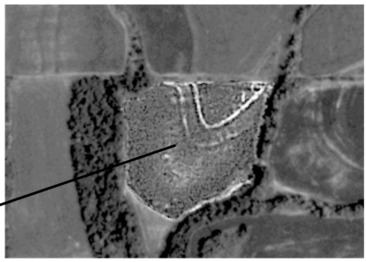


Draw the selection polygon.



Add End Drag Vertex Stretch

The Line / Polygon Edit Controls are described in detail in *Getting Started: Editing Vector Geodata*.



Lower left portion of output image with High Pass filtered area surrounded by unaltered image.

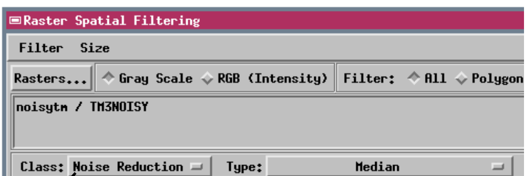
Median Filter (Noise Reduction)

Some images contain spurious cell values (much brighter or darker than their surroundings) that represent "noise" imposed by the imaging system or by later processing. The filters in the Noise Reduction class provide several approaches to removing image noise.

The Median filter ranks the input values from the current filter window in numerical order and assigns the median (middle) value to the output cell. Because the median value is not affected by the actual value of the noise cells, the Median filter is particularly good at removing isolated random noise, as in this example. It also preserves edges and line features better than the Low Pass / Average filter, but does produce some blurring.

STEPS
- ☑ turn on the Filter: All toggle button
- ☑ click [Rasters...] on the Spatial Filtering window and select raster object TM3NOISY from the NOISYTM Project File in the FILTER data collection
- ☑ select 3 x 3 from the Size option menu
- ☑ select Noise Reduction from the Class option menu and accept the default selection of Median on the Type option menu
- ☑ select Run from the Filter menu and direct the output raster to the FILTOUT Project File

The filters in the Noise Reduction, Enhancement, Radar, and Texture classes do not use a simple kernel of weighting coefficients to perform the filter operation. The Kernel array tables are dimmed and inoperative when you choose a filter in one of these classes.



Choose Noise Reduction from the Class: option menu.

Lower left portion of input image with random and horizontal line noise.

Same area with 3 x 3 Median filter applied.

Olympic Filter (Noise Reduction)

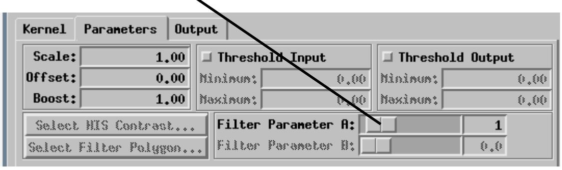
STEPS

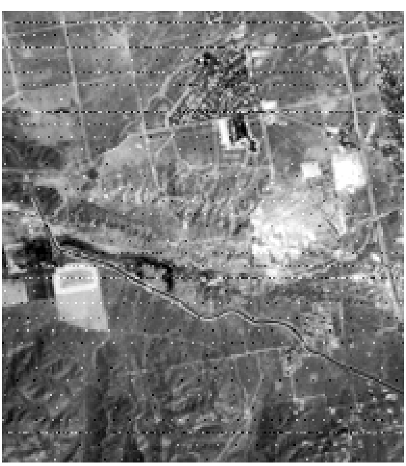
- ☑ select Olympic from the Type option menu
- ☑ use the slider on the Parameters tabbed panel to set the value of Filter Parameter A to 1
- ☑ select Run from the Filter menu and direct the output raster to the FILTOUT Project File

Parameter A for the Olympic filter is an integer value which determines the number of values discarded at each end of the ranked list of values in the filter window. When Parameter A is set to 1, the single highest and single lowest values are discarded before averaging.

The Low Pass / Average filter discussed earlier can be used to reduce image noise, but it is not an ideal choice for this purpose because the mean value for the filter window (the filter output) can be skewed by the extreme values of noise cells. The Olympic filter is a variant of the Low Pass filter which attempts to correct this problem.

The Olympic filter is named for the system of scoring used in certain Olympic events, in which the highest and lowest scores are dropped and the remaining ones are averaged. The Olympic filter likewise discards the high and low values in the filter window before determining the mean of the remaining values. Since noise cells are likely to rank as the highest or lowest values in the window, this procedure prevents the noise cells from biasing the output value. In this example the 3 x 3 Olympic filter removes the image noise, but causes some loss of image detail.





Lower left portion of noisy input image.

Same area with 3 x 3 Olympic filter applied.

P-Median Filter (Noise Reduction)

The P-Median filter is designed to suppress noise while preserving edge and line detail. The filter calculates median values for two subsets of values in the filter window: 1) combined horizontal and vertical transects through the center cell, and 2) two diagonal transects through the center cell. These two median values are then averaged. The output of the filter is a weighted average of the averaged median and the original center cell value. The weighting is controlled by Filter Parameter A, which can vary in value from 0 to 1. The value of 0.20 for Parameter A in this exercise means that the original input value contributes 20% to the output cell value, and the averaged median value contributes 80%. Decreasing the value of Parameter A will increase the degree of noise removal, at the expense of increasing degradation of edges and line features.

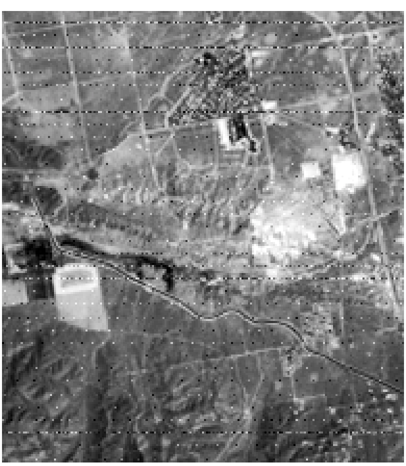
In this example, the 3 x 3 P-Median filter preserves edges and linear features (roads and canals) better than the Median or Olympic filters. Isolated noise cells are effectively eliminated, but a few of the continuous horizontal noise lines are still present, though less visible.

STEPS
- ☑ select P-Median (PM) from the Type option menu
- ☑ select Run from the Filter menu and direct the output raster to the FILTOUT Project File

Filter Parameter A for the P-Median filter assigns the weights used in averaging the input value and the P-Median filter value to create the final output cell value.

You can also set parameter values by typing the desired value into the text field to the right of the slider.

Linear features such as this canal still appear sharp in the P-Median filtered image.



Lower left portion of noisy input image.

Image with 3 x 3 P-Median filter applied.

Modal Filtering of Classification Results

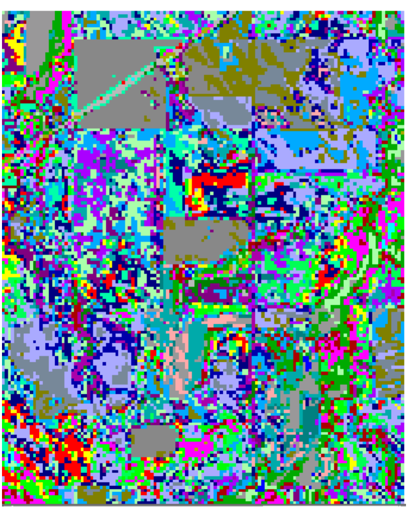
STEPS

- ☑ click [Rasters...] and select raster object CLS_ISODATA from the CB_CLASS Project File in the FILTER data collection
- ☑ choose Modal from the Type option menu, and retain the 3 x 3 window size
- ☑ select Run from the Filter menu and direct the output raster to the FILTOUT Project File

The Automatic Classification process (Process / Raster / Interpret / Auto-Classify) performs a cell-by-cell classification using a multiband set of input rasters. The resulting Class raster is usually quite “noisy,” in that there are many isolated class areas consisting of only one or two cells, and one-cell wide fringes of a “mixture” class may separate larger homogeneous class areas.

You can use the Modal Noise Reduction filter to smooth and simplify a noisy class raster. The Modal filter finds the modal (most frequent) value within the filter window and writes it to the output raster. Since no averaging is performed, this filter is appropriate to use with a categorical (class) raster, in which the cell values serve only as labels and have no numerical significance.

Consult the booklet *Getting Started: Image Classification* for an introduction to Automatic Classification.



Upper right corner of color-mapped class raster with 40 classes. There are many isolated cells or small groups of cells whose class is different from that of their neighbors.

Class raster after smoothing with the 3 x 3 Modal filter. Many isolated single-cell class areas have been removed, and areas of intermixed classes are greatly simplified.

CS Filter (Enhancement)

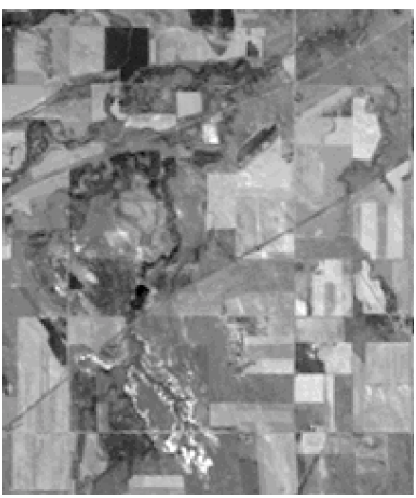
The filters in the Enhancement class are designed to improve the appearance of images by sharpening edges, corners, and line detail. Most of them also suppress noise so that only real image content is accentuated. The Comparison and Selection (CS) filter is one of the simpler enhancement filters.

The CS filter ranks the values in the filter window in numerical order, and calculates the mean value. Parameter A identifies a pair of rank numbers (measured inward from the top and bottom of the rank list) whose corresponding raster values provide the two possible filter output values. If the center cell value is less than the window mean, the lower output value is assigned, and if it is greater than the mean, the higher output value is used. The CS filter sharpens blurred edges while smoothing non-edge areas. The sharpening effect increases with lower values of Parameter A (which move the filter output values farther from the mean). The default value for Parameter A is 2.

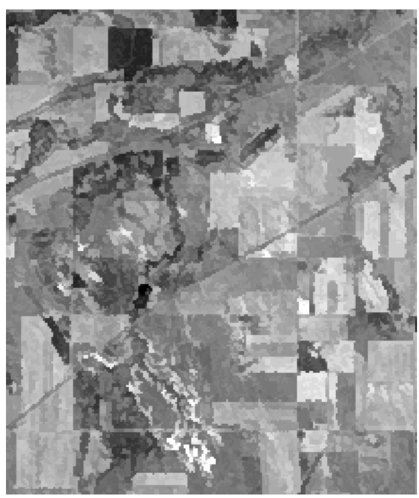
STEPS

- ☑ click [Rasters...] and select raster object RED from the CB_TM321 Project File in the FILTER data collection
- ☑ select Enhancement from the Class option menu
- ☑ choose Comparison and Selection (CS) from the Type option menu, and retain the 3 x 3 window size
- ☑ select Run from the Filter menu and direct the output raster to the FILTOUT Project File

The degree of edge-enhancement by the CS filter also increases as the size of the filter window increases (for constant values of Parameter A).



Upper left portion of input image with blurred field boundaries.



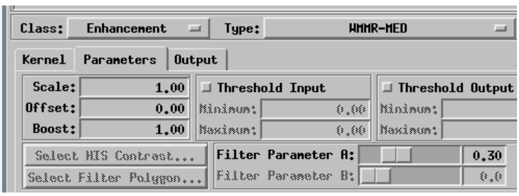
Same area with 3 x 3 CS filter applied (displayed with auto-linear contrast). Field boundaries and linear features are clearer.

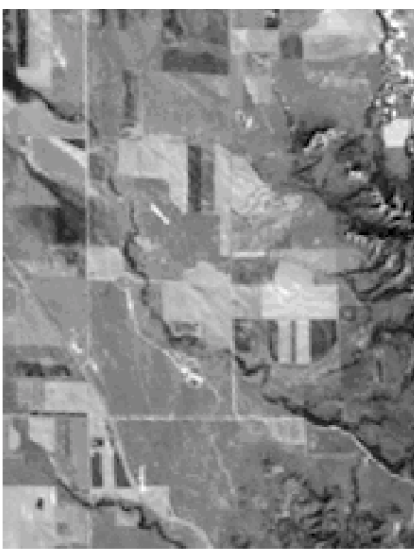
WMMR-MED Filter (Enhancement)

STEPS

- ☑ choose WMMR-MED from the Type option menu, and retain the 3 x 3 window size
- ☑ set the value of Parameter A to 0.30
- ☑ select Run from the Filter menu and direct the output raster to the FILTOUT Project File

The WMMR-MED (weighted majority with minimum range-median) filter combines considerable smoothing (noise suppression) with mild edge enhancement. The filter finds the subset of cells in the filter window in which the cell values are most closely spaced, and calculates a median value from it (the WMMR-MED value). This procedure tends to exclude noise values during the determination of the median. The output of the filter is a weighted average of the input raster value and the WMMR-MED value. The weighting is controlled by Filter Parameter A, which varies from 0 (WMMR-MED value only) to 1.0 (input value only). Decreasing the value for Parameter A increases the enhancement in the final image (both smoothing and edge enhancement).





Lower left portion of input image.

Same area with 3 x 3 WMMR-MED filter applied (displayed with auto-linear contrast). The image has been smoothed while edges are preserved and enhanced.

Volterra / Unsharp Filter (Enhancement)

Our ability to see a boundary with a fixed brightness difference across it varies with the background brightness: the brighter the background, the more difficult it is to see the boundary. For this reason, edge details in bright areas require more enhancement than those in dark areas of an image. The Volterra / Unsharp filter addresses this problem by providing edge enhancement that is proportional to the local image brightness.

The initial output of the Volterra filter process is approximately equivalent to the product of the local mean and a high-pass filter. This result is scaled and added to the original input image value to produce the final output. The scaling is controlled by Filter Parameter A, which varies from 0.001 to 0.1, with a default value of 0.005. Increasing the value of Parameter A increases the amount of edge enhancement.

STEPS
- ☑ choose Volterra / Unsharp from the Type option menu, and retain the 3 x 3 window size
- ☑ set the value of Parameter A to 0.002
- ☑ select Run from the Filter menu and direct the output raster to the FILTOUT Project File

Setting the value for Volterra Filter Parameter A close to the minimum will usually produce a realistic image with noticeable sharpening, but values higher than 0.005 generally produce very high-contrast images which over-emphasize edges.

Upper left portion of input image.

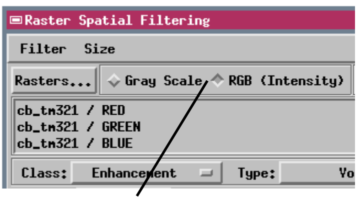
Same image area with 3 x 3 Volterra / Unsharp filter applied (displayed with auto-linear contrast), providing significant enhancement of edges and line features.

Filtering RGB Images

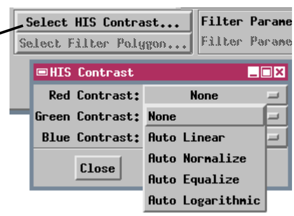
STEPS

- ☑ turn on the RGB (Intensity) toggle button; this clears the input raster list
- ☑ click [Rasters...] and select raster objects RED, GREEN, and BLUE from the CB_TM321 Project File
- ☑ keep the value of Parameter A set at 0.002
- ☑ select Run from the Filter menu and direct the output rasters to the FILTOUT Project File

Any of the filters available in the Spatial Filters process can be applied to an RGB raster set by choosing the RGB (Intensity) option and selecting rasters for the Red, Green, and Blue components. The filter process converts the RGB components to the Hue, Intensity, and Saturation color model, in which the Intensity component represents the average brightness of the color image. The process applies the selected filter to the Intensity raster, then uses the filtered Intensity raster in the reconversion to RGB color space. This procedure maintains the color balance of the original image.



Choose the RGB (Intensity) option.



Choose the Select HIS Contrast option on the Parameters panel to apply a standard contrast-enhancement function to the RGB rasters during conversion to HIS (use None for this exercise).

Upper right portion of RGB input image.

Same area with 3 x 3 Volterra filter applied (displayed with auto-linear contrast), showing enhanced detail.

Range Filter (Texture)

The filters in the Texture class use the local statistical variations in brightness in an image to reveal elements of its texture. Image texture includes the local spatial pattern, scale, and magnitude of brightness variations, including the "smoothness" or "roughness" of the image. The output images might be used as the basis for further image analysis, such as image segmentation, or as additional raster components in automatic image classification.

The Range filter produces an image of one of the simplest elements of texure, the local range of values. The output of the filter is the range of values in the filter window (difference between maximum and minimum values) multiplied by an adjustable gain factor to provide suitable brightness and contrast. Filter Parameter A determines the gain factor: it can vary from 0.01 to 9.99, and has a default setting of 1.00.

STEPS

☑ turn on the Grayscale toggle button

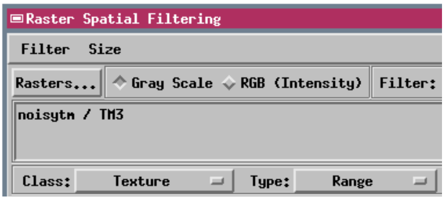
☑ click [Rasters...] and select raster object TM3 from the NOISYTM Project File in the FILTER data collection

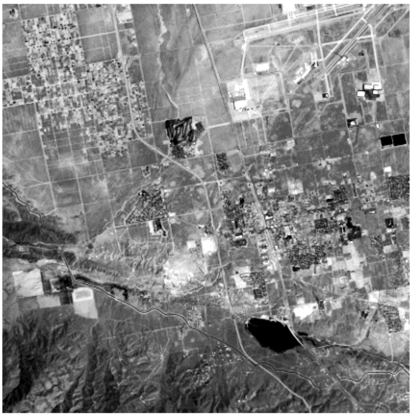
☑ choose Texture from the Class option menu

☑ select Range from the Type option menu, and retain the 3 x 3 window size

☑ set the value of Parameter A to 2.00

☑ select Run from the Filter menu and direct the output raster to the FILTOUT Project File





Input image TM3.

Choose Exit from the Filter menu on the Spatial Filtering window when you have completed this exercise.

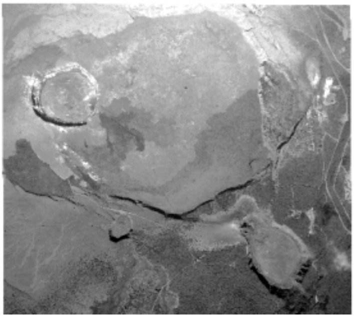
Same image with 3 x 3 Range filter applied (displayed with auto-normalized contrast enhancement). Brightness represents local range of raster values.

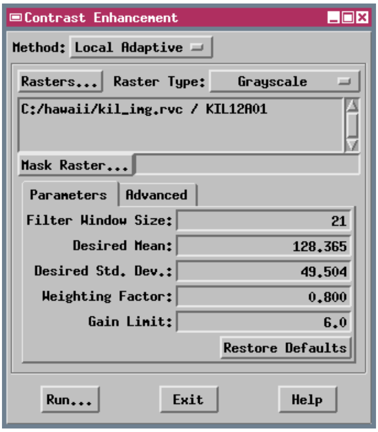
Grayscale LACE Filter

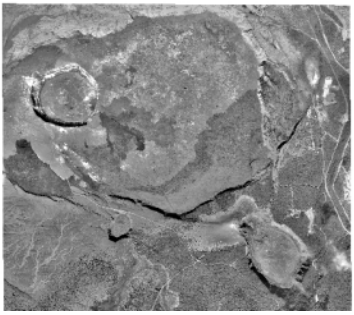
STEPS
- ☑ launch the LACE filter process (Process / Raster / Filter / Locally Adaptive Contrast...)
- ☑ select Local Adaptive from the Method option menu
- ☑ press the Rasters button and select raster object KIL12A01 from the KIL_IMG Project File in the HAWAII data collection
- ☑ on the Parameters tabbed panel, set the Filter Window Size to 21 and the Weighting Factor to 0.800, and accept the other default settings
- ☑ press the Run button and direct the output raster to the FILTOUT Project File

The Locally Adaptive Contrast Enhancement (LACE) filter process provides a spatially-varying contrast enhancement for grayscale, color, or multiband images. The LACE filter is particularly appropriate for images with both large bright areas and large dark areas, where global contrast enhancements (such as linear or normalized) cannot bring out adequate detail in both bright and dark areas. The LACE filter adjusts brightness values in each local area so that the local mean and standard deviation closely match output values that you specify on the Parameters panel. This procedure improves local contrast while reducing the overall contrast between bright and dark areas.

The LACE filter can produce an enhanced image with good local contrast and image detail throughout, so you can more easily make visual interpretations of surface features. Because the process produces significant, locally-variable changes in raster values, a LACE-enhanced image is not appropriate for use with quantitative classification or raster analysis processes.







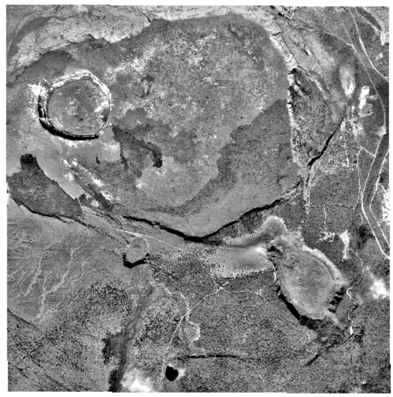
Air photo of Kilauea Caldera, Hawaii. Input image (top) shows little detail in brighter areas. LACE-enhanced image (bottom) has better local contrast.

Adjust LACE Filter Parameters

The Desired Mean and Desired Standard Deviation (Std. Dev.) parameters are target values that control the brightness and contrast of the output image. The default value for the Desired Mean is the overall mean brightness of the image, but you can change this value to brighten or darken the image. The default value for Desired Std. Dev. generally produces adequate contrast, but you can increase this value to increase the overall image contrast.

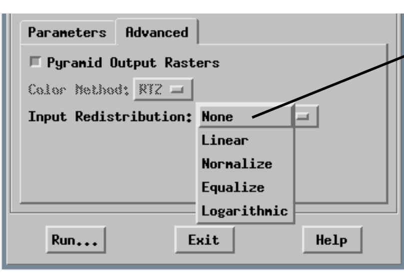
STEPS
- ☑ change the Desired Std. Dev. parameter value to 80.000
- ☑ press the Run button and direct the output raster to the FILTOUT Project File

The output raster of the LACE process is a weighted average of the LACE enhancement and the original image. The relative weighting is controlled by the Weighting Factor parameter. When this parameter is set to 0.8, for example, the LACE filter value will contribute 80% to the value of each output cell and the original input value will contribute 20%. You can adjust this parameter to vary the amount of enhancement applied to the original image.



The LACE filter process adjusts the brightness of input cells by calculating a gain coefficient for each cell based on the local standard deviation. The Gain Limit parameter sets an upper limit on the value of this coefficient and on the degree of contrast enhancement that results in a given area.

Kilauea airphoto with the LACE filter applied using higher Desired Std. Dev. value. Image has higher contrast than the output image on the previous page.



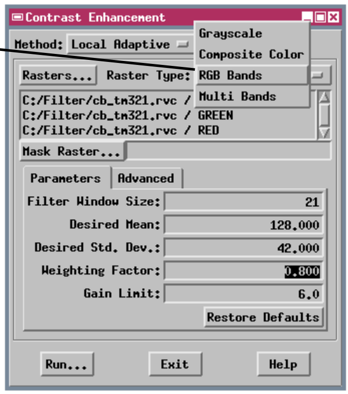
The Input Redistribution option menu on the Advanced panel gives you several choices for redistributing the input raster values before applying the LACE filter. The default is None. The other choices duplicate the automatic contrast enhancement options available in Spatial Data Display.

LACE Filter with RGB Image

STEPS
- ☑ choose RGB Bands from the Raster Type option menu
- ☑ press the Rasters button and select raster objects RED, GREEN, and BLUE from the CB_TM321 Project File in the FILTER data collection
- ☑ accept the current parameter settings as shown in the illustration
- ☑ press the Run button and direct the output raster to the FILTOUT Project File

When you are working with an RGB raster set or a color composite raster, the LACE filter process is designed to enhance local contrast while minimizing changes in the color balance of the image. The local contrast enhancement is applied to a computed intensity raster, in which each cell value is the average of the red, green, and blue component values. The contrast-enhanced intensity raster is then used to compute red, green, and blue components for the enhanced output image.

Choose the type of raster input from the Raster Type menu.



RGB image of Crow Butte Landsat Thematic Bands 3-2-1. Each of these bands was modified from the basic data in the standard CB_TM Project File by designing an exponential contrast table in the Spatial Data Display process, then producing a new raster with the exponential contrast stretch applied (using the Prepare / Raster / Apply Contrast process.)

Same image with the LACE filter applied.

What Next?

Other Spatial Filter Types

This booklet has introduced only a sampling of the filters available in TNTmips. Additional filters are available in each of the spatial filter classes described here. There are also two additional classes of spatial filters with more specialized filter functions for which no sample exercises are provided:

Edge Detection Filters Filters in the Edge Detection class are designed to detect and highlight boundaries between image areas that have distinctly different brightness. The output raster is a grayscale image of the edges, with the cell brightness proportional to the difference in neighboring cell brightness in the original image. The resulting image can be used as the basis for additional image interpretation and analysis, such as image segmentation.

Radar Filters Filters in the Radar class are designed to remove the speckle noise that is characteristic of radar images.

Frequency Filtering

Frequency filtering offers an alternative approach to improving the appearance of raster images. The frequency filtering process (Process / Raster / Filter / Frequency Filter) uses Fourier analysis to mathematically separate an image into its fundamental spatial frequency components, each of which is modeled as a pure, cyclic sine function. Spatial frequencies are calculated in line and column directions, and two-dimensional plots of the resulting frequency information can be used to identify particular frequencies for removal. Frequency filtering is most effective for removing regular, periodic image noise (striping) introduced by the imaging system.

References

The following references are good places to start if you want additional information on image enhancement and filtering:

Baxes, Gregory A. (1994). *Digital Image Processing: Principles and Applications*. Chapter 4, Image Enhancement and Restoration. New York: John Wiley and Sons. pp. 69-122.

Jensen, John R. (1996). *Introductory Digital Image Processing: a Remote Sensing Perspective* (2nd ed.). Chapter 7, Image Enhancement. Upper Saddle River, NJ: Prentice-Hall, pp. 139-195.

Lillesand, Thomas M. and Kiefer, Ralph W. (1994). *Remote Sensing and Image Interpretation* (3rd ed.). Chapter 7, Digital Image Processing. New York: John Wiley and Sons. pp. 585-618.

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