IMAQ™ Vision for G Reference Manual

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E-mail: `support@natinst.com`
`info@natinst.com`
FTP Site: `ftp.natinst.com`
Web Address: `http://www.natinst.com`

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About This Manual

The *IMAQ Vision for G Reference Manual* describes the features, functions, and operation of IMAQ Vision for G. To use this manual effectively, you should be familiar with image processing, your image capture hardware, and LabVIEW or BridgeVIEW.

Organization of This Manual

The *IMAQ Vision for G Reference Manual* is organized as follows:

- Chapter 1, *Algorithms and Principles of Image Files and Data Structures*, contains an overview of image files and data structures.
- Chapter 2, *Tools and Utilities*, describes the tools and utilities used in IMAQ Vision.
- Chapter 3, *Lookup Transformations*, provides an overview of lookup table transformations.
- Chapter 4, *Operators*, describes the arithmetic and logic operators used in IMAQ Vision.
- Chapter 5, *Spatial Filtering*, provides an overview of the spatial filters, including linear and nonlinear filters, used in IMAQ Vision.
- Chapter 6, *Frequency Filtering*, describes the frequency filters used in IMAQ Vision.
- Chapter 7, *Morphology Analysis*, provides an overview of morphology image analysis.
- Chapter 8, *Quantitative Analysis*, provides an overview of quantitative image analysis.
- Chapter 9, *IMAQ Vision Programming Concepts*, contains an overview of IMAQ Vision programming concepts, a description of the Base and Advanced versions of IMAQ Vision, and a listing of the VIs included in these versions. It also provides a summary of the icons used in the function reference chapters of this manual.
- Chapter 10, *Management VIs*, describes the Management VIs in IMAQ Vision.
- Chapter 11, *File VIs*, describes the File VIs in IMAQ Vision.

- Chapter 12, *Display VIs*, describes various Display VIs in IMAQ Vision.
- Chapter 13, *Tool VIs*, describes the image, pixel, and diverse Tool VIs in IMAQ Vision.
- Chapter 14, *Conversion VIs*, describes the Conversion VIs in IMAQ Vision.
- Chapter 15, *Operator VIs*, describes the Operator VIs in IMAQ Vision.
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- Chapter 19, *Analysis VIs*, describes the Analysis VIs in IMAQ Vision.
- Chapter 20, *Geometry VIs*, describes the Geometry VIs in IMAQ Vision.
- Chapter 21, *Complex VIs*, describes the Complex VIs in IMAQ Vision.
- Chapter 22, *Color VIs*, describes the Color VIs in IMAQ Vision.
- Chapter 23, *External Library Support VIs*, describes the External Library Support VIs in IMAQ Vision.
- Appendix A, *Customer Communication*, contains forms you can use to request help from National Instruments or to comment on our products and manuals.
- The *Glossary* contains an alphabetical list and description of terms used in this manual, including abbreviations, acronyms, metric prefixes, mnemonics, and symbols.
- The *Index* contains an alphabetical list of key terms and topics in this manual, including the page where you can find each one.

Conventions Used in This Manual

The following conventions are used in this manual:

bold — Bold text denotes the names of menus, menu items, parameters, dialog box buttons or options, icons, Windows 95 tabs, or LEDs.

italic — Italic text denotes variables, emphasis, a cross reference, or an introduction to a key concept.

bold italic — Bold italic text denotes an activity objective, note, caution, or warning.

`monospace` — Text in this font denotes text or characters that you should literally enter from the keyboard, sections of code, programming examples, and syntax examples. This font also is used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, filenames, and extensions, and for statements and comments taken from program code.

`bold monospace` — Bold text in this font denotes the messages and responses that the computer automatically prints to the screen. This font also emphasizes lines of code that are different from the other examples.

<> — Angle brackets enclose the name of a key on the keyboard—for example, <PageDown>.

\- — A hyphen between two or more key names enclosed in angle brackets denotes that you should simultaneously press the named keys—for example, <Control-Alt-Delete>.

<Control> — Key names are capitalized.

» — The » symbol leads you through nested menu items and dialog box options to a final action. The sequence **File»Page Setup»Options»Substitute Fonts** directs you to pull down the **File** menu, select the **Page Setup** item, select **Options**, and finally select the **Substitute Fonts** option from the last dialog box.

paths — Paths in this manual are denoted using backslashes (\) to separate drive names, directories, and files, as in `C:\dir1name\dir2name\filename`.

☞ — This icon to the left of bold italicized text denotes a note, which alerts you to important information.

The *Glossary* lists abbreviations, acronyms, metric prefixes, mnemonics, symbols, and terms.

Related Documentation

The following documents contain information that you may find helpful as you read this manual:

- *LabVIEW User Manual*
- *LabVIEW Tutorial*
- *BridgeVIEW User Manual*
- *G Programming Reference Manual*

Customer Communication

National Instruments wants to receive your comments on our products and manuals. We are interested in the applications you develop with our products, and we want to help if you have problems with them. To make it easy for you to contact us, this manual contains comment and configuration forms for you to complete. These forms are in Appendix A, *Customer Communication*, at the end of this manual.

Chapter 1

Algorithms and Principles of Image Files and Data Structures

This chapter describes the algorithms and principles of image files and data structures.

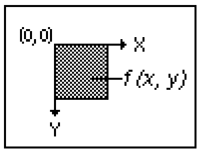
Introduction to Digital Images

An *image* is a function of the light intensity

$$f(x, y)$$

where f is the brightness of the point (x, y), and x and y represent the spatial coordinates of a *picture element* (abbreviated *pixel*).

By default the spatial reference of the pixel with the coordinates (0, 0) is located at the upper-left corner of the image.



In *digital image processing*, an acquisition device converts an image into a discrete number of pixels. This device assigns a numeric location and *gray-level* value which specifies the brightness of pixels.

Properties of a Digitized Image

A digitized image has three basic properties: *image resolution*, *image definition*, and *number of planes*.

Image Resolution

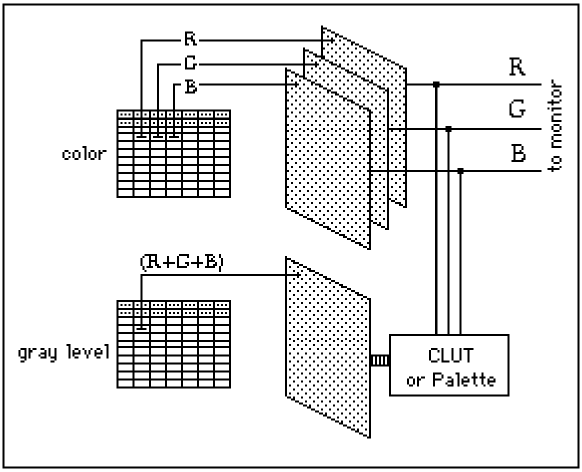
The *spatial resolution* of an image is its number of rows and columns of pixels. An image composed of m rows and n columns has a resolution of mn. This image has n pixels along its horizontal axis and m pixels along its vertical axis.

Image Definition

The definition of an image, also called *pixel depth*, indicates the number of colors or shades that you can see in the image. Pixel depth is the number of bits used to code the intensity of a pixel. For a given definition of n, a pixel can take 2^n different values. For example, if n equals 8-bits, a pixel can take 256 different values ranging from 0 to 255. If n equals 16 bits, a pixel can take 65,536 different values ranging from 0 to 65,535 or –32,768 to 32,767.

Number of Planes

The number of planes in an image is the number of arrays of pixels that compose the image. A gray-level or pseudo-color image is composed of one plane, while a true-color image is composed of three planes (one for the red component, one for the blue, and one for the green), as shown in the following figure.



In gray-level images, the red, green, and blue intensities (*RGB*) of a pixel combine to produce a single value. This single value is converted back to an RGB intensity when displayed on a monitor. This conversion is performed by a *color lookup table* (CLUT) transformation.

In three-plane or true color images, the red, green, and blue intensities of a pixel are coded into three different values. The image is the combination of three arrays of pixels corresponding to the red, green, and blue components.

Image Types and Formats

The IMAQ Vision libraries can manipulate three types of images: *gray-level*, *color*, and *complex* images.

Gray-Level Images

Gray-level images are composed of a single plane of pixels. Standard gray-level formats are 8-bit *PICT* (Macintosh only), *BMP* (PC only), *TIFF*, *RASTR*, and *AIPD*. Standard 16-bit gray-level formats are TIFF and AIPD. AIPD is an internal file format that offers the advantage of storing the spatial calibration of an image. Gray-level images that use other formats and have a pixel depth of 8-bit, 16-bit or 32-bit can be imported into the IMAQ Vision libraries.

Color Images

Color images are composed of three planes of pixels in which each pixel has a red, green, and blue intensity, each coded on 8-bit planes. Color images coded using the *RGB-chunky* standard contain an extra 8-bit plane, called the *alpha channel*. These images have a definition of 32-bit or 4 × 8-bit. Standard color formats are PICT, BMP, TIFF and AIPD.

Complex Images

Complex images are composed of complex data in which pixel values have a real part and an imaginary part. Such images are derived from the *Fast Fourier Transform* of gray-level images. Four representations of a complex image can be given: the real part, imaginary part, magnitude, and phase.

The following table shows how many bytes are used per pixel in gray-level, color, and complex images. For an identical spatial resolution, a color image occupies four times the memory space used by an 8-bit gray-level image and a complex image occupies eight times this amount.

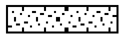
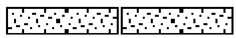
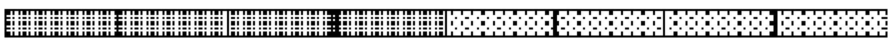
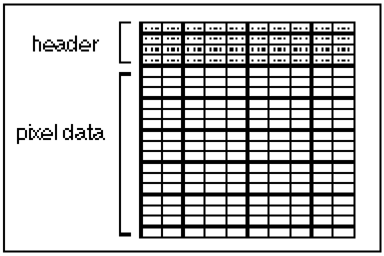
Image Type	Number of Bytes Per Pixel Data
8-bit (Unsigned) Integer Gray-Level (1 byte or 8-bit)	 8-bit for the gray-level intensity
16-bit (Signed) Integer Gray-Level (2 bytes or 16-bit)	 16-bit for the gray-level intensity
32-bit Floating-Point Gray-Level (4 bytes or 32-bit)	 32-bit floating for the gray-level intensity
Color (3 bytes or 24-bit)	 8-bit for the alpha value (not used); 8-bit for the red intensity; 8-bit for the green intensity; 8-bit for the blue intensity
Complex (8 bytes or 64-bit)	 32-bit floating for the real part; 32-bit floating for the imaginary part

Image Files

An *image file* is composed of a header followed by pixel values. Depending on the file format, the header contains information such as the image horizontal and vertical resolution, its pixel definition, the physical calibration, and the original palette.



Processing Color Images

Most image-processing and analysis functions apply to 8-bit images. However, you also can process color images by manipulating their color components individually.

You can break down a color image into various sets of primary components such as RGB (red, green, and blue), *HSL* (hue, saturation, and lightness), or *HSV* (hue, saturation, and value). Each component becomes an 8-bit image and can be processed as any gray-level image.

You can reassemble a color image later from a set of three 8-bit images taking the place of its RGB, HSL, or HSV components.

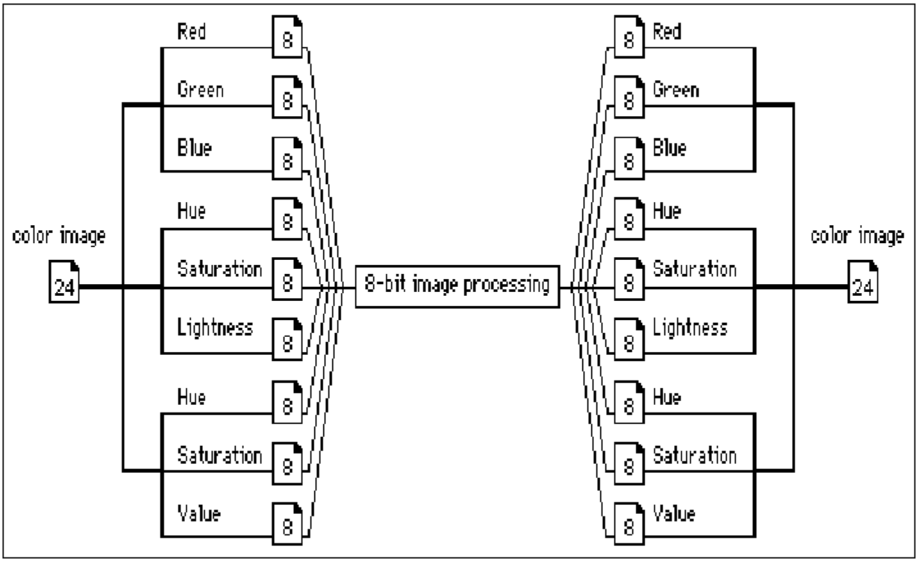
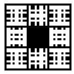
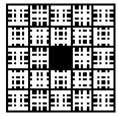
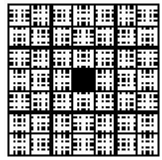
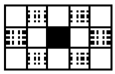
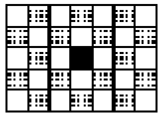
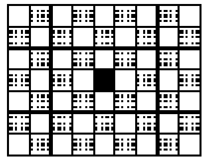


Image Pixel Frame

As introduced earlier, a digital image is a two-dimensional array of pixel values. Using this definition, you might assume that pixels are arranged in a regular rectangular frame. However from an image processing point of view you can consider another grid arrangement, such as a hexagonal pixel frame which offers the advantage that the six neighbors of a pixel are equidistant.

The pixels in an image are arranged in a rectangular grid. However, some image processing algorithms can reproduce a hexagonal neighborhood using the representations illustrated in the following table. The pixels considered as neighbors of the given pixel (shown in solid) are indicated by the shaded pattern.

Pixel Frame	Neighborhood Size		
Rectangular	3 × 3 	5 × 5 	7 × 7 
Hexagonal	5 × 3 	7 × 5 	9 × 7 

Rectangular Frame

Each pixel is surrounded by eight neighbors.

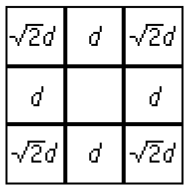


Figure 1-1. Rectangular Frame

If d is the distance from the vertical and horizontal neighbors to the central pixel, then the diagonal neighbors are at a distance of $\sqrt{2}d$ from the central pixel.

Hexagonal Frame

Each pixel is surrounded by six neighbors. Each neighbor is found at an equal distance *d* from the central pixel.

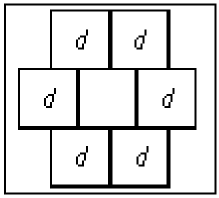


Figure 1-2. Hexagonal Frame

This notion of pixel frame is important for a category of image processing functions called *neighborhood operations*. These functions alter the value of pixels depending on the intensity values of their neighbors. They include *spatial filters*, which alter the intensity of a pixel with respect to variations in intensities of neighboring pixels, and *morphological transformations*, which extract and alter the structure of objects in an image.

Chapter 2

Tools and Utilities

This chapter describes the tools and utilities used in IMAQ Vision.

Palettes

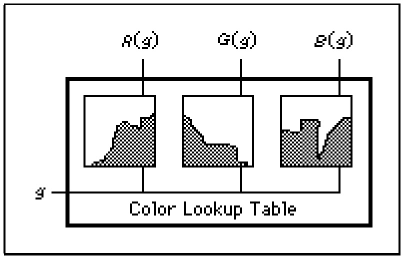
At the time an image is displayed on the screen, the value of each pixel is converted into a red, green, and blue intensity which produces a color. This conversion is defined in a table called color lookup table (CLUT). For 8-bit images, it associates a color to each gray-level value and produces a gradation of colors, called a *palette*.

With palettes, you can produce different visual representations of an image without altering the pixel data. Palettes can generate effects such as a photonegative display or color-coded displays. In the latter case, palettes are useful for detailing particular image constituents in which the total number of colors are limited.

Displaying images in different palettes helps emphasize regions with particular intensities, identify smooth or abrupt gray-level variations, and convey details that might be lost in a gray-scale image.

In the case of 8-bit resolution, pixels can take 2^8 or 256 values ranging from 0 to 255. A black and white palette associates different shades of gray to each value so as to produce a linear and continuous gradation of gray, from black to white. At this point, the palette can be set up to assign the color black to the value 0 and white to 255, or vice versa. Other palettes can reflect linear or nonlinear gradations going from red to blue, light brown to dark brown, and so forth.

The gray-level value of a pixel acts as an address that is indexed into three tables, with three values corresponding to a red, green, and blue (RGB) intensity. This set of three conversion tables defines a palette in which varying amounts of red, green, and blue are mixed to produce a color representation of the value range [0, 255].



Five pseudo-color palettes are predefined in the programs and libraries. Each palette emphasizes different shades of gray. However, they all use the following conventions:

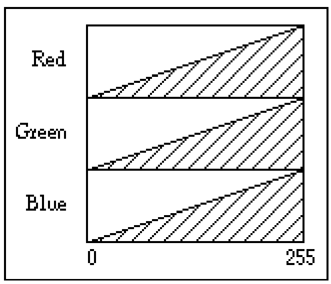
- Gray level 0 is assigned to black.
- Gray level 255 is assigned to white.

Because of these conventions, you can associate bright areas to the presence of pixels with high gray-level values, and dark areas to the presence of pixels with low gray-level values.

The following sections introduce the five predefined palettes. The graphs in each section represent the three RGB lookup tables used by each palette. The horizontal axes of the graphs represent the input gray-level range [0, 255], while the vertical axes give the RGB intensities assigned to a given gray-level value.

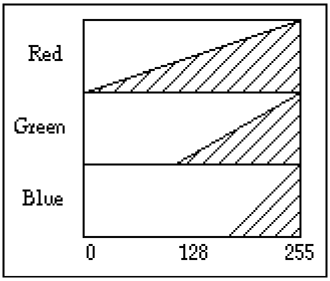
B&W (Gray) Palette

This palette has a gradual gray-level variation from black to white. Each value is assigned to an equal amount of the RGB intensities.



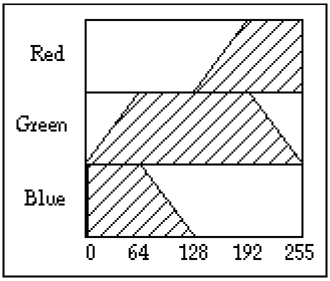
Temperature Palette

This palette has a gradation from light brown to dark brown. 0 is black and 255 is white.



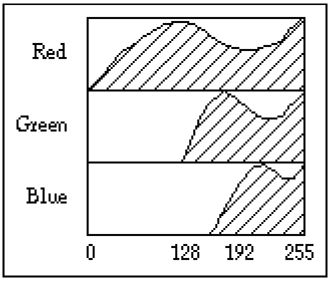
Rainbow Palette

This palette has a gradation from blue to red with a prominent range of greens in the middle value range. 0 is black and 255 is white.



Gradient Palette

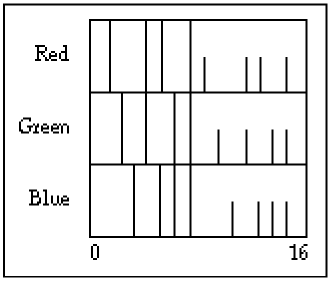
This palette has a gradation from red to white with a prominent range of light blue in the upper value range. 0 is black and 255 is white.



Binary Palette

This palette has 16 cycles of 16 different colors, *where* g is the gray-level value and

$g = 0$ corresponds to $R = 0$, $G = 0$, $B = 0$, which appears black;
$g = 1$ corresponds to $R = 1$, $G = 0$, $B = 0$,which appears red;
$g = 2$ corresponds to $R = 0$, $G = 1$, $B = 0$ which appears green;
and so forth.



This periodic palette is appropriate for the display of binary and labeled images.

Image Histogram

The *histogram* of an image indicates the quantitative distribution of pixels per gray-level value. It provides a general description of the appearance of an image and helps identify various components such as the background, objects, and noise.

Definition

The histogram is the function H defined on the gray-scale range $[0, \ldots, k, \ldots, 255]$ such that the number of pixels equal to the gray-level value k is

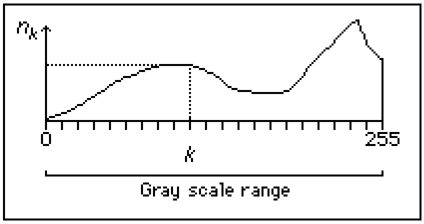
$$H(k) = n_k$$

where k is the gray-level value,

n_k is the number of pixels in an image with a gray-level value equal to k,

and $\sum n_k = n$ is the total number of pixels in an image.

The following histogram plot reveals which gray levels occur frequently and which occur rarely.



Two types of histograms can be plotted per image: the linear and cumulative histograms.

In both cases, the horizontal axis represents the gray-level range from 0 to 255. For a gray-level value k, the vertical axis of the linear histogram indicates the number of pixels n_k set to the value k, and the vertical axis of the cumulative histogram indicates the percentage of pixels set to a value less than or equal to k.

Linear Histogram

The *density function* is

$$H_{Linear}(k) = n_k$$

where $H_{Linear}(k)$ is the number of pixels equal to k.

The *probability function* is

$$P_{Linear}(k) = n_k / n$$

where $P_{Linear}(k)$ is the probability that a pixel is equal to k.

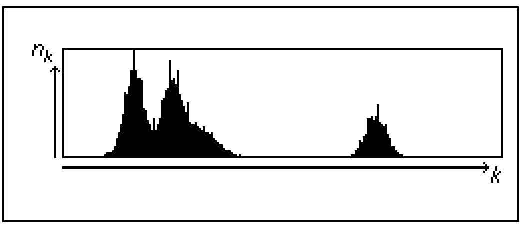


Figure 2-1. Linear Vertical Scale

Cumulative Histogram

The distribution function is

$$H_{Cumul}(k) = \sum_{0}^{k} n_k$$

where $H_{Cumul}(k)$ is the number of pixels that are less than or equal to k.

The probability function is

$$P_{Cumul}(k) = \sum_{0}^{k} \frac{n_k}{n}$$

where $P_{Cumul}(k)$ is the probability that a pixel is less than or equal to k.

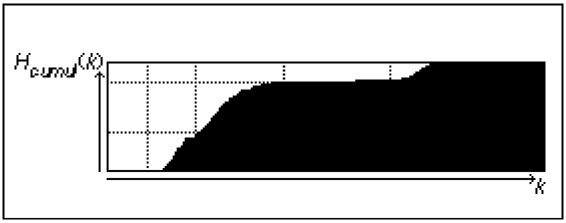


Figure 2-2. Linear Cumulative Scale

Interpretation

The gray-level intervals with a concentrated set of pixels reveal the presence of significant components in the image and their respective intensity ranges.

In the previous example, the linear histogram reveals that the image is composed of three major elements. The cumulative histogram shows that the two left-most peaks compose approximately 80 percent of the image, while the remaining 20 percent corresponds to the third peak.

Histogram of Color Images

The histogram of a color image is expressed as a series of three tables corresponding to the histograms of the three primary components (*R*, *G*, and *B*; *H*, *S*, and *L*; or *H*, *S*, and *V*).

Histogram Scale

The vertical axis of a histogram plot can be shown in a linear or logarithmic scale. A logarithmic scale lets you visualize gray-level values used by small numbers of pixels. These values might appear unused when the histogram is displayed in a linear scale.

In the case of a logarithmic scale, the vertical axis of the histogram gives the logarithm of the number of pixels per gray-level value. The use of minor gray-level values is made more prominent at the expense of the dominant gray-level values.

The following two figures illustrate the difference between the display of the histogram of the same image in a linear and logarithmic scale. In this particular image, three pixels are equal to 0. This information is unobservable in the linear representation of the histogram but evident in the logarithmic representation.

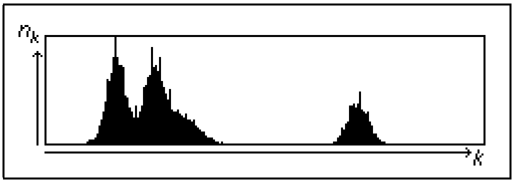


Figure 2-3. Linear Vertical Scale

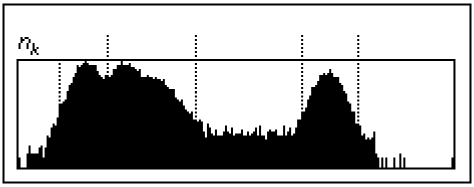
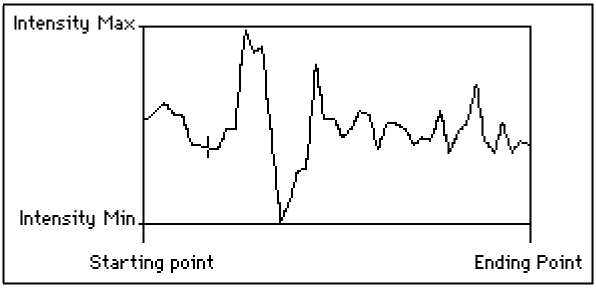


Figure 2-4. Logarithmic Vertical Scale

Line Profile

A *line profile* plots the variations of intensity along a line. This utility is helpful for examining boundaries between components, quantifying the magnitude of intensity variations, and detecting the presence of repetitive patterns. The following figure illustrates a line profile.

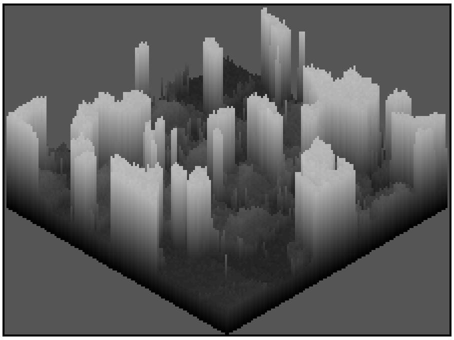


The peaks and valleys reveal increases and decreases of the light intensity along the line selected in the image. Their width and magnitude are proportional to the size and intensity of their related regions.

For example, a bright object with uniform intensity appears in the plot as a plateau. The higher the contrast between an object and its surrounding background, the steeper the slopes of the plateau. Noisy pixels, on the other hand, produce a series of narrow peaks.

3D View

The *3D view* illustrated in the following graphic displays a three-dimensional perspective of the light intensity in an image. It gives a relief map of the image in which high-intensity values are associated to summits and low-intensity values are associated to valleys.



Lookup Transformations

Chapter 3

This chapter provides an overview of lookup table transformations.

About Lookup Table Transformations

The *lookup table* (LUT) transformations are basic image-processing functions that you can use to improve the contrast and brightness of an image by modifying the intensity dynamic of regions with poor contrast. The LUT transformations can highlight details in areas containing significant information, at the expense of other areas. These functions include *histogram equalization*, *histogram inversion*, *Gamma corrections*, *Inverse Gamma corrections*, *logarithmic corrections*, and *exponential corrections*.

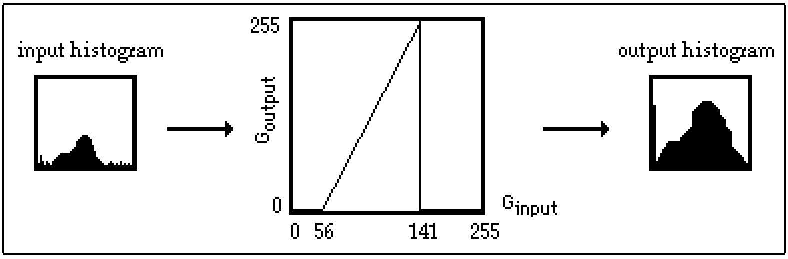
An LUT transformation converts input gray-level values (those from the source image) into other gray-level values (in the transformed image). The transfer function has an intended effect on the brightness and contrast of the image.

Each input gray-level value is given a new value such that

$$\textit{output value} = F(\textit{input value}),$$

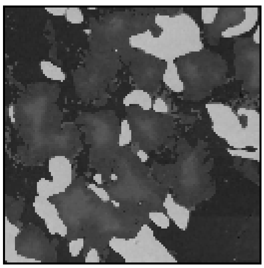
where F is a linear or nonlinear, continuous or discontinuous transfer function defined over the interval [0, max].

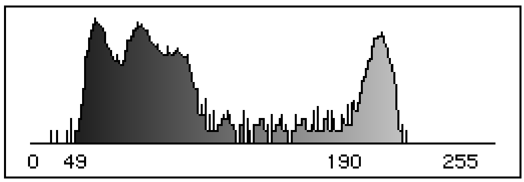
In the case of an 8-bit resolution, an LUT is a table of 256 elements. Each element of the array represents an input gray-level value. Its content indicates the output value.



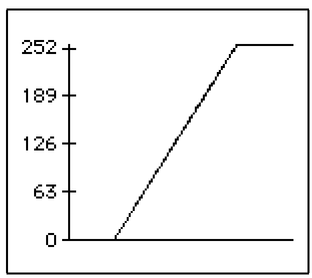
Example

In this example, the following source image is used. In the histogram of the source image, the gray-level intervals [0, 49] and [191, 255] do not contain significant information.

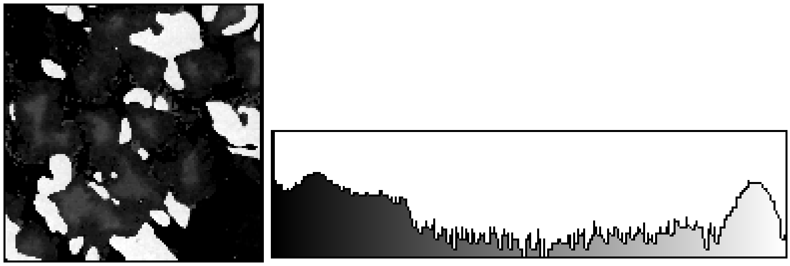




Using the following LUT transformation, any pixel with a value less than 49 is set to 0, and any pixel with a value greater than 191 is set to 255. The interval [50, 190] expands to [1, 255], increasing the intensity dynamic of the regions with a concentration of pixels in the gray-level range [50, 190].

If G_{input} is between [0, 49] or [191, 255], ***then*** $F(G_{input}) = 0$, ***else*** $F(G_{input}) = 1.8 \times G_{input} - 91$.	

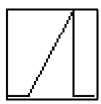
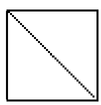
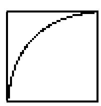
The LUT transform produces the following image. The histogram of the new image only contains the two peaks of the interval [50, 190].

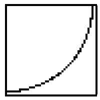


Predefined Lookup Tables

Eight predefined LUTs are available in IMAQ Vision: Reverse, Equalize, Logarithmic, Power 1/Y, Square Root, Exponential, Power Y, and Square.

The following table shows the transfer function for each LUT and describes its effect on an image displayed in a palette that associates dark colors to low intensity values and bright colors to high intensity values (such as the B&W or Gray palette).

LUT	Transfer Function	Shading Correction
Equalize		Increases the intensity dynamic by evenly distributing a given gray-level interval [min, max] over the full gray scale [0, 255]. Min and max default values are 0 and 255 for an 8-bit image.
Reverse		Reverses the pixel values, producing a photometric negative of the image.
Logarithmic Power 1/Y Square Root		Increases the brightness and contrast in dark regions. Decrease the contrast in bright regions.

LUT	Transfer Function	Shading Correction
Exponential Power Y Square		Decreases the brightness and increases the contrast in bright regions. Decreases the contrast in the dark regions.

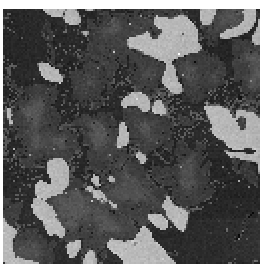
Equalize

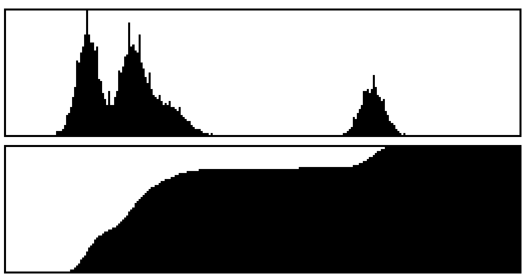
The *Equalize function* alters the gray-level value of pixels so they become distributed evenly in the defined gray-scale range (0 to 255 for an 8-bit image). The function associates an equal amount of pixels per constant gray-level intervals and takes full advantage of the available shades of gray. Use this transformation to increase the contrast of images in which gray-level intervals are not used.

The equalization can be limited to a gray-level interval, also called the equalization range. In this case, the function evenly distributes the pixels belonging to the equalization range over the full interval (0 to 255 for an 8-bit image) and the other pixels are set to 0. The image produced reveals details in the regions that have an intensity in the equalization range; other areas are cleared.

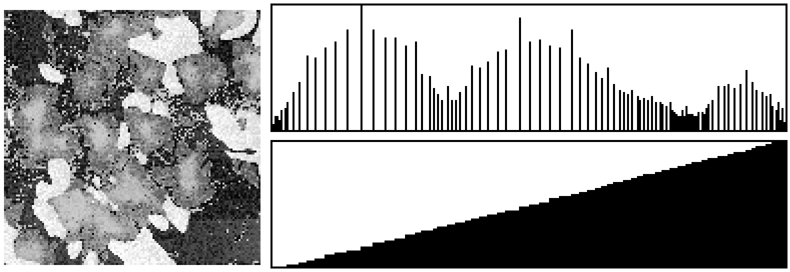
Example 1

This example shows how an equalization of the interval [0, 255] can spread the information contained in the three original peaks over larger intervals. The transformed image reveals more details about each component in the original image. The following graphics show the original image and histograms.





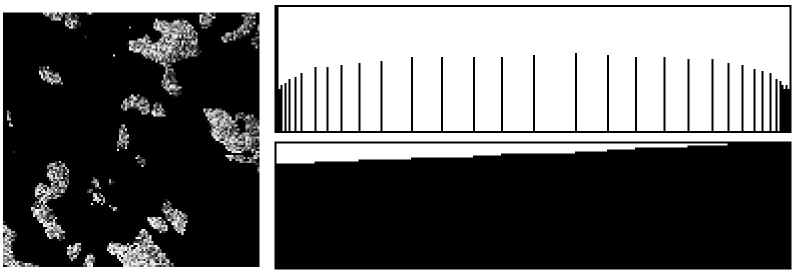
An equalization from [0, 255] to [0, 255] produces the following image and histograms.



Note: ***The cumulative histogram of an image after a histogram equalization always has a linear profile, as seen in the preceding example.***

Example 2

This example shows how an equalization of the interval [166, 200] can spread the information contained in the original third peak (ranging from 166 to 200) to the interval [1, 255]. The transformed image reveals details about the component with the original intensity range [166, 200] while all other components are set to black. An equalization from [166, 200] to [0, 255] produces the following image and histograms.



Reverse

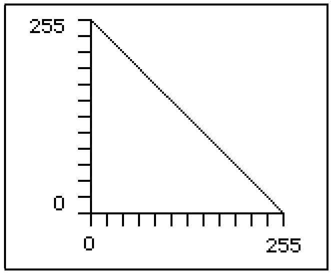
The Reverse function displays the photometric negative of an image.

$G_{output} = Maximum - G_{input}$

For an 8-bit image, *Maximum* = 255. Therefore,

$G_{output} = 255 - G_{input}$

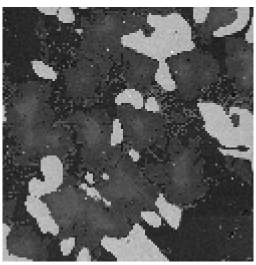
0	corresponds to	255
1	corresponds to	254
2	corresponds to	253
...		
128	corresponds to	128
...		
253	corresponds to	2
254	corresponds to	1
255	corresponds to	0



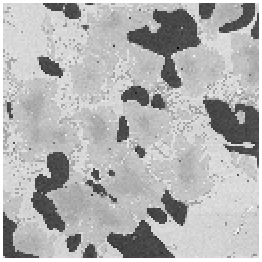
The histogram of a reversed image is equal to the histogram of the original image after a vertical symmetry centered on the gray-level value 128 (when processing an 8-bit image).

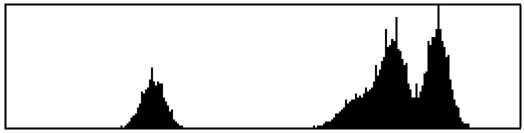
Example

This example uses the following original image and histogram.



A Reverse transformation produces the following histogram and image.

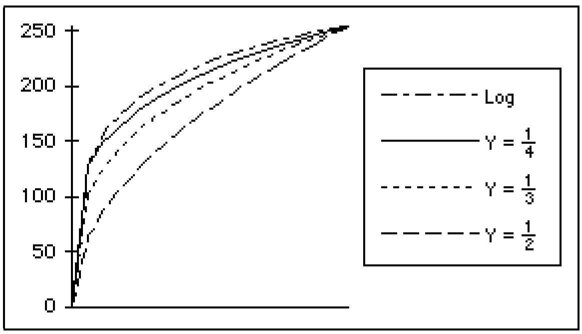




Logarithmic and Inverse Gamma Correction

The *logarithmic and inverse gamma corrections* expand low gray-level ranges while compressing high gray-level ranges. When using the B&W (or Gray) palette, these transformations increase the overall brightness of an image and increase the contrast in dark areas at the expense of the contrast in bright areas.

The following graphs show how the transformations behave. The horizontal axis represents the input gray-level range and the vertical axis represents the output gray-level range. Each input gray-level value is plotted vertically, and its point of intersection with the lookup curve is plotted horizontally to give an output value.

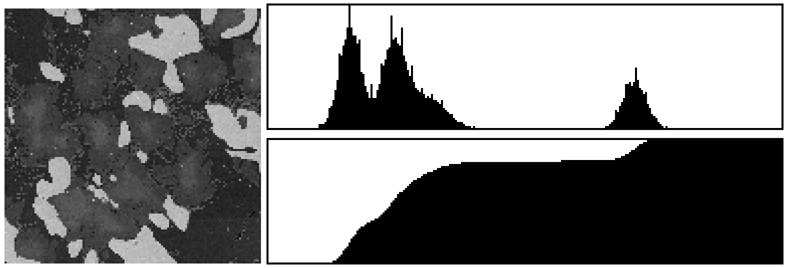


The *Logarithmic*, *Square Root*, and *Power 1/Y* functions expand intervals containing low gray-level values while compressing intervals containing high gray-level values.

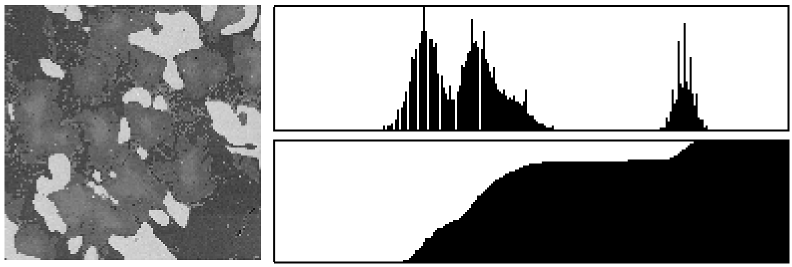
The higher the gamma coefficient *Y*, the stronger the intensity correction. The Logarithmic correction has a stronger effect than the Power 1/Y function.

The following series of illustrations presents the linear and cumulative histograms of an image after various LUT transformations. The more the histogram is compressed on the right, the brighter the image.

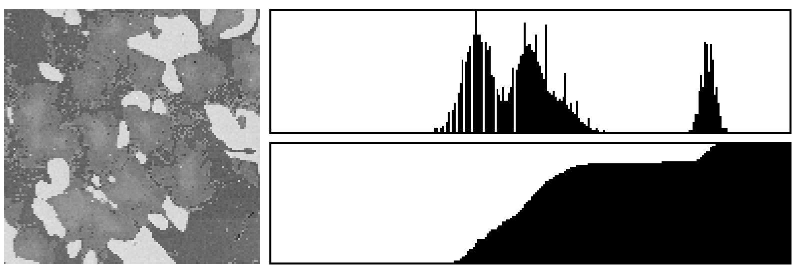
The following graphic shows the original image and histograms.



A Power 1/Y transformation (*where Y* = 1.5) produces the following image and histograms.



A Square Root or Power 1/Y transformation (*where Y* = 2) produces the following image and histograms.

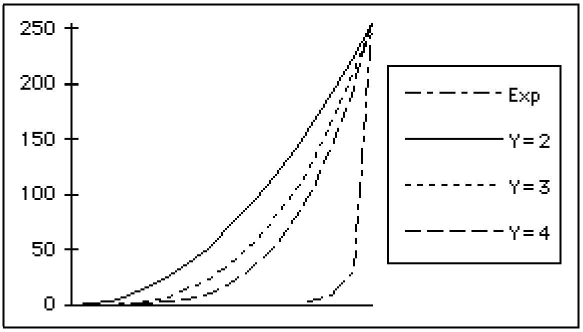


A Logarithm transformation produces the following image and histograms.

Exponential and Gamma Correction

The *exponential and gamma corrections* expand high gray-level ranges while compressing low gray-level ranges. When using the B&W (or Gray) palette, these transformations decrease the overall brightness of an image and increase the contrast in bright areas at the expense of the contrast in dark areas.

The following graphs show how the transformations behave. The horizontal axis represents the input gray-level range and the vertical axis represents the output gray-level range. Each input gray-level value is plotted vertically, and its point of intersection with the lookup curve then is plotted horizontally to give an output value.

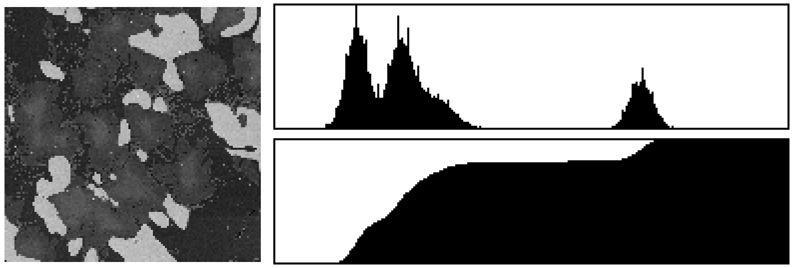


The *Exponential*, *Square*, and *Power Y* functions expand intervals containing high gray-level values while compressing intervals containing low gray-level values.

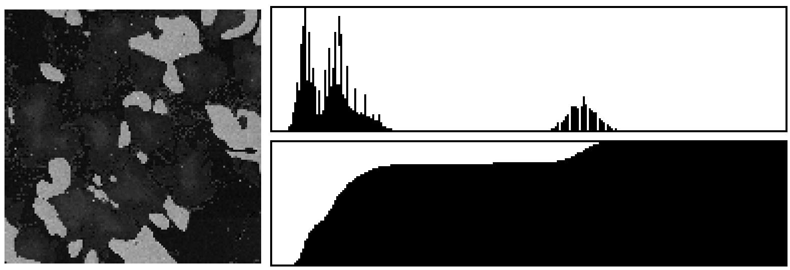
The higher the gamma coefficient *Y*, the stronger the intensity correction. The Exponential correction has a stronger effect than the Power Y function.

The following series of illustrations presents the linear and cumulative histograms of an image after various LUT transformations. The more the histogram is compressed on the left, the darker the image.

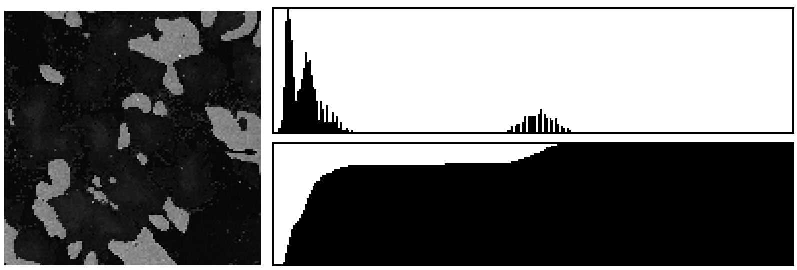
The following graphic shows the original image and histograms.



A Power Y transformation (*where Y* = 1.5) produces the following image and histograms.



A Square or Power Y transformation (*where Y* = 2) produces the following image and histograms.



An Exponential transformation produces the following image and histograms.

Chapter 4

Operators

This chapter describes the arithmetic and logic operators used in IMAQ Vision.

Concepts and Mathematics

Arithmetic and logic *operators* mask, combine, and compare images. Common applications of these operators include time-lapse comparisons, identification of the union or intersection between images, and comparisons between several images and a model. Operators also can be used to *threshold* or *mask* images and to alter contrast and brightness.

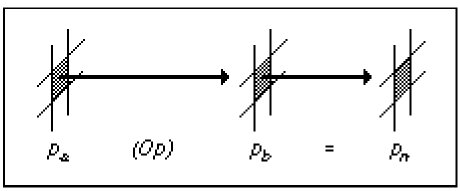
An arithmetic or logic operation between images is a pixel-by-pixel transformation. It produces an image in which each pixel derives from the values of pixels with the same coordinates in other images.

If A is an image with a resolution XY, B is an image with a resolution XY, and Op is the operator,

then the image N resulting from the combination of A and B through the operator Op is such that each pixel P of N is assigned the value

$$p_n = (p_a)(Op)(p_b),$$

where p_a is the value of pixel P in image A, and p_b is the value of pixel P in image B.



Arithmetic Operators

In the case of images with 8-bit resolution, the following equations describe the usage of the *arithmetic operators*:

Operator	Equation
Multiply	$p_n = \min(p_a \times p_b, 255)$
Divide	$p_n = \max(p_a/p_b, 0)$
Add	$p_n = \min(p_a + p_b, 255)$
Subtract	$p_n = \max(p_a - p_b, 0)$
Remainder	$p_n = p_a \mathrm{mod} p_b$

If the resulting pixel value p_n is negative, it is set to 0. If it is greater than 255, it is set to 255.

Logic Operators

Logic operators are bit-wise operators. They manipulate gray-level values coded on one byte at the bit level. The *truth tables* for logic operators are presented in the *Truth Tables* section.

Operator	Equation
AND	$p_n = p_a$ AND p_b
NAND	$p_n = p_a$ NAND p_b
OR	$p_n = p_a$ OR p_b
NOR	$p_n = p_a$ NOR p_b
XOR	$p_n = p_a$ XOR p_b
Difference	$p_n = p_a$ AND (NOT p_b)

Operator	Equation
Mask	*if* $p_b = 0$, *then* $p_n = 0$, *else* $p_n = p_a$
Mean	$p_n = \text{mean}[p_a, p_b]$
Max	$p_n = \text{max}[p_a, p_b]$
Min	$p_n = \text{min}[p_a, p_b]$

In the case of images with 8-bit resolution, logic operators mainly are designed to combine gray-level images with mask images composed of pixels equal to 0 or 255 (in binary format 0 is represented as 00000000 and 255 is represented as 11111111).

The following table illustrates how logic operations can be used to extract or remove information in an image.

For a given p_a,	***if* p_b = 255, *then***	***if* p_b = 0, *then***
(AND)	p_a AND 255 = p_a	p_a AND 0 = 0
(NAND)	p_a NAND 255 = NOT p_a	p_a NAND 0 = 255
(OR)	p_a OR 255 = 255	p_a OR 0 = p_a
(NOR)	p_a NOR 255 = 0	p_a NOR 0 = NOT p_a
(XOR)	p_a XOR 255 = NOT p_a	p_a XOR 0 = p_a
(Logic Difference)	p_a – NOT 255 = p_a	p_a – NOT 0 = 0

Truth Tables

The following truth tables describe the rules used by the logic operators. The top row and left column give the values of input bits. The cells in the table give the output value for a given set of two input bits.

AND

	***b* = 0**	***b* = 1**
***a* = 0**	0	0
***a* = 1**	0	1

NAND

	***b* = 0**	***b* = 1**
***a* = 0**	1	1
***a* = 1**	1	0

OR

	***b* = 0**	***b* = 1**
***a* = 0**	0	1
***a* = 1**	1	1

NOR

	***b* = 0**	***b* = 1**
***a* = 0**	1	0
***a* = 1**	0	0

XOR

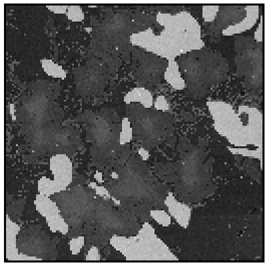
	***b* = 0**	***b* = 1**
***a* = 0**	0	1
***a* = 1**	1	0

NOT

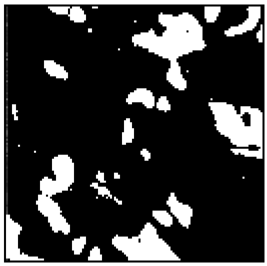
	NOT *a*
***a* = 0**	1
***a* = 1**	0

Example 1

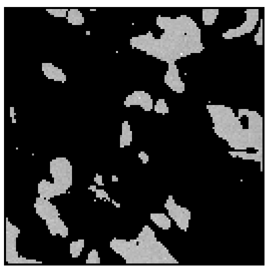
The following series of graphics illustrates images in which regions of interest have been isolated in a binary format, retouched with morphological manipulations, and finally multiplied by 255. The following gray-level source image is used for this example.



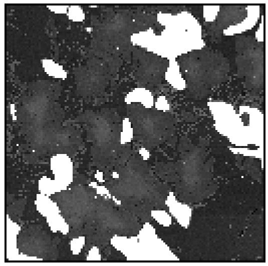
The following *mask image* results.



The operation (*source image* AND *mask image*) has the effect of restoring the original intensity of the object regions in the mask.



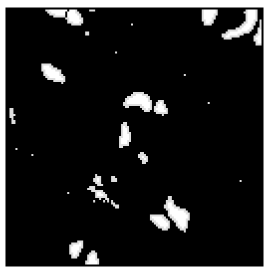
The operation (*source image* OR *mask image*) has the effect of restoring the original intensity of the background region in the mask.



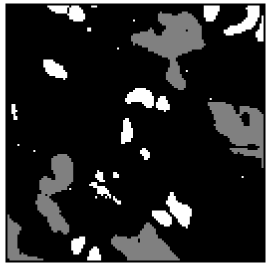
Example 2

An image revealing two groups of objects that require different processing results in two binary images. Multiplying each binary image by a constant and applying an OR operation produces an image that shows their union, as illustrated in the following series of graphics. The following image illustrates *Object Group #1* × 128.

The following image illustrates *Object Group #2* × 255.



Object Group #1 OR *Object Group #2* produces a union, as shown in the following image.



Spatial Filtering

Chapter 5

This chapter provides an overview of the spatial filters, including linear and nonlinear filters, used in IMAQ Vision.

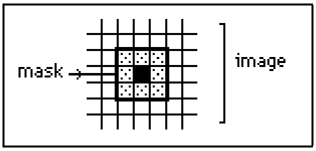
Concept and Mathematics

Spatial filters alter pixel values with respect to variations in light intensity in their neighborhood. The neighborhood of a pixel is defined by the size of a matrix, or mask, centered on the pixel itself. These filters can be sensitive to the presence or absence of light intensity variations. Spatial filters can serve a variety of purposes, such as the detection of edges along a specific direction, the contouring of patterns, noise reduction, and detail outlining or smoothing.

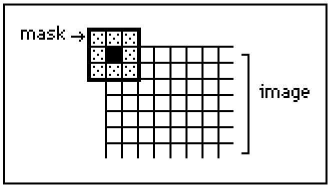
Spatial filters can be divided into two categories:

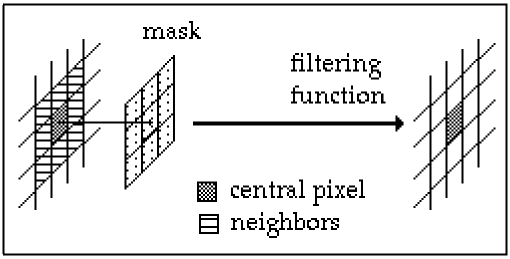
- *Highpass filters* emphasize significant variations of the light intensity usually found at the boundary of objects.
- *Lowpass filters* attenuate variations of the light intensity. They have the tendency to smooth images by eliminating details and blurring edges.

In the case of a 3 × 3 matrix as illustrated in the following illustration, the value of the central pixel (shown in solid) derives from the values of its eight surrounding neighbors (shown in shaded pattern).



A 5 × 5 matrix specifies 24 neighbors, a 7 × 7 matrix specifies 48 neighbors, and so forth.





If $P_{(i, j)}$ represents the intensity of the pixel P with the coordinates (i, j), the pixels surrounding $P_{(i, j)}$ can be indexed as follows (in the case of a 3 × 3 matrix):

$P_{(i-1, j-1)}$	$P_{(i, j-1)}$	$P_{(i+1, j-1)}$
$P_{(i-1, j)}$	$P_{(i, j)}$	$P_{(i+1, j)}$
$P_{(i-1, j+1)}$	$P_{(i, j+1)}$	$P_{(i+1, j+1)}$

A *linear filter* assigns to $P_{(i, j)}$ a value that is a linear combination of its surrounding values. For example,

$$P_{(i, j)} = (P_{(i, j-1)} + P_{(i-1, j)} + 2P_{(i, j)} + P_{(i+1, j)} + P_{(i, j+1)}).$$

A *nonlinear filter* assigns to $P_{(i, j)}$ a value that is not a linear combination of the surrounding values. For example,

$$P_{(i, j)} = \max(P_{(i-1, j-1)}, P_{(i+1, j-1)}, P_{(i-1, j+1)}, P_{(i+1, j+1)}).$$

Spatial Filter Classification Summary

The following table describes the classification of spatial filters.

	Highpass Filters	Lowpass Filters
Linear Filters	Gradient, Laplacian	Smoothing, Gaussian
Nonlinear Filters	Gradient, Roberts, Sobel, Prewitt, Differentiation, Sigma	Median, Nth Order, Lowpass

Linear Filters or Convolution Filters

A *convolution* is a mathematical function that replaces each pixel by a weighted sum of its neighbors. The matrix defining the neighborhood of the pixel also specifies the weight assigned to each neighbor. This matrix is called the *convolution kernel*.

For each pixel $P_{(i, j)}$ in an image (*where i* and *j* represent the coordinates of the pixel), the convolution kernel is centered on $P_{(i, j)}$. Each pixel masked by the kernel is multiplied by the coefficient placed on top of it. $P_{(i, j)}$ becomes the sum of these products.

In the case of a 3 × 3 neighborhood, the pixels surrounding $P_{(i, j)}$ and the coefficients of the kernel, *K*, can be indexed as follows:

$P_{(i-1, j-1)}$	$P_{(i, j-1)}$	$P_{(i+1, j-1)}$
$P_{(i-1, j)}$	$P_{(i, j)}$	$P_{(i+1, j)}$
$P_{(i-1, j+1)}$	$P_{(i, j+1)}$	$P_{(i+1, j+1)}$

$K_{(i-1, j-1)}$	$K_{(i, j-1)}$	$K_{(i+1, j-1)}$
$K_{(i-1, j)}$	$K_{(i, j)}$	$K_{(i+1, j)}$
$K_{(i-1, j+1)}$	$K_{(i, j+1)}$	$K_{(i+1, j+1)}$

The pixel $P_{(i, j)}$ is given the value $(1/N)\Sigma K_{(a, b)}P_{(a, b)}$, with *a* ranging from $(i-1)$ to $(i+1)$, and *b* ranging from $(j-1)$ to $(j+1)$. *N* is the normalization factor, equal to $\Sigma K_{(a, b)}$ or 1, whichever is greater.

Finally, if the new value $P_{(i, j)}$ is negative, it is set to 0. If the new value $P_{(i, j)}$ is greater than 255, it is set to 255 (in the case of 8-bit resolution).

The greater the absolute value of a coefficient $K_{(a, b)}$, the more the pixel $P_{(a, b)}$ contributes to the new value of $P_{(i, j)}$. If a coefficient $K_{(a, b)}$ is null, the neighbor $P_{(a, b)}$ does not contribute to the new value of $P_{(i, j)}$ (notice that $P_{(a, b)}$ might be $P_{(i, j)}$ itself).

If the convolution kernel is

0	0	0
–2	1	2
0	0	0

then

$$P_{(i, j)} = (-2P_{(i-1, j)} + P_{(i, j)} + 2P_{(i+1, j)}).$$

If the convolution kernel is

0	1	0
1	0	1
0	1	0

then

$$P_{(i, j)} = (P_{(i, j-1)} + P_{(i-1, j)} + P_{(i+1, j)} + P_{(i, j+1)}).$$

If the kernel contains both negative and positive coefficients, the transfer function is equivalent to a weighted differentiation, and produces a sharpening or highpass filter. Typical highpass filters include gradient and Laplacian filters.

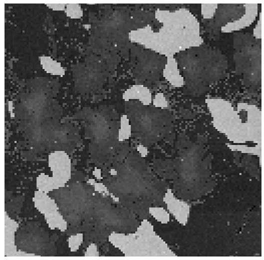
If all coefficients in the kernel are positive, the transfer function is equivalent to a weighted summation and produces a smoothing or lowpass filter. Typical lowpass filters include smoothing and Gaussian filters.

Gradient Filter

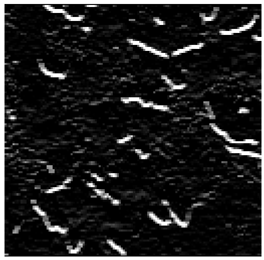
A *gradient filter* highlights the variations of light intensity along a specific direction, which has the effect of outlining edges and revealing texture.

Example

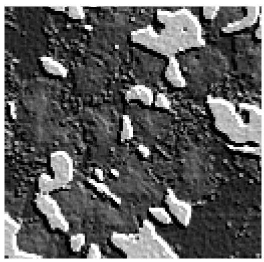
This example uses the following source image.



A gradient filter extracts horizontal edges to produce the following image.



A gradient filter highlights diagonal edges to produce the following image.



Kernel Definition

A *gradient convolution filter* is a first order derivative and its kernel uses the following model:

$$\begin{matrix} a & -b & c \\ b & x & -d \\ c & d & -a \end{matrix}$$

where a, b, and c are integers and $x = 0$ or 1.

This kernel has an axis of symmetry that runs between the positive and negative coefficients of the kernel and through the central element. This axis of symmetry gives the orientation of the edges to outline.

Filter Axis and Direction

The axis of symmetry of the gradient kernel gives the orientation of the edges to outline. For example,

where $a = 0$, $b = -1$, $c = -1$, $d = -1$, and $x = 0$, the kernel is the following:

$$\begin{matrix} 0 & 1 & 1 \\ -1 & 0 & 1 \\ -1 & -1 & 0 \end{matrix}$$

The axis of symmetry is at 135 degrees.

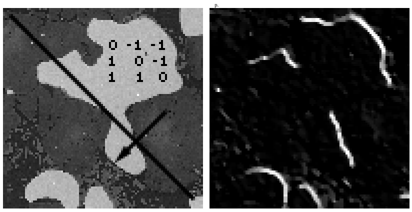
For a given direction, you can design a gradient filter to highlight or darken the edges along that direction. The filter actually is sensitive to the variations of intensity perpendicular to the axis of symmetry of its kernel. Given the direction D going from the negative coefficients of the kernel towards the positive coefficients, the filter highlights the pixels where the light intensity increases along the direction D, and darkens the pixels where the light intensity decreases.

Examples

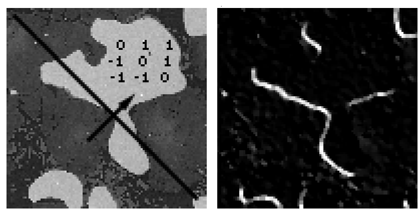
The following two kernels emphasize edges oriented at 135 degrees.

<table>
<tr><th>Gradient #1</th><th>Gradient #2</th></tr>
<tr><td>0 –1 –1
1 0 –1
1 1 0

Gradient #1 highlights pixels where the light intensity increases along the direction going from northeast to southwest. It darkens pixels where the light intensity decreases along that same direction. This processing outlines the northeast front edges of bright regions such as the ones in the illustration.

</td><td>0 1 1
–1 0 1
–1 –1 0

Gradient #2 highlights pixels where the light intensity increases along the direction going from southwest to northeast. It darkens pixels where the light intensity decreases along that same direction. This processing outlines the southwest front edges of bright regions such as the ones in the illustration.

</td></tr>
</table>

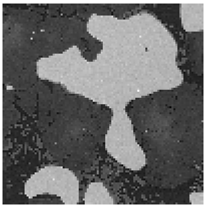
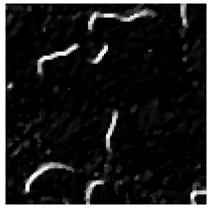
☞ **Note:** ***Applying Gradient #1 to an image gives the same results as applying Gradient #2 to its photometric negative, because reversing the lookup table of an image converts bright regions into dark regions and vice versa.***

Edge Extraction and Edge Highlighting

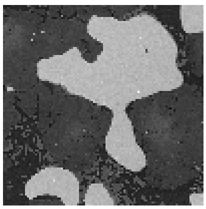
The gradient filter has two effects, depending on whether the central coefficient *x* is equal to 1 or 0:

- If the central coefficient is null ($x = 0$), the gradient filter highlights the pixels where variations of light intensity occur along a direction specified by the configuration of the coefficients *a*, *b*, *c*, and *d*.

The transformed image contains black-white borders at the original edges and the shades of the overall patterns are darkened.

Source Image	**Gradient #1**	**Filtered Image**
	$\begin{matrix} -1 & -1 & 0 \\ -1 & \mathbf{0} & 1 \\ 0 & 1 & 1 \end{matrix}$	

- If the central coefficient is equal to 1 ($x = 1$), the gradient filter detects the same variations as mentioned above, but superimposes them over the source image. The transformed image looks like the source image with edges highlighted. You can use this type of kernel for grain extraction and perception of texture.

Source Image	**Gradient #2**	**Filtered Image**
	$\begin{matrix} 1 & 1 & 0 \\ -1 & \mathbf{1} & 1 \\ 0 & 1 & 1 \end{matrix}$	

Notice that the kernel Gradient #2 can be decomposed as follows:

$$\begin{matrix} -1 & -1 & 0 \\ -1 & \mathbf{1} & 1 \\ 0 & 1 & 1 \end{matrix} \quad = \quad \begin{matrix} -1 & -1 & 0 \\ -1 & \mathbf{0} & 1 \\ 0 & 1 & 1 \end{matrix} \quad + \quad \begin{matrix} 0 & 0 & 0 \\ 0 & \mathbf{1} & 0 \\ 0 & 0 & 0 \end{matrix}$$

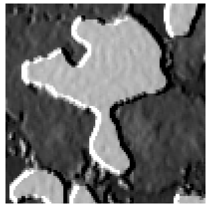
Note: ***The convolution filter using the second kernel on the right side of the equation reproduces the source image. All neighboring pixels are multiplied by 0 and the central pixel remains equal to itself:*** **($P_{(i, j)} = 1 \times P_{(i, j)}$).**

This equation indicates that Gradient #2 adds the edges extracted by the Gradient #1 to the source image.

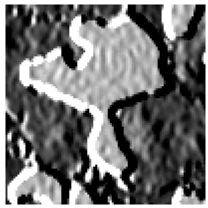
$$\text{Gradient \#2} = \text{Gradient \#1} + \text{Source Image}$$

Edge Thickness

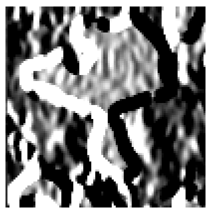
The larger the kernel, the larger the edges. The following image illustrates gradient west–east 3 × 3.



The following image illustrates gradient west–east 5 × 5.



Finally, the following image illustrates gradient west–east 7 × 7.



Predefined Gradient Kernels

The tables in this section list the predefined gradient kernels.

Prewitt Filters

The *Prewitt filters* have the following kernels. The notations West (W), South (S), East (E), and North (N) indicate which edges of bright regions they outline.

Table 5-1. Prewitt Filters

W/Edge	W/Image	SW/Edge	SW/Image
–1 0 1	–1 0 1	0 1 1	0 1 1
–1 0 1	–1 1 1	–1 0 1	–1 1 1
–1 0 1	–1 0 1	–1 –1 0	–1 –1 0
S/Edge	**S/Image**	**SE/Edge**	**SE/Image**
1 1 1	1 1 1	1 1 0	1 1 0
0 0 0	0 1 0	1 0 –1	1 1 –1
–1 –1 –1	–1 –1 –1	0 –1 –1	0 –1 –1
E/Edge	**E/Image**	**NE/Edge**	**NE/Image**
1 0 –1	1 0 –1	0 –1 –1	0 –1 –1
1 0 –1	1 1 –1	1 0 –1	1 1 –1
1 0 –1	1 0 –1	1 1 0	1 1 0
N/Edge	**N/Image**	**NW/Edge**	**NW/Image**
–1 –1 –1	–1 –1 –1	–1 –1 0	–1 –1 0
0 0 0	0 1 0	–1 0 1	–1 1 1
1 1 1	1 1 1	0 1 1	0 1 1

Sobel Filters

The *Sobel filters* are very similar to the Prewitt filters except that they highlight light intensity variations along a particular axis that is assigned a stronger weight. The Sobel filters have the following kernels. The notations West (W), South (S), East (E), and North (N) indicate which edges of bright regions they outline.

Table 5-2. Sobel Filters

W/Edge			**W/Image**			**SW/Edge**			**SW/Image**		
–1	0	1	–1	0	1	0	1	2	0	1	2
–2	0	2	–2	1	2	–1	0	1	–1	1	1
–1	0	1	–1	0	1	–2	–1	0	–2	–1	0
S/Edge			**S/Image**			**SE/Edge**			**SE/Image**		
1	2	1	1	2	1	2	1	0	2	1	0
0	0	0	0	1	0	1	0	–1	1	1	–1
–1	–2	–1	–1	–2	–1	0	–1	–2	0	–1	–2
E/Edge			**E/Image**			**NE/Edge**			**NE/Image**		
1	0	–1	1	0	–1	0	–1	–2	0	–1	–2
2	0	–2	2	1	–2	1	0	–1	1	1	–1
1	0	–1	1	0	–1	2	1	0	2	1	0
N/Edge			**N/Image**			**NW/Edge**			**NW/Image**		
–1	–2	–1	–1	–2	–1	–2	–1	0	–2	–1	0
0	0	0	0	1	0	–1	0	1	–1	1	1
1	2	1	1	2	1	0	1	2	0	1	2

The following tables list the predefined gradient 5 × 5 and 7 × 7 kernels.

Table 5-3. Gradient 5 × 5

W/Edge

0	–1	0	1	0
–1	–2	0	2	1
–1	–2	0	2	1
–1	–2	0	2	1
0	–1	0	1	0

W/Image

0	–1	0	1	0
–1	–2	0	2	1
–1	–2	1	2	1
–1	–2	0	2	1
0	–1	0	1	0

Table 5-4. Gradient 7 × 7

W/Edge

0	–1	–1	0	1	1	0
–1	–2	–2	0	2	2	1
–1	–2	–3	0	3	2	1
–1	–2	–3	0	3	2	1
–1	–2	–3	0	3	2	1
–1	–2	–3	0	3	2	1
0	–1	–1	0	1	1	0

W/Image

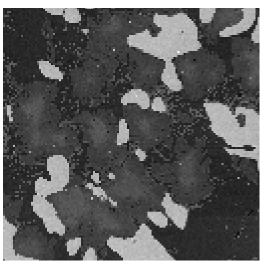
0	–1	–1	0	1	1	0
–1	–2	–2	0	2	2	1
–1	–2	–3	0	3	2	1
–1	–2	–3	1	3	2	1
–1	–2	–3	0	3	2	1
–1	–2	–3	0	3	2	1
0	–1	–1	0	1	1	0

Laplacian Filters

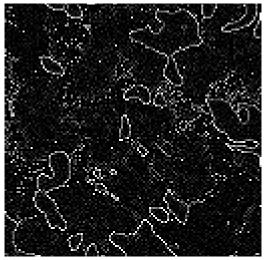
A *Laplacian filter* highlights the variation of the light intensity surrounding a pixel. The filter extracts the contour of objects and outlines details. Unlike the gradient filter, it is omni-directional.

Example

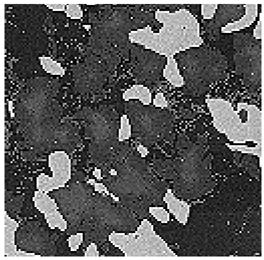
This example uses the following source image.



A Laplacian filter extracts contours to produce the following image.



A Laplacian filter highlights contours to produce the following image.



Kernel Definition

The Laplacian convolution filter is a second order derivative and its kernel uses the following model:

$$\begin{matrix} a & d & c \\ b & x & b \\ c & d & a \end{matrix}$$

where a, *b*, *c*, and *d* are integers.

The Laplacian filter has two different effects, depending on whether the central coefficient x is equal to or greater than the sum of the absolute values of the outer coefficients:

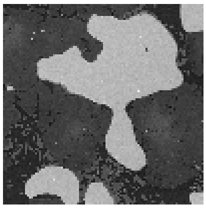
$$x \geq 2(|a| + |b| + |c| + |d|) .$$

Contour Extraction and Highlighting

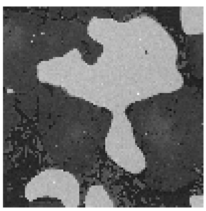
If the central coefficient is equal to this sum $(x = 2(|a| + |b| + |c| + |d|))$, the Laplacian filter extracts the pixels where significant variations of light intensity are found. The presence of sharp edges, boundaries between objects, modification in the texture of a background, noise, and other effects can cause these variations. The transformed image contains white contours on a black background.

Examples

Notice the following source image, Laplacian kernel, and filtered image.

Source Image	Laplacian #1	Filtered Image
	–1 –1 –1 –1 **8** –1 –1 –1 –1	

If the central coefficient is greater than the sum of the outer coefficients $(x > 2(a + b + c + d))$, the Laplacian filter detects the same variations as mentioned above, but superimposes them over the source image. The transformed image looks like the source image, with all significant variations of the light intensity highlighted.

Source Image	Laplacian #2	Filtered Image
	–1 –1 –1 –1 **9** –1 –1 –1 –1	

Notice that the Laplacian #2 kernel can be decomposed as follows:

$$\begin{matrix} -1 & -1 & -1 \\ 1 & \mathbf{9} & -1 \\ 0 & 1 & -1 \end{matrix} \quad = \quad \begin{matrix} 1 & -1 & -1 \\ 1 & \mathbf{8} & -1 \\ 1 & 1 & -1 \end{matrix} \quad + \quad \begin{matrix} 0 & 0 & 0 \\ 0 & \mathbf{1} & 0 \\ 0 & 0 & 0 \end{matrix}$$

☞ **Note:** ***The convolution filter using the second kernel on the right side of the equation reproduces the source image. All neighboring pixels are multiplied by 0 and the central pixel remains equal to itself:*** **$(P_{(i, j)} = 1 \times P_{(i, j)})$.**

This equation indicates that the Laplacian #2 kernel adds the contours extracted by the Laplacian #1 kernel to the source image.

Laplacian #1 = Laplacian #2 + Source Image

For example, if the central coefficient of Laplacian #2 kernel is 10, the Laplacian filter adds the contours extracted by Laplacian #1 kernel to the source image times 2, and so forth. A greater central coefficient corresponds to less-prominent contours and details highlighted by the filter.

Contour Thickness

Larger kernels correspond to larger contours. The following image is a Laplacian 3 × 3.

The following image is a Laplacian 5 × 5.

The following image is a Laplacian 7 × 7.

Predefined Laplacian Kernels

The following tables list the predefined Laplacian kernels.

Table 5-5. Laplacian 3 × 3

Contour 4	**+ Image × 1**	**+ Image × 2**
0 –1 0 –1 4 –1 0 –1 0	0 –1 0 –1 5 –1 0 –1 0	0 –1 0 –1 6 –1 0 –1 0
Contour 8	**+ Image × 1**	**+ Image × 2**
–1 –1 –1 –1 8 –1 –1 –1 –1	–1 –1 –1 –1 9 –1 –1 –1 –1	–1 –1 –1 –1 10 –1 –1 –1 –1
Contour 12	**+ Image × 1**	
–1 –2 –1 –2 12 –2 –1 –2 –1	–1 –2 –1 –2 13 –2 –1 –2 –1	

Table 5-6. Laplacian 5 × 5

Contour 24						**+ Image × 1**				
–1	–1	–1	–1	–1		–1	–1	–1	–1	–1
–1	–1	–1	–1	–1		–1	–1	–1	–1	–1
–1	–1	24	–1	–1		–1	–1	25	–1	–1
–1	–1	–1	–1	–1		–1	–1	–1	–1	–1
–1	–1	–1	–1	–1		–1	–1	–1	–1	–1

Table 5-7. Laplacian 7 × 7

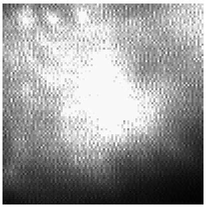
Contour 48								**+ Image × 1**						
–1	–1	–1	–1	–1	–1	–1		–1	–1	–1	–1	–1	–1	–1
–1	–1	–1	–1	–1	–1	–1		–1	–1	–1	–1	–1	–1	–1
–1	–1	–1	–1	–1	–1	–1		–1	–1	–1	–1	–1	–1	–1
–1	–1	–1	48	–1	–1	–1		–1	–1	–1	49	–1	–1	–1
–1	–1	–1	–1	–1	–1	–1		–1	–1	–1	–1	–1	–1	–1
–1	–1	–1	–1	–1	–1	–1		–1	–1	–1	–1	–1	–1	–1
–1	–1	–1	–1	–1	–1	–1		–1	–1	–1	–1	–1	–1	–1

Smoothing Filter

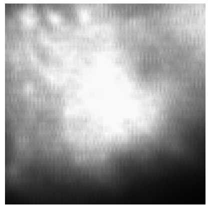
A *smoothing filter* attenuates the variations of light intensity in the neighborhood of a pixel. It smoothes the overall shape of objects, blurs edges, and removes details.

Example

This example uses the following source image.



A smoothing filter produces the following image.



Kernel Definition

A smoothing convolution filter is an averaging filter and its kernel uses the following model:

$$\begin{matrix} a & d & c \\ b & x & b \\ c & d & a \end{matrix}$$

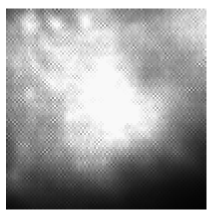
where a, b, c, and d are integers and $x = 0$ or 1.

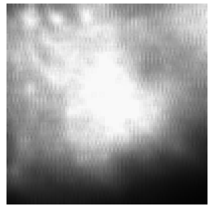
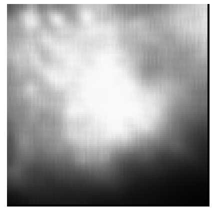
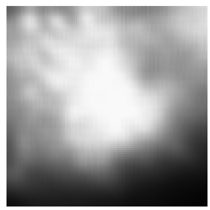
Because all the coefficients in a smoothing kernel are positive, each central pixel becomes a weighted average of its neighbors. The stronger the weight of a neighboring pixel, the more influence it has on the new value of the central pixel.

For a given set of coefficients (a, b, c, d), a smoothing kernel with a central coefficient equal to 0 ($x = 0$) has a stronger blurring effect than a smoothing kernel with a central coefficient equal to 1 ($x = 1$).

Examples

Notice the following smoothing kernels and filtered images. A larger kernel size corresponds to a stronger smoothing effect.

Kernel #1	Filtered Image
0 1 0 1 0 1 0 1 0	

Kernel #2	**Filtered Image**
2 2 2 2 1 2 2 2 2	
Kernel #3	**Filtered Image**
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	
Kernel #4	**Filtered Image**
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	

Predefined Smoothing Kernels

The following tables list the predefined smoothing kernels.

Table 5-8. Smoothing 3 × 3

0 1 0 1 0 1 0 1 0	0 1 0 1 1 1 0 1 0	0 2 0 2 1 2 0 2 0	0 4 0 4 1 4 0 4 0
1 1 1 1 0 1 1 1 1	1 1 1 1 1 1 1 1 1	2 2 2 2 1 2 2 2 2	4 4 4 4 1 4 4 4 4

Table 5-9. Smoothing 5 × 5

1	1	1	1	1		1	1	1	1	1
1	1	1	1	1		1	1	1	1	1
1	1	0	1	1		1	1	1	1	1
1	1	1	1	1		1	1	1	1	1
1	1	1	1	1		1	1	1	1	1

Table 5-10. Smoothing 7 × 7

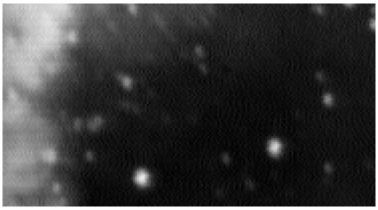
1	1	1	1	1	1	1		1	1	1	1	1	1	1
1	1	1	1	1	1	1		1	1	1	1	1	1	1
1	1	1	1	1	1	1		1	1	1	1	1	1	1
1	1	1	0	1	1	1		1	1	1	1	1	1	1
1	1	1	1	1	1	1		1	1	1	1	1	1	1
1	1	1	1	1	1	1		1	1	1	1	1	1	1
1	1	1	1	1	1	1		1	1	1	1	1	1	1

Gaussian Filters

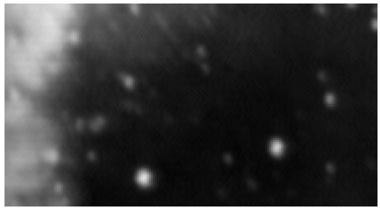
A *Gaussian filter* attenuates the variations of light intensity in the neighborhood of a pixel. It smoothes the overall shape of objects and attenuates details. It is similar to a smoothing filter, but its blurring effect is more subdued.

Example

This example uses the following source image.



A Gaussian filter produces the following image.



Kernel Definition

A *Gaussian convolution filter* is an averaging filter and its kernel uses the following model:

$$\begin{matrix} a & d & c \\ b & x & b \\ c & d & a \end{matrix}$$

where a, b, c, and d are integers and $x > 1$.

Since all the coefficients in a Gaussian kernel are positive, each pixel becomes a weighted average of its neighbors. The stronger the weight of a neighboring pixel, the more influence it has on the new value of the central pixel.

Unlike a smoothing kernel, the central coefficient of a Gaussian filter is greater than 1. Therefore the original value of a pixel is multiplied by a weight greater than the weight of any of its neighbors. As a result, a greater central coefficient corresponds to a more subtle smoothing effect. A larger kernel size corresponds to a stronger smoothing effect.

Predefined Gaussian Kernels

The following tables list the predefined Gaussian kernels.

Table 5-11. Gaussian 3 × 3

0	1	0		0	1	0		1	1	1
1	2	1		1	4	1		1	2	1
0	1	0		0	1	0		1	1	1
1	1	1		1	2	1		1	4	1
1	4	1		2	4	2		4	16	4
1	1	1		1	2	1		1	4	1

Table 5-12. Gaussian 5 × 5

1	2	4	2	1
2	4	8	4	2
4	8	16	8	4
2	4	8	4	2
1	2	4	2	1

Table 5-13. Gaussian 7 × 7

1	1	2	2	2	1	1
1	2	2	4	2	2	1
2	2	4	8	4	2	2
2	4	8	16	8	4	2
2	2	4	8	4	2	2
1	2	2	4	2	2	1
1	1	2	2	2	1	1

Nonlinear Filters

A *nonlinear filter* replaces each pixel value with a nonlinear function of its surrounding pixels. Like the convolution filters, the nonlinear filters operate on a neighborhood. The following notations describe the behavior of the nonlinear spatial filters.

If $P_{(i, j)}$ represents the intensity of the pixel P with the coordinates (i, j), the pixels surrounding $P_{(i, j)}$ can be indexed as follows (in the case of a 3 × 3 matrix):

$P_{(i-1, j-1)}$	$P_{(i, j-1)}$	$P_{(i+1, j-1)}$
$P_{(i-1, j)}$	$P_{(i, j)}$	$P_{(i+1, j)}$
$P_{(i-1, j+1)}$	$P_{(i, j+1)}$	$P_{(i+1, j+1)}$

In the case of a 5 × 5 neighborhood, the i and j indexes vary from –2 to 2, and so forth. The series of pixels including $P_{(i, j)}$ and its surrounding pixels is annotated as $P_{(n, m)}$.

Nonlinear Prewitt Filter

The *nonlinear Prewitt filter* is a highpass filter that extracts the outer contours of objects. It highlights significant variations of the light intensity along the vertical and horizontal axes.

Each pixel is assigned the maximum value of its horizontal and vertical gradient obtained with the following Prewitt convolution kernels:

Kernel #1

–1	0	1
–1	0	1
–1	0	1

Kernel #2

–1	–1	–1
0	0	0
1	1	1

$$P_{(i,\,j)} = \max[|P_{(i+1,\,j-1)} - P_{(i-1,\,j-1)} + P_{(i+1,\,j)} - P_{(i-1,\,j)} + P_{(i+1,\,j+1)} - P_{(i-1,\,j+1)}|,\ |P_{(i-1,\,j+1)} - P_{(i-1,\,j-1)} + P_{(i,\,j+1)} - P_{(i,\,j-1)} + P_{(i+1,\,j+1)} - P_{(i+1,\,j-1)}|]$$

Nonlinear Sobel Filter

The *nonlinear Sobel filter* is a highpass filter that extracts the outer contours of objects. It highlights significant variations of the light intensity along the vertical and horizontal axes.

Each pixel is assigned the maximum value of its horizontal and vertical gradient obtained with the following Sobel convolution kernels:

Kernel #1

–1	0	1
–2	0	2
–1	0	1

Kernel #2

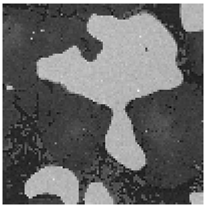
–1	–2	–1
0	0	0
1	2	1

As opposed to the Prewitt filter, the Sobel filter assigns a higher weight to the horizontal and vertical neighbors of the central pixel:

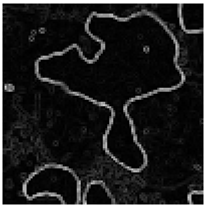
$$P_{(i,\,j)} = \max[|P_{(i-1,\,j-1)} - P_{(i+1,\,j-1)} + \mathbf{2}P_{(i-1,\,j)} - \mathbf{2}P_{(i+1,\,j)} + P_{(i-1,\,j+1)} - P_{(i+1,\,j+1)}|,\ |P_{(i-1,\,j-1)} - P_{(i-1,\,j+1)} + \mathbf{2}P_{(i,\,j-1)} - \mathbf{2}P_{(i,\,j+1)} + P_{(i+1,\,j-1)} - P_{(i+1,\,j+1)}|]$$

Example

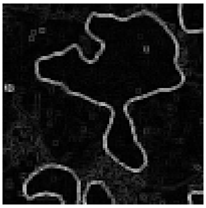
This example uses the following source image.



A nonlinear Prewitt filter produces the following image.



A nonlinear Sobel filter produces the following image.



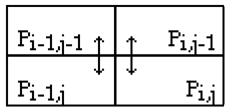
Both filters outline the contours of the objects. Because of the different convolution kernels they combine, the nonlinear Prewitt has the tendency to outline curved contours while the nonlinear Sobel extracts square contours. This difference is noticeable when observing the outlines of isolated pixels.

Nonlinear Gradient Filter

The *nonlinear gradient filter* outlines contours where an intensity variation occurs along the vertical axis.

The new value of a pixel becomes the maximum absolute value between its deviation from the upper neighbor and the deviation of its two left neighbors.

$$P_{(i,\,j)} = \max[|P_{(i,\,j-1)} - P_{(i,\,j)}|,\ |P_{(i-1,\,j-1)} - P_{(i-1,\,j)}|]$$

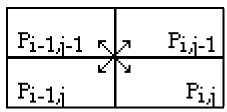


Roberts Filter

The *Roberts filter* outlines the contours that highlight pixels where an intensity variation occurs along the diagonal axes.

The new value of a pixel becomes the maximum absolute value between the deviation of its upper-left neighbor and the deviation of its two other neighbors.

$$P_{(i,\,j)} = \max[|P_{(i-1,\,j-1)} - P_{(i,\,j)}|,\ |P_{(i,\,j-1)} - P_{(i-1,\,j)}|]$$

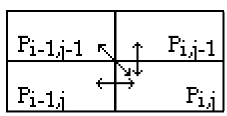


Differentiation Filter

The *differentiation filter* produces continuous contours by highlighting each pixel where an intensity variation occurs between itself and its three upper-left neighbors.

The new value of a pixel becomes the absolute value of its maximum deviation from its upper-left neighbors.

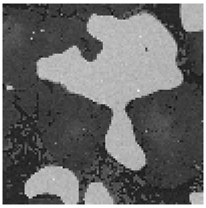
$$P_{(i,\,j)} = \max[|P_{(i-1,\,j)} - P_{(i,\,j)}|,\ |P_{(i-1,\,j-1)} - P_{(i,\,j)}|,\ |P_{(i,\,j-1)} - P_{(i,\,j)}|]$$



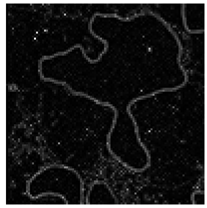
Sigma Filter

The *Sigma filter* is a highpass filter. It outlines contours and details by setting pixels to the mean value found in their neighborhood, if their deviation from this value is not significant.

Given M, the mean value of $P_{(i, j)}$ and its neighbors and S, their standard deviation, each pixel $P_{(i, j)}$ is set to the mean value M if it falls inside the range $[M - S, M + S]$.



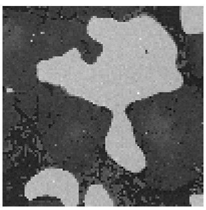
$$\begin{array}{rl} \textit{If} & P_{(i,j)} - M > S, \\ \textit{then} & P_{(i,j)} = P_{(i,j)}, \\ \textit{else} & P_{(i,j)} = M. \end{array}$$



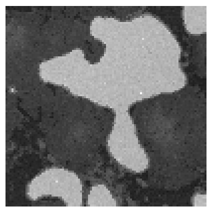
Lowpass Filter

The *lowpass filter* reduces details and blurs edges by setting pixels to the mean value found in their neighborhood, if their deviation from this value is large.

Given M, the mean value of $P_{(i, j)}$ and its neighbors and S, their standard deviation, each pixel $P_{(i, j)}$ is set to the mean value M if it falls outside the range $[M - S, M + S]$.



$$\begin{array}{rl} \textit{If} & P_{(i,j)} - M < S, \\ \textit{then} & P_{(i,j)} = P_{(i,j)}, \\ \textit{else} & P_{(i,j)} = M. \end{array}$$



Median Filter

The *median filter* is a lowpass filter. It assigns to each pixel the median value of its neighborhood, effectively removing isolated pixels and reducing details. However, the median filter does not blur the contour of objects.

$$P_{(i,j)} = \text{median value of the series } [P_{(n,m)}].$$

Nth Order Filter

The *Nth order filter* is an extension of the median filter. It assigns to each pixel the *N*th value of its neighborhood (when sorted in increasing order). The value *N* specifies the order of the filter, which you can use to moderate the effect of the filter on the overall light intensity of the image. A lower order corresponds to a darker transformed image; a higher order corresponds to a brighter transformed image.

Each pixel is assigned the *N*th value of its neighborhood, *N* being specified by the user.

$$P_{(i,j)} = N\text{th value in the series } [P_{(n,m)}],$$

where the $P_{(n,m)}$ are sorted in increasing order.

The following example uses a 3 × 3 neighborhood:

$P_{(i-1,j-1)}$	$P_{(i,j-1)}$	$P_{(i+1,j-1)}$		13	10	9
$P_{(i-1,j)}$	$P_{(i,j)}$	$P_{(i+1,j)}$	=	12	4	8
$P_{(i-1,j+1)}$	$P_{(i,j+1)}$	$P_{(i+1,j+1)}$		5	5	6

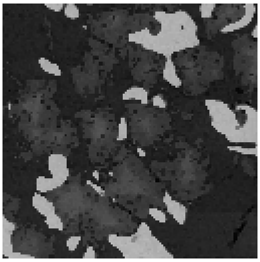
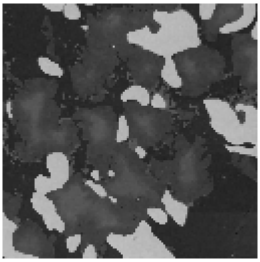
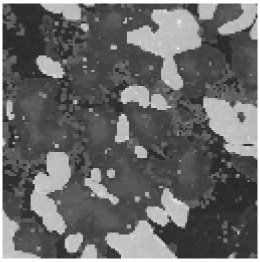
The following table shows the new output value of the central pixel for each *N*th order value:

*N*th Order	0	1	2	3	4	5	6	7	8
New Pixel Value	4	5	5	6	8	9	10	12	13

Note that for a given filter size *f*, the *N*th order can rank from 0 to $f^2 - 1$. For example, in the case of a filter size 3, the *N*th order ranges from 0 to 8 ($3^2 - 1$).

Examples

To see the effect of the Nth order filter, notice the example of an image with bright objects and a dark background. When viewing this image with the B&W (or Gray) palette, the objects have higher gray-level values than the background.

For a Given Filter Size $f \times f$	Example of a Filter Size 3 × 3	
• If $N < (f^2 - 1)/2$, the Nth order filter has the tendency to erode bright regions (or dilate dark regions). • If $N = 0$, each pixel is replaced by its local minimum.	Order 0 (smoothes image, erodes bright objects)	
• If $N = (f^2 - 1)/2$, each pixel is replaced by its local median value. Dark pixels isolated in objects are removed, as well as bright pixels isolated in the background. The overall area of the background and object regions does not change.	Order 4 (equivalent to a median filter)	
• If $N > (f^2 - 1)/2$, the Nth order filter has the tendency to dilate bright regions (or erode dark regions). • If $N = f^2 - 1$, each pixel is replaced by its local maximum.	Order 8 (smoothes image, dilates bright objects)	

Chapter 6

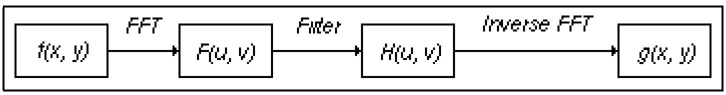
Frequency Filtering

This chapter describes the frequency filters used in IMAQ Vision.

Introduction to Frequency Filters

Frequency filters alter pixel values with respect to the periodicity and spatial distribution of the variations in light intensity in the image. Highpass frequency filters help isolate abruptly varying patterns which correspond to sharp edges, details, and noise. Lowpass frequency filters help emphasize gradually varying patterns such as objects and the background. Frequency filters do not apply directly to a spatial image, but to its frequency representation. The latter is obtained via a function called the *Fast Fourier Transform* (FFT). It reveals information about the periodicity and dispersion of the patterns found in the source image.

The spatial frequencies seen in an FFT image can be filtered and the Inverse FFT then restores a spatial representation of the filtered FFT image.

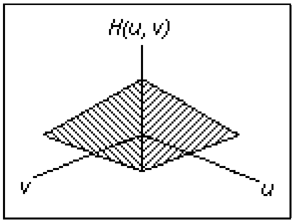


In an image, details and sharp edges are associated to high spatial frequencies because they introduce significant gray-level variations over short distances. Gradually varying patterns are associated to low spatial frequencies.

For example, an image can have extraneous noise such as periodic stripes introduced during the digitization process. In the frequency domain, the periodic pattern is reduced to a limited set of high spatial frequencies. Truncating these particular frequencies and converting the filtered FFT image back to the spatial domain produces a new image in which the grid pattern has disappeared, yet the overall features remain.

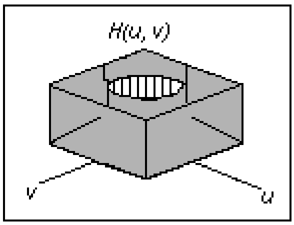
Lowpass FFT Filters

A *lowpass FFT filter* attenuates or removes high frequencies present in the FFT plane. It has the effect of suppressing information related to rapid variations of light intensities in the spatial image. In this case, the Inverse FFT command produces an image in which noise, details, texture, and sharp edges are smoothed.



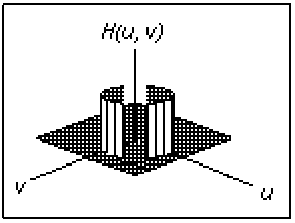
Highpass FFT Filters

A *highpass FFT filter* attenuates or removes low frequencies present in the FFT plane. It has the effect of suppressing information related to slow variations of light intensities in the spatial image. In this case, the Inverse FFT command produces an image in which overall patterns are attenuated and details are emphasized.



Mask FFT Filters

A *mask filter* removes frequencies contained in a mask specified by the user. Depending on the mask definition, this filter may behave as a lowpass, bandpass, highpass, or any type of selective filter.



Definition

The spatial frequencies of an image are calculated by a function called the *Fourier Transform*. It is defined in the continuous domain as

$$F(u, v) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x, y)e^{-j2\pi(xu + yv)}dxdy$$

where $f(x, y)$ is the light intensity of the point (x, y), and (u, v) are the horizontal and vertical spatial frequencies. The Fourier Transform assigns a complex number to each set (u, v).

Inversely, a Fast Fourier Transform $F(u, v)$ can be transformed into a spatial image $f(x, y)$ using the following formula:

$$f(x, y) = \sum_{u=0}^{N-1}\sum_{v=0}^{M-1} F(u, v)e^{j2\pi\left(\frac{ux}{N} + \frac{vy}{M}\right)}$$

In the discrete domain, the Fourier Transform is calculated with an efficient algorithm called the Fast Fourier Transform (FFT). This algorithm requires that the resolution of the image be $2^n 2^m$. Notice that the values and n and m can be different, which indicates that the image does not have to be square.

$$F(u, v) = \frac{1}{NM}\sum_{x=0}^{N-1}\sum_{y=0}^{M-1} f(x, y)e^{-j2\pi\left(\frac{ux}{N} + \frac{vy}{M}\right)}$$

where NM is the resolution of the spatial image $f(x, y)$.

Because $e^{-j2\pi ux} = \cos 2\pi ux - j\sin 2\pi ux$, $F(u, v)$ is composed of an infinite sum of sine and cosine terms. Each pair (u, v) determines the frequency of its corresponding sine and cosine pair. For a given set (u, v), note that all values $f(x, y)$ contribute to $F(u, v)$. Because of this complexity, the FFT calculation is time consuming.

The relation between the sampling increments in the spatial domain (Δx, Δy) and the frequency domain (Δu, Δv) is:

$$\Delta u = \frac{1}{N \times \Delta x} \qquad \Delta v = \frac{1}{M \times \Delta y}$$

The FFT of an image, $F(u, v)$, is a two dimensional array of complex numbers, or a complex image. It represents the frequencies of occurrence of light intensity variations in the spatial domain. The low frequencies (u, v) correspond to smooth and gradual intensity variations found in the overall patterns of the source image. The high frequencies (u, v) correspond to abrupt and short intensity variations found at the edges of objects, around noisy pixels, and around details.

FFT Display

An FFT image can be visualized using any of its four complex components: real part, imaginary part, magnitude, and phase. The relation between these components is expressed by

$$F(u, v) = R(u, v) + jI(u, v),$$

where $R(u, v)$ is the real part and $I(u, v)$ is the imaginary part, and

$$F(u, v) = |F(u, v)| \times e^{j\varphi\langle u, v\rangle},$$

where $|F(u, v)|$ is the magnitude and $\varphi(u, v)$ is the phase.

The magnitude of $F(u, v)$ is also called the *Fourier spectrum* and is equal to

$$|F(u, v)| = \sqrt{R(u, v)^2 + I(u, v)^2}$$

The Fourier spectrum to the power of two is known as the power spectrum or spectral density.

The phase $\varphi(u, v)$ is also called the phase angle and is equal to

$$\varphi(u, v) = \operatorname{atan}\left[\frac{I(u, v)}{R(u, v)}\right].$$

Given an image with a resolution *NM* and given Δx and Δy the spatial step increments, the FFT of the source image has the same resolution *NM* and its frequency step increments Δu and Δv, which are defined in the following equations:

$$\Delta u = \frac{1}{N \times \Delta x} \qquad \Delta v = \frac{1}{M \times \Delta y}.$$

The FFT of an image has the following two properties:

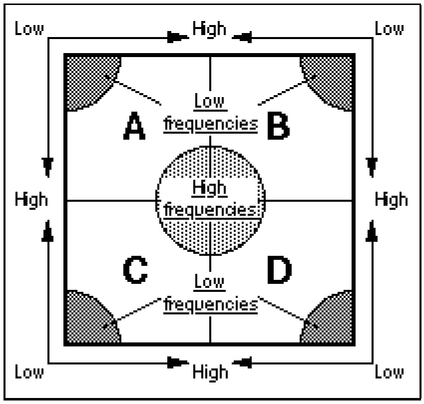
- It is periodic: $F(u, v) = F(u + N, v + M)$
- It is conjugate-symmetric: $F(u, v) = F^*(-u, -v)$

These properties result in two possible representations of the Fast Fourier Transform of an image: the *standard representation* and the *optical representation*.

Standard Representation

High frequencies are grouped at the center while low frequencies are located at the edges. The constant term, or null frequency is in the upper-left corner of the image. The frequency range is

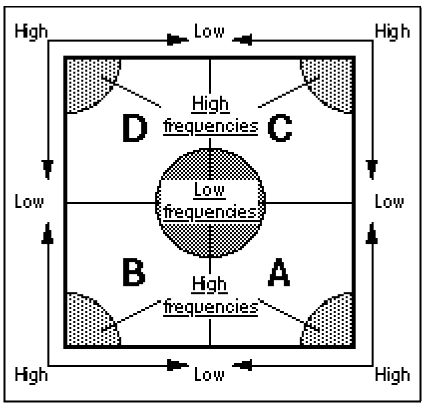
$$[0, N\Delta u] \times [0, M\Delta v].$$



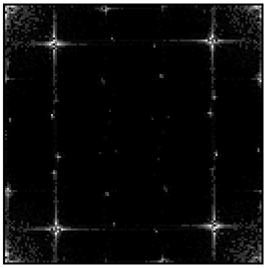
Optical Representation

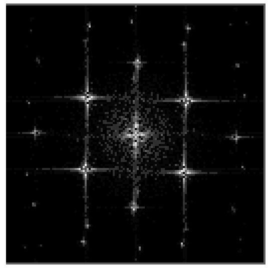
Low frequencies are grouped at the center while high frequencies are located at the edges. The constant term, or null frequency, is at the center of the image. The frequency range is

$$\left[-\frac{N}{2}\Delta u, \frac{N}{2}\Delta u\right] \times \left[-\frac{M}{2}\Delta v, \frac{M}{2}\Delta v\right].$$



You can switch from the standard representation to the optical representation by permuting the *A*, *B*, *C* and *D* quarters.





Intensities in the FFT image are proportional to the amplitude of the displayed component.

Frequency Filters

This section describes the frequency filters in detail and includes information on lowpass and highpass attenuation and truncation.

Lowpass Frequency Filters

A *lowpass frequency filter* attenuates or removes high frequencies present in the FFT plane. This filter suppresses information related to rapid variations of light intensities in the spatial image. In this case, the Inverse FFT command produces an image in which noise, details, texture, and sharp edges are smoothed.

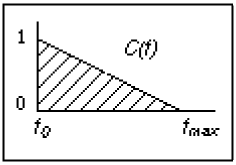
A lowpass frequency filter removes or attenuates spatial frequencies located outside a frequency range centered on the fundamental (or null) frequency.

Lowpass Attenuation

Lowpass attenuation applies a linear attenuation to the full frequency range, decreasing from f_0 to f_{max}. This is done by multiplying each frequency by a coefficient *C* which is a function of its deviation from the fundamental and maximum frequencies.

$$C(f) = \frac{f_{max} - f}{f_{max} - f_0},$$

where $C(f_0) = 1$ and $C(f_{max}) = 0$.



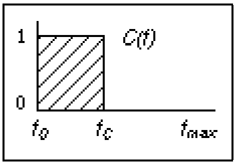
Lowpass Truncation

Lowpass truncation removes a frequency f if it falls outside the truncation range $[f_0, f_c]$. This is done by multiplying each frequency f by a coefficient C equal to 0 or 1, depending on whether the frequency f is greater than the truncation frequency f_c.

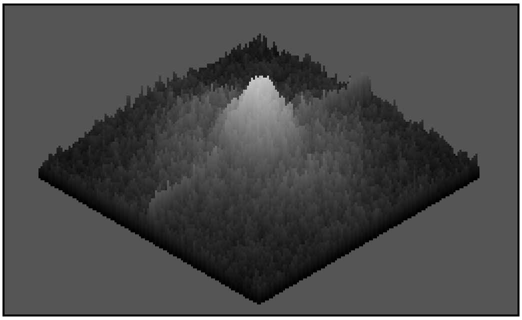
If $f > f_c$,

then $C(f) = 0$

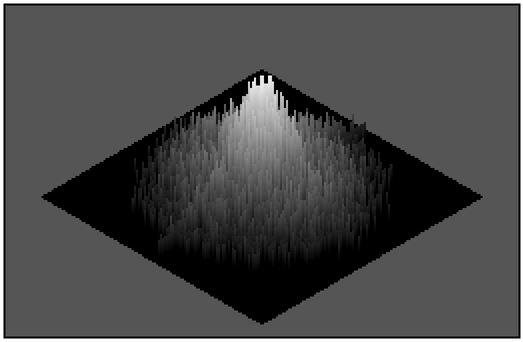
else $C(f) = 1$.



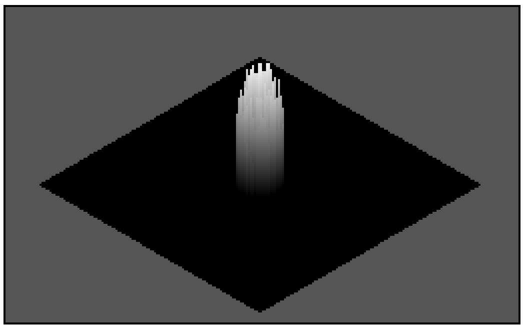
The following series of graphics illustrates the behavior of each type of filter. They give the 3D-view profile of the magnitude of the FFT. This example uses the following original FFT.



After lowpass attenuation, the magnitude of the central peak has been attenuated, and variations at the edges almost have disappeared.



After lowpass truncation with $f_c = f_0 + 20\%(f_{max} - f_0)$, spatial frequencies outside the truncation range $[f_0, f_c]$ are removed. The part of the central peak that remains is identical to the one in the original FFT plane.



Highpass Frequency Filters

A *highpass frequency filter* attenuates or removes low frequencies present in the FFT plane. It has the effect of suppressing information related to slow variations of light intensities in the spatial image. In this case, the inverse FFT produces an image in which overall patterns are attenuated and details are emphasized.

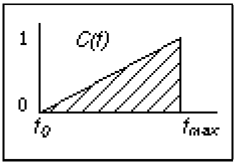
A highpass frequency filter removes or attenuates spatial frequencies located inside a frequency range centered on the fundamental (or null) frequency.

Highpass Attenuation

Highpass attenuation applies a linear attenuation to the full frequency range, decreasing from f_{max} to f_0. This is done by multiplying each frequency by a coefficient C which is a function of its deviation from the fundamental and maximum frequencies.

$$C(f) = \frac{f - f_0}{f_{max} - f_0},$$

where $C(f_0) = 1$ and $C(f_{max}) = 0$.



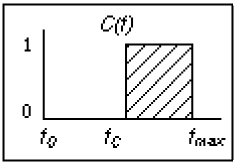
Highpass Truncation

Highpass truncation removes a frequency f if it falls inside the truncation range $[f_0, f_c]$. This is done by multiplying each frequency f by a coefficient C equal to 1 or 0, depending on whether the frequency f is greater than the truncation frequency f_c.

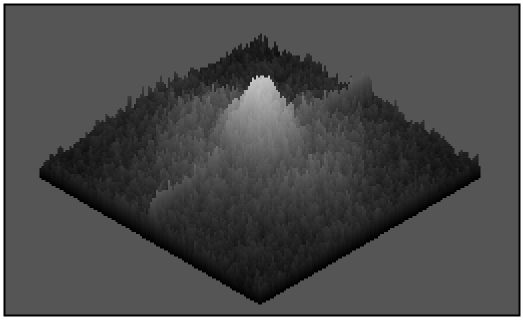
If $f < f_c$,

then $C(f) = 0$

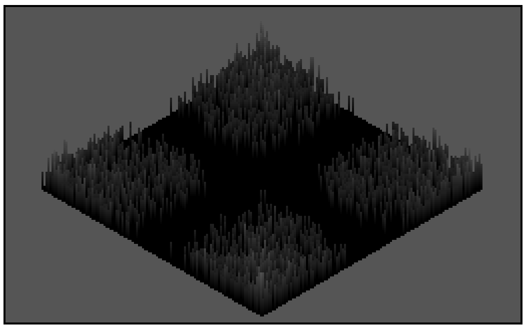
else $C(f) = 1$.



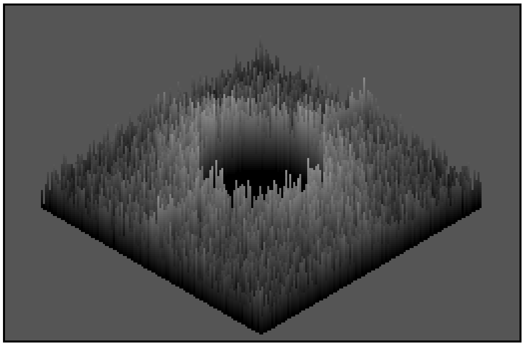
The following series of graphics illustrates the behavior of each type of filter. They give the 3D-view profile of the magnitude of the FFT. This example uses the following original FFT image.



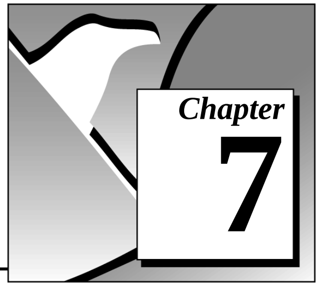
After highpass attenuation, the central peak has been removed and variations present at the edges remain.



After highpass truncation with $f_c = f_0 + 20\%(f_{max} - f_0)$, spatial frequencies inside the truncation range $[f_0, f_c]$ are set to 0. The remaining frequencies are identical to the ones in the original FFT plane.



Morphology Analysis



This chapter provides an overview of morphology image analysis.

Morphological transformations extract and alter the structure of objects in an image. You can use these transformations to prepare objects for quantitative analysis, observe the geometry of regions, extract the simplest forms for modeling and identification purposes, and so forth.

The morphological transformations can be used for expanding or reducing objects, filling holes, closing inclusions, smoothing borders, removing dendrites, and more. They can be divided into two categories:

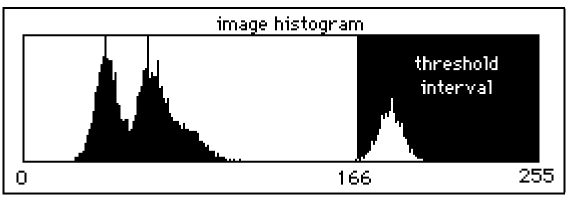
- *Gray-level morphology* functions, which apply to gray-level images.
- *Binary Morphology* functions, which apply to binary images.

A *binary image* is an image that has been segmented into an object region (pixels equal to 1) and a background region (pixels equal to 0). Such an image is generated by the *thresholding* process.

Thresholding

Thresholding consists of segmenting an image into two regions: an object region and a background region. This is performed by setting to 1 all pixels that belong to a gray-level interval, called the threshold interval. All other pixels in the image are set to 0.

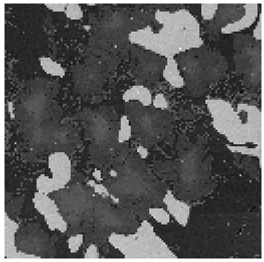
You can use this operation to extract areas that correspond to significant structures in an image and to focus the analysis on these areas.



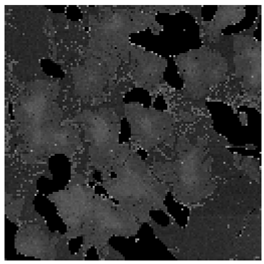
Pixels outside the threshold interval are set to 0 and considered as part of the background area. Pixels inside the threshold interval are set to 1 and considered as part of an object area.

Example

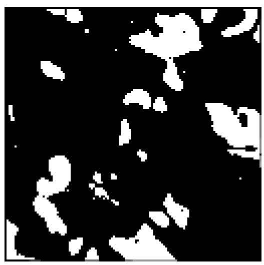
This example uses the following source image.



Highlighting the pixels that belong to the threshold interval [166, 255] (the darkest areas) produces the following image.



Highlighting produces the following binary image.



A critical and frequent problem in segmenting an image into an object and a background region occurs when the boundaries are not sharply demarcated. In such a case, the choice of a correct threshold becomes subjective. Therefore, it is highly recommended that images be enhanced prior to thresholding, so as to outline where the correct borders lie. Observing the intensity profile of a line crossing a boundary area can also be helpful in selecting a correct threshold value. Finally, keep in mind that morphological transformations can help you retouch the shape of binary objects and therefore correct unsatisfactory selections that occurred during the thresholding.

Thresholding a Color Image

To threshold a color image, three threshold intervals need to be specified, one for each color component. The final binary image is the intersection of the three binary images obtained by thresholding each color component separately.

Automatic Threshold

A number of different automatic thresholding techniques are available, including clustering, entropy, metric, moments, and interclass variance. In contrast to manual thresholding, these methods do not require that the user set the minimal and maximal light intensities. These techniques are well suited for conditions in which the light intensity varies.

Depending on your source image, it is sometimes useful to invert (reverse) the original gray scale image before applying an automatic threshold function (for example, moments and entropy). This is especially true for cases in which the region you want to threshold is black and the background you want to eliminate is red (when viewing with a binary palette).

Clustering is the only multi-class thresholding method available. Clustering operates on multiple classes so you can create tertiary or even higher level images. The other four methods (entropy, metric, moments, and interclass variance) are reserved for strictly binary thresholding techniques. The choice of which algorithm to apply depends on the type of image to threshold.

Clustering

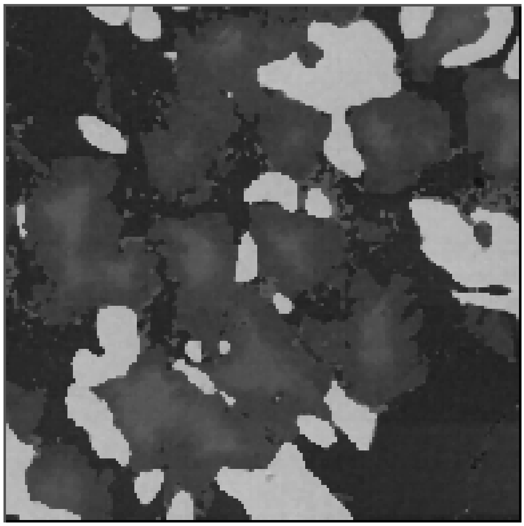
In this rapid technique, the image is randomly sorted within a discrete number of classes corresponding to the number of phases perceived in an image. The gray values are determined and a *barycenter* is determined for each class. This process is repeated until a value is obtained that represents the center of mass for each phase or class.

Example

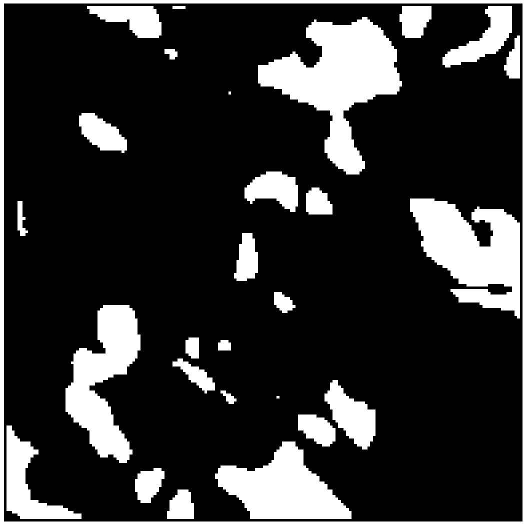
The automatic thresholding method most frequently used is clustering, also known as multi-class thresholding.

This example uses a clustering technique in two and three phases on an image. Note that the results from this function are generally independent of the lighting conditions as well as the histogram values from the image.

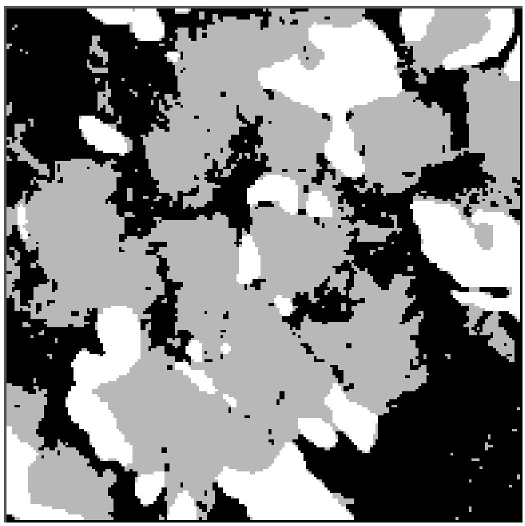
This example uses the following original image.



Clustering in two phases produces the following image.



Clustering in three phases produces the following image.



Entropy

Based on a classical image analysis technique, this method is best suited for detecting objects that are present in minuscule proportions on the image. For example, this function would be suitable for default detection.

Metric

Use this technique in situations similar to interclass variance. For each threshold, a value is calculated that is determined by the surfaces representing the initial gray scale. The optimal threshold corresponds to the smallest value.

Moments

This technique is suited for images that have poor contrast (an overexposed image is better processed than an underexposed image). The moments method is based on the hypothesis that the observed image is a blurred version of the theoretically binary original. The blurring that is produced from the acquisition process (electronic noise or slight defocalization) is treated as if the statistical moments (average and variance) were the same for both the blurred image and the original image. This function recalculates a theoretical binary image.

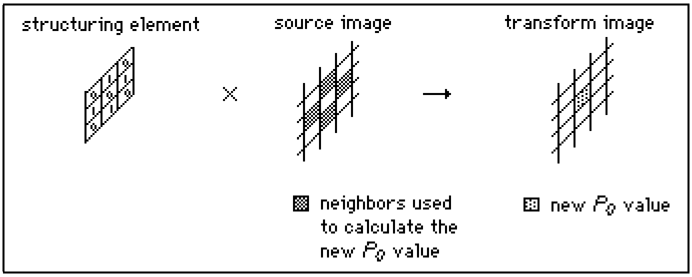
Interclass Variansce

Interclass variance is a classical statistic technique used in discriminating factorial analysis. This method is well-suited for images in which classes are not too disproportionate. For satisfactory results, the smallest class must be at least five percent of the largest one. Note that this method has the tendency to underestimate the class of the smallest standard deviation if the two classes have a significant variation.

Structuring Element

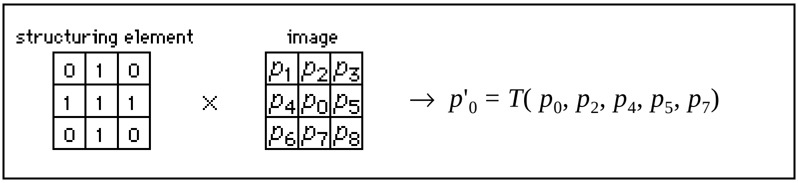
A *structuring element* is a binary mask used by most morphological transformations. You can use a structuring element to weigh the effect of these functions on the shape and the boundary of objects.

A morphological transformation using a structuring element alters a pixel P_0 so that it becomes a function of its neighboring pixels. These neighboring pixels are masked by 1 when the structuring element is centered on P_0. A neighbor masked by 0 simply is discarded by the function.



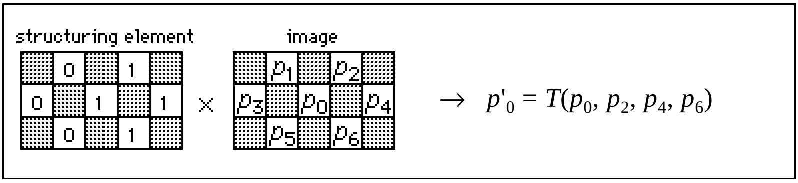
The structuring element is a binary mask (composed of 1 and 0 values). It is used to determine which neighbors of a pixel contribute to its new value. A structuring element can be defined in the case of a rectangular or hexagonal pixel frame, as shown in the following examples.

The following graphic illustrates a morphological transformation using a structuring element. This example uses a 3 × 3 image which has a rectangular frame.



Rectangular Frame, Neighborhood 3 × 3

The next graphic illustrates a morphological transformation using a structuring element for an image that has a hexagonal frame. This example uses a 5 × 3 image.



Hexagonal Frame, Neighborhood 5 × 3

The default configuration of the structuring element is a 3 × 3 matrix with each coefficient set to 1:

$$\begin{matrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{matrix}$$

Primary Binary Morphology Functions

The *primary morphology* functions apply to binary images in which objects have been set to 1 and the background is equal to 0. They include three fundamental binary processing functions: erosion, dilation, and hit-miss. The other transformations derive from combinations of these three functions.

The primary morphology transformations are described in detail in this section of the manual. They include: erosion, dilation, opening, closing, inner gradient, outer gradient, hit-miss, thinning, thickening, proper-opening, proper-closing, and auto-median.

☞ **Note:** ***In the following descriptions, the term pixel denotes a pixel equal to 1 and the term object denotes a group of pixels equal to 1.***

Erosion Function

An *erosion* eliminates pixels isolated in the background and erodes the contour of objects with respect to the template defined by the structuring element.

Concept and Mathematics

For a given pixel P_0, the structuring element is centered on P_0. The pixels masked by a coefficient of the structuring element equal to 1 are then referred as P_i. In the example of a structuring element 3 × 3, the P_i can range from P_0 itself to P_8.

1. *If* the value of one pixel P_i is equal to 0, *then* P_0 is set to 0, *else* P_0 is set to 1.
2. *If* AND(P_i) = 1, *then* $P_0 = 1$, *else* $P_0 = 0$.

Dilation Function

A *dilation* has the reverse effect of an erosion because dilating objects is equivalent to eroding the background. This function eliminates tiny holes isolated in objects and expands the contour of the objects with respect to the template defined by the structuring element.

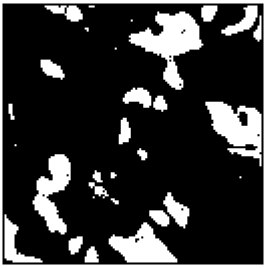
Concept and Mathematics

For a given pixel P_0, the structuring element is centered on P_0. The pixels masked by a coefficient of the structuring element equal to 1 then are referred to as P_i. In the example of a structuring element 3 × 3, the P_i can range from P_0 itself to P_8.

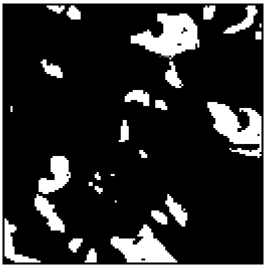
1. *If* the value of one pixel P_i is equal to 1, *then* P_0 is set to 1, *else* P_0 is set to 0.
2. *If* OR(P_i) = 1, *then* P_0 = 1, *else* P_0 = 0.

Erosion and Dilation Examples

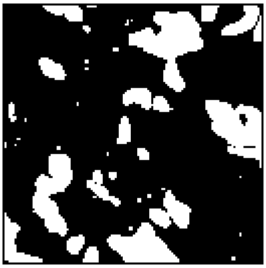
This example uses the following binary source image.



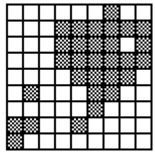
The erosion function produces the following image.



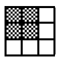
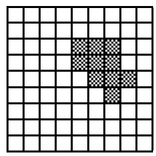
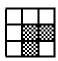
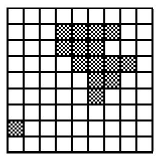
The dilation function produces the following image.

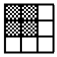
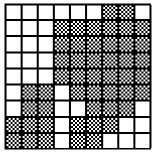
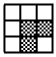
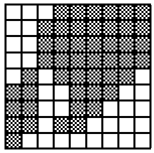


The next example uses the following source image. Gray cells indicate pixels equal to 1.



The following tables show how the structuring element can be used to control the effect of an erosion or a dilation. The larger the structuring element, the more templates can be edited and the more selective the effect.

Structuring Element	After Erosion	Description
		A pixel is cleared if it is equal to 1 and does not have its three upper-left neighbors equal to 1. The erosion truncates the upper-left borders of the objects.
		A pixel is cleared if it is equal to 1 and does not have its lower and right neighbors equal to 1. The erosion truncates the bottom and right borders of the objects, but retains the corners.

Structuring Element	After Dilation	Description
		A pixel is set to 1 if it is equal to 1 or if it has one of its three upper-left neighbors equal to 1. The dilation expands the lower-right borders of the objects.
		A pixel is set to 1 if it is equal to 1 or if it has its lower or right neighbor equal to 1. The dilation expands the upper and left borders of the objects.

Opening Function

The *opening function* is an erosion followed by a dilation. This function removes small objects and smoothes boundaries. *If I* is an image,

$$opening(I) = dilation(erosion(I)).$$

This operation does not alter the area significantly and shape of objects because erosion and dilation are dual transformations. Borders removed by the erosion are restored by the dilation. However, small objects that vanish during the erosion do not reappear after the dilation.

Closing Function

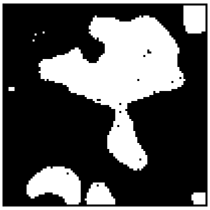
The *closing function* is a dilation followed by an erosion. It fills tiny holes and smoothes boundaries. *If I* is an image,

$$closing(I) = erosion(dilation(I)).$$

This operation does not alter significantly the area and shape of objects because dilation and erosion are morphological complements. Borders expanded by the dilation function are reduced by the erosion function. However, tiny holes filled during the dilation do not reappear after the erosion.

Opening and Closing Examples

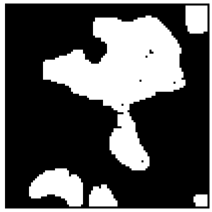
The following series of graphics illustrate examples of openings and closings.



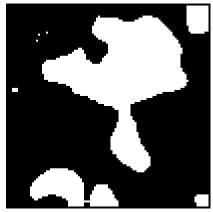
Original Image

$$\begin{matrix}1 & 1 & 1\\ 1 & 1 & 1\\ 1 & 1 & 1\end{matrix}$$

Structuring Element



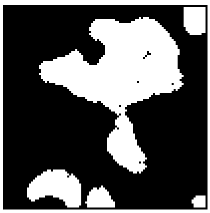
After Opening



After Closing

$$\begin{matrix}1 & 1 & 1 & 1 & 1\\ 1 & 1 & 1 & 1 & 1\\ 1 & 1 & 1 & 1 & 1\\ 1 & 1 & 1 & 1 & 1\\ 1 & 1 & 1 & 1 & 1\end{matrix}$$

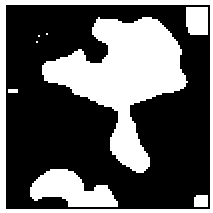
Structuring Element



After Opening

$$\begin{matrix}0 & 0 & 1 & 0 & 0\\ 1 & 1 & 1 & 1 & 1\\ 0 & 1 & 1 & 1 & 0\\ 0 & 0 & 1 & 0 & 0\end{matrix}$$

Structuring Element



After Closing

External Edge Function

The *external edge* subtracts the source image from the dilated image of the source image. The remaining pixels correspond to the pixels added by the dilation. *If I* is an image,

$$\textit{external edge}(I) = \textit{dilation}(I) - I = \mathrm{XOR}(I, \textit{dilation}(I)).$$

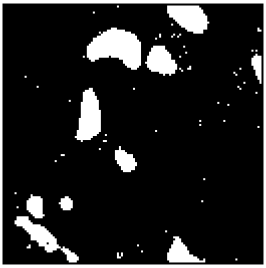
Internal Edge Function

The *internal edge* subtracts the eroded image from its source image. The remaining pixels correspond to the pixels eliminated by the erosion. If *I* is an image,

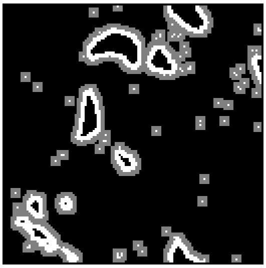
$$\textit{internal edge}(I) = I - \textit{erosion}(I) = \mathrm{XOR}(I, \textit{dilation}(I)).$$

External and Internal Edge Example

This example uses the following binary source image.



Extraction using a 5 × 5 structuring element produces the following image. The superimposition of the internal edge is in white and the external edge is in gray.



The thickness of the extracted contours depends on the size of the structuring element.

Hit-Miss Function

You can use the *hit-miss function* to locate particular configurations of pixels. It extracts each pixel of an image that is placed in a neighborhood matching exactly the template defined by the structuring element. Depending on the configuration of the structuring element, the hit-miss function can be used to locate single isolated pixels, cross-shape or longitudinal patterns, right angles along the edges of objects, and other user-specified shapes. The larger the size of the structuring element, the more specific the researched template can be.

Concept and Mathematics

For a given pixel P_0, the structuring element is centered on P_0. The pixels masked by the structuring element are then referred as P_i. In the example of a structuring element 3 × 3, the P_i range from P_0 to P_8.

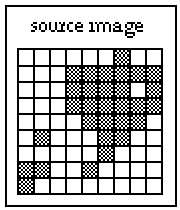
If the value of each pixel P_i is equal to the coefficient of the structuring element placed on top of it, *then* the pixel P_0 is set to 1, *else* the pixel P_0 is set to 0.

In other words, *if* the pixels P_i define the exact same template as the structuring element, *then* P_0 is set to 1, *else* P_0 is set to 0.

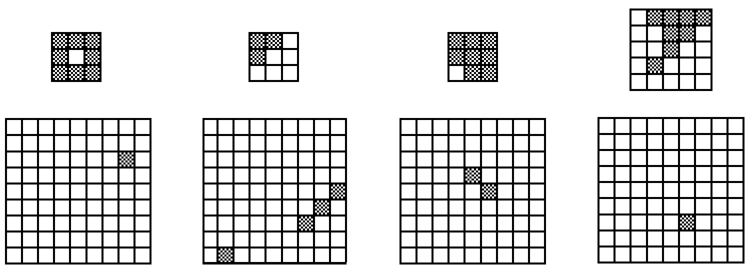
A hit-miss function using a structuring element with a central coefficient equal to 0 changes all pixels set to 1 in the source image to the value 0.

Example 1

This example uses the following source image.

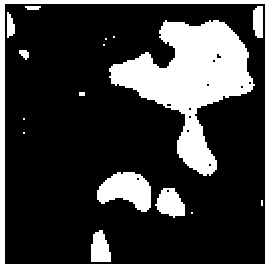


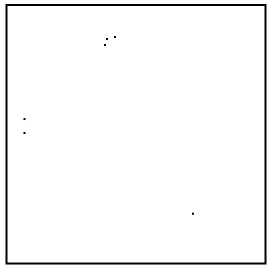
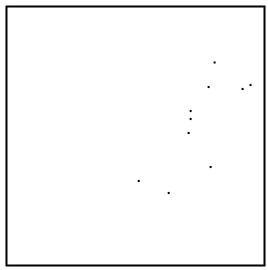
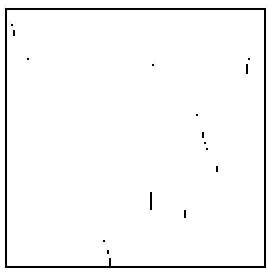
The following series of graphics shows the results of three hit-miss functions applied to the same source image. Each hit-miss function uses a different structuring element (specified above each transformed image). Gray cells indicate pixels equal to 1.



Example 2

This example uses the following binary source image. Given this binary image, the hit-miss function can be used to locate pixels surrounded by various patterns specified via the structuring element.



Use the hit-miss function to locate pixels isolated in a background. The structuring element presented on the right extracts all pixels equal to 1 that are surrounded by at least two layers of pixels equal to 0.	0 0 0 0 0 0 0 0 0 0 0 0 **1** 0 0 0 0 0 0 0 0 0 0 0 0	
Use the hit-miss function to locate single pixel holes in objects. The structuring element presented on the right extracts all pixels equal to 0 that are surrounded by at least one layer of pixels equal to 1.	1 1 1 1 **0** 1 1 1 1	
Use the hit-miss function to locate pixels along a vertical left edge. The structuring element presented on the right extracts pixels surrounded by at least one layer of pixels equal to 1 to the left and pixels equal to 0 to the right.	1 1 0 1 **1** 0 1 1 0	

Thinning Function

The *thinning function* eliminates pixels that are located in a neighborhood that matches a template specified by the structuring element. Depending on the configuration of the structuring element, thinning can be used to remove single pixels isolated in the background and right angles along the edges of objects. The larger the size of the structuring element, the more specific the template can be.

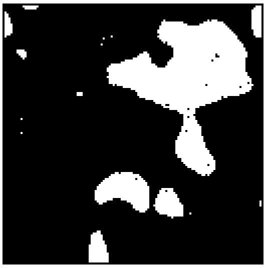
The thinning function extracts the intersection between a source image and its transformed image after a hit-miss function. In binary terms, the operation subtracts its hit-miss transformation from a source image. *If I* is an image,

$$thinning(I) = I - hit\text{-}miss(I) = \text{XOR}\,(I, hit\text{-}miss(I)).$$

This operation is useless when the central coefficient of the structuring element is equal to 0. In such cases, the hit-miss function can only change the value of certain pixels in the background from 0 to 1. The subtraction of the thinning function then resets these pixels back to 0 anyway.

Examples

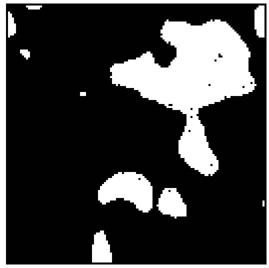
This example uses the following binary source image.



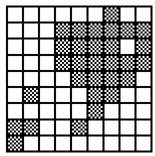
This example uses the thinning function and the following structuring element:

0	0	0
0	1	0
0	0	0

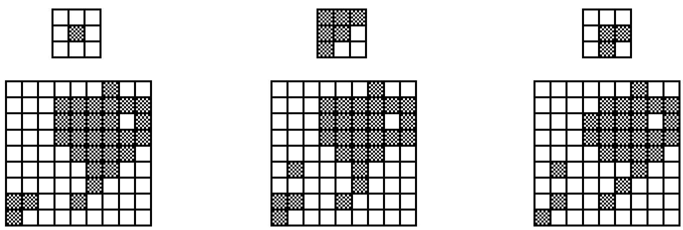
Thinning produces the following image. Single pixels in the background of this image have been removed.



The next example uses the following source image.



The following series of graphics shows the results of three thinnings applied to the source image. Each thinning uses a different structuring element (specified above each transformed image). Gray cells indicate pixels equal to 1.



Thickening Function

The *thickening function* adds to an image those pixels located in a neighborhood that matches a template specified by the structuring element. Depending on the configuration of the structuring element, thickening can be used to fill holes, smooth right angles along the edges of objects, and so forth. The larger the size of the structuring element, the more specific the template can be.

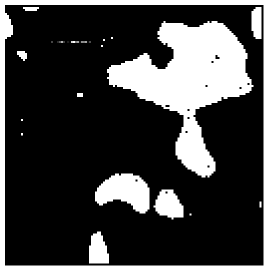
The thickening function extracts the union between a source image and its transformed image after a hit-miss function that uses the structuring element specified for the thickening. In binary terms, the operation adds a hit-miss transformation to a source image. *If I* is an image,

$$thickening(I) = I + hit\text{-}miss(I) = \text{OR}\ (I, hit\text{-}miss(I)).$$

This operation is useless when the central coefficient of the structuring element is equal to 1. In such case, the hit-miss function only can turn certain pixels of the objects from 1 to 0. The addition of the thickening function resets these pixels to 1 anyway.

Examples

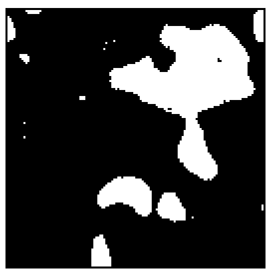
This example uses the following binary source image.



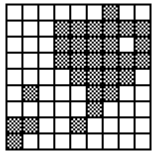
Thickening using the structuring element

$$\begin{matrix} 1 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 1 \end{matrix}$$

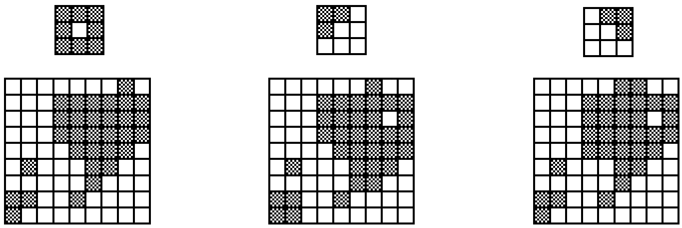
produces the following image. Single pixel holes are filled.



The next example uses the following source image.



The following series of graphics shows the results of three thickenings applied to the source image. Each thickening uses a different structuring element (specified on top of each transformed image). Gray cells indicate pixels equal to 1.



Proper-Opening Function

The *proper-opening function* is a finite and dual combination of openings and closings. It removes small particles and smoothes the contour of objects with respect to the template defined by the structuring element.

If I is the source image, the proper-opening extracts the intersection between the source image *I* and its transformed image obtained after a closing, followed by and opening, and followed by another closing.

$$proper\text{-}opening(I) = \text{AND}(I, OCO(I)), \text{ or}$$
$$proper\text{-}opening(I) = \text{AND}(I, DEEDDE(I)),$$

where I is the source image,

E is an erosion,

D is a dilation,

O is an opening,

C is a closing,

F(*I*) is the image obtained after applying the function *F* to the image *I*, and

GF(*I*) is the image obtained after applying the function *F* to the image *I* followed by the function *G* to the image *I*.

Proper-Closing Function

The *proper-closing function* is a finite and dual combination of closings and openings. It fills tiny holes and smoothes the inner contour of objects with respect to the template defined by the structuring element.

If I is the source image, the proper-closing extracts the union of the source image *I* and its transformed image obtained after an opening, followed by and closing, and followed by another opening.

$$proper\text{-}closing(I) = \mathrm{OR}(I, COC(I)), \text{ or}$$
$$proper\text{-}closing(I) = \mathrm{OR}(I, EDDEED(I)),$$

where I is the source image,

E is an erosion,

D is a dilation,

O is an opening,

C is a closing,

F(*I*) is the image obtained after applying the function *F* to the image *I*, and

GF(*I*) is the image obtained after applying the function *F* to the image *I* followed by the function *G* to the image *I*.

Auto-Median Function

The *auto-median function* uses dual combinations of openings and closings. It generates simpler objects that have fewer details.

If I is the source image, the auto-median function extracts the intersection between the proper-opening and proper-closing of the source image *I*.

$$auto\text{-}median(I) = \mathrm{AND}(OCO(I), COC(I)), \text{ or}$$
$$auto\text{-}median(I) = \mathrm{AND}(DEEDDE(I), EDDEED(I)),$$

where I is the source image,

E is an erosion,

D is a dilation,

O is an opening,

C is a closing,

$F(I)$ is the image obtained after applying the function F to the image I, and

$GF(I)$ is the image obtained after applying the function F to the image I followed by the function G to the image I.

Advanced Binary Morphology Functions

The advanced morphology functions are conditional combinations of fundamental transformations such as the binary erosion and dilation. They apply to binary images in which a threshold of 1 has been applied to objects and the background is equal to 0. The advanced binary morphology functions include the border, hole filling, labeling, lowpass filters, highpass filters, separation, skeleton, segmentation, distance, Danielsson, circle, and convex functions.

Note: ***In this section of the manual, the term pixel denotes a pixel equal to 1 and the term object denotes a group of pixels equal to 1.***

Border Function

The *border function* removes objects that touch the border of the image. These objects may have been truncated during the digitization of the image, and their elimination might be useful to avoid erroneous particle measurements and statistics.

Hole Filling Function

The *hole filling function* fills the holes within objects.

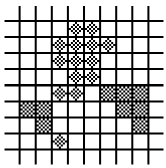
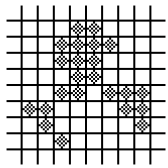
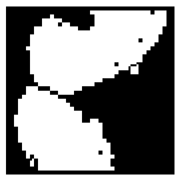
Labeling Function

The *labeling function* assigns a different gray-level value to each object. The image produced is not a binary image, but a labeled image using a number of gray-level values equal to the number of objects in the image plus the gray level 0 used in the background area.

The labeling function can identify objects using connectivity-4 or connectivity-8 criteria.

Lowpass Filters

The *lowpass filter* removes small objects with respect to their width (specified by a parameter called *filter size*).

	Connectivity-4	**Connectivity-8**
Definition Two pixels are considered as part of the same object if they are horizontally or vertically adjacent.	The pixels are considered as part of two different objects if they are diagonally adjacent.	The pixels are considered as part of the same object if they are horizontally, vertically, or diagonally adjacent.
Illustration For a same pixel pattern, different sets of objects can be identified.		
Example		

For a given filter size N, the lowpass filter eliminates objects with a width less than or equal to $(N - 1)$ pixels. These objects are those that would disappear after $(N - 1)/2$ erosions.

Highpass Filters

The *highpass filter* removes large objects with respect to their width (specified by a parameter called filter size).

For a given filter size N, the highpass filter eliminates objects with a width greater than or equal to N pixels. These objects are those which would not disappear after ($N/2 + 1$) erosions.

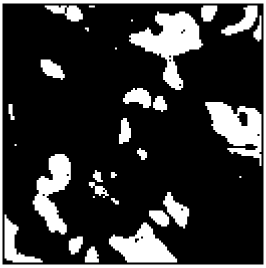
Both the highpass and lowpass morphological filters use erosions to determine if an object is to be removed. Therefore, they cannot discriminate objects with a width of $2k$ pixels from objects with a width of $2k - 1$ pixels. For example, one erosion eliminates both objects that are 2-pixels and 1-pixel wide.

The precision of the filters then depends on the parity of the filter size N.

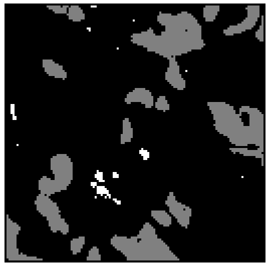
	Highpass filter	**Lowpass filter**
***If N* is an even number (*N* = 2*k*)**	• removes objects with a width greater than or equal to $2k$ • uses $k - 1$ erosions	• removes objects with a width less than or equal to $2k - 2$ • uses $k - 1$ erosions
***If N* is an odd number (*N* = 2*k* + 1)**	• removes objects with a width greater than or equal to $2k + 1$ • uses k erosions	• removes objects with a width less than or equal to $2k$ • uses k erosions

Lowpass and Highpass Example

This example uses the following binary source image.



For a given filter size, a highpass filter produces the following image. Gray objects and white objects are filtered out by a lowpass and highpass filter, respectively.



Separation Function

The *separation function* breaks narrow isthmuses and separates objects that touch each other with respect to an user-specified filter size.

For example, after thresholding an image, two gray-level objects overlapping one another might appear as a single binary object. A narrowing can be observed where the original objects intersected each other. *If* the narrowing has a width of M pixels, a separation using a filter size of $(M + 1)$ breaks it and restore the two original objects. This applies at the same time to all objects that contain a narrowing shorter than N pixels.

For a given filter size N, the separation function segments objects having a narrowing shorter than or equal to $(N – 1)$ pixels. These objects are those that are divided into two parts after $(N – 1)/2$ erosions.

This operation uses erosions, labeling, and conditional dilations.

The above definition is true when N is an odd number. It needs to be modified slightly when N is an even number. This modification is due to the use of erosions to determine if a narrowing has to be broken or kept. The function cannot discriminate a narrowing with a width of $2k$ pixels from a narrowing with a width of $(2k – 1)$ pixels. For example, one erosion breaks both a narrowing that is two pixels wide and a narrowing that is one pixel wide.

The precision of the separation is then limited to the elimination of constrictions having a width lesser than an even number of pixels:

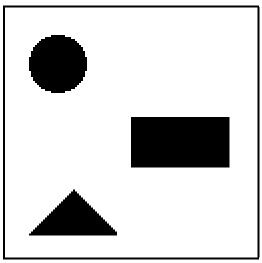
- *If N* is an even number (2*k*), the separation breaks a narrowing with a width smaller than or equal to (2*k* – 2) pixels. It uses (*k* – 1) erosions.
- *If N* is an odd number (2*k* + 1), the separation breaks a narrowing with a width smaller than or equal to 2*k*. It uses *k* erosions.

Skeleton Functions

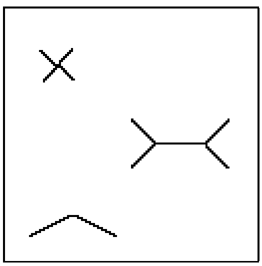
A *skeleton function* applies a succession of thinnings until the width of each object becomes equal to one pixel. The skeleton functions are both time- and memory-consuming. They are based on conditional applications of thinnings and openings using various configurations of structuring elements.

L-Skeleton Function

The *L-skeleton function* indicates the L-shaped structuring element skeleton function. For example, notice the following original image.

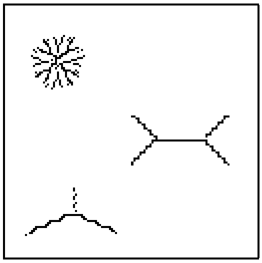


The L-skeleton function produces the following rectangle pixel frame image.



M-Skeleton Function

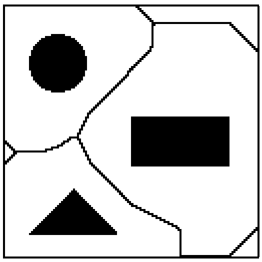
The *M-skeleton* (M-shaped structuring element) function extracts a skeleton with more dendrites or branches. Using the same original image as in the previous example, the M-skeleton function produces the following image.



Skiz Function

The *skiz* (skeleton of influence zones) function behaves like an L-skeleton applied to the background regions, instead of the object regions. It produces median lines that are at an equal distance from the objects.

Using the same source image as in the previous example, the skiz function produces the following image (shown after superimposition on top of the source image).

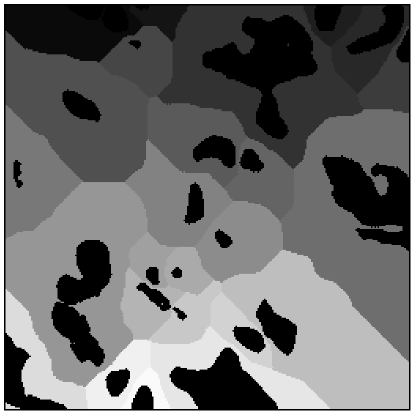


Segmentation Function

The *segmentation function* is only applied to labeled images. It partitions an image into segments, each centered on an object, such that they do not overlap each other or leave empty zones. This result is obtained by dilating objects until they touch one another.

☞ **Note:** ***The segmentation function is time-consuming. It is recommended that you reduce the image to its minimum significant size before selecting this function.***

In the following image, binary objects (shown in black) are superimposed on top of the segments (shown in gray shades).



When applied to an image with binary objects, the transformed image turns entirely red because it is entirely composed of pixels set to 1.

Comparisons Between Segmentation and Skiz Functions

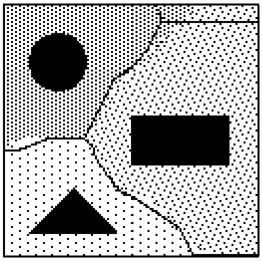
The segmentation function extracts segments that each contain one object and represent the area in which this object can be moved without intercepting another object (assuming that all objects move at the same speed).

The edges of these segments give a representation of the external skeletons of the objects. As opposed to the skiz function, segmentation does not involve median distances.

Segments are obtained by successive dilations of objects until they touch each other and cover the entire image. The final image contains as many segments as there were objects in the original image. On the other hand, if you consider the inside of closed skiz lines as segments, you might produce more segments than objects originally present in the image. Notice the upper-right region in the following example.

The following image shows:

- Original objects in black
- Segments in dotted patterns
- Skiz lines



Distance Function

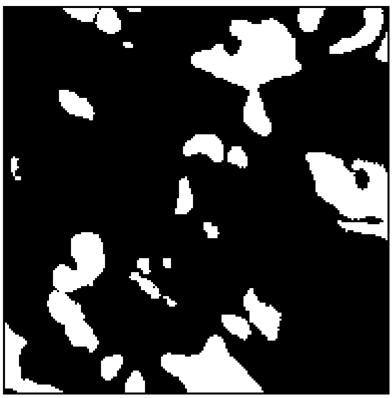
The *distance function* assigns to each pixel a gray-level value equal to the shortest distance to the border of the object. That distance may be equal to the distance to the outer border of the object or to a hole within the object.

Danielsson Function

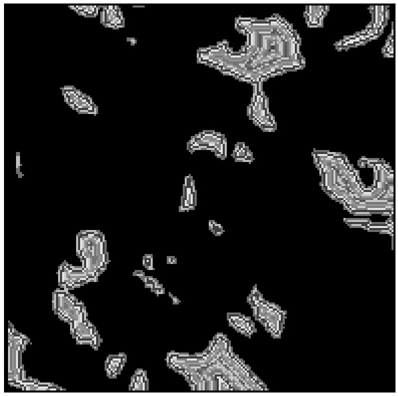
The *Danielsson function* also creates a distance map, but is a more accurate algorithm than the classical distance function. Use the Danielsson function instead of the distance function when possible.

Example

This example uses the following source threshold image.



The image is sequentially processed with a lowpass filter, hole filling, and the Danielsson function. The Danielsson function produces the following distance map image.



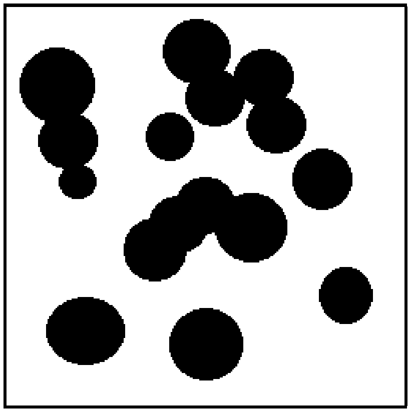
It is useful to view this final image with a binary palette. In this case, each level corresponds to a different color. The user easily can determine the relation of a set of pixels to the border of an object. The first layer (the layer that forms the border) is colored red. The second layer (the layer closest to the border) is green, the third layer is blue, and so forth.

Circle Function

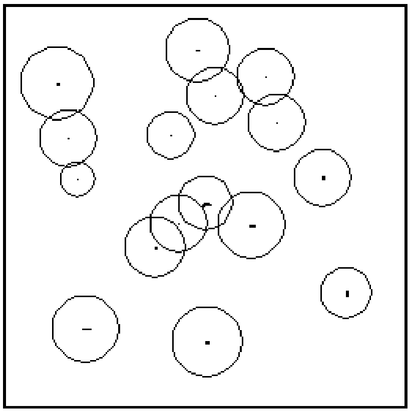
The *circle* function enables the user to separate overlapping circular objects. The circle function uses the Danielsson coefficient to reconstitute the form of an object, provided that the objects are essentially circular. The objects are treated as a set of overlapping discs that is then separated into separate discs. Therefore, it is possible to trace circles corresponding to each object.

Example

This example uses the following source image.



The circle function produces the following processed image.



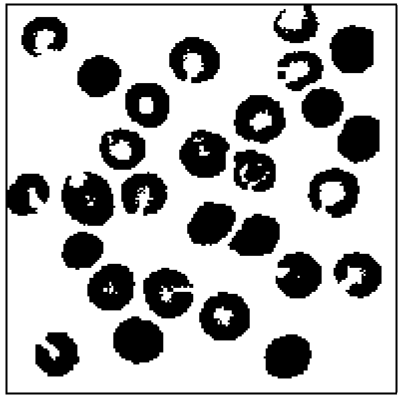
Convex Function

The *convex function* is useful for closing particles so that measurements can be made on the particle, even though the contour of the object is discontinuous. This command is usually needed in cases in which the sample object is cut because of the acquisition process.

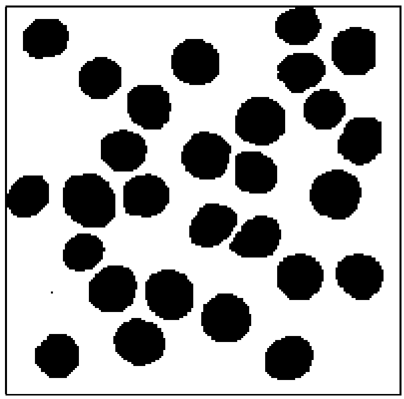
The convex function calculates a convex envelope around the perimeter of each object, effectively closing the object. The image to be treated must be both binary and labeled.

Example

This example uses the following original binary labeled image.



The convex function produces the following image.



Gray-Level Morphology

The gray-level morphology functions apply to gray-level images. You can use these functions to alter the shape of regions by expanding bright areas at the expense of dark areas and vice-versa. These functions smooth gradually varying patterns and increase the contrast in boundary areas. The gray-level morphology functions include the erosion, dilation, opening, closing, proper-opening, proper-closing, and auto-median functions. These functions derive from the combination of gray-level erosions and dilations that use the structuring element.

Erosion Function

A gray-level *erosion* reduces the brightness of pixels that are surrounded by neighbors with a lower intensity. The concept of neighborhood is determined by the template of the structuring element.

Concept and Mathematics

Each pixel P_0 in an image becomes equal to the minimum value of its neighbors. For a given pixel P_0, the structuring element is centered on P_0. The pixels masked by a coefficient of the structuring element equal to 1 are then referred as P_i. In the example of a 3 × 3 structuring element, P_i can range from P_0 to P_8.

$$P_0 = \min(P_i).$$

☞ **Note:** ***A gray-level erosion using a structuring element f × f with all its coefficients set to 1 is equivalent to an Nth order filter with a filter size f × f and the value N equal to 0 (refer to the nonlinear spatial filters).***

Dilation Function

The *gray-level dilation* has the same effect as the gray-level erosion, because dilating bright regions is equivalent to eroding dark regions. This function increases the brightness of each pixel that is surrounded by neighbors with a higher intensity. The concept of neighborhood is determined by the structuring element.

Concept and Mathematics

Each pixel P_0 in an image becomes equal to the maximum value of its neighbors. For a given pixel P_0, the structuring element is centered on P_0. The pixels masked by a coefficient of the structuring element equal to 1 are then referred as P_i. In the example of a structuring element 3 × 3, P_i can range from P_0 to P_8.

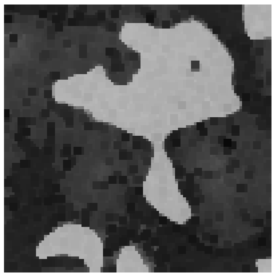
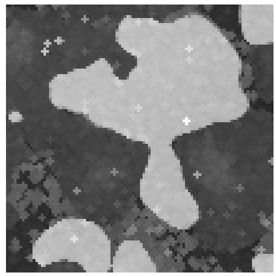
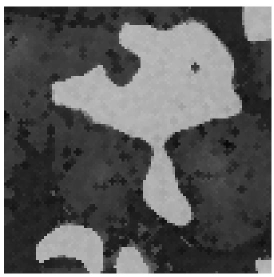
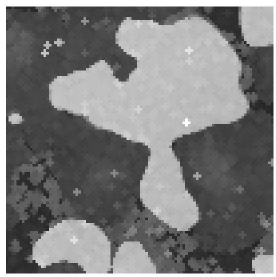
$$P_0 = \max(P_i).$$

☞ **Note:** ***A gray-level dilation using a structuring element f × f with all its coefficients set to 1 is equivalent to an Nth order filter with a filter size f × f and the value N equal to f × f – 1 (refer to the nonlinear spatial filters).***

Erosion and Dilation Examples

This example uses the following source image.

The following table provides example structuring elements, and the corresponding eroded and dilated images.

Structuring Element	Erosion	Dilation
1 1 1 1 1 1 1 1 1		
0 1 0 1 1 1 0 1 0		

Opening Function

The gray-level *opening function* consists of a gray-level erosion followed by a gray-level dilation. It removes bright spots isolated in dark regions and smoothes boundaries. The effects of the function are moderated by the configuration of the structuring element.

$$opening(I) = dilation(erosion\ (I)).$$

This operation does not alter significantly the area and shape of objects because erosion and dilation are morphological opposites. Bright borders reduced by the erosion are restored by the dilation. However, small bright objects that vanish during the erosion do not reappear after the dilation.

Closing Function

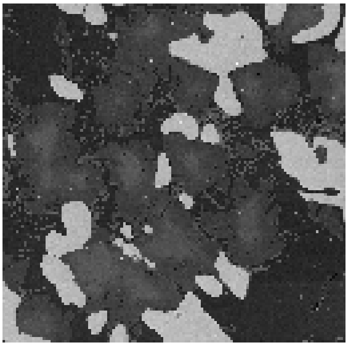
The gray-level *closing function* consists of a gray-level dilation followed by a gray-level erosion. It removes dark spots isolated in bright regions and smoothes boundaries. The effects of the function are moderated by the configuration of the structuring element.

$$closing(I) = erosion(dilation\ (I)).$$

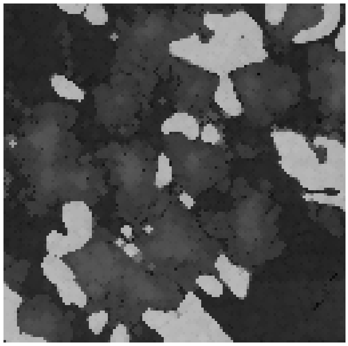
This operation does not alter significantly the area and shape of objects because dilation and erosion are morphological opposites. Bright borders expanded by the dilation are reduced by the erosion. However, small dark objects that vanish during the dilation do not reappear after the erosion.

Opening and Closing Examples

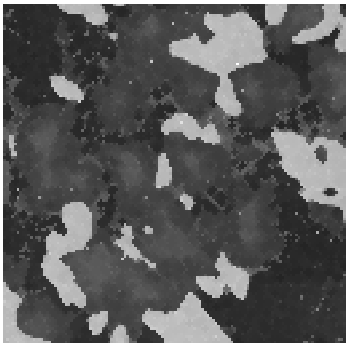
This example uses the following source image.



The opening function produces the following image.



Consecutive applications of an opening or closing command always give the same results. A closing function produces the following image.



Proper-Opening Function

The gray-level *proper-opening* is a finite and dual combination of openings and closings. It removes bright pixels isolated in dark regions and smoothes the boundaries of bright regions. The effects of the function are moderated by the configuration of the structuring element.

If I is the source image, the proper-opening extracts the minimum value of each pixel between the source image *I* and its transformed image obtained after a closing, followed by an opening, and followed by another closing.

$$proper\text{-}opening(I) = \min(I, OCO\,(I)), \text{ or}$$
$$proper\text{-}opening(I) = \min(I, DEEDDE(I)),$$

where I is the source image,

E is an erosion,

D is a dilation,

O is an opening,

C is a closing,

$F(I)$ is the image obtained after applying the function F to the image I, and

$GF(I)$ is the image obtained after applying the function F to the image I followed by the function G to the image I.

Proper-Closing Function

The *proper-closing* is a finite and dual combination of closings and openings. It removes dark pixels isolated in bright regions and smoothes the boundaries of dark regions. The effects of the function are moderated by the configuration of the structuring element.

If I is the source image, the proper-closing extracts the maximum value of each pixel between the source image I and its transformed image obtained after an opening, followed by a closing, and followed by another opening.

$$proper\text{-}closing(I) = \max(I, COC(I)), \text{ or}$$
$$proper\text{-}closing(I) = \max(I, EDDEED(I)),$$

where I is the source image,

E is an erosion,

D is a dilation,

O is an opening,

C is a closing,

$F(I)$ is the image obtained after applying the function F to the image I, and

$GF(I)$ is the image obtained after applying the function F to the image I followed by the function G to the image I.

Auto-Median Function

The *auto-median function* uses dual combinations of openings and closings. It generates simpler objects that have fewer details.

If I is the source image, the auto-median extracts the minimum value of each pixel between the two images obtained by applying a proper-opening and a proper-closing of the source image *I*.

$$auto\text{-}median(I) = \min(OCO(I), COC(I)), \text{ or}$$
$$auto\text{-}median(I) = \min(DEEDDE(I), EDDEED(I)),$$

where I is the source image,

E is an erosion,

D is a dilation,

O is an opening,

C is a closing,

F(*I*) is the image obtained after applying the function *F* to the image *I*, and

GF(*I*) is the image obtained after applying the function *F* to the image *I* followed by the function *G* to the image *I*.

Chapter 8

Quantitative Analysis

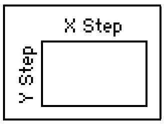
This chapter provides an overview of quantitative image analysis. The *quantitative analysis* of an image consists of obtaining *densitometry* and object measurements. Before starting this analysis, it is necessary to calibrate the image spatial dimensions and intensity scale to obtain measurements expressed in real units.

Spatial Calibration

Spatial calibration consists of correlating the area of a pixel with physical dimensions. The latter can be defined by three parameters: **X Step**, **Y Step**, and **Unit**.

X Step and **Y Step** are the horizontal and vertical lengths of a pixel. **Unit** is the selected unit of distance.

The area of a pixel is then equal to $(X\ Step \times Y\ Step)Unit^2$.



If a pixel represents a square area, *then*

$$X\ Step = Y\ Step = Sampling\ Step.$$

The spatial calibration of an image can be performed using two methods:

- *Pixel calibration*, or editing the dimensions of a single pixel
- *Distance calibration*, or editing a the length of a line selected in the image

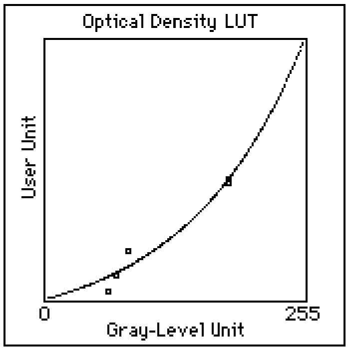
Intensity Calibration

Intensity calibration consists of correlating the gray-scale values to user-defined quantities such as optical densities or concentrations.

The intensity calibration of an image is performed in two steps:

- Selection of sample points in an image and calibration of their gray-level value
- Selection of a curve-fitting algorithm to calibrate the entire gray scale

The following example uses an 8-bit image, or 256 gray levels.



Definition of a Digital Object

In digital images, objects can be defined by three criteria: *intensity threshold*, *connectivity*, and *area threshold*.

Intensity Threshold

Objects are characterized by an *intensity range*. They are composed of pixels with gray-level values belonging to a given threshold interval (overall luminosity or gray shade). Then other pixels are considered part of the background.

The *threshold interval* is defined by the two parameters [**Lower Threshold**, **Upper Threshold**]. In the case of binary objects the Threshold Interval is [1, 1].

Connectivity

Once the pixels belonging to a specified intensity threshold are identified, they are grouped into objects. This process introduces the notion of adjacent pixels or connectivity.

In a rectangular pixel frame, each pixel P_0 has eight neighbors, as shown in the following graphic. From a mathematical point of view, the pixels P_1, P_3, P_5, P_7 are closer to P_0 than the pixels P_2, P_4, P_6, and P_8.

$$\begin{bmatrix} P_8 & P_1 & P_2 \\ P_7 & P_0 & P_3 \\ P_6 & P_5 & P_4 \end{bmatrix}$$

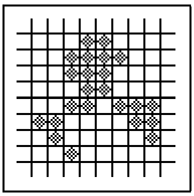
If D is the distance from P_0 to P_1, then the distances between P_0 and its eight neighbors can range from D to $\sqrt{2}\,D$, as shown in the following graphic.

$$\begin{bmatrix} \sqrt{2}D & D & \sqrt{2}D \\ D & 0 & D \\ \sqrt{2}D & D & \sqrt{2}D \end{bmatrix}$$

Connectivity-8

A pixel belongs to an object if it is at a distance D or $\sqrt{2}\,D$ from another pixel in the object.

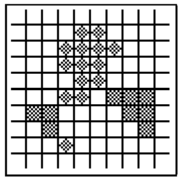
Two pixels are considered as part of a same object if they are horizontally, vertically, or diagonally adjacent. In the following image, the object count equals 1.



Connectivity-4

A pixel belongs to an object if it is at a distance *D* from another pixel in the object.

Two pixels are considered as part of a same object if they are horizontally or vertically adjacent. They are considered as part of two different objects if they are diagonally adjacent. In the following image, the object count equals 4.



Area Threshold

Finally a size criteria can be specified to detect only objects falling in a given area range.

The area threshold is defined by the two parameters [**Minimum Area**, **Maximum Area**].

Examples

In the following example, 1 pixel = 1 square inch.

Objects to Detect	Lower Threshold	Upper Threshold	Minimum Area	Maximum Area
Black objects (gray level 0) as small as 1 sq-µi.	0	0	1	65536
White objects (gray level 255) bigger than 500 sq-µi.	255	255	500	65536
Labeled objects placed in a black background and ranging from 200 to 1000 sq-µi.	1	255	200	1000
Light-gray objects belonging to the gray-level range [190, 200] and smaller than 3000 sq-µi.	190	200	1	3000

☞ **Note:** ***The most straightforward way to isolate objects is to use the threshold function and convert them to binary objects. This method offers the advantage of clearly showing the objects while the threshold interval remains constant and equal to [1, 1].***

Object Measurements

A digital object can be characterized by a set of morphological and intensity parameters described in the *Areas*, *Lengths*, *Coordinates*, *Chords and Axes*, *Shape Equivalence*, *Shape Features*, *Densitometry*, and *Diverse Measurements* sections.

Areas

This section describes the following area parameters:

- **Number of pixels**—Area in number of pixels
- **Particle area**—Area expressed in real units (based on image spatial calibration)
- **Scanned area**—Area of the entire image expressed in real units
- **Ratio**—Ratio of the object area to the entire image area
- **Number of holes**—Number of holes within the object
- **Holes' area**—Total area of the holes
- **Total area**—Area of the object including its holes' area (equals **Particle Area** + **Holes' Area**)

Particle Number

Identification number assigned to an object. Particles are numbered starting from 1 in increasing order from the upper-left corner of the image to the lower-right corner.

Number of Pixels

Number of pixels in an object. This value gives the area of an object, without holes, in pixel units.

Particle Area

Area of an object expressed in real units. This value is equal to **Number of pixels** when the spatial calibration is such that one pixel represents one square unit.

Scanned Area

Area of the entire image expressed in real units. This value is equal to the product (**Resolution X** × **X-Step**)(**Resolution Y** × **Y-Step**).

Ratio

The percentage of the image occupied by all objects.

$$\text{Ratio} = \frac{\textit{particle area}}{\textit{scanned area}}$$

Number of Holes

Number of holes inside an object. The software detects holes inside an object as small as 1 pixel.

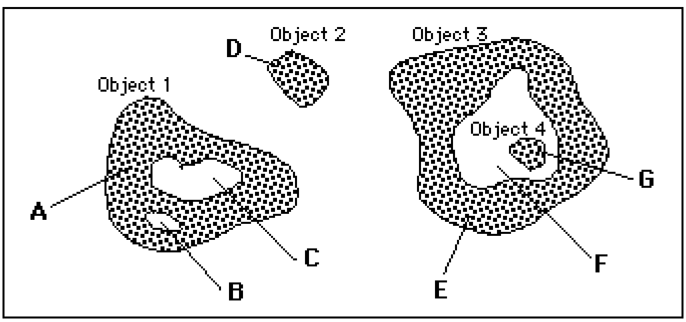
Holes' Area

Total area of the holes within an object.

Total area

Area of an object including the area of its holes. This value is equal to (**Particle Area** + **Holes' Area**).

☞ **Note:** ***An object located inside a hole of a bigger object is identified as a separate object. The area of a hole that contains an object includes the area covered by the object.***



Object #	**Particle Area**	**Holes' Area**	**Total Area**
Object 1	A	B + C	A + B + C
Object 2	D	0	D
Object 3	E	F + G	E + F + G
Object 4	G	0	G

Lengths

This section describes the following length parameters:

- **Particle perimeter**—Length of the outer contour.
- **Holes' perimeter**—Sum of the perimeters of the holes within the object
- **Width**—Distance between the left-most and right-most pixels in the object
- **Height**—Distance between the upper-most and lower-most pixels in the object

Particle Perimeter

Length of the outer contour of an object.

Holes' Perimeter

Sum of the perimeters of the holes within an object.

☞ **Note:** ***Holes' measurements can turn into valuable data when studying constituents A and B such that B is occluded in A. If the image can be processed so that the B regions appear as holes in A regions after a threshold, the ratio (Holes Area ÷ Particle Total Area) gives the percentage of B in A. Holes' perimeter gives the length of the boundary between A and B.***

Breadth

Distance between the left-most and right-most pixels in an object, or $\max(X_i) - \min(X_i)$. It is also equal to the horizontal side of the smallest horizontal rectangle containing the object, or the difference $\max X - \min X$.

Height

Distance between the upper-most and lower-most pixels in an object, or max(Y_i) – min(Y_i). It is also equal to the vertical side of the smallest horizontal rectangle containing the object, or the difference max$Y$ – min$Y$.

Coordinates

Coordinates are expressed with respect to an origin (0, 0), located at the upper-left corner of the image. This section describes the following coordinate parameters:

- **Center of Mass (X, Y)**—Coordinates of the center of gravity
- **Min X, Min Y**—Upper-left corner of the smallest horizontal rectangle containing the object
- **Max X, Max Y**—Lower-right corner of the smallest horizontal rectangle containing the object
- **Max chord X and Y**—Left-most point along the longest horizontal chord

Center of Mass X and Center of Mass Y

Coordinates of the center of gravity of an object. The center of gravity of an object composed of N pixels P_i is defined as the point G such that

$$\overline{OG} = \frac{1}{N}\sum_{i=1}^{i=N}\overline{OP_i}\text{, and}$$

$$\text{center of mass } X_G = \frac{1}{N}\sum_{i=1}^{i=N}X_i\,.$$

X_G gives the average location of the central points of horizontal segments in an object.

Center of Mass $Y_G = \frac{1}{N}\sum_{i=1}^{i=N}Y_i$.

Y_G gives the average location of the central points of horizontal segments in an object.

Note: ***G can be located outside an object if the latter has a convex shape.***

Min(X, Y) and Max(X, Y)

Coordinates of the upper-left and lower-right corners of the smallest horizontal rectangle containing an object.

The origin (0, X, Y) has two pixels that have the coordinates (min$X$, min$Y$) and (max$X$, max$Y$) such that

$$\text{min}X = \min(X_i)$$

$$\text{min}Y = \min(Y_i)$$

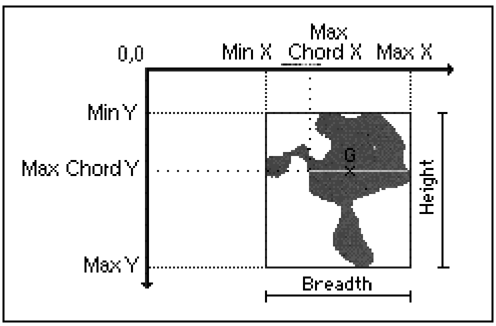
$$\text{max}X = \max(X_i)$$

$$\text{max}Y = \max(Y_i)$$

where X_i and Y_i are the coordinates of the pixels P_i in an object.

Max Chord X and Max Chord Y

Coordinates of the left-most pixel along the longest horizontal chord in an object.



Chords and Axes

This section describes the following chord and axis parameters:

- **Max chord length**—Length of the longest horizontal chord
- **Mean chord X**—Mean length of horizontal segments
- **Mean chord Y**—Mean length of vertical segments
- **Max intercept**—Length of the longest segment (in all possible directions)

- **Mean intercept perpendicular**—Mean length of the segments perpendicular to the max intercept
- **Particle orientation**—Orientation in degree with respect to the horizontal axis

Max Chord Length

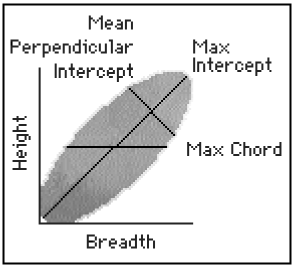
Length of the longest horizontal chord in an object.

Mean Chord X

Mean length of horizontal segments in an object.

Mean Chord Y

Mean length of vertical segments in an object.



Max Intercept

Length of the longest segment in an object (in all possible directions of projection).

Mean Intercept Perpendicular

Mean length of the segments in an object perpendicular to the max intercept.

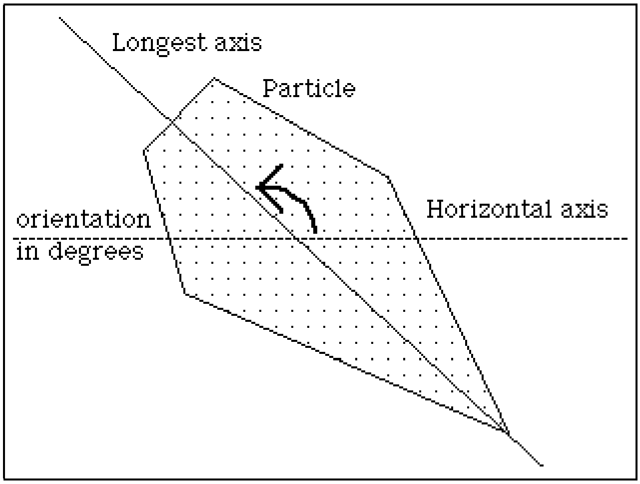
$$\text{Mean intercept perpendicular} = \frac{\textit{paricle area}}{\textit{max intercept}}$$

Particle Orientation

The angle of the longest axis with respect to the horizontal axis. The value can be between 0° and 180°.

Notice that this value does not give information regarding the symmetry of the particle.

Therefore, an angle of 190° is considered the same as 10°.



Shape Equivalence

This section describes the following shape-equivalence parameters:

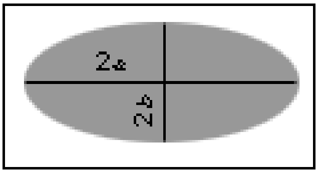
- **Equivalent ellipse minor axis**—Minor axis of the ellipse that has the same area as the object and a major axis equal to half its max intercept
- **Ellipse major axis**—Major axis of the ellipse that has the same area and same perimeter as the object
- **Ellipse minor axis**—Minor axis of the ellipse that has the same area and same perimeter as the object
- **Ellipse Ratio**—Ratio of the major axis of the equivalent ellipse to its minor axis
- **Rectangle big side**—Big side of the rectangle that has the same area and same perimeter as the object
- **Rectangle small side**—Small side of the rectangle that has the same area and same perimeter as the object
- **Rectangle ratio**—Ratio of the big side of the equivalent rectangle to its small side

Equivalent Ellipse Minor Axis

The *equivalent ellipse minor axis* is the minor axis of the ellipse that has the same area as the object and a major axis equal to half the max intercept of the object.

This definition gives the following set of equations:

$$\text{particle area} = \pi ab\text{, and}$$
$$\text{max intercept} = 2a.$$



The equivalent ellipse minor axis is defined as

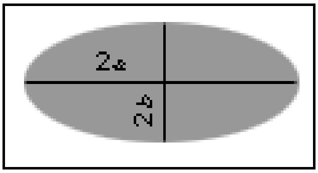
$$2b = \frac{4 \times \textit{particle area}}{\pi \times \textit{max intercept}}.$$

Ellipse Major Axis

The *ellipse major axis* is the total length of the major axis of the ellipse that has the same area and same perimeter as an object. This length is equal to $2a$.

This definition gives the following set of equations

$$\textit{Area} = \pi ab$$
$$\textit{Perimeter} = \pi\sqrt{2(a^2 + b^2)}$$



This set of equations can be expressed so that the sum $a + b$ and the product ab become functions of the parameters **Particle Area** and **Particle Perimeter**. a and b then become the two solutions of the polynomial equation $X^2 - (a + b)X + ab = 0$.

Notice that for a given area and perimeter, only one solution (*a*, *b*) exists.

Ellipse Minor Axis

The *ellipse minor axis* is the total length of the minor axis of the ellipse that has the same area and same perimeter as an object. This length is equal to 2*b*.

Ellipse Ratio

The *ellipse ratio* is the ratio of the major axis of the equivalent ellipse to its minor axis.

It is defined as $\frac{ellipse\ major\ axis}{ellipse\ minor\ axis} = \frac{a}{b}$.

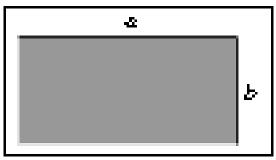
The more elongated the equivalent ellipse, the higher the ellipse ratio. The closer the equivalent ellipse is to a circle, the closer to 1 the ellipse ratio.

Rectangle Big Side

Rectangle big side is the length of the big side (*a*) of the rectangle that has the same area and same perimeter as an object.

This definition gives the following set of equations

$$Area = ab$$
$$Perimeter = 2(a + b)$$



This set of equations can be expressed so that the sum $a + b$ and the product ab become functions of the parameters **Particle Area** and **Particle Perimeter**. a and b then become the two solutions of the polynomial equation $X^2 - (a + b)X + ab = 0$.

Notice that for a given area and perimeter, only one solution (*a*, *b*) exists.

Rectangle Small Side

Rectangle small side is the length of the small side of the rectangle that has the same area and same perimeter as an object. This length is equal to b.

Rectangle Ratio

Rectangle ratio is the ratio of the big side of the equivalent rectangle to its small side.

It is defined as $\frac{\textit{rectangle big side}}{\textit{rectangle small side}} = \frac{a}{b}$.

The more elongated the equivalent rectangle, the higher the **Rectangle ratio**.

The closer the equivalent rectangle is to a square, the closer to 1 the **Rectangle ratio**.

Shape Features

This section describes the following shape-feature parameters:

- **Moments of Inertia**—Moments of Inertia I_{xx}, I_{yy}, I_{xy} with respect to the center of gravity
- **Elongation factor**—Ratio of the longest segment within the object to the mean length of the perpendicular segments
- **Compactness factor**—Ratio of the object area to the area of the smallest rectangle containing the object
- **Heywood Circularity factor**—Ratio of the object perimeter to the perimeter of the circle with the same area
- **Hydraulic Radius**—Ratio of the object area to its perimeter
- **Waddel Disk Diameter**—Diameter of the disk with the same area as the object

Moments of Inertia I_{xx}, I_{yy}, I_{xy}

The *moments of inertia* give a representation of the distribution of the pixels in an object with respect to its center of gravity.

Elongation Factor

The *elongation factor* is the ratio of the longest segment within an object to the mean length of the perpendicular segments. It is defined as

$$\frac{max\ intercept}{mean\ perpendicular\ intercept}.$$

The more elongated the shape of an object, the higher its elongation factor.

Compactness Factor

The *compactness factor* is the ratio of an object area to the area of the smallest rectangle containing the object. It is defined as

$$\frac{particle\ area}{breadth \times width}.$$

The compactness factor belongs to the interval [0, 1]. The closer the shape of an object is to a rectangle, the closer to 1 the compactness factor.

Heywood Circularity Factor

The *Heywood circularity factor* is the ratio of an object perimeter to the perimeter of the circle with the same area. It is defined as

$$\frac{particle\ perimeter}{perimeter\ of\ circle\ with\ same\ area\ as\ particle} = \frac{particle\ perimeter}{2\sqrt{\pi \times particle\ area}}.$$

The closer the shape of an object is to a disk, the closer the Heywood circularity factor to 1.

Hydraulic Radius

The *hydraulic radius* is the ratio of an object area to its perimeter. It is defined as

$$\frac{particle\ area}{particle\ perimeter}.$$

If a particle is a disk with a radius R, *then* its hydraulic radius is equal to

$$\frac{\pi R^2}{2\pi R} = \frac{R}{2}.$$

The hydraulic radius is equal to half the radius R of the circle such that

$$\frac{\textit{circle area}}{\textit{circle perimeter}} = \frac{\textit{particle area}}{\textit{particle perimeter}}.$$

Waddel Disk Diameter

Diameter of the disk with the same area as the particle. It is defined as

$$\frac{2\sqrt{\textit{particle area}}}{\sqrt{\pi}}.$$

The following tables list the definition of the primary measurements and the measurements that are derived from them.

Definitions of Primary Measurements

A	Area
p	Perimeter
Left	Left-most point
Top	Top-most point
Right	Right-most point
Bottom	Bottom-most point
P_x	Projection x
P_y	Projection y

Derived Measurements

Symbol	Derived Measurement	Primary Measurement
l	**Width**	Right – Left
h	**Height**	Bottom – Top
d	**Diagonal**	$\sqrt{l^2 + h^2}$
M_x	**Center of Mass X**	$(\Sigma x)/A$
M_y	**Center of Mass Y**	$(\Sigma y)/A$
I_{xx}	**Inertia XX**	$(\Sigma x^2) - A \times M_{x^2}$
I_{yy}	**Inertia YY**	$(\Sigma y^2) - A \times M_{y^2}$
I_{xy}	**Inertia XY**	$(\Sigma xy) - A \times M_x \times M_y$
C_x	**Mean Chord X**	A/P_y
C_y	**Mean Chord X**	A/P_x
$S_{\max}$	**Max Intercept**	$(C_{\max}/h)^2 \times \max(h, l) + d(1 - (C_{\max}/l)^2)$
C	**Mean Perpendicular Intercept**	$A/S_{\max}$
A_{2b}	**Equivalent Ellipse Minor Axis**	$4 \times A / (\pi S_{\max})$
$d°$	**Orientation**	*If* $I_{xx} = I_{yy}$, *then* $d° = 45$, *else* $d° = \dfrac{90}{\operatorname{atan}(2 \times I_{XY} \div (I_{XX} - I_{YY}))}$ *If* $I_{xx} \geq I_{yy}$ and $I_{xy} \geq 0$, *then* $d° = 180 - d°$ *If* $I_{xx} \geq I_{yy}$ and $I_{xy} < 0$, *then* $d° = -d°$ *If* $I_{xx} < I_{yy}$, *then* $d° = 90 - d°$ *If* $d° < 0$, *then* $d° = 0°$
E_{2a}	**Ellipse major axis (2*a*)**	$E_{2a} = \sqrt{\dfrac{p^2}{2\pi^2} + \dfrac{2\pi}{A}} + \sqrt{\dfrac{p^2}{2\pi^2} - \dfrac{2\pi}{A}}$

Symbol	Derived Measurement	Primary Measurement
E_{2b}	**Ellipse minor axis (2*b*)**	$E_{2b} = \sqrt{\frac{p^2}{2\pi^2} + \frac{2\pi}{A}} - \sqrt{\frac{p^2}{2\pi^2} - \frac{2\pi}{A}}$
E_{ab}	**Ellipse Ratio**	$E2_a / E2_b$
R_c	**Rectangle big side**	¼ $(p + t')$ *where* $t' = \sqrt{p^2 - 16A}$
r_c	**Rectangle small side**	¼ $(p - t')$ *where* $t' = \sqrt{p^2 - 16A}$
R_{Rr}	**Rectangle Ratio**	R_c / r_c
F_e	**Elongation factor**	$S_{\max} / C\pi$
F_c	**Compactness factor**	$A/(h \times l)$
F_H	**Heywood Circularity factor**	$\frac{p}{2\sqrt{\pi A}}$
F_t	**Type factor**	$\frac{A^2}{4\pi\sqrt{I_{XX} \times I_{YY}}}$
R_h	**Hydraulic Radius**	A/p
R_d	**Waddel Disk Diameter**	$2\sqrt{\frac{A}{\pi}}$

Densitometry

IMAQ Vision contains the following densitometry parameters:

- **Minimum Gray Value**—Minimum intensity value in gray-level units
- **Maximum Gray Value**—Maximum intensity value in gray-level units
- **Sum Gray Value**—Sum of the intensities in the object expressed in gray-level units
- **Mean Gray Value**—Mean intensity value in the object expressed in gray-level units
- **Standard deviation**—Standard deviation of the intensity values
- **Minimum User Value**—Minimum intensity value in user units

- **Maximum User Value**—Maximum intensity value in user units
- **Sum User Value—**Sum of the intensities in the object expressed in user units
- **Mean User Value** —Mean intensity value in the object expressed in user units
- **Standard deviation (Unit)**—Standard deviation of the intensity values in user units

Diverse Measurements

These primary coefficients are used in the computation of measurements such as moments of inertia and center of gravity. IMAQ Vision contains the following diverse-measurement parameters

- **SumX**—Sum of the *x* coordinates of each pixel in a particle
- **SumY**—Sum of the *y* coordinates of each pixel in a particle
- **SumXX, SumYY, SumXY**—Sum of *x* coordinates squared, sum of *y* coordinates squared, and sum of *x*y coordinates for each pixel in a particle
- **Corrected Projection X**—Sum of the horizontal segments that do not superimpose any other horizontal segment
- **Corrected Projection Y**—Sum of the vertical segments that do not superimpose any other horizontal segment

Chapter 9

VI Overview and Programming Concepts

This chapter contains an overview of IMAQ Vision programming concepts, describes the Base and Advanced versions of IMAQ Vision, and lists the VIs included in these versions. It also provides a summary of the icons used in the function reference chapters of this manual.

Images

An *image* is a function of the light intensity *f*(*x*, *y*) *where x* and *y* represent the spatial coordinates of a point in an image and *f* is the brightness of the point (*x*, *y*).

The pixel depth and the number of planes in an image determines the image type. Multiple image types are supported by IMAQ Vision.

The decision to encode an image in 8 bits, 16 bits, or in a floating value is influenced by several factors: the nature of the image, the type of image processing you need to use, and the type of analysis you need to perform. For example, 8-bit encoding is sufficient if you plan to perform a morphology analysis (for example, surface or elongation factor). On the other hand, if the goal is to obtain a highly precise quantification of the light intensity from an image or a region of an image, then 16-bit or 32-bit (floating-point) encoding is required.

VIs that perform frequency-domain operations can be applied to images that are Fourier transformed. Each pixel in a Fourier-transformed image, called a complex image, is encoded as 2 × 32-bit floating.

It is also possible to acquire and process a real color image, known as RGB chunky. This image type is encoded in 32 bits, 8 bits for the alpha channel (not used in IMAQ Vision), and 8 bits each for the red, green, and blue planes. The most common operation applied to this image type is the extraction of the color, light, saturation, or hue component from the image. The final result is an 8-bit image that can be processed as a classical monochrome image.

The image types mentioned above are all supported by IMAQ Vision. However, certain operations on specific image types do not have any practical sense (for example, applying the logic operator AND to a complex image). Other image types, particularly images encoded in files as 1-bit, 2-bit, or 4-bit images are not directly supported by IMAQ Vision. In these cases, IMAQ Vision automatically transforms the image into an 8-bit image (minimum for IMAQ Vision) when opening the image file. This transformation is transparent and has no effect on the use of these image types in IMAQ Vision.

In IMAQ Vision, the image type is defined at the creation of the image object by the VI IMAQ Create. The default image type is 8-bit (a single image plane encoded in 8 bits per pixel), the most prevalent image type for the scientific and industrial fields. IMAQ Vision, however, is designed to acquire and process images encoded in 10-bit, 12-bit, or 16-bit as well as in floating point and true color (RGB).

IMAQ Vision VIs

This section describes the organization of the IMAQ Vision VIs. It also describes the icons used in both IMAQ Vision and the VI reference chapters in this manual.

Image-Type Icons

In this manual, the following icons describe the image types supported by each VI.

Icon	Type	Description
	0	8 bits per pixel (unsigned, standard monochrome)
	1	16 bits per pixel (signed)
	2	32 bits (floating point) per pixel
	3	2 × 32 bits (floating point) per pixel (native format after a FFT)
	4	32 bits per pixel (RGB chunky, standard color)

An IMAQ Vision image has other attributes in addition to its type and size. The calibration attribute defines the physical horizontal and vertical dimensions of the pixels. The ability to calibrate two axes permits you to correct defaults resulting from the captor (not uncommon). These coefficients are used only when performing calculations (for example, surface or perimeter) based on morphological transformations. They have no effect on either processing or operations between images.

For optimization reasons, a border also exists. This border is a space that is physically reserved in the image and it is completely transparent to you. This border is necessary when you want to perform a morphological transformation, a convolution, or particle analysis. These processes all use neighboring operations between pixels. These operations consist of applying a new value to a pixel in relation to the value of its neighbor. The advantage of the border is that all pixels can be treated the same when performing these types of operations.

A detailed discussion of the techniques used for image analysis can be found in chapters 1 through 8 of this manual. These methods can be applied directly to an application built with IMAQ Vision and LabVIEW or BridgeVIEW.

MMX Compatibility of IMAQ Vision for G

This section discusses MMX technology and the MMX features available in IMAQ Vision for G.

About Intel MMX Technology

Intel released its first Pentium chip with MMX technology early in 1997 and since then has released the Pentium II chip, a Pentium Pro chip with MMX technology. These new chips are completely compatible with existing Intel architecture and operating systems and are applications transparent. MMX technology consists of 57 new instructions, which operate on a new 64-bit data type (QWORD), and eight new 64-bit registers. Those instructions can do calculations on eight BYTE, four WORD, or two DWORD simultaneously, which theoretically can speed up calculations two, four, or eight times. However, MMX has some restrictions. A significant restriction is that MMX instructions cannot handle floating-point calculations, and extra CPU time is need to switch from MMX instructions to regular floating-point instructions.

Overview of MMX Features in IMAQ Vision for G

Currently IMAQ Vision supports Intel MMX technology in the areas of arithmetic operations, logic operations, comparison operations, linear filtering, morphology, and processing operations. Only those algorithms suitable for MMX optimization were chosen.

At the first instance of a VI from IMAQ Vision, the presence of the MMX capability of the CPU is automatically detected and a MMX enabling flag is set. During subsequent VI executions, IMAQ Vision will execute MMX instructions if the MMX enabling flag is set and regular instructions if the MMX enabling flag is not set.

The following special considerations apply to the use of MMX with IMAQ Vision:

- Only 8-bit image types are optimized.
- For operations where the use of a mask is permitted, only the case where no mask is specified is optimized.
- For the maximum optimization of the MMX instructions, you should try to align your image data width to a multiple of eight pixels. For the following operations, alignment of four pixels is required to achieve maximum optimization: multiply, multiply constant, average, average constant, sigma, Sobel, Prewitt, lowpass, convolute, and correlate.
- Convolution is best optimized when the scaling factor is 1.

MMX Icon

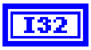
In this manual, the following symbol designates functions that are optimized for MMX.

IMAQ VI Error Clusters

Your IMAQ VIs use a standard control and indicator (**error in** and **error out**) to notify you that an error has occurred. The **error in** and **error out** parameters are described here.

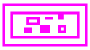
error in (no error) is a cluster that describes the error status before this VI executes. If **error in** indicates that an error occurred before this VI was called, this VI might choose not to execute its function, but just pass the error through to its **error out** cluster. If no error has occurred, this VI executes normally and sets its own error status in **error out**. Use the Error Handler VIs to look up the error code and to display the corresponding error message. Using **error in** and **error out** clusters is a convenient way to check errors and to specify execution order by wiring the error output from one subVI to the error input of the next.

status is TRUE if an error occurred before this VI was called, or FALSE if not. If **status** is TRUE, **code** is a nonzero error code. If **status** is FALSE, **code** can be 0 or a warning code.



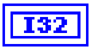
code is the number identifying an error or warning. If **status** is TRUE, **code** is a nonzero error code. If **status** is FALSE, **code** can be 0 or a warning code. Use the Error Handler VIs to look up the meaning of this code and to display the corresponding error message.

source is a string that indicates the origin of the error, if any. Usually, **source** is the name of the VI in which the error occurred.



error out is a cluster that describes the error status after this VI executes. If an error occurred before this VI was called, **error out** is the same as **error in**. Otherwise, **error out** shows the error, if any, that occurred in this VI. Use the Error Handler VIs to look up the error code and to display the corresponding error message. Using **error in** and **error out** clusters is a convenient way to check error and to specify execution order by wiring the error output from one subVI to the error input of the next.

status is TRUE if an error occurred, or FALSE if not. If **status** is TRUE, **code** is a nonzero error code. If **status** is FALSE, **code** can be 0 or a warning code.

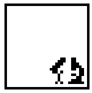


code is the number identifying an error or warning. If **status** is TRUE, **code** is a nonzero error code. If **status** is FALSE, **code** can be 0 or a warning code. Use the Error Handler VIs to look up the meaning of this code and to display the corresponding error message.

source is a string that indicates the origin of the error, if any. Usually, **source** is the name of the VI in which the error occurred.

Base and Advanced Versions of IMAQ Vision

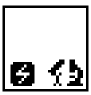
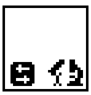
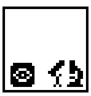
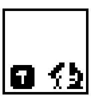
IMAQ Vision is available in both a Base version and an Advanced version.



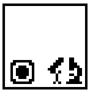
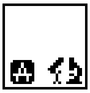
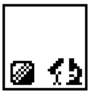
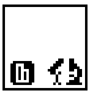
The description of each VI is accompanied by an icon that denotes whether the VI is included in both the Base and Advanced versions  or the Advanced version only  .

VIs in the Base and Advanced Versions

Both versions of IMAQ Vision contain the following VI families.

Icon	Name of VI Family	Chapter	Functionality of VIs
	Management	10	Creating, listing, and disposing of image structures Error handling for all the VIs in IMAQ Vision
	Files	11	Image acquisition Reading and writing images to and from disk files
	Display (basics, special, tools, and user)	12	All aspects of image visualization (color palettes) and its control; you can control up to 16 image windows as well as six user floating windows Image window managers that you can use to select various tools for creating and manipulating a region of interest
	Tools* (pixels, image, and diverse)	13	Manipulation of images (for example, reduction, expansion, extraction, and modification of pixel values) Transformation of the contents of an image to and from a LabVIEW array

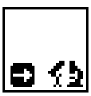
*Certain Tools and Analysis VIs are restricted to the Advanced version of IMAQ Vision.

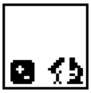
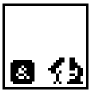
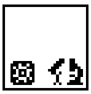
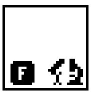
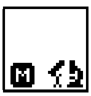
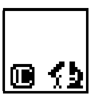
	Analysis*	19	Analysis of the contents of an image
	Geometry	20	3D view, rotate, shift, and symmetry
	Color	22	Color image processing and analysis (histogram, threshold) Manipulation of color images planes (conversions)
	External Library Support	23	Access to information about image pixel organization. Useful for creating device-driver VIs

*Certain Tools and Analysis VIs are restricted to the Advanced version of IMAQ Vision.

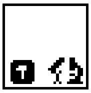
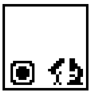
VIs in the Advanced Version Only

IMAQ Vision Advanced contains all the functions found in Base as well as an additional set of VIs.

Icon	Name of VI Family	Chapter	Functionality of VIs
	Conversion	14	Linear or nonlinear conversions from one image type into another

Icon	Name of VI Family	Chapter	Functionality of VIs
 	Operators (Arithmetic, Logic, and Comparison)	15	Addition, Subtraction, Multiplication, Division, Ratio and Modulo between two images or between one image and a constant Logic operators include AND, NAND, OR, NOR, XOR, XNOR, and LogDiff between two images or between one image and a constant. Clear or Set as a function of a relational operator between two images or between one image and a constant Masking and the extraction of a minimum, maximum, or average can be performed between two images or between an image and a constant
	Processing	16	Threshold, Label, LUT (lookup table), Transformation, and so forth
	Filters	17	Convolutions, construction and choosing of user-defined kernels Nonlinear Filters (for example, gradient, lowpass, Prewitt, Sobel, and Roberts)
	Morphology	18	Morphology functions for editing binary images, including erosions, dilations, closings, openings, edge detection, thinning, thickening, hole filling, low pass, high pass, distance mapping, and rejection of particles touching the border Morphology functions for modifying gray scale images, including erosions, dilations, closings, openings, and auto-median
	Complex	21	Frequency processing including FFT, Inverse FFT, Truncation, Attenuation, Addition, Subtraction, Multiplication, and Division for complex images Functions for extraction and manipulation of planes

In the Advanced version, the following VIs are added to the existing VI families.

Icon	Name of VI Family	Chapter	Functionality of VIs
	Tools	13	Calibration, control of offset, and the ability to create a mask starting from a user-selected point and a user-defined tolerance value
	Analysis	19	Simple and complex particle detection Extraction of measurement and morphological coefficients for each object in an image

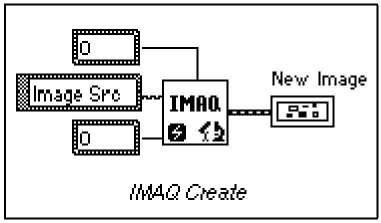
Manipulation of Images by IMAQ Vision

An 8-bit encoded image, possessing a resolution 512 × 512 occupies 262,144 bytes or 256 KB of memory. Because LabVIEW and BridgeVIEW cannot realistically handle these large regions of memory, IMAQ Vision itself is responsible for managing these image spaces.

Inherent in all VIs belonging to the IMAQ Vision library is an input of one or more image structures. These structures are managed directly by IMAQ Create. Each image must be given a unique name that is a generic structure representing all aspects contained and associated with an image. An image structure can contain different data or information. The image structure is dependent on the image processing and type of functions that you need to perform.

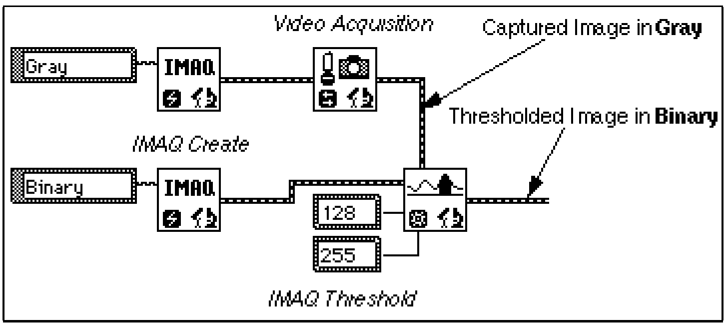
This image structure which enters each VI is a specific data type (a cluster in the *G* programming language) resulting directly or indirectly form the execution of IMAQ Create. In order to execute its operation, the VI must have information about which image is processed and which image (the original or another) should receive the results. This image structure provides this information when entering a VI.

To create an image, use the procedure illustrated in the following graphic.



An image is created and referenced by the name **Image Src**. This name is displayed in the VI front panel of all VIs that receive data from this image structure. The cluster **New Image** resulting from the output must be connected with the **Image type** input. This connection identifies the image to be processed.

Multiple images can be created by executing IMAQ Create the number of times corresponding to the number of images desired. Each image created requires a unique name. The number or required images can be determined from an analysis of your intended application. The decision is based upon different processing phases and your need to keep the original image (after each processing step).

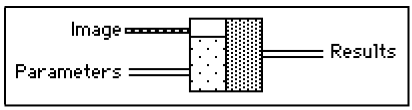


In the preceding example, two images (Gray and Binary) are created, and at the first stage are completely empty (the size is equal to (0, 0)). After the video acquisition, the Gray image contains the captured image at a size (*x*, *y*). Then a thresholding is performed using the VI IMAQ Threshold. Note that this VI possesses two inputs, **Image Src** and **Image Dst,** that receive the images Gray and Binary, respectively. Immediately prior to the execution of this function (IMAQ Threshold), the size of the Binary image is (0, 0). Immediately following this threshold, the Binary image has the exact same size as the Gray image and contains the data resulting from the threshold Gray image.

Depending on the type of function performed by a VI, different combinations of input and output are possible. In the above example, the Gray image is intact because it is connected only to the input **Image Src**. You can use this flexibility to decide, as in the case above, which image is to be processed and where the resulting image is to be stored. The output **Image Dst** Out from a VI gives the same image cluster as that which is connected to the input **Image Dst**. Therefore, it would seem that the connections from the input **Image Dst** or the output **Image Dst Out** to subsequent VIs (downstream in the processing flow) are equivalent.

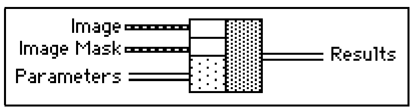
However, the difference between the two is that **Image Dst Out** can be used to synchronize processes without resorting to using a LabVIEW or BridgeVIEW sequence structure.

The following graphic shows several connection types used in IMAQ Vision.



This connection schema applies only to VIs that analyze an image and therefore do not modify either the size or contents of the image. Examples of these types of operations include particle analysis and histogram calculations.

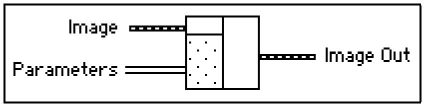
In the following schema, an **Image Mask** is introduced.



The presence of an Image Mask input indicates that the processing or analysis is dependent on the contents of another image (the **Image Mask**). The processing of each pixel in **Image** is dependent on the corresponding pixel (residing in the **Image Mask**) having a value different than zero. This image mask must be an 8-bit image type and its contents are considered to be binary (zero or different than zero).

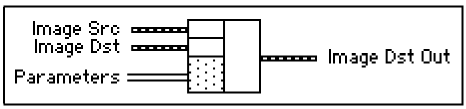
If you want to apply a processing or analysis function to the entire image, do not connect the **Image Mask** input. The connection of the same image to both inputs **Image** and **Image Mask** also gives the same effect as leaving the input **Image Mask** unconnected, except in this case the **Image** must be an 8-bit image.

The following connection schema applies to VIs performing an operation that fills an image.



Examples of this type of operation include reading a file, a video acquisition, or transforming a G 2D array (IMAQ ArrayToImage) into an image. This type of VI can modify the size of an image.

The following connection schema applies to VIs that process an image.



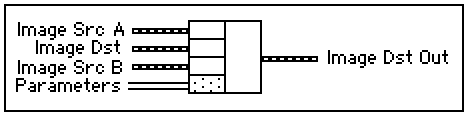
This connection is the most common type in IMAQ Vision. The **Image Src** input receives the image to process. The **Image Dst** output can receive either another image or the original, depending on your goals. If two different images are connected to the two inputs, then the original **Image Src** image is not modified. If the **Image Dst** and **Image Src** inputs receive the same image, then the processed image is placed into the original image and the original image data is lost.

A shortcut exists to join the two inputs if you prefer to have a single image for both source and destination. In this case, you can connect only the **Image Src** input. Functionally this shortcut is equivalent to connecting the same image to **Image Dst**. The following graphic illustrates the two functionally equivalent connections.

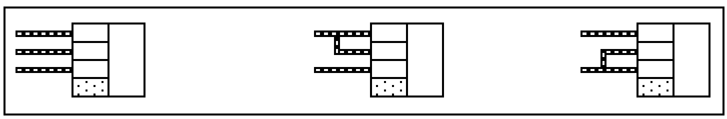
The **Image Dst** image is the image that receives the processing results. Depending on the functionality of the VI, this image can be either the same or a different image type as that of the source image.

The description of each VI and the type of image that can be connected to their **Image** inputs are described in the VI reference chapters (10 through 23) of this manual. In all cases, the size of an image connected to **Image Dst** is irrelevant as it is modified automatically by the VI to correspond to the source image size. The existence of the output **Image Dst Out** enables you to synchronize the various processes without systematically creating a new LabVIEW or BridgeVIEW sequence structure. The name available from the output **Image Dst Out** is the same as that supplied by the **Image Dst** except its contents are different after executing the VI.

The following connection schema applies to VIs that perform arithmetic or logical operations between two images.



Two source images exist for the destination image. The user can perform an operation between two images A and B and then either store the result in another image or in one of the two source images. In the latter case, you can consider the original data to be unnecessary after the processing has occurred. The following combinations are possible in this schema.



In the schema on the left, the three images are all different. **Image Src A** and **Image Src B** are intact after processing and the results from this operation are stored in **Image Dst**. In the schema in the center, **Image Src A** is also connected to the **Image Dst** which therefore receives the results from the operation. In this operation the source data for **Image Src A** is overwritten. In the schema on the right, **Image Src B** receives the results from the operation.

Any operation between two images requires that the images have the same size. However, arithmetic operations can be performed between two different types of images (for example, 8-bit and 16-bit).

Certain other data structures are frequently used in IMAQ Vision. All VIs that use coordinates (for example, line or rectangle) use an array of integers.

[I32]

Rectangle

The entity **Rectangle** is composed of four coordinates (Left / Top / Right / Bottom). A rectangle is specified by constructing an array of integers containing the following information:

Rectangle[0] = *L*, *where L* is the left-horizontal position.
Rectangle[1] = *T*, *where T* is the top-vertical position.
Rectangle[2] = *R*, *where R* is the right-horizontal position.
Rectangle[3] = *B*, *where B* is the bottom-vertical position.

An image with a resolution of 256 × 256 is composed of the points [0, 0] to [255, 255] but the rectangle takes into account the entirety of the image [0, 0, 256, 256]. The right-horizontal and the bottom-vertical positions must be greater than 1 for the last specified column and line. The default coordinates for a rectangle are [0, 0, 32767, 32767]. If these coordinate values are shown (in the front panel of the VI), the rectangle input is not connected. In this case the entire image is taken into account when the operation is performed.

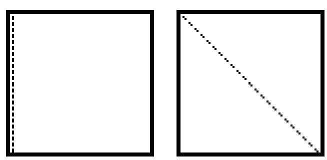
[I32]

Line

The entity **Line** is composed of four coordinates distributed in two points. Each point contains horizontal and vertical information. An array of integers must be constructed to specify a line. This includes the following information.

Line[0] = x_1 *where* x_1 is the horizontal starting position.
Line[1] = y_1 *where* y_1 is the vertical starting position.
Line[2] = x_2 *where* x_2 is the horizontal end-point position.
Line[3] = y_2 *where* y_2 is the vertical end-point.

No default vector is defined. In executing this type of VI, you must connect a table of four elements. Note that a line contains 256 points; the line [0, 0, 255, 255] also contains 256 points.



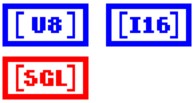


Table of pixels

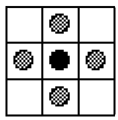
The entity **table of pixels** is represented as a 2D array. The first dimension in a G array is the vertical axis and the second dimension is the horizontal axis. In memory, the pixels are stored in the order of the X axis.

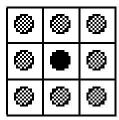
Y Dimension (**I32**)
X Dimension (**I32**)

$$\begin{bmatrix} Array\,[0][0] & \cdots & Array\,[1][0] & \cdots & Array\,[X\ Dimension-1][0] \\ \vdots & & & & \vdots \\ Array\,[0][Y\ Dimension-1] & \cdots & & & Array\,[X\ Dimension-1][Y\ Dimension-1] \end{bmatrix}$$

Connectivity 4/8

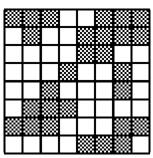
Specific-label and particle-measurement VIs possess the input **Connectivity 4/8**. This parameter determines how the algorithm determines whether two adjacent pixels are part of the same particle.

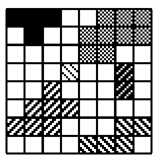

Connectivity 4

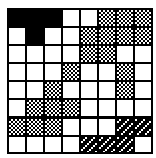

Connectivity 8

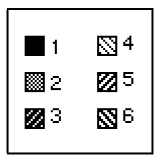
Example

The gray points in the original image define the particle. In connectivity 4, six particles are detected. In connectivity 8, three particles are detected


Original Image


Connectivity 4


Connectivity 8

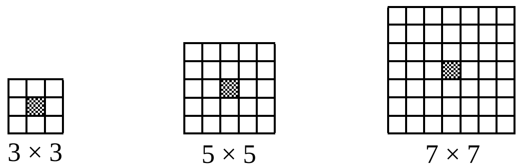


Particles

Structuring Element

A *structuring element* is a 2D G array. It is used specifically for morphological transformations. The values contained in this array are either 0 or 1. These values dictate which pixels are to be taken into account during processing.

The use of a structuring element requires that the image contain a border. The application of a 3 × 3 structuring element requires a minimal border size of 1. In the same way, a structuring elements of 5 × 5 and 7 × 7 require a minimal border size of 2 and 3, respectively. Structuring elements greater than these sizes require corresponding increases in the image border.



The coordinate locations of the central pixel (the pixel being processed) is determined as a function of the structuring element. In this example the coordinates of the processed pixels are (1, 1), (2, 2), and (3, 3). Note that the origin is always the upper left-hand corner pixel.

Square/Hexa

Remember that a digital image is a 2D array of pixels arranged in a regular rectangular grid. In image processing, this grid can have two different (pixel) frames: square or hexagonal. Therefore the structuring element that is applied during a morphological transformation can have either a *square* frame or *hexagonal* frame; you decide whether to use a square frame or hexagonal frame. This decision affects how the algorithm perceives the image during processing, when using those functions that use this concept of a frame. The chosen pixel frame directly affects the output from morphological measurements (for example, perimeter and surface). Notice, however, that the frame has no effect on the availability of the pixel in memory.

By default, the square frame is used in IMAQ Vision. The use of a hexagonal frame is advised for obtaining highly precise results. As shown in the following graphics, the even lines (with respect to the odd lines) have shifted a half pixel right. The hexagonal frame places the pixels in a configuration approaching a true circle. In those cases when the hexagonal frame is used, not all the structuring element values are used. Only the values possessing an *x* are used. All VIs that use this information have the input **Square/Hexa**.

Square 3 × 3 Hexagonal 3 × 3

The size of the structuring element directly determines the speed of the morphological transformation. Different results occur when the contents of the structuring element are changed. It is recommended that you understand morphology or learn how to use these elements before changing the standard structuring element.

The structuring elements shown below each give a different result.

1	1	0
1	1	0
1	1	0

0	1	1
0	1	1
0	1	1

1	1	1
1	1	1
0	0	0

0	0	0
1	1	1
1	1	1

Chapter 10

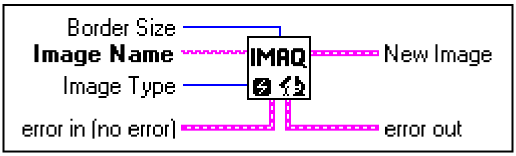
Management VIs

This chapter describes the functionality of the IMAQ Vision Management VIs.

IMAQ Create

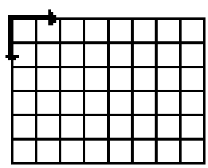
Creates an image.

Note: ***IMAQ Create must be used in conjunction with IMAQ Dispose in order to avoid saturating the memory reserved for LabVIEW or BridgeVIEW.***

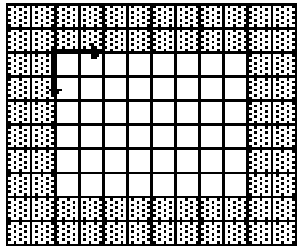


I32

Border Size determines the width in pixels of the border created around an image. These pixels are used only for specific VIs. You should create a border at the beginning of your application if an image is to be processed later using functions that require a border (for example, labeling and morphology). The default value, 0, creates no border. To optimize transfer time, especially for real-time acquisition, use a border that is an even number of pixels wide. The following graphic illustrates an 8 × 6 image with a border equal to 0.



In the following 8 × 6 image, the border equals 2.



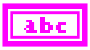


Image Name is a name that is associated with the created image. Each image created must have a unique name.

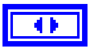
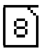


Image Type. This parameter specifies the image type. This input can accept the following values:

0 

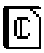
8 bits per pixel (unsigned, standard monochrome)

1 

16 bits per pixel (signed)

2 

32 bits (floating point) per pixel

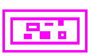
3 

2 × 32 bits (floating point) per pixel (native format after an FFT)

4  32 bits per pixel (RGB chunky, standard color)

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

New Image is the **Image** structure that is supplied as input to all subsequent (downstream) functions used by IMAQ Vision. Multiple images can be created in a LabVIEW or BridgeVIEW application. Activating the **IMAQ ImageStatus** VI shows you all created images and the space they occupy in memory during the execution of your application.

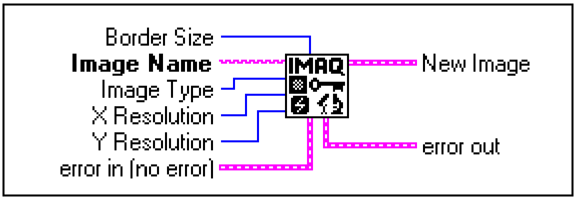


error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section

IMAQ VI Error Clusters in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ Create&LockSpace

Creates a new image that has a permanently-allocated maximum memory space. Using this VI, the pixel memory space allocated to an image can increase but never decreases. This mechanism guarantees that an image that has filled a certain amount of memory always is able to occupy the same space, regardless of memory fragmentation.



Note: ***IMAQ Create is recommended over IMAQ Create&LockSpace for most applications. IMAQ Create&LockSpace must be used only in applications in which the memory requirements are stringent. IMAQ Create&LockSpace must be used in conjunction with IMAQ Dispose to avoid saturating the memory reserved for LabVIEW or BridgeVIEW.***

Note: ***IMAQ Create&LockSpace is hidden in the Image palette but can be found in*** `Manage.llb`**.**

I32 — **Border Size** determines the width in pixels of the border created around an image. These pixels are used only for specific VIs. You should create a border at the beginning of your application if an image is to be processed later using functions that require a border (for example, labeling and morphology). The default value, 0, creates no border. To optimize transfer time, especially for real-time acquisition, use a border that is an even number of pixels wide.

abc — **Image Name** is the name that is associated with the created image.

Image Type specifies the image type. Refer to the *IMAQ Create* section for a description of the various image types supported in IMAQ Vision.

I32 — **X Resolution** specifies the X size of the image to be created.

Y Resolution specifies the Y size of the image to be created. This parameter, **X Resolution**, and **Border Size** define the memory that is allocated permanently for this image.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

New Image is the image structure that is supplied as input to all subsequent functions used by IMAQ Vision.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ Dispose

Destroys an image and frees the space it occupied in memory. This VI must be used for each image created in an application to free the memory allocated to IMAQ Create. IMAQ Dispose is only executed when the image reference is no longer used in an application. You can use IMAQ Dispose for each call to IMAQ Create or just once for all images created with IMAQ Create.

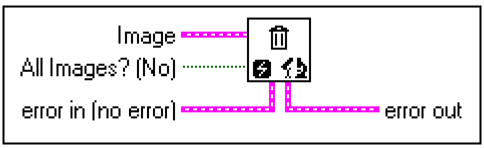
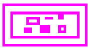


Image is the name of the image to be destroyed.

All Images? (No) determines whether the user wants to destroy a single image or all previously created images. Giving a TRUE value on input destroys all images previously created. The default is FALSE. This function must be used at the end of an application to free the memory occupied by the images.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section

IMAQ VI Error Clusters in Chapter 9, VI Overview and Programming Concepts.



error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Note: ***When a LabVIEW or BridgeVIEW application is aborted the image space remains occupied.***

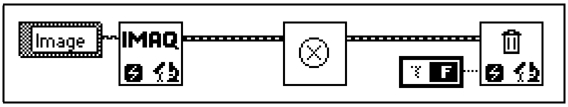
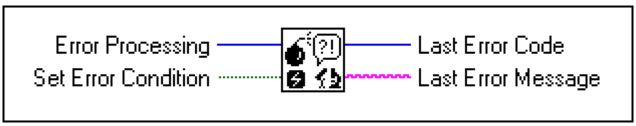
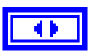


Image Processing (Generic)

IMAQ Error

An error-management facility for IMAQ Vision that can be programmed to perform specific actions in case of an error. The previous error code also can be read.





Error Processing is a number representing the type of error processing you need to use. This value is used only when the Boolean **Set Error Condition** is set to TRUE. The following values are possible:

0 Dialog	Displays a **Stop/Continue** dialog box, to determine whether to stop or continue when an error occurs. **Dialog** is the default value.
1 Stop	Stops in case of error.
2 Ignore	Ignores all errors and does not display an error message.

Set Error Condition rereads the last occurring error (FALSE) or programs a procedure when an error occurs (TRUE). The default value is FALSE.

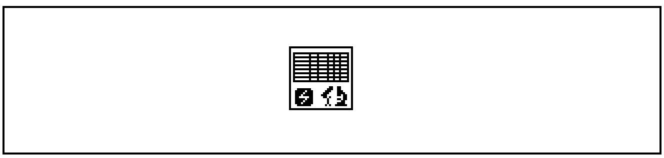
Last Error Code contains the last occurring error code if the Boolean **Set Error Condition** is set to FALSE. This error code is accessible only once and is reset automatically after reading.

Last Error Message contains the message associated with the last error code if the Boolean **Set Error Condition** is set to FALSE. As in **Last Error Code**, this error message is accessible only once and is reset automatically after reading

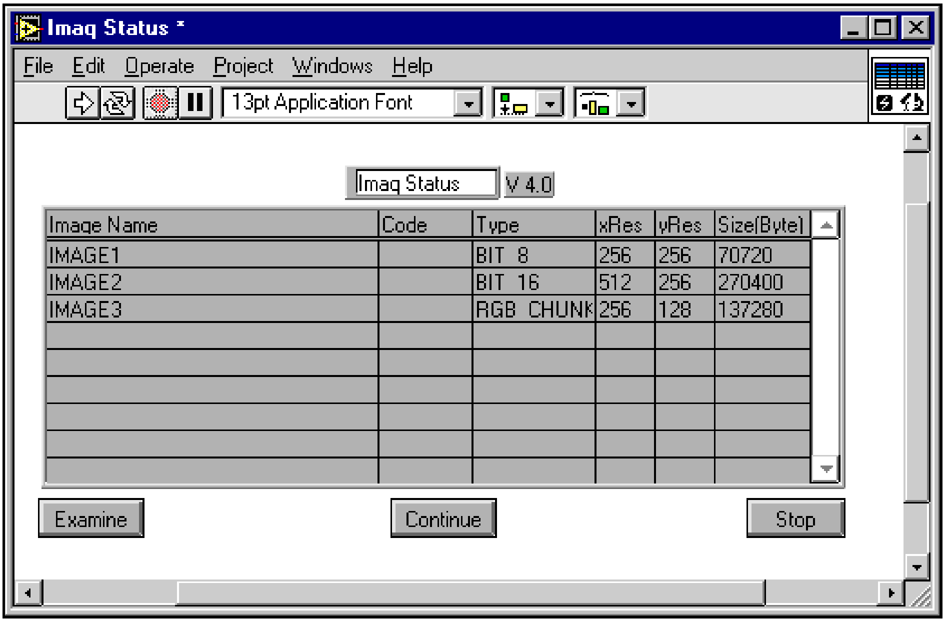
Note: ***Error codes returned from the VIs in IMAQ Vision are not accessible directly. If an error occurs, depending on the error condition chosen (Dialog, Stop, or Ignore), a programmed action is taken. The reading of the last occurring error then is reset.***

IMAQ Status

Lists all the images created and the space in memory occupied.



This VI can not be used as a subVI; it must be executed from its front panel. All existing images are written at intervals or step-by-step depending on the action chosen. This VI also gives the total space in kilobytes occupied by the existing images. It can be used during the writing of an application.



Chapter 11

File VIs

This chapter describes the File VIs in IMAQ Vision.

IMAQ ReadFile

Reads an image file. The file format can be a standard format [APD, TIF, BMP, and PICT (Macintosh Only)] or a non-standard format known to the user. In all cases, the read pixels are converted automatically into the image type passed by **Image**.

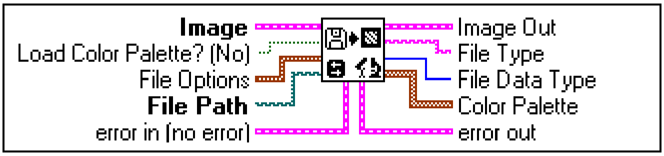


Image is the reference to the image structure to which the data from the image file is applied.

Load Color Palette? (No) determines whether the user wants to load the color table present in the file (if it exists). If loaded, this table is read and made available to the output **Color palette**. The default is FALSE.

File Options is a cluster of user-optional values that permits the user to read non-standard file formats. The file structure must be known to the user. This cluster consists of the following elements:

File Data Type indicates how the image file is encoded. The possible formats are:

0 1 bit

1 2 bits

2 4 bits

3 8 bits (default)

4	16 bits (unsigned)
5	16 bits (signed)
6	16 bits (RGB chunky)
7	24 bits (RGB chunky)
8	24 bits (RGB planar)
9	32 bits (unsigned)
10	32 bits (signed)
11	32 bits (RGB chunky)
12	32 bits (float)
13	48 bits (Complex 2 × 24 int)
14	64 bits (Complex 2 × 32 float)

Offset to Data specifies the size, in bytes, of the file header. This part of the file is not taken into account when read. The pixel values are read from the byte immediately after the offset size. The default is 0.

Use Min Max determines if the user is using a predetermined minimum and maximum. The technique to determine this minimum and maximum depends on the following input values:

0	Don’t use min max	Minimum and maximum are dependent on the type of image. For an 8-bit image, min = 0 and max = 255.
1	Use file values	Pixel values from the file are scanned one time to determine the minimum and maximum. Then a linear interpolation is performed before loading the image.
2	Use optional values	Uses the two values described below.

Optional Min Value is the minimum value of the pixels if **Use Min Max** is selected in mode 2 (Use optional values). In this case, pixels with a smaller value are altered to match the chosen minimum. The default is 0.

SGL

Optional Max Value is the maximum value of the pixels if **Use Min Max** was selected in mode 2 (Use optional values). In this case, pixels with a greater value are truncated to match the chosen maximum. The default is 255.

TF

Byte Order determines if the byte weight is to be swapped (Intel or Motorola). The default is FALSE, which specifies Big endian (Motorola). TRUE specifies Little endian (Intel). This function is only useful if the pixels are encoded on more than 8 bits.

File Path is the complete path name, including drive, directory, and filename, for the file to be loaded. This path can be supplied either by the user or the VI File Dialog from LabVIEW or BridgeVIEW.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Out is the reference to the image structure containing the data read from the image file.

abc

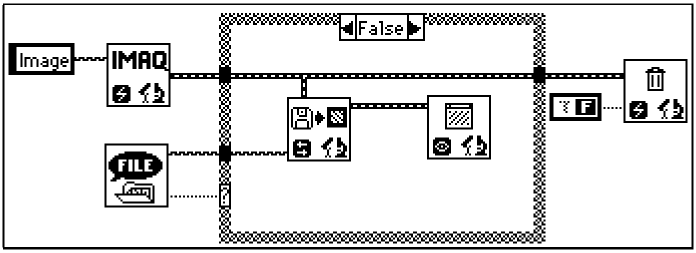
File Type indicates the file type that is read. This string contains the three indicative characters of the read file: APD (internal file format), TIF, BMP (Windows only) and PICT (Macintosh only). File Type returns xxx if the file format is unknown.

I32

File Data Type indicates the pixel size defined in the header for standard image file types. **File Options** are not necessary for reading standard image files. For other types of image files, the returned values are passed from **File Options / File Data Type**. Note that the original file type is never modified because only the image in memory is converted.

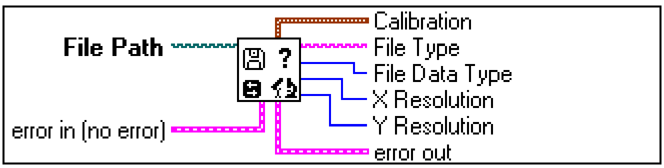
Color Palette contains the RGB color table (if the file has one) read from the file when the user passes the value TRUE for the input **Load Color Palette? (No)**.

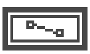
You can use this VI to open and display an image, as illustrated in the following graphic.



IMAQ GetFileInfo

Obtains information regarding the contents of the file. This information is supplied only if the file has a standard file format (APD, BMP, TIF, PICT).





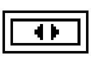
File Path is the complete path name, including drive, directory, and filename, for the file to be loaded. This path can be supplied either by the user or the VI File Dialog from LabVIEW or BridgeVIEW.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Calibration is a cluster containing the following elements.

X Step is the horizontal distance separating two adjacent pixels in user units.

Y Step is the vertical distance separating two adjacent pixels in user units.



Unit is the measuring unit associated with the image. It can have the following values.

Note: ***This data is accessible only if the image is saved in the internal APD file format. For all other file types, this VI returns the values (in mm) X Step = 1, Y Step = 1, and Unit = 3.***

File Type indicates the file type that is read. This string contains the three indicative characters of the read file: **APD** (internal file format), **BMP**, **TIF**, or **PICT** (Macintosh only).

File Data Type indicates the pixel size defined in the header for standard image file types.

X Resolution indicates the horizontal resolution in pixels of the image file.

Y Resolution indicates the vertical resolution in pixels of the image file.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ WriteFile

Writes an image in a file.

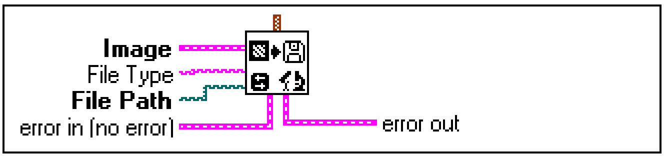
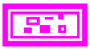


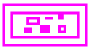
Image is the reference to the image structure to which the data from the image file is applied.

File Type describes the file type to be written. The default file type is **APD**. The file types supported are: **BMP**, **TIFF**, **PICT** (Macintosh only), and **AIPD** (internal file format).

File Path is the complete path name, including drive, directory, and filename, for the file to be loaded. This path can be supplied either by the user or the VI File Dialog from LabVIEW or BridgeVIEW.



error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.



error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Note: ***The options regulating the saving of an image file can be used for certain file types. These options exist as a cluster that is not visible from the connection panel but is visible from the front panel of the VI. For example, the cluster TIFF Options allows the user to specify the value of certain tags (for example, RowsPerStrip, PhotometricInterpretation, or ByteOrder). To change the default values for a TIFF file it is sufficient to modify the parameter in the front panel of IMAQ WriteFile.***

Display

Chapter 12

This chapter describes the Display VIs in IMAQ Vision.

Introduction

The control of image visualization is of primary importance in an imagery application. *Image processing* and *image visualization* are distinct and separate elements that should not be confused. An IMAQ Vision image is controlled by IMAQ Create, which is responsible for the manipulation of the image data and its proper preparation for the various processing and analysis functions that can be applied to the image data. On the other hand, image visualization involves the presentation of the image data to the user and how the user works with the visualized images. Note that a typical imagery application has many more images than the number of image windows.

IMAQ Vision is used for a wide variety of imagery needs by users with varying skill levels. Four Display sections exist so that the novice user can easily access the basic Display functions while OEMs and other professional users can create imagery applications containing sophisticated display and control capabilities.

The **Display (basics)** library contains VIs that control the display of images in image windows as well as the positioning, opening, and closing of these windows on the display screen. These image windows can be resized, and the user can place scroll bars in these image windows. The user also can regulate when the image data is displayed. Note that these image windows are not LabVIEW or BridgeVIEW panels, and they are directly managed by IMAQ Vision.

The **Display (tools)** library contains VIs for controlling image window tools. These tools include points, lines, rectangles, ovals, and freehand contours that can be used to physically access the image data displayed in the image window. Once accessed, this data can be converted into a region of interest or *ROI*. The VIs also regulate the user interaction in the IMAQ Vision image windows as well as the events that occur in these image windows.

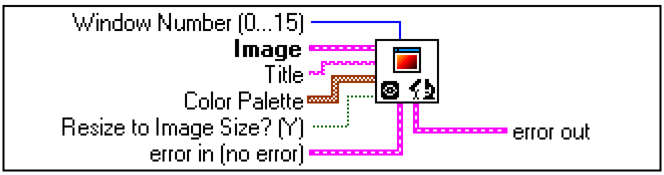
The **Display (user)** library enables the advanced user to create and manipulate user windows. These palettes (user windows) are defined by the user and can be used to create sophisticated applications.

The **Display (Special)** library contains advanced functionalities and user-interface management.

Display (Basics)

IMAQ WindDraw

Displays an image in an image window. The image window appears automatically when the VI is executed. Note that by default the image window does not have scroll bars. Scroll bars can be added by using the IMAQ WindSize VI.



Window Number (0…15) specifies the image window in which the image is displayed. As many as 16 windows can be displayed simultaneously. Each window is specified with an indicator ranging from 0 to 15. Only the specified image window is affected, and all other image windows remain the same. The default value is 0.

Image specifies the image reference for the displayed image.

Note: ***16-bit and floating-point images can be displayed by using an 8-bit image buffer (Tmp). This 8-bit image buffer, used only to display the image, is calculated as a function of the dynamic range from the image source. The minimum value (min) and the maximum value (max) are calculated automatically. Then the following formula is applied to each pixel:***

$$Tmp(x, y) = (Src(x, y) - \min) \times 255/(\max - \min).$$

Title is an image window name. If a string is attached to this input then the image window automatically takes that name. The default name for the image window is `Image #<Window Number>`.

Color Palette is used to apply a color palette to an image window. **Color Palette** is an array of clusters constructed by the user or supplied by IMAQ GetPalette. This palette is composed of 256 elements for each of the three color planes. A specific color is the result of applying a value between 0 and 255 for each of the three color planes (red, green, and blue). If the three planes have the identical value, then a gray level is obtained. (0 specifies black and 255 specifies white).

Note: ***A color palette is not used for a true color image (RGB).***

Note: ***You should use a screen capable of displaying thousands (15/16-bit) or 16 million colors (24-bit). Currently, LabVIEW and BridgeVIEW do not display a full palette of 256 colors (or gray scales) unless your monitor has a display capability of 16 million colors. A true color image does not use a display palette and therefore displays in true color if your monitor is in a 24-bit display mode.***

Note: ***(Macintosh only) You can change the palette tolerance in a Macintosh or Power Macintosh. You can display a full palette of 256 colors (or gray scales) even with an 8-bit display mode. In this case it is necessary to use the IMAQ PaletteTolerance VI and change from*** Tolerant ***mode to*** Exact ***mode.***

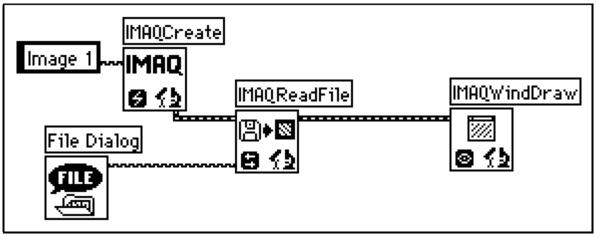
Resize to Image Size? (Y) specifies whether the user wants to resize the image window automatically to fit the image size. The default is set to TRUE (yes), in which case the user does not have to know the size of a source image prior to displaying it.

Note: ***You must use the IMAQ WindSize function to place scroll bars in an image window.***

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

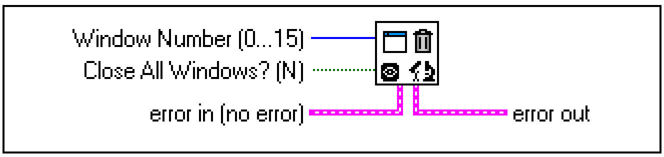
error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The following graphic illustrates how to use IMAQ WindDraw.



IMAQ WindClose

Closes an image window. Note that this VI also clears the space reserved in memory for the image window.



Window Number (0…15) specifies the image window to close. It is specified by a number from 0 to 15. The default value is 0.

Close All Windows? (N) specifies if all the image windows are to be closed. The default value FALSE (No) closes only the specified window. Setting this value to TRUE closes all windows simultaneously.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

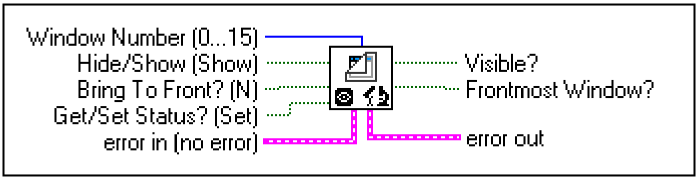
error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Note: ***At the end of an application it is necessary to remove all image windows from memory. Otherwise, LabVIEW or BridgeVIEW will not have sufficient memory, possibly causing stability problems. The use of this VI is similar to the use of IMAQ Dispose. In the case of IMAQ WindClose, you***

remove image windows from memory; and in the case of IMAQ Dispose, you remove image data from memory. In both cases you reallocate free memory to LabVIEW or BridgeVIEW after executing these functions.

IMAQ WindShow

Shows or hides an image window.



Window Number (0…15) specifies the image window to show or hide. It is specified by a number from 0 to 15. The default value is 0.

Hide/Show (Show) specifies if an image window is visible. This input is used only when **Get/Set Status?** is TRUE (Set).

Bring To Front? (N) determines if a windows is to be brought to the front. This input is only used when **Get/Set Status?** is TRUE (Set) and **Hide/Show** is also TRUE.

Get/Set Status? (Set) specifies if the user wants to know if the image window is visible or if the user wants to modify the visibility of an image window. The default is set to TRUE (Set).

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

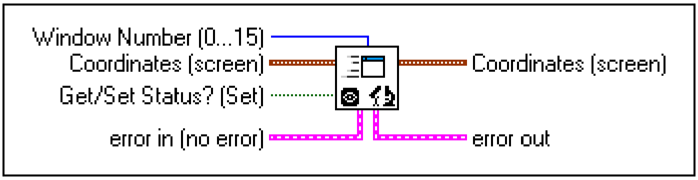
Visible? returns the present visibility status of the window. A visible image window returns TRUE.

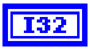
Frontmost Window? returns TRUE if an image window is in the front.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ WindMove

Indicates and sets the position of an image window.

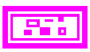




Window Number (0…15) is a number from 0 to 15 that specifies the image window. The default value is 0.

Coordinates (screen) is a structure that contains the screen coordinates, in X and Y positions, where the image window is located or where the image window will be placed. This input is only necessary when the input **Get/Set Status** is set to Set.

Get/Set Status? (Set) specifies if the user wants to know the coordinates of an image window or change the position of an image window. The default is set to TRUE (Set).



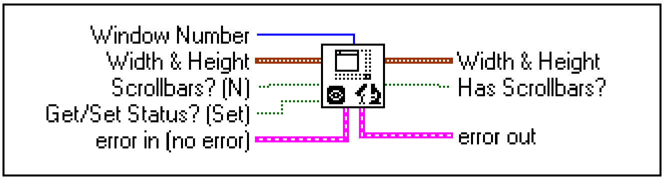
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Coordinates (screen) returns the present coordinates (X and Y) of an image window.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ WindSize

Indicates and sets the size of an image window. You also can use this VI to set scroll bars for image windows and test for the presence of scroll bars in an image window.



Window Number is a number from 0 to 15 that specifies the image window. The default value is 0.

Width & Height is a cluster containing two elements. Setting the input **Get/Set Status** to TRUE (Set) allows the user to specify the width and height of an image window. If the input is not connected, or if the value is (0, 0), the image window is resized automatically to the image associated with it.

Note: ***This value is independent of the size of the scroll bars.***

Scrollbars? (N) controls the presence of scroll bars in an image window. By default, scroll bars are not used. An image window can be resized and moved by the user in the presence or absence of scroll bars.

Get/Set Status? (Set) determines if the user wants to know the position of an image window or specify the position of an image window. The default value is TRUE (Set).

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Width & Height returns the present width and height of an image window.

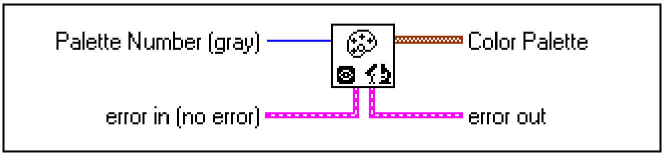
Note: ***The returned value includes the size of the scroll bars.***

Has Scrollbars? returns the present scroll-bar status for an image window.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ GetPalette

Selects a display palette. Five predefined palettes are available. To activate a color palette choose a code (0 to 4) for **Palette Number** and connect the output **Color Palette** to the input **Palette Number** of IMAQ WindDraw.



Palette Number (gray) enables the user to select one of the five predefined palettes. The relationship between the value and **Palette Number** is described below.

Gray	Gray scale is the default palette. The color tables are all identical.
Binary	Binary palette is designed especially for binary images.
Gradient	Gradient palette.
Rainbow	Rainbow palette.
Temperature	Temperature palette.

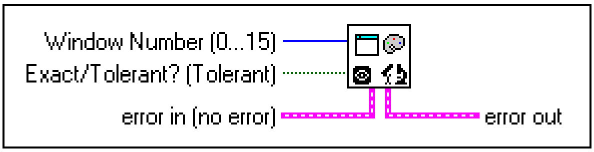
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Color Palette indicates an array of clusters composed of 256 elements for each of the three color planes. A specific color is the result of applying a value between 0 and 255 for each of the three color planes (red, green, and blue). If the three planes have the identical value, then a gray level is obtained (0 specifies black and 255 specifies white). This output is to be directly connected to the input **Color Palette** of IMAQ WindDraw.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ PaletteTolerance (Macintosh/Power Macintosh only)

Defines the tolerance for the colors associated to an image window.

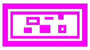


Note: ***This VI is specific to Macintosh or Power Macintosh users of IMAQ Vision.***

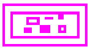
Note: ***This VI is useful only if the display is limited to 8 bits (256 colors or gray scales). By changing the palette tolerance using this VI, you can display a full palette of 256 colors (or gray scales) even with an 8-bit display mode.***

I32 **Window Number (0…15)** is a number from 0 to 15 that specifies the image window. The default value is 0.

TF **Exact/Tolerant? (Tolerant)** sets the tolerance level of the image window. In the Exact mode, 256 colors are associated with an image window (and therefore the other inactive image windows temporarily lose their color). In Exact mode the user can have 256 colors or gray scale even when the display is limited to 8 bits. The user only has a limited number (about 12) of gray scales or colors when working under LabVIEW in the Tolerant mode while in 8-bit display mode. The default mode is Tolerant.



error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.



error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Display (Tools)

This library enables the user to perform the following functions:

- Select a region tool for defining an ROI
- Manage a standard palette of display tools
- Retrieve both the events generated by a user and the associated data from an image window

With IMAQ WindToolStatus you can select from a number of region tools including: point, line, rectangle, oval, polygon and freehand.

With these tools you can decide which sub-region of an image to analyze or process. These selected regions then can be transformed into an image mask with IMAQ WinGetROI and IMAQ ROIToMask.

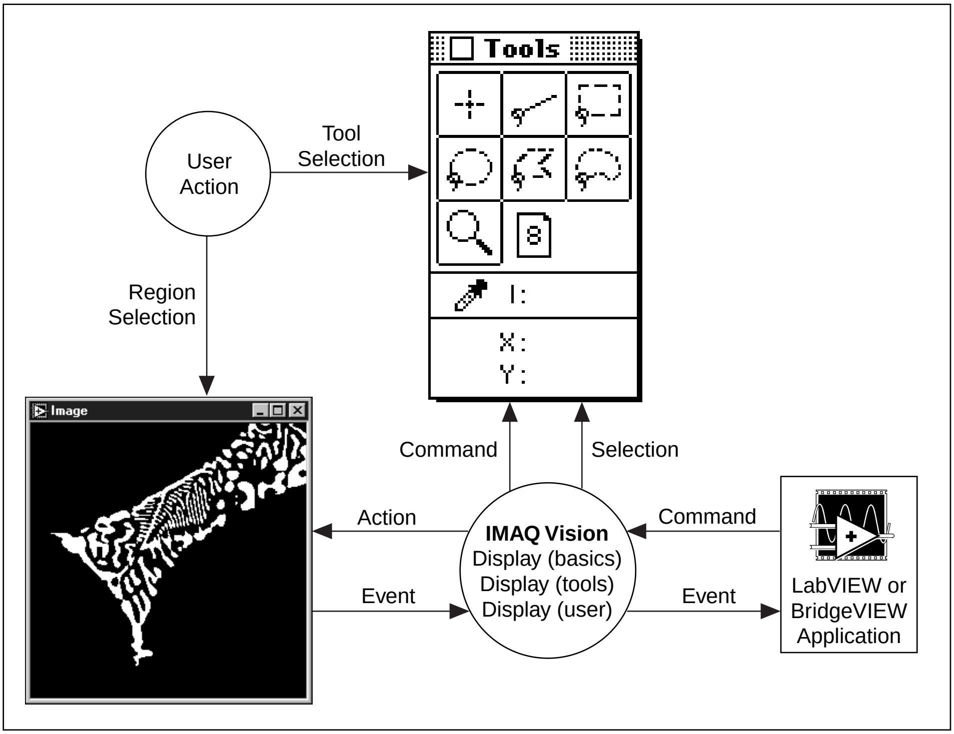
It is possible to program a region by using the VIs IMAQ MaskToROI and IMAQ WindSetROI.

Also you can configure a floating palette of tools from which you can choose a tool by clicking its icon. This palette displays the coordinates of the cursor within the image and the parameters of the active region.

You can also magnify (zoom) an image.

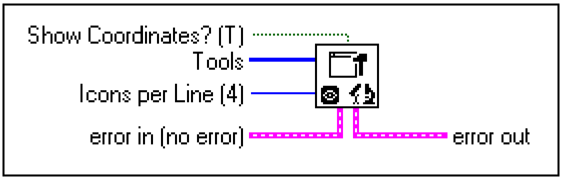
IMAQ WindLastEvent is used to retrieve and manage the events resulting from the interaction in an image window.

The following figure illustrates the possible interactions found between a user, IMAQ Vision, and LabVIEW or BridgeVIEW.



IMAQ WindToolsSetup

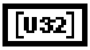
Configures the appearance and availability of the region tools found in the WindTools palette. By default, with no input connections, a palette is displayed containing all nine region tools. The WindTools palette is a floating palette and is always visible.



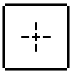
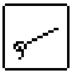
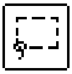
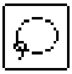
Show Coordinates? (T) specifies if the active pixel coordinates are shown. Coordinates are shown (TRUE) by default.

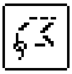
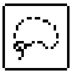
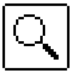
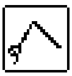
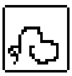
Note: ***Unlike an image window, the WindTools window is not visible unless activated by calling IMAQ WindToolsShow.***

Note: ***You must have LabVIEW version 3.1 (or higher) to access the pixel-coordinate and parameter information.***



Tools specifies which icons are displayed in the WindTools window. There are seven region tools available:

Number	Icon	Tool Name	Function
0	NA	No Selection	NA
1		Point	Select a pixel in the image.
2		Line	Draw a line in the image.
3		Rectangle	Draw a rectangle (or square) in the image.
4		Oval	Draw an oval (or circle) in the image.

Number	Icon	Tool Name	Function
5		Polygon	Draw a polygon in the image.
6		Free	Draw a freehand region in the image
7	NA	Unused 1	NA.
8		Zoom	Zoom-in or zoom-out in an image.
9	NA	Unused 2	NA.
10		Broken Line	Draw a broken line in the image.
11		Free Hand Line	Draw a free hand line in the image.

Icons per Line (4) determines the number of icons per line. The subsequent lines are set as a function of the number of remaining available icons.

Note: ***The WindTools palette automatically displays cursor information if the input*** Icons per Line ***is set to 3 (or higher) for the Macintosh version and 4 (or higher) for the Windows version.***

With IMAQ WindLastEvent you can find the coordinates of a selected region.

The functionality of region tools can be altered by using a tool while pressing certain keyboard keys. Keyboard options are the same for all platforms:

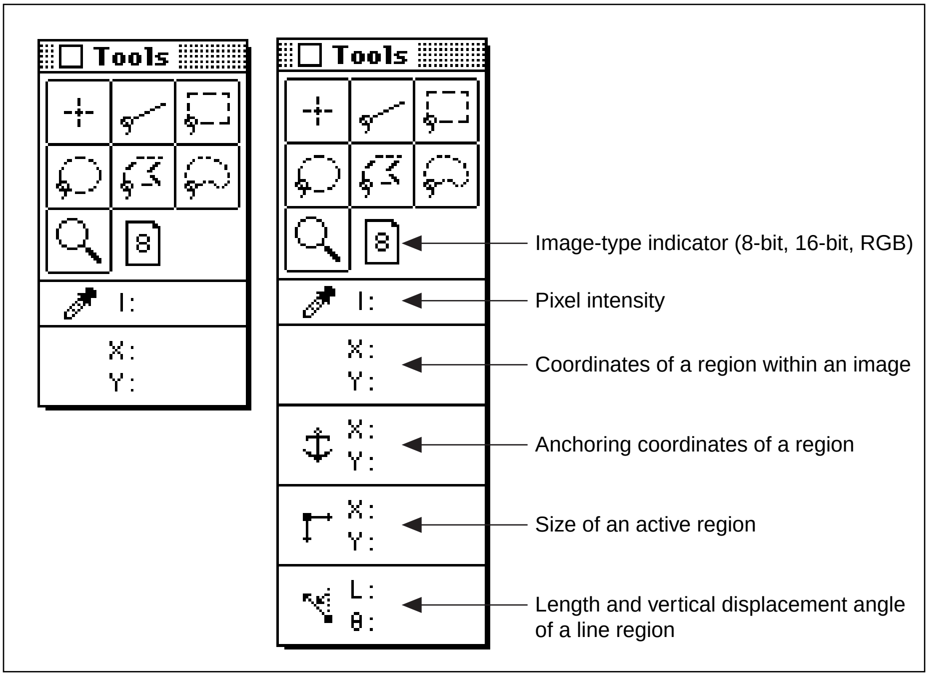
`<Shift>` before a `<Click>` adds an ROI.

`<Shift>` while drawing constrains square angles.

`<Control>` before a `<Click>` displaces an ROI.

`<Control>` and `<Click>` while drawing produces the last point of a polygon.

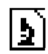
The following examples of the WindTools palette have three icons per line.

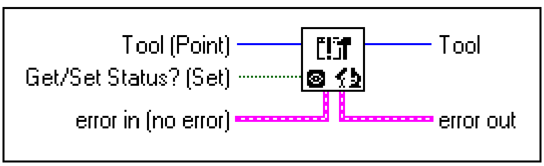


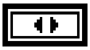
The WindTools palette on the left is transformed automatically to the palette on the right when the user manipulates a region tool in an image window.

IMAQ WindToolsSelect

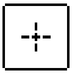
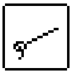
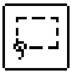
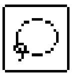
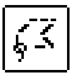
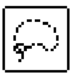
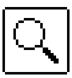
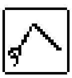
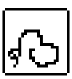
Obtains or modifies the status of the region tools.







Tool (Point) can have the following values:

Number	Icon	Tool Name	Function
0	NA	No Selection	NA.
1		Point	Select a pixel in the image.
2		Line	Draw a line in the image.
3		Rectangle	Draw a rectangle or square in the image.
4		Oval	Draw an oval or circle in the image.
5		Polygon	Draw a polygon in the image.
6		Free	Draw a freehand region in the image
7	NA	Unused 1	NA.
8		Zoom	Zoom-in or zoom-out in an image.
9	NA	Unused 2	NA.
10		Broken Line	Draw a broken line in the image.
11		Free Hand Line	Draw a free hand line in the image.

Get/Set Status? (Set) specifies if the user wants to know the present status or modify the status of the available region tools. The default is TRUE (Set).

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

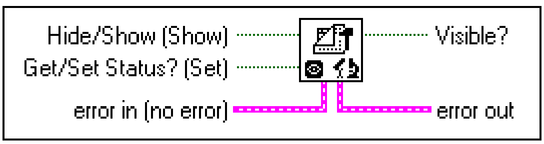
Tool returns the chosen region tool.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Note: ***This VI can be used even if the WindTools palette is not displayed.***

IMAQ WindToolsShow

Shows or hides the **WindTools** palette and sets the region status. This VI functions in the same way as IMAQ WindShow, which is used for displaying image windows.



Hide/Show (Show) specifies whether the tools palette is visible. Use this input only when **Get/Set Status (Set)** is TRUE (Set).

Get/Set Status (Set) specifies if the user wants to know the present status or modify the status of the available region tools. The default is TRUE (Set).

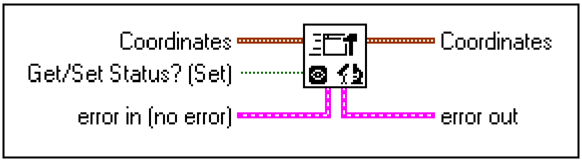
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Visible? returns the present visibility status of the tools palette. A visible tools palette returns TRUE.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ WindToolsMove

Obtains or sets the position of the **WindTools** palette. This VI functions in the same way as IMAQ WindMove, which is used for moving image windows.



Coordinates is a structure that contains the screen coordinates (in X and Y positions) where the tools palette is located or where the tools palette will be placed. This input is necessary only when **Get/Set Status (Set)** is set to TRUE (Set).

Get/Set Status (Set) specifies if the user wants to know the present status or modify the status of the available region tools. The default is TRUE (Set).

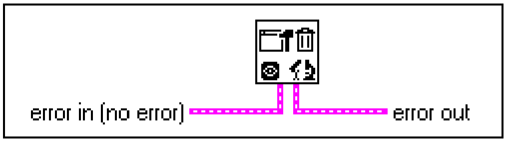
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

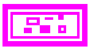
Coordinates indicates the relative position of the event.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ WindToolsClose

Closes the **WindTools** window. This VI functions in the same way as IMAQ WindClose, which is used for closing image windows. Note that this function also destroys the space reserved in memory for the **WindTools** window.



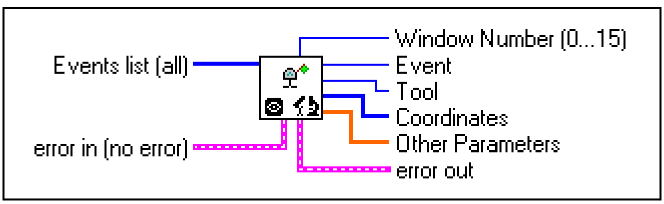


error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ WindLastEvent

Returns the events generated through the image windows as well as the data associated with them.



Event list (all) specifies which events to obtain. The default case returns all events generated through the image windows as well as the data associated with them. This VI enables you to specify the image window events that interest you.

0 No event	No event.
1 Click event	A user has clicked in an image window.
2 Draw event	A user has drawn in an image window.
3 Move event	A user has moved an image window.
4 Size event	A user has resized an image window.
5 Scroll event	A user has moved the scroll bars in an image window.
6 Activate event	A user has chosen (clicked once to activate) an image window.
7 Close event	A user has closed an image window.
8 Reserved	

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Window Number (0...15) indicates the image window that is queried for events.

Event indicates the type of event.

Tool returns a code indicating the region tool used.

Coordinates indicates the relative position of the event.

Other Parameters supplies information associated with an event, such as positioning and region distances.

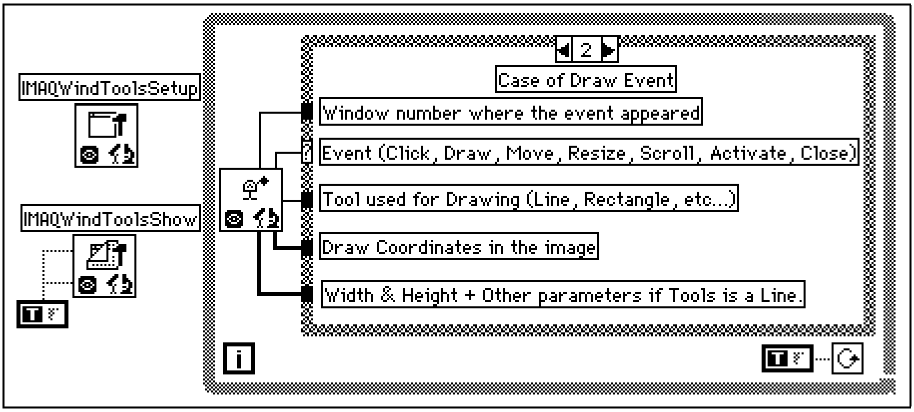
The following table describes the possible values for the **Event**, **Tool**, **Coordinates**, and **Other Parameters** indicators.

Event	Tool	Coordinates	Other Parameters
0 None	NA	empty	empty
1 Click	0 Cursor	[0, 1] position (*x*, *y*) of click	[0, 1, 2] pixel value*
	8 Zoom	[0, 1] position of click [2, 3] position of image center	[0] zoom factor
2 Draw	1 Line	[0, 1] position of starting point [2, 3] position of ending point	[0, 1] width and height [2] vertical segment angle [3] segment length
	2 Rectangle	[0...3] bounding rectangle	[0, 1] width and height
	3 Oval	[0...3] bounding rectangle	[0, 1] width and height
	4 Polygon	[0...3] bounding rectangle	[0, 1] width and height
	5 Freehand	[0...3] bounding rectangle	[0, 1] width and height
3 Move	NA	[0, 1] position of image window	empty
4 Size	NA	[0, 1] width and height of image window	empty
5 Scroll	NA	[0, 1] center position of image	empty
6 Activate	NA	empty	empty
7 Close	NA	empty	empty

* Pixel values are stored in the first element of the array for 8-bit, 16-bit, and floating-point images. The RGB values of color images are stored in the order [0, 1, 2]. The real and imaginary values of a complex image are stored in the order [0, 1].

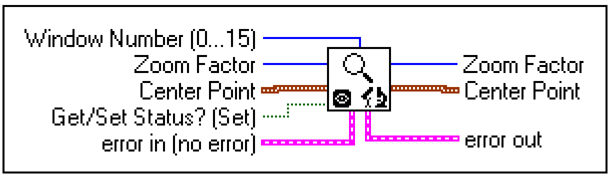
error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The following graphic illustrates how to use IMAQ WindLastEvent.



IMAQ WindZoom

Obtains or modifies the status of the zoom factor.



Window Number (0…15) is a number from 0 to 15 that specifies the image window. The default value is 0.

Zoom Factor can have the following values: 1 to 16 and –1 to –16. The default value is 1 (image is displayed at its original size).

Center Point is a structure containing two elements containing the (*x*, *y*) coordinates used to center the image in the image window. This enables the user to center an image with respect to a user-chosen region. Additionally, **Center Point** can be used to place only a part of an image into an image window.

This value is adjusted automatically when **Center Point** is not coherent with the size of the image window and the zoom factor. For example, an image at 256 × 256 displayed in an image window of 256 × 256 containing a zoom factor of 1 by definition has a single

Center point of (127, 127). An erroneously entered figure is corrected automatically, making the output value different than the input value.

Get/Set Status? (Set) specifies if the user wants to know the present status or modify the **Zoom Factor** and **Center Point**. The default is TRUE (Set).

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

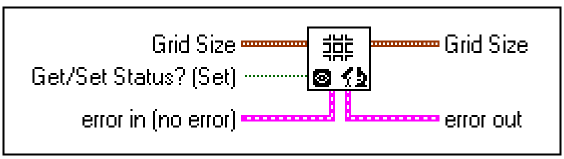
Zoom Factor returns the present zoom factor.

Center Point returns the present coordinates of the **Center Point.**

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

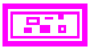
IMAQ WindGrid

Obtains or modifies the status of the grid. The grid can be used to help trace a region of interest accurately.



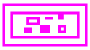
Grid Size is a structure containing two elements that encode the size of the horizontal and vertical steps for the grid. The cursor is moved by steps, as defined in this VI, when tracing a region of interest. The default value is (1, 1).

Get/Set Status? (Set) specifies whether the user wants to know the present status or modify the step values for the grid. The default is TRUE (Set).



error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Grid Size returns the present grid-step size.



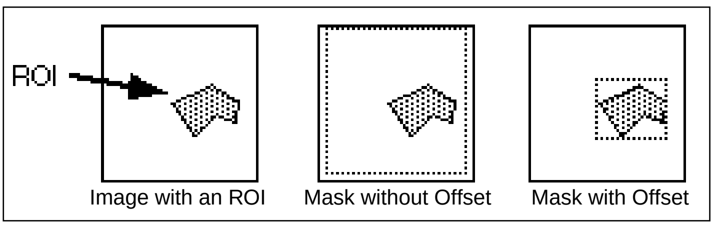
error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Regions of Interest

Regions of interest can be used to focus your processing and analysis on part of an image. An ROI can be traced using standard contours (oval, rectangle, and so forth) or free contours (freehand). The IMAQ Vision user has the following options:

- Associate an ROI with an image window
- Extract an ROI associated with an image window
- Erase the current ROI from an image window
- Transform an ROI into an image mask
- Transform an image mask into an ROI

An image mask that is converted into an ROI must support an offset. The offset is used to place a newly converted ROI into the space of another image. This offset associates the ROI with an image window that possesses the image data. The offset defines the upper left hand corner coordinates (x, y) for the bounding rectangle belonging to the ROI. The default value of the offset is (0, 0).

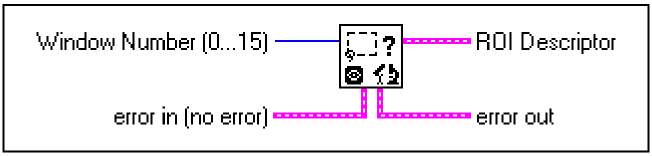


(Advanced users only) The **ROI Descriptor** cluster contains the following two elements:

- **Bounding rectangle** for an ROI
- **Regions list**, which contains
    - **contour identifier**, *where* 0 specifies an exterior contour and 1 specifies an interior contour,
    - **contour type** (point, line, rectangle, oval, freehand, and so forth), and
    - **list of points** (*x*, *y*) describing the contour.

IMAQ WindGetROI

Returns the descriptor for an ROI.



Window Number (0…15) is a number from 0 to 15 that specifies the image window. The default value is 0.

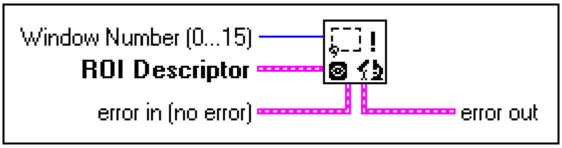
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

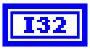
ROI Descriptor returns the descriptor for an ROI.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

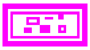
IMAQ WindSetROI

Associates an ROI with an image window.

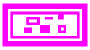




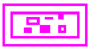
Window Number (0…15) is a number from 0 to 15 that specifies the image window. The default value is 0.



ROI Descriptor is the descriptor that defines the region of interest that is associated with an image window.

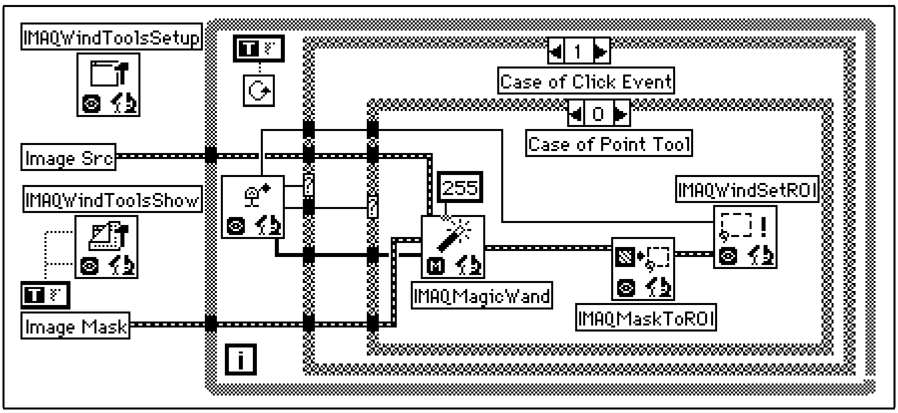


error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.



error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

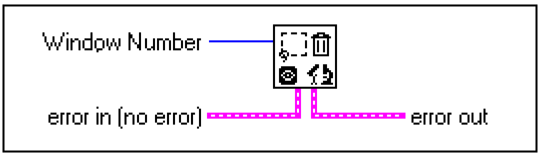
The following graphic illustrates how an ROI can be created from events generated in an image window.



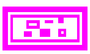
This example creates a very useful type of ROI called Magic Wand. A Magic Wand is a technique of selecting an ROI based on the pixel intensity value selected by the user. A Magic Wand ROI selects the contours of those pixels with values that fall in the range determined by an input pixel value. In this example IMAQ WindLastEvent is used to retrieve the pixel value directly from a user click in an image window. This value is released to the Tools VI IMAQ MagicWand which creates an image mask based on the input pixel value and a tolerance level also set in IMAQ MagicWand. The mask is then transformed into an ROI (IMAQ MaskToROI and IMAQ WindSetROI).

IMAQ WindEraseROI

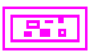
Erases the active region of interest associated with an image window.



Window Number (0…15) is a number from 0 to 15 that specifies the image window. The default value is 0.



error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.



error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Note: ***You can erase an ROI in an image window by pressing*** <Backspace> ***when the current image window is active.***

IMAQ ROIToMask

Transforms a region of interest into a mask.

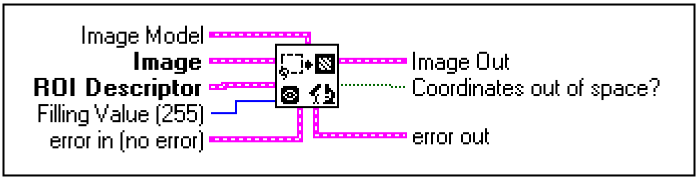


Image Model serves as a template for the destination image where the mask is placed. **Image** takes the characteristics of **Image Model** (size and location of ROI) when **Image Model** is connected. However, the connection of **Image Model** is optional. This can be any image type supported by **IMAQ Vision**.

Image is the destination image where the mask is copied. This image must be an 8-bit image type.

ROI Descriptor is the descriptor that defines the region of interest.

Filling Value (255) is the pixel value of the mask. All pixels inside the region of interest take this value. The default value is 255.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Out is the reference to the image mask transformed from the ROI descriptor.

Coordinates out of space? returns TRUE if any ROI data is found outside the space associated with the image.

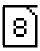
error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

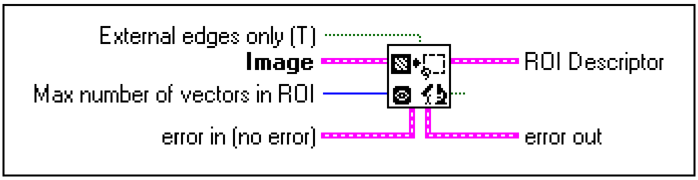
You can use this VI in two ways. The simplest technique is to connect the input **Image Model**. In this case you can use the source image, in which the image ROI was drawn, as a template for the final destination image by connecting it to **Image Model**. The output image (**Image Out**) automatically acquires the size of the image and location of the ROI as found in the original source image.

However, you do not have to connect an **Image Model**. In this case the ROI requires an offset that is determined automatically from the upper-left corner of the bounding rectangle described by the ROI. The bounding-rectangle information is part of the **ROI Descriptor**.

IMAQ MaskToROI

Transforms an image mask into a region of interest.

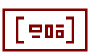




External edges only (T) specifies whether only the external edges are transformed. The default is TRUE.

Image is the image containing the image mask that is transformed into a region of interest. This image must be an 8-bit image.

Max number of vectors in ROI is the limit of points that define the contour of a region of interest. This value is 2500 by default but can be increased if necessary.



ROI Descriptor returns the descriptor for a region of interest.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Display (User)

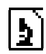
This library enables the advanced user to create and manipulate user windows. These palettes (user windows) are defined by the user and can be used to create sophisticated applications. The user window is constructed from two images that are dynamically loaded. Within these images there are defined *zones* that respond to a user click, just like the buttons in LabVIEW or BridgeVIEW. These zones can be used to control events and their actions interpreted and processed by LabVIEW or BridgeVIEW.

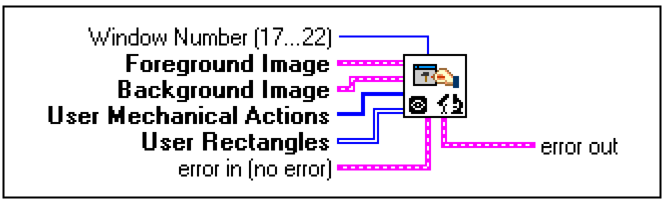
These palettes are created in the following manner:

- Loading a foreground image that appears when a zone has not been chosen
- Loading a background image that appears when a zone has been chosen
- Specifying the coordinates of the zones and their *mechanical action* (how they function)

IMAQ WindUserSetup

Loads and configures the user window.





Window Number (17…22) is a number from 17 to 22 that specifies the user window. It is possible to manipulate six different user windows. The default value is 17.

Foreground Image is an 8-bit or RGB user image. The corresponding part of the image is displayed when a zone within this image is FALSE.

Background Image is an 8-bit or RGB user image. The corresponding part of the image is displayed when a zone within this image is TRUE.

User Mechanical Actions specifies the method of operation of each *zone*. Two modes are possible:

0 **Switch** The first click causes the zone to change to TRUE. A second click on the same zone causes it to change to FALSE.

1 **Latch** A click on the zone causes it to change to TRUE temporarily.

Note: ***In both cases the status of the zone can be determined using IMAQ WindUserEvent or IMAQ WindUserStatus.***

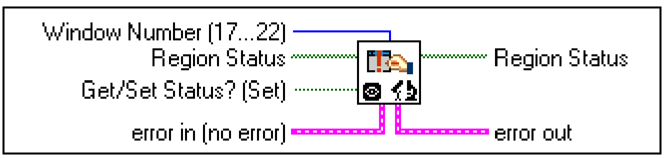
User Rectangles is a 2D array that defines the coordinates of each zone in the user window. Each line in this array must contain the four coordinates that specify the position of the zone.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ WindUserStatus

Obtains or modifies the status of each zone in a user window.



Window Number (17…22) is a number from 17 to 22 that specifies the user window. The default value is 17.

Region Status modifies the status of a user zone (TRUE or FALSE) when the input **Get/Set Status?** is TRUE (Set).

Get/Set Status? (Set) specifies whether the user needs to know the present status or modify the status of the zones. The default is TRUE (Set).

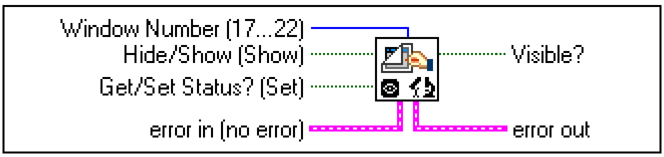
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Regions Status returns the present status (TRUE or FALSE) of each zone.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ WindUserShow

Obtains or modifies the status regarding the visibility of a user window. This VI functions in the same way as IMAQ WindShow, which is used for displaying image windows.



Window Number (17…22) is a number from 17 to 22 that specifies the user window. The default value is 17.

Hide/Show (Show) specifies whether the tools palette is visible. Use this input only when **Get/Set Status (Set)** is TRUE (Set).

Get/Set Status? (Set) specifies whether the user needs to know the present status or modify the status of the zones. The default is TRUE (Set).

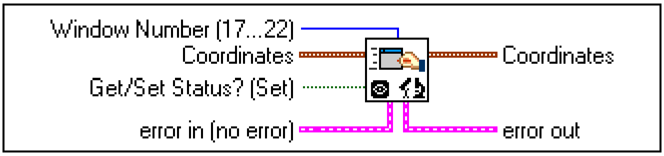
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Visible? returns the present visibility status of the tools palette. A visible tools palette returns TRUE.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ WindUserMove

Obtains or sets the position of a user window. This VI functions in the same way as IMAQ WindMove, which is used for moving image windows.



Window Number (17…22) is a number from 17 to 22 that specifies the user window. The default value is 17.

Coordinates is a structure that contains the screen coordinates (in X and Y positions) where the tools palette is located or where the tools palette will be placed. This input is necessary only when **Get/Set Status (Set)** is set to TRUE (Set).

Get/Set Status? (Set) specifies whether the user needs to know the present status or modify the status of the zones. The default is TRUE (Set).

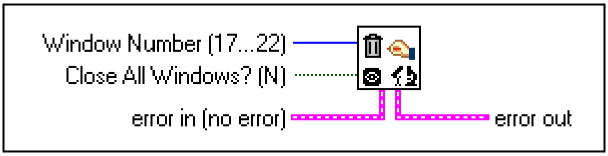
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Coordinates indicates the relative position of the event.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

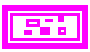
IMAQ WindUserClose

Closes a user window. This VI functions in the same way as IMAQ WindClose, which is used for closing image windows.

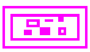


Window Number (17…22) is a number from 17 to 22 that specifies the user window. The default value is 17.

Close All Windows? (N) specifies if all the image windows are to be closed. The default value FALSE (No) closes only the specified window. Setting this value to TRUE closes all windows simultaneously.



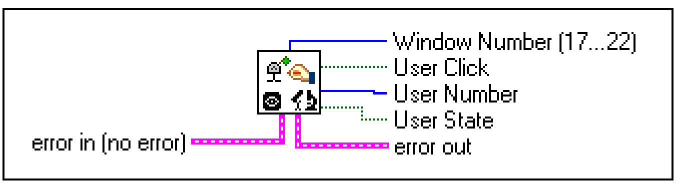
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.



error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ WindUserEvent

Returns the events generated through the user windows and the data associated with them.



error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Window Number (17…22) indicates the image window that is queried for events.

User Click returns TRUE if a zone has been chosen by a user.

User Number returns the zone number chosen by the user.

User State returns the present status (TRUE or FALSE) of each zone. after a click has been registered. This output is by definition TRUE when the Mechanical Action of the zone is Latch; reading this event causes the zone to pass to FALSE.

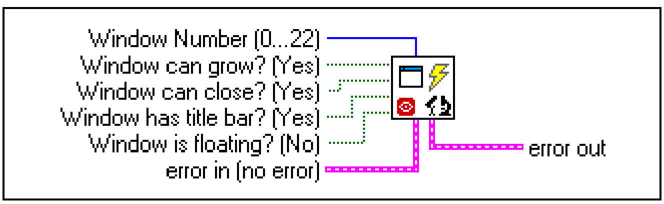
error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Display (Special)

The Display (special) library contains 12 new VIs that help you make more sophisticated user front panels.

IMAQ WindSetup

Configures the look and attributes of an image window



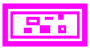
Window Number (0…22) selects the window to configure. The default is 0.

Window can grow? (Yes) enables or disables the user resize window box. Default is TRUE, which indicates windows the user can resize.

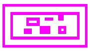
Window can close? (Yes) shows or does not show the close box of the window. The default is TRUE, which shows the close box.

Window has title bar? (Yes) shows or does not show the title bar. The default is TRUE, which shows the title bar.

Window is floating? (No) produces either a normal or a floating window. The default is FALSE, which produces a floating window.



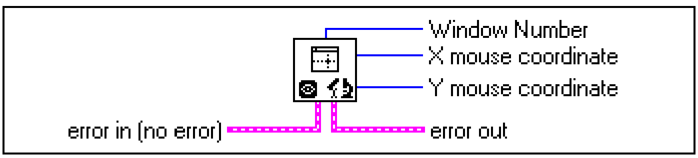
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.



error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ WindGetMouse

When the mouse is moved over an active window, this VI returns the window number and the mouse coordinates.



error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Window Number gives the number of active windows.

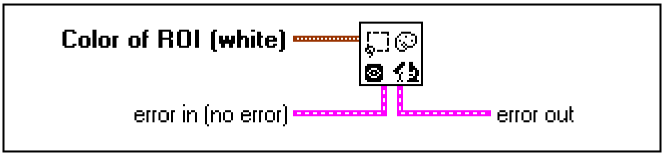
X mouse coordinate gives the X coordinate of the mouse in the active screen.

Y mouse coordinate gives the Y coordinate of the mouse in the active screen.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ WindROIColor

Selects the color of ROI lines.



Color of ROI is a cluster that specifies the color of the ROI. The default color is white.

Red gives the red plane intensity. The default is 255.

Green gives the green plane intensity. The default is 255.

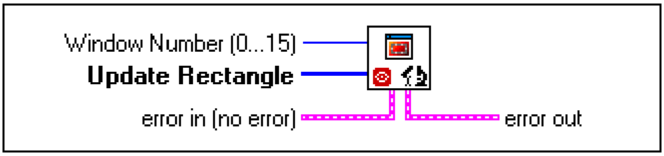
Blue gives the blue plane intensity. The default is 255.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ WindDrawRect

Refreshes a rectangle in an image window. The advantage of this VI is that refreshing part of an image is always faster than drawing the whole image.



Window Number (0…15) selects the window to refresh. The default is 0.

Update Rectangle is an array of elements. They are the coordinates of the rectangle to be refreshed (Left / Top / Right / Bottom).

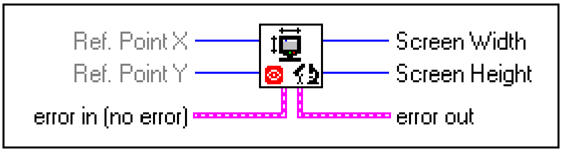
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator,see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Note: ***There is a direct relationship between a window number and the last drawn image. Therefore, specifying only the window number is enough to know which image is to be refreshed.***

IMAQ GetScreenSize

Returns the screen size in pixels.



Ref. Point X. Unused.

Ref. Point Y. Unused.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

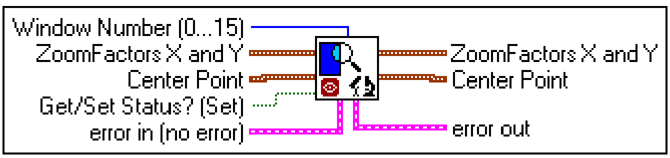
Screen Width gives the X size of screen.

Screen Height gives the Y size of screen.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ WindXYZoom

This VI is similar to **IMAQ WindZoom**, but allows the user to zoom the image at different scales in X and Y. IMAQ WindXYZoom produces rectangular pixels in displaying the image.



Window number (0…15) is a number that specifies the image window. The default value is 0.

ZoomFactors X and Y is a cluster containing the zoom factors for X and Y scale.

Zoom Factor X ranges from –16 to +16.

Zoom Factor Y ranges from –16 to +16.

Center Point is a structure containing two elements that describe the (*x*, *y*) coordinates used to center the image in the image window. Using **Center Point**, you can center an image with respect to a user-chosen region. Additionally, you can use **Center Point** to place only a part of an image into an image window.

X is the horizontal coordinate of the center point.

Y is the vertical coordinate of the center point.

This value is adjusted automatically in cases in which the **Center Point** value is not coherent with the size of the image window and zoom factor. For example, an image at 256 × 256 displayed in an image window of 256 × 256 containing a zoom factor of (1, 1) by definition has a single **Center Point** of (127, 127). An erroneously entered value is corrected, which produces an output value that is different than the input value.

Get/Set Status? (Set) specifies whether the user wants to know the present status or modify the **Zoom Factor** and **Center Point**.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Zoom Factors X and Y returns the actual **Zoom Factor** in both the axis.

Zoom Factor X returns the horizontal **Zoom Factor.**

Zoom Factor Y returns the vertical **Zoom Factor**.

Center Point returns the actual **Center Point**.

X is the horizontal coordinate.

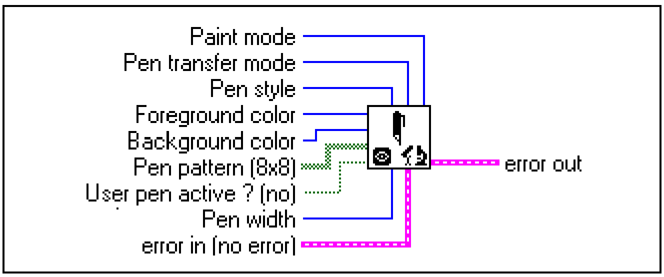
Y is the vertical coordinate.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Note: ***The interactive zoom tool produces the same results as a homogeneous X and Y zoom: it doubles (or reduces, by shift-clicking) the dimensions of the pixels in the image window by a factor of 2. For example, if you have a 5 × 3 zoom and you click with the zoom tool, you produce a 10 × 6 zoom. If you shift-click, you produce a 2 × 1 zoom. Note that zoom is bounded by the highest absolute value in X or Y: if you have a 10 × 2, you cannot zoom in because the double of 10 is greater than 16.***

IMAQ SetUserPen

Defines a pen with user specified features. The user pen affects each region tracked with the freehand tools. No other ROI selection tools work with user pen.



Paint mode indicates the mode of painting in zoom mode. **Paint mode** has three possible values: don’t change, Paint, or Frame.

Note: ***This mode is useful only in positive zoom mode greater than 3: in this mode the ROI is tracked using pen size 1 and ignoring the pen width value.***

Pen transfer mode describes the mode in which the foreground and the background of the pen affect the image. **Pen transfer mode** has five possible values:

don’t change (Default)

srcCopy	Overwrites the background and foreground with specified colors.
srcOr	Overwrites only the foreground.
srxXor	Inverts the pixels below the foreground pixels. The new value equals 255 minus the old value; this operation occurs for each plane of an RGB image.
srcBic	Forces the background color on foreground pixels.

Pen style specifies the pen style. **Pen Style** has six possible values: Don't change, Solid, Dash, Dot, DashDot, and DashDotDot.

Foreground color specifies the color of the foreground pixels. Use a LabVIEW or BridgeVIEW color box for color specification.

Background color specifies the color of the background pixels. Use a LabVIEW or BridgeVIEW color box for color specification.

Pen pattern (8x8). This Boolean 2D array describes the pattern associated with the user pen. TRUE value is associated to foreground, while FALSE is associated to background. The pattern is always an 8×8 matrix. The default is FALSE, which specifies that the current pattern is not changed.

User pen active? (no) enables the pen when set to TRUE. The default value is FALSE, which specifies the use of the standard pen.

Pen width specifies the pen width. The default value is 0, which specifies no change.

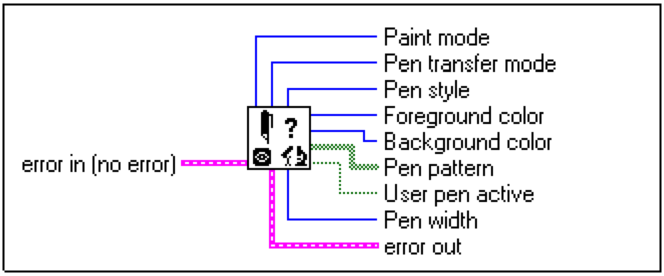
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Note: ***In zoom mode greater than 3, the values of* Paint mode *and* Pen Style *are ignored.***

IMAQ GetUserPen

Returns the user pen status.



error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Paint mode is used for zoom factors greater than 3. If the value is Paint, the rectangles which compose the ROI bounds are painted; if the value if Frame, these rectangles are framed (only the contour is traced).

Pen transfer mode is the actual transfer mode. **Pen transfer mode** has four possible values:

srcCopy	Overwrites the background and foreground with specified colors.
srcOr	Overwrites only the foreground.
srxXor	Inverts the pixels below the foreground pixels. The new value equals 255 minus the old value; this operation occurs for each plane of an RGB image.
srcBic	Forces the background color on foreground pixels.

Pen style is the actual pen style. **Pen Style** has five possible values: Solid, Dash, Dot, DashDot, and DashDotDot.

Foreground color is the actual foreground color.

Foreground color is the actual foreground color.

Background color is the actual background color.

Pen pattern is the actual pen pattern. TRUE values are assigned to the foreground while FALSE values are assigned to the background. The pattern size is a 8 × 8 2D array.

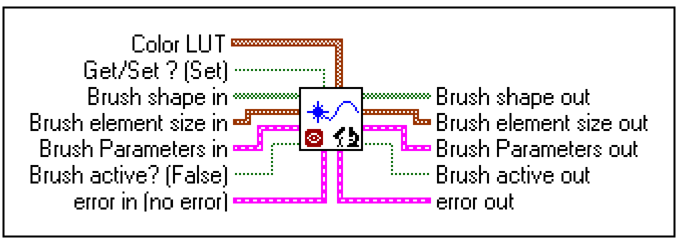
User pen active. If TRUE, the user pen is active.

Pen width is the actual pen width.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ SetupBrush

Configures the shape of a brush used in ROI tracing in conjunction with freehand tools. A brush is a mask that indicates the neighborhood of pixels that are colored when painting. Normally you use a brush in which the only pixel involved in drawing is the one under the cursor. However, with this VI you can define any shape.



Note: ***Do not use this VI in zoom mode.***

Color LUT is an array of clusters with the following fields: **Pixvalue**, **R**, **G**, and **B**. This array of clusters changes the value of a pixel in the image, making a multicolored brush possible. The new pixel value is given by **Pixvalue**. On the display window, the appearance of this pixel changes to the color specified by **R**, **G**, and **B**.

This array has 256 clusters, each containing the following fields.

Pixvalue. This field indicates the new pixel value. Pixels affected include those in the last image connected to the window specified by the parameter **Brush Window**. When touched by the brush, each pixel that has a value equal to the array entry is changed. For example, if entry 7 of the **Color LUT** array parameter specifies a **Pixvalue** of 127, every pixel with a value of 7 that the brush touches is changed to 127.

R, **G**, and **B**. These three parameters specify the color on the display window of pixels that have a value equal to **Pixvalue**. For example, if entry 7 of the **Color LUT** array parameter specifies (**R** = 255, **G** = 0, **B** = 0), every pixel with value 7 that the brush touches is painted red.

Get/Set? (Set) specifies that input parameters are set when the value is TRUE (Set). If the value is FALSE (Get), input parameters are ignored. Output parameters are always effective.

Brush shape in. This Boolean 2D array specifies the shape of the brush. TRUE values (in conjunction with brush width) define the pixels that are affected in your drawing. If your shape is described in a 3 × 3 grid, use a pen size of 3 for viewing a complete portion of the shape. If all values are FALSE, the brush shape is not changed.

Brush element size in specifies parameters that define the dimension of the brush element.

Brush Parameters in. is a cluster consisting of the following parameters.

Brush Window is the number of the window in which the brush is active.

Density is a parameter with a value between 1 and 100 that defines the probability (*D*/100) that a pixel will be written. Use this parameter to generate spray effects.

Left 1 pix? (No) is a Boolean that specifies whether a separation pixel is used between brush elements.

Synchronous. If this parameter is TRUE, the drawing of the brush is denied until the previous ROI is recovered using IMAQ WindGetROI. Use this parameter to synchronize brush drawing with ROI recovering.

Brush active? (False) activates or deactivates the special brush feature.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Brush shape out indicates the current shape of the brush.

Brush element size out indicates the X and Y dimensions of the brush.

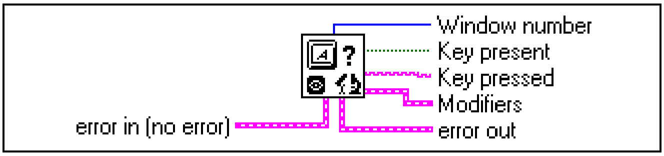
Brush Parameters out indicates the current settings of the brush parameters **Brush Window, Density, Left 1 Pix? (No),** and **Synchronous**.

Brush active out indicates whether the brush is active.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ GetLastKey

Returns the last key pressed when the focus was on the window indicated by the **Window ID** input.



error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Window number indicates the window in which the key was caught.

Key present. If TRUE, a new key was pressed. If FALSE, no new keys were pressed and the VI returns the last key pressed.

Key pressed indicates the last key pressed.

Modifiers specifies a set of flags that identifies the modifiers. Some flags are platform dependent.

- Option
- Shift
- Caps Lock
- Cmd
- Ctrl
- Menu

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Chapter 13

Tool VIs

This chapter describes the Tool VIs used in IMAQ Vision for G.

Tools (Image)

IMAQ Copy

Copies the specifications and pixels of one image into another image of the same type. This function is used for keeping an original copy of an image (for example, before processing an image).

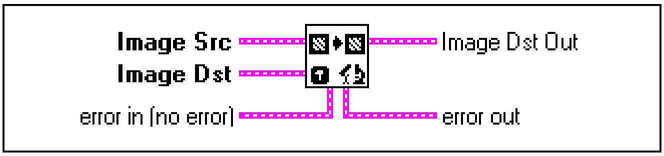


Image Src is the reference to the source (input) image.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Note: ***The images to be copied must be the same type. The full definition of the source image as well as the pixel data are copied to the destination image. The border size of the destination image also is modified to be equal to that of the source image.***

IMAQ GetImageSize

Gives information regarding the size (resolution) of the image.

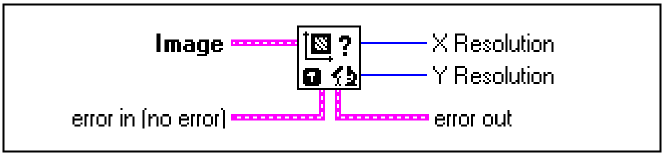


Image is the reference to the image whose size has to be determined.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

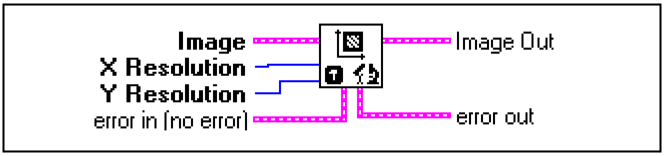
X Resolution gives the number of pixels per line.

Y Resolution gives the number of pixels per column.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ SetImageSize

Modifies the resolution of an image.



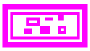


Image is the reference to the image whose size has to be modified.

X Resolution gives the new horizontal resolution of the image.

Y Resolution gives the new vertical resolution of the image.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

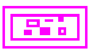
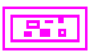


Image Out is the reference to the image whose size is modified to a resolution specified by the **X Resolution** and **Y Resolution** parameters.

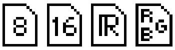


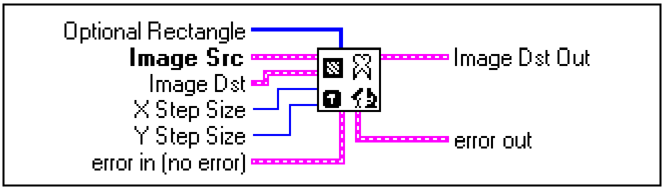
error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Note: ***This function reuses the space previously occupied by the pixels of the image. This function is used in preparation for a fill-in and does not transfer the original image into a new memory space. The original image is lost.***

IMAQ Extract

Extracts (reduces) an image or part of an image with adjustment of the horizontal and vertical resolution.





Optional Rectangle defines an array (four elements) containing the coordinates (Left / Top / Right / Bottom) of the region to extract. The operation is applied to the entire image if the input is empty or not connected.

Image Src is the reference to the source (input) image.

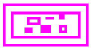
Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

X Step Size is the vertical sampling step, which defines the columns to be extracted (the horizontal reduction ratio). For example, with an **X Step Size** equal to 3, one out of every three columns is extracted from the **Image Src** into the **Image Dst**. Each column is extracted if the default value (1) is used.

Y Step Size is the horizontal sampling step, which defines the lines to be extracted (the vertical reduction ratio). Each row is extracted if the default value (1) is used.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

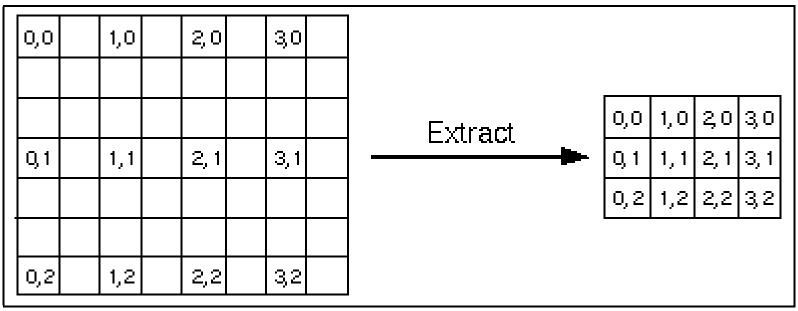


error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

For example, if a 512 × 512 image is connected and the **X Step Size** and **Y Step Size** are both equal to 2, then the resulting image has a resolution of 256 × 256. The resulting image contains the lines from the **Image Src** 0, 2, 4, …, 510 and the columns 0, 2, 4, …, 510 from the **Image Src**.

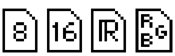
The input images must be of the same image type.

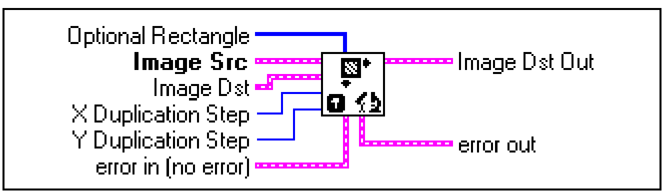
The following graphic illustrates an extraction of an image where **X Step Size** equals 2 and **Y Step Size** equals 3.



IMAQ Expand

Expands (duplicates) an image or part of an image with adjustment of the horizontal and vertical resolution.



Optional Rectangle defines an array (four elements) containing the coordinates (Left / Top / Right / Bottom) of the region to expand. The operation is applied to the entire image if the input is empty or not connected.

Image Src is the reference to the source (input) image.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

X Duplication Step specifies the number of pixel duplications per column. The column is recopied if the default value (1) is used.

Y Duplication Step specifies the number of pixel duplications per line. The row is recopied if the default value (1) is used.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

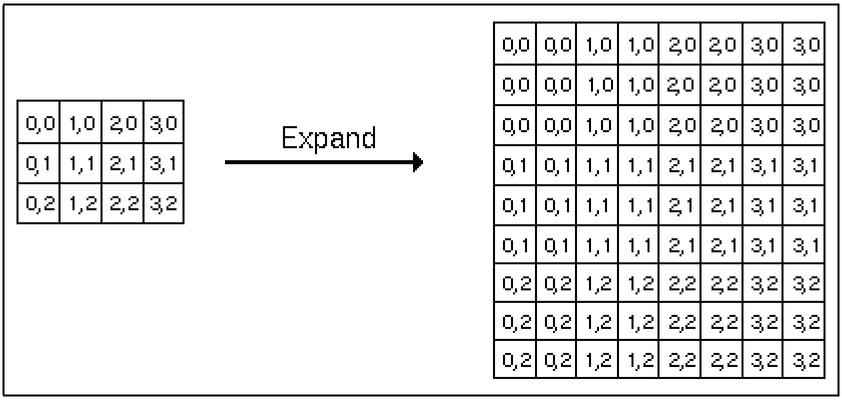
Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

For example, if a 256 × 256 image is connected and the **X Duplication Step** and **Y Duplication Step** are both equal to 2, then the resulting image has a resolution of 512 × 512. Each pixel in the original image now is represented by four pixels in new image (2 × 2).

The input images must be of the same image type.

The following graphic illustrates an expansion of an image where **X Duplication Step** equals 2 and **Y Duplication Step** equals 3.



IMAQ GetOffset

Returns the position of an image mask in relation to the origin of the coordinate system (0, 0). The default offset value [0, 0] is established when the image is initially created by IMAQ Create. The offset is used only for masked images. With this offset, the mask can be moved to any location in the image without having to create a new image for each mask.

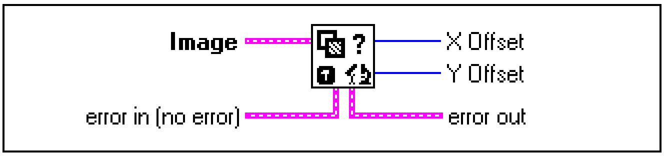
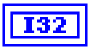


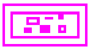
Image is the reference to the source (input) image.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

X Offset specifies the horizontal offset of the image mask.

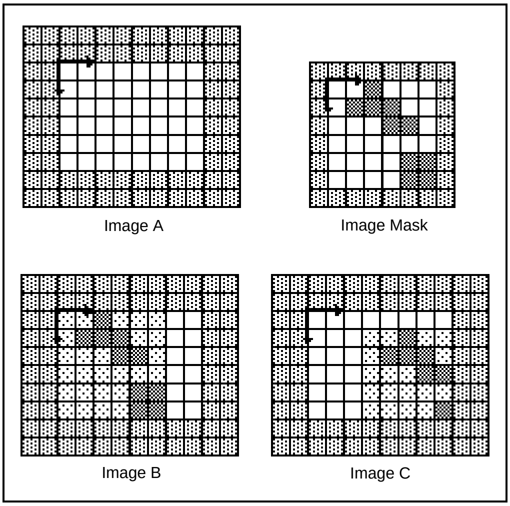


Y Offset specifies the vertical offset of the image mask.



error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The following graphic illustrates the use of a mask with two different offsets [0, 0] and [3, 1].



A VI processing **Image A** and using the **Image Mask** with an offset of [0, 0] and [3, 1] gives the results as shown in **Image B** and **Image C** respectively. Notice the location of the pixels.

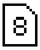
 Pixels from the border

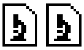
  Pixels outside the mask

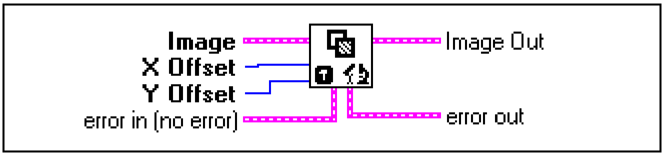
 Pixels from the **Image Mask**

IMAQ SetOffset

Defines the position of an image mask in relation to the origin of the coordinate system (0, 0).







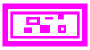
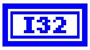
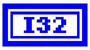


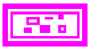
Image is the reference to the source (input) image.



X Offset specifies the horizontal offset of the image mask.



Y Offset specifies the vertical offset of the image mask.



error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

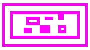
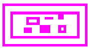


Image Out is the reference to the destination (output) image.

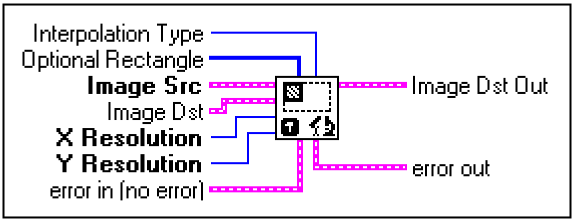


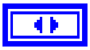
error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ Resample

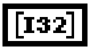
Redraws an image in a user-defined size. This VI is useful for displaying a reduced or enlarged image (for example, a zoom-in or zoom-out image).







Interpolation Type specifies the type of interpolation (zero-order or bilinear) used to resample the image.



Optional Rectangle defines an array (four elements) containing the coordinates (Left / Top / Right / Bottom) of the region to redraw. The operation is applied to the entire image if the input is empty or not connected.

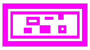


Image Src is the reference to the source (input) image.

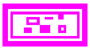
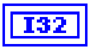
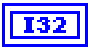


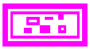
Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.



X Resolution gives the final horizontal size of the image.



Y Resolution gives the final vertical size of the image.



error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

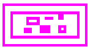


Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ GetCalibration

Obtains the present image calibration.

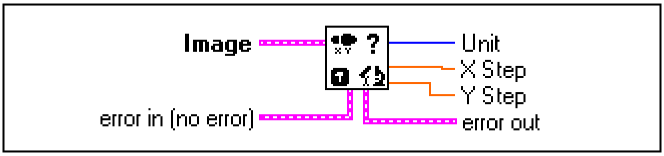


Image is the reference to the source (input) image.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Unit is the measuring unit associated with the image. It can have the following values.

0	Undefined
1	Angstrom
2	micrometer
3	millimeter
4	centimeter
5	meter
6	kilometer
7	microinch

8 inch

9 feet

10 nautical miles

11 standard miles

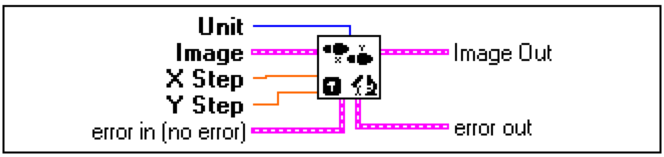
X Step specifies the horizontal distance separating two adjacent pixels in the specified **Unit**.

Y Step specifies the vertical distance separating two adjacent pixels in the specified **Unit**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ SetCalibration

Sets the calibration scale for an image.



Unit is the measuring unit associated with the image. It can have the following values.

0 Undefined

1 Angstrom

2 micrometer

3 millimeter

4 centimeter

5 meter

6 kilometer

7 microinch

8 inch

9 feet

10 nautical miles

11 standard miles

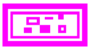
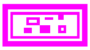


Image is the reference to the source (input) image.

X Step specifies the horizontal distance separating two adjacent pixels in the specified **Unit**.

Y Step specifies the vertical distance separating two adjacent pixels in the specified **Unit**.



error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

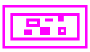
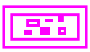


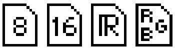
Image Out is the reference to the destination (output) image.

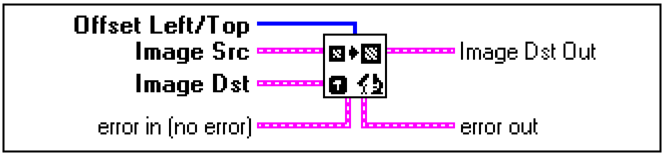


error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ImageToImage

Copies a small image into part of another larger image. This VI is useful for making thumbnail sketches from multiple miniature images.





Offset Left/Top is an array specifying the **Image Dst** pixel coordinates that receive the image copied from **Image Src**.

Image Src is the reference to the source (input) image.

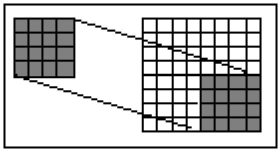
Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

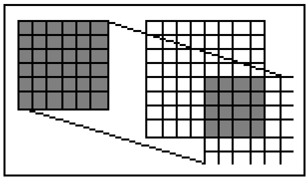
Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

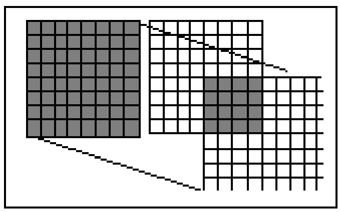
For example, an **Image Dst** with a resolution of 512 × 512 and an **Image Src** with a resolution of 256 × 256, having an **Offset Left/Top** value [256,256], produce the following operation.



However, using an **Offset Left/Top** value [256, 256] and a resolution of 384 × 384 for the **Image Src** produce the following operation.



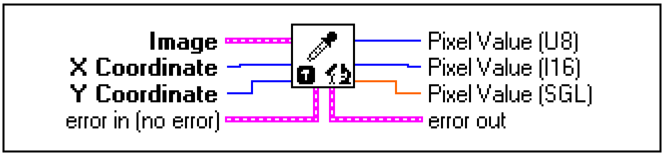
With an **Image Dst** with a resolution of 512 × 512 and an **Image Src** with a resolution of 512 × 512 produce the following operation.



Tools (Pixel)

IMAQ GetPixelValue

Reads or extracts a pixel value from an image.



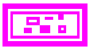
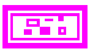


Image is the reference to the source (input) image.

X Coordinate is the horizontal coordinate of the pixel to read.

Y Coordinate is the vertical coordinate of the pixel to read.

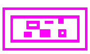


error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Pixel Value (U8) returns the specified pixel value. This output is used only for an 8-bit image.

Pixel Value (I16) returns the specified pixel value. This output is used only for an 8-bit or 16-bit image.

Pixel Value (SGL) returns the specified pixel value. The SGL format can accept values from all supported image types (8-bit, 16-bit, or 32-bit floating point).



error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ SetPixelValue

Changes the pixel value in an image.

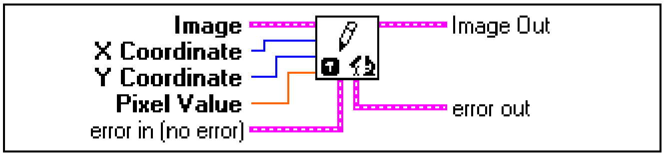


Image is the reference to the source (input) image.

X Coordinate is the horizontal coordinate of the pixel to modify.

Y Coordinate is the vertical coordinate of the pixel to modify.

Pixel Value contains the replacement pixel value.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Out is the reference to the destination (output) image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ GetPixelLine

Extracts the intensity values of a line of pixels.

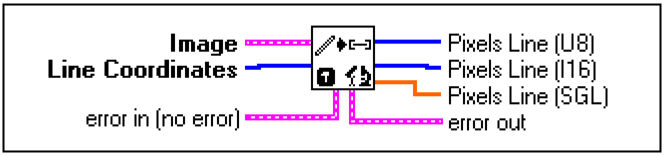


Image is the reference to the source (input) image.

Line Coordinates are the coordinates of the line to extract. These coordinates are in the form of an array specifying the endpoints of the line. Note that a line with the coordinates (0, 0, 0, 255) is formed from 256 pixels. The output **Pixels Line** is an array containing the intensity values of the pixels in the selected line. Any pixels designated by the **Line Coordinates** found outside the actual image are set to zero in **Pixels Line**.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Pixels Line (U8) returns the intensity values for the specified line of pixels. This output is used only for an 8-bit image.

Pixels Line (I16) returns the intensity values for the specified line of pixels. This output is used only for a 16-bit image.

Pixels Line (SGL) returns the intensity values for the specified line of pixels. This output is used only for a 32-bit floating-point image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ GetRowCol

Extracts a range of pixel values, either a row or column, from an image.

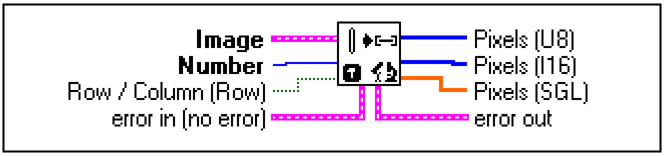


Image is the reference to the source (input) image.

Number is the row or column number to be extracted.

Row / Column uses the row **Number** by default (the default is FALSE). When the TRUE value is connected, the column **Number** is used.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Pixels (U8) returns the intensity values for the specified row or column of pixels. This output is used only for an 8-bit image.

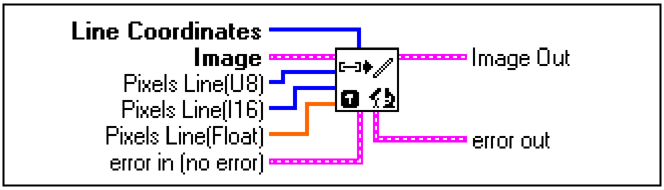
Pixels (I16) returns the intensity values for the specified row or column of pixels. This output is used only for a 16-bit image.

Pixels (SGL) returns the intensity values for the specified row or column of pixels. This output is used only for a 32-bit floating-point image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ SetPixelLine

Changes the intensity values in a line of pixels from an image.



Note: ***Each*** Pixels Line ***input is specific for a particular type of data.***

[I32] **Line Coordinates** are the coordinates of the line to change. These coordinates are in the form of an array specifying the endpoints of the line. Any pixels designated by the **Line Coordinates** found outside the actual image are not replaced.

Image is the reference to the source (input) image.

[U8] **Pixels Line (U8)** is an array containing the coordinates of the pixel line to be drawn. This input must be used if the image connected is an 8-bit image. The drawing is made between the endpoints of the line and contains the values supplied from **Pixels Line**.

[I16] **Pixels Line (I16)** is an array of 16-bit integers. This input must be used if the image connected is a 16-bit image.

[SGL] **Pixels Line (float)** is an array of floating-point values. This input must be used if the image connected is a 32-bit floating-point image.

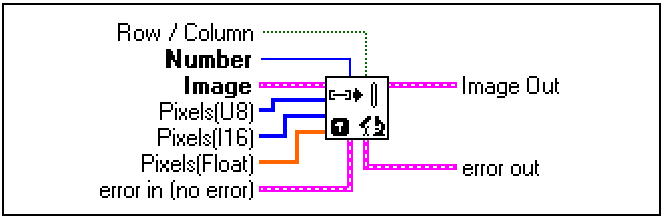
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Out is the reference to the destination (output) image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ SetRowCol

Changes the intensity values in either a row or a column of pixels in an image.



Note: ***Each*** Pixels ***input is specific for a particular type of data.***

Row / Column uses the row **Number** by default (the default is FALSE). When the TRUE value is connected, the column **Number** is used.

Number is the row or column number to be replaced in the image.

Image is the reference to the source (input) image.

Pixels is an array specifying the coordinates of the pixel row or column to be drawn. This input must be used if the image connected is an 8-bit image. The drawing is made between the endpoints of the line and contains the values supplied from **Pixels**.

Pixels (I16) is an array of 16-bit integers specifying the coordinates of the pixel row or column to be drawn. This input must be used if the image connected is a 16-bit image. The drawing is made between the endpoints of the line and contains the values supplied from **Pixels**.

Pixels (float) is an array of floating-point values specifying the coordinates of the pixel row or column to be drawn. This input must be used if the image connected is a 32-bit floating-point image. The drawing is made between the endpoints of the line and contains the values supplied from **Pixels**.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Out is the reference to the destination (output) image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ImageToArray

Extracts (copies) the pixels from an image, or part of an image, into a 2D array encoded in 8 bits, 16 bits, or floating point, which is determined by the type of input image. Various processing can be applied to this array. These arrays can be programmed either from LabVIEW or BridgeVIEW, or from standard programming languages (such as C) via a Code Interface Node.

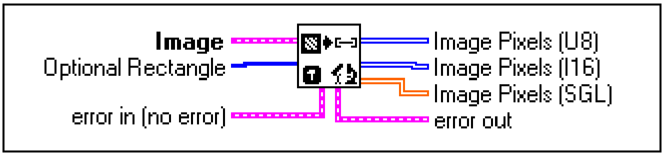


Image is the reference to the source (input) image.

[I32] **Optional Rectangle** defines an array (four elements) containing the coordinates (Left / Top / Right / Bottom) of the region to extract. The operation is applied to the entire image if the input is empty or not connected.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

[U8] **Image Pixels (U8)** returns the extracted pixel values into a 2D array (line, column). This output is used only for an 8-bit image.

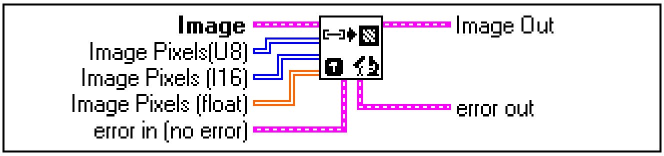
[I16] **Image Pixels (I16)** returns the extracted pixel values into a 2D array (line, column). This output is used only for a 16-bit image.

Image Pixels (SGL) returns the extracted pixel values into a 2D array (line, column). This output is used only for a 32-bit floating-point image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ArrayToImage

Creates an image from a 2D array.



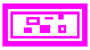
Note: ***For this VI you have a choice of inputs, depending on how the data is encoded (see the following descriptions).***

Image is the reference to the source (input) image.

Image Pixels is a 2D array (Line, Column) containing all the pixel values that form the image. The first index corresponds to the vertical axis and the second to the horizontal index. The final size of the image is equal to the size of the array. The image passed in the input image is forced to the same size as the array encoded by **Input Pixels**. This input should only be used to create an 8-bit image.

Image Pixels (I16) is a 2D array of 16-bit integers. This input must be used if the image connected is a 16-bit image. This input should only be used to create a 16-bit signed image.

Image Pixels (float) is a 2D array of floating-point values. This input must be used if the image connected is a 32-bit floating-point image. This input only should be used to create single plane images that are not encoded as 8-bit, 16-bit signed, or complex.



error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

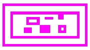
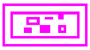


Image Out is the reference to the destination (output) image.



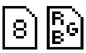
error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

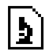
See the additional VIs in Chapter 21, *Complex VIs*, for performing array-to-image transformations with complex images.

Tools (Diverse)

IMAQ ImageToClipboard

Copies the image to the clipboard.





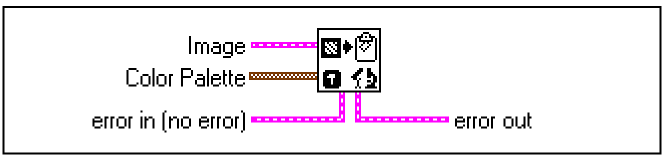
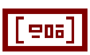


Image is the reference to the source (input) image.



Color Palette can be applied to an 8-bit image. It can be taken directly from the output of IMAQ GetPalette or specified by the user. It is formed from an array of clusters composed of 256 elements for each of the three color planes. A specific color is the result of affecting a value between 0 and 255 for each of the three color planes (red, green, and blue). If the three planes have the identical value, then a gray level is obtained. (0 specifies black and 255 specifies white). By default the palette is a gray-scale ramp.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ClipboardToImage

Copies the clipboard data into an image.

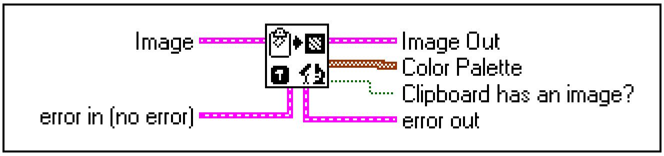


Image is the reference to the source (input) image.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Out contains a copy of the clipboard if the clipboard is an image.

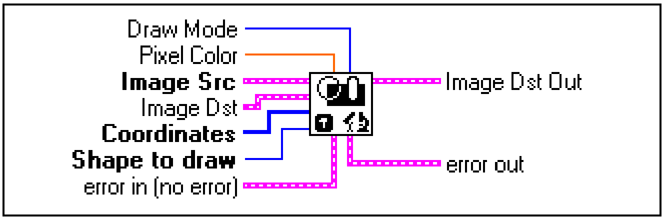
Color Palette is the color palette that is stored on the clipboard. A gray ramp is returned if no color palette is found on the clipboard.

Clipboard has an image? returns a TRUE value if the clipboard contains an image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ Draw

Draws geometric objects in an image.



Draw Mode defines how to draw the object and has the following choices:

0	Frame	(Default) Specifies the use of **Pixel Color** in tracing the contour
1	Paint	Specifies the use of **Pixel Color** in tracing the contour and the interior of the shape
2	Invert Frame	Specifies the use of the inverse of the pixel values when drawing the contour
3	Invert Paint	Specifies the use of the inverse of the pixel values when drawing the contour and the interior of the shape

Pixel Color is the pixel value used for tracing the design. This value is not used when in the mode **Invert Frame** or **Invert Paint**. The default is 0.

Image Src is the reference to the source (input) image.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

Coordinates is an array of four elements. A line is specified by the two points forming it. Rectangles and ovals are specified by their bounding rectangle, with the format (Left / Top / Right / Bottom). In these cases, the tracing of a rectangle or oval stops at the column (*Right* – 1) and at the row (*Bottom* – 1). The values by default are (0, 0, *SizeX*, *SizeY*) *where* (*SizeX*, *SizeY*) is the resolution of the image. The default is used if the input is 0 or is not connected.

Shape to draw is the form to draw. The following shapes are available:

0	Line	(Default) Defined by the two points specified in the array **Coordinates**
1	Rectangle	Defined by the bounding rectangle specified in the array **Coordinates**
2	Oval	Defined by the bounding rectangle specified in the array **Coordinates**

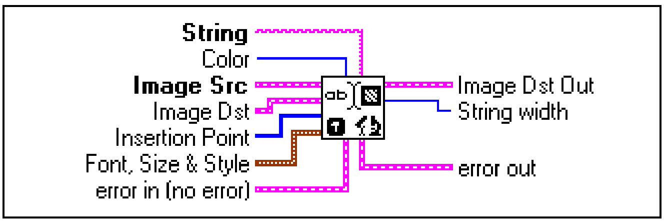
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ DrawText

Inserts text in an image.



String (empty by default) is the text to write in an image. The string can be composed of multiple lines separated by a hard return.

Color is the mode for writing the text. The default is 0, which specifies white.

0	White	(Default) White on the image background
1	Black	Black on the image background
2	Inverted	Text inverted on the image background
3	Black on White	
4	White on Black	

Image Src is the image reference source. It must be an 8-bit or RGB image.

Image Dst is the reference of the image destination. If it is connected, it must be the same type as the **Image Src**.

Insertion Point is an array (*x* and *y*) specifying the location in which the text is inserted. The text position depends on the alignment mode chosen. The default is (0, 0).

Font, Size & Style is a cluster that enables the user to choose the font, size, style, and alignment and contains the following elements:

desired font (Application) specifies the character type of the text. The following values are possible:

0	User-specified Font
1	(Default) Application Font
2	System Font
3	Dialog Font

user-specified font is a cluster containing the specific font characteristics for the text to draw. This specification is ignored unless the **desired font** control is set to user-specified font.

Note: ***The list of fonts on a Macintosh and Windows are different.***

Font Name is the name of the user-specified font.

Strikeout? If TRUE, text appears in strikeout.

Italic? If TRUE, text appears in italic.

Underline? If TRUE, text appears underlined.

Outline? If TRUE, text appears outlined.

Shadow? If TRUE, text appears shadowed.

Bold? If TRUE, text appears in bold.

Size is the size of the font. The default is 9.

Alignment specifies the alignment of the text. The following values are possible: Left (default), Center, and Right.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

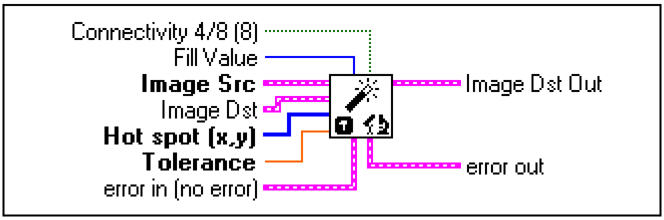
Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

StringWidth returns the string length from the text.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ MagicWand

Creates an image mask by extracting a region surrounding a reference pixel, called the **origin**, and using a tolerance (+ or –) of intensity variations based on this reference pixel. Using this origin, the VI searches for its neighbors with an intensity equal to, or falling within the tolerance value, of the point of reference. The resulting image is binary. The image passed as input for **Image Dst** must be an 8-bit image. If the same image is entered for **Image Src** and **Image Dst** then both must be 8-bit images.



Connectivity 4/8 (8) determines the type of connectivity to be used by the algorithm creating the mask. The default is 8.

Fill Value is the value that is used for the lit pixels in the destination image. The default is 1.

Image Src is the image reference source. It must be an 8-bit or RGB image.

Image Dst is the reference of the image destination. It must be an 8-bit image.

Hot spot (x,y) is an array counting the (*x*, *y*) coordinates of the origin pixel chosen from the image source.

Tolerance is the maximum authorized deviation from the origin. All pixels satisfying the tolerance criteria (origin pixel – tolerance / origin pixel + tolerance) and connectivity criteria, as specified in **Connect 4/8 (8),** are lit and all other pixels are turned off. The default is 20.

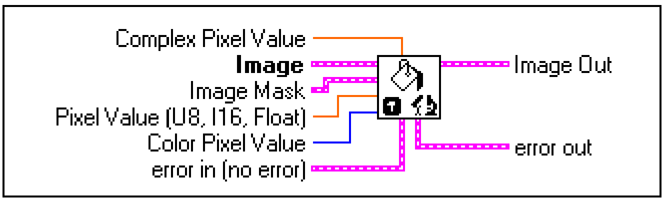
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ FillImage

Fills an image and its border with a specified value.



Complex Pixel Value specifies the value used for filling a complex image.

Image is the reference to the source (input) image.

Image Mask is an 8-bit image that specifies the region in the image to modify. Only pixels in the original image that correspond to the equivalent pixel in the mask are replaced by the values in the lookup table (provided that the value in the mask is not 0). All pixels not corresponding to this criteria keep their original value. The complete image is modified if **Image Mask** is not connected.

Pixel Value (U8, I16, Float) specifies the value with which the image is to be filled. This value is used for 8-bit, 16-bit and 32-bit floating-point images.

Color Pixel Value specifies the value used for filling a color image.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Out contains the image that has been filled with the specified pixel value.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Chapter 14

Conversion VIs

This chapter describes the Conversion VIs in IMAQ Vision.

IMAQ Convert

Converts the image type specified by **Image Src** into the image type specified by **Image Dst**.

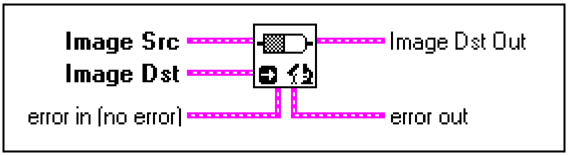


Image Src is the reference to the source (input) image.

Image Dst is the reference to the destination image.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The conversion rules are performed as a function of the image type specified by **Image Src** and **Image Dst**. The image type encoded by **Image Dst** defines the how the conversion is performed. The conversion rules are described in the following table.

8 to 16 ℝ	Pixel values are recopied (0 to 255).
8 to RGB	Pixel values are copied into each of the three color planes (red, green, and blue).
16 to 8	Pixel values less than 0 are set to 0. Pixel values between 0 and 255 are recopied. Pixel values greater than 255 are set to 255.
16 to ℝ	Pixel values are recopied (–32768 to 32767).
16 to RGB	Pixel values are copied into each of the three color planes (red, green, and blue) with the same conversion rule as 16-bit to 8-bit.
ℝ to 8	Pixel values less than 0 are set to 0. Pixel values between 0 and 255 are recopied. Pixel values greater than 255 are forced to 255.
ℝ to 16	Pixel values less than –32768 are set to –32768. Pixel values between –32768 and 32767 are recopied. Pixel values greater than 32767 are set to 32767.
ℝ to RGB	Same conversion rule as 16-bit to RGB.

IMAQ Cast

Converts the current image type of an image to the image type specified by **Image Type**.

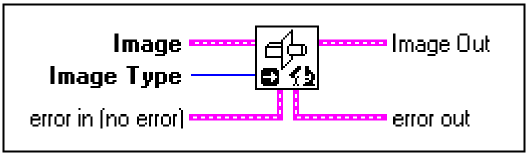


Image is both the image to be converted (input) and the image that receives the conversion (output). With this VI only the image type of the image changes. The conversion rules are the same as described in IMAQ Convert.

Image Type determines into what image type the input **Image** is converted. The following values are valid:

0	8 bits	8 bits per pixel (unsigned, standard monochrome)
1	16 bits	16 bits per pixel (signed)
2	float	32 bits (floating-point) per pixel
3	Unused	
4	RGB	32 bits per pixel (RGB chunky, standard color)
5	Unused	

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

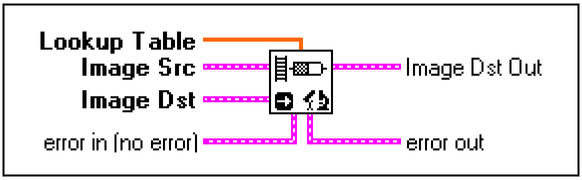
Image Out is the reference to the input image with the new image type.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The conversion rules are the same as the rules for IMAQ Convert.

IMAQ ConvertByLookup

Converts an image by using a lookup table which is encoded in floating-point values.



Lookup Table is an array consisting of 256 elements maximum if **Image Src** has an 8-bit or a maximum of 65536 elements if the **Image Src** has a 16-bit image. This array is filled with values equal to the index if it has less elements than the amount demanded by the image type in **Image Src**. The lookup table can be used to calculate a polynomial giving a relation between a gray-level value and a user value. VIs capable of analyzing floating-point type images can be used to directly quantify an image, or regions from an image, in user values after converting the image into a floating-point type image.

Image Src is the image to be converted. It must be an 8-bit or 16-bit image.

Image Dst is the image that receives the conversion. The image type for **Image Dst** can take the following values:

- 16-bit if **Image Src** has an 8-bit image
- 32-bit floating point if **Image Src** has an 8-bit or 16-bit image

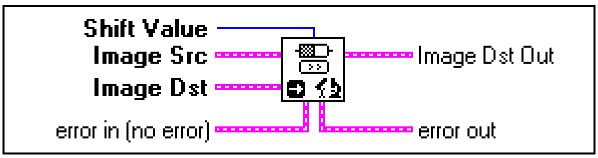
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ Shift16to8

Converts a 16-bit image to an 8-bit image. The VI executes this conversion by shifting the 16-bit pixel values right by the specified number (from 1 to 8) of shift operations and then truncating to get an 8-bit value.



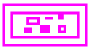
Shift Value specifies the number of right shifts (between 1 and 8) by which each pixel value in the input image is shifted.

Image Src is the reference to the 16-bit image.

Image Dst is the reference to the 8-bit output image.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.



error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Chapter 15

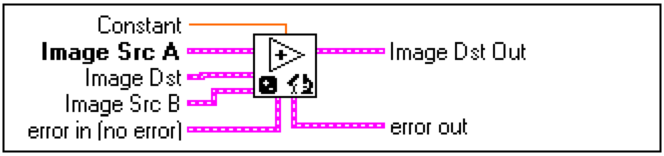
Operator VIs

This chapter describes the Operator VIs in IMAQ Vision.

Arithmetic Operators

IMAQ Add

Adds two images or an image and a constant.



Constant is the value added to the input **Image Src A** for image-constant operations. The constant is rounded down in the cases in which the image is encoded as an integer. The default is 0.

Image Src A is the reference to the source (input) image A.

Image Dst is the reference to the destination image.

Image Src B is the reference to the source (input) image B.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

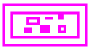
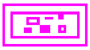


Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src A**.



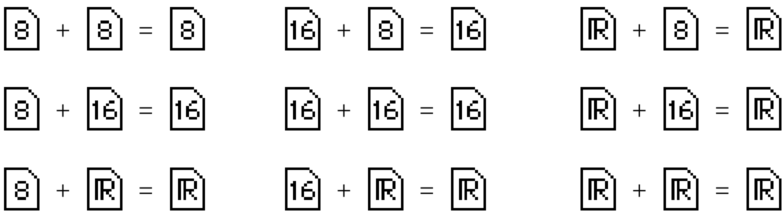
error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

An operation between an image and a constant occurs when the input **Image Src B** is not connected. The two possibilities are distinguished in the following equations:

$$Dst(x, y) = SrcA(x, y) + SrcB(x, y), \text{ or}$$

$$Dst(x, y) = SrcA(x, y) + Constant.$$

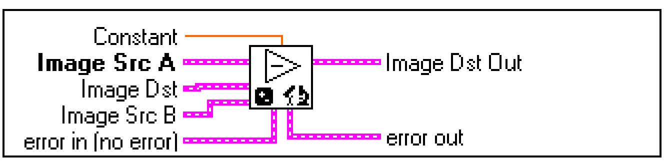
The different image type-combinations supported by this VI are described in the following equations. The first symbol represents the image connected to **Image Src A** and the second symbol represents the image type connected to **Image Src B**. The third symbol represents the image type that should be connected to the output **Image Dst**.



To add a constant to an image, the output **Image Dst** must be connected to the same image type as the input **Image Src A**.

IMAQ Subtract

Subtracts one image from another or a constant from an image.



Constant is the value subtracted from the input **Image Src A** for image-constant operations. The constant is rounded down in the cases in which the image is encoded as an integer. The default is 0.

Image Src A is the reference to the source (input) image A.

Image Dst is the reference to the destination image.

Image Src B is the reference to the source (input) image B.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src A**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

An operation between an image and a constant occurs when the input **Image Src B** is not connected. The two possibilities are distinguished in the following equations:

$$Dst(x, y) = SrcA(x, y) - SrcB(x, y), \text{ or}$$

$$Dst(x, y) = SrcA(x, y) - Constant.$$

The different image-type combinations supported by this VI are described in the following equations. The first symbol represents the image connected to **Image Src A** and the second symbol represents the image type connected to **Image Src B**. The third symbol represents the image type that should be connected to the output **Image Dst**.

8 – 8 = 8   16 – 8 = 16   R – 8 = R

16 – 16 = 16   R – 16 = R

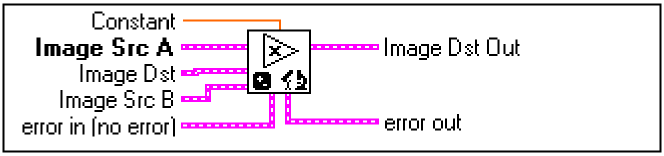
R – R = R

To subtract a constant from an image, the output **Image Dst** must be connected to the same image type as the input **Image Src A**.

If one of the two source images is empty, the result is a copy of the other.

IMAQ Multiply

Multiplies two images or an image and a constant.



Constant. The input **Image Src A** is multiplied by the Constant value for image-constant operations. The default is 1.

Image Src A is the reference to the source (input) image A.

Image Dst is the reference to the destination image.

Image Src B is the reference to the source (input) image B.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src A**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

An operation between an image and a constant occurs when the input **Image Src B** is not connected. The two possibilities are distinguished in the following equations:

$$Dst(x, y) = SrcA(x, y) \times SrcB(x, y), \text{ or}$$

$$Dst(x, y) = SrcA(x, y) \times Constant.$$

The different image-type combinations supported by this VI are described in the following equations. The first symbol represents the image connected to **Image Src A** and the second symbol represents the image type connected to **Image Src B**. The third symbol represents the image type that should be connected to the output **Image Dst**.

8 × 8 = 8	16 × 8 = 16	R × 8 = R
8 × 16 = 16	16 × 16 = 16	R × 16 = R
8 × R = R	16 × R = R	R × R = R

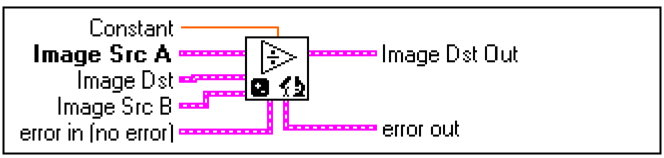
To multiply a constant and an image, the output **Image Dst** must be connected to the same image type as the input **Image Src A**.

If one of the two source images is empty, the result is a copy of the other.

IMAQ Divide

Divides one image by another or an image by a constant.

8 16 R



Constant. The input **Image Src A** is divided by the Constant value for image-constant operations. The default is 1.

Image Src A is the reference to the source (input) image A.

Image Dst is the reference to the destination image.

Image Src B is the reference to the source (input) image B.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src A**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

An operation between an image and a constant occurs when the input **Image Src B** is not connected. The two possibilities are distinguished in the following equations.

$$Dst(x, y) = SrcA(x, y) \div SrcB(x, y), \text{ or}$$

$$Dst(x, y) = SrcA(x, y) \div Constant.$$

The different image-type combinations, supported by this VI, are described below. The first symbol represents the image connected to **Image Src A** and the second symbol represents the image type connected to **Image Src B**. The third symbol represents the image type that should be connected to the output **Image Dst**.

8 ÷ 8 = 8   16 ÷ 8 = 16   R ÷ 8 = R

16 ÷ 16 = 16   R ÷ 16 = R

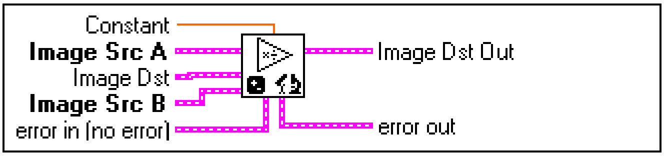
R ÷ R = R

To divide an image by a constant, the output **Image Dst** must be connected to the same image type as the input **Image Src A**.

Division by 0 is not allowed. If the constant is 0 it automatically is replaced by 1. If one of the two source images is empty, the result is a copy of the other.

IMAQ MulDiv

Computes a ratio between two images. Each pixel in input **Image Src A** is multiplied by the integer value specified in the input Constant before being divided by the equivalent pixel found in input **Image Src B**. If the background is lighter than the image, this function can be used to correct the background. In a background correction image, **Image Src A** is the acquired image, and **Image Src B** is the light background.



Constant. Each pixel in **Image Src A** is multiplied by the Constant value prior to being divided by the equivalent pixel in **Image Src B**. The default is 255, which corresponds to the maximum value for a pixel encoded in an 8-bit image.

Image Src A is the reference to the source (input) image A.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src A**.

Image Src B is the reference to the source (input) image B.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src A**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

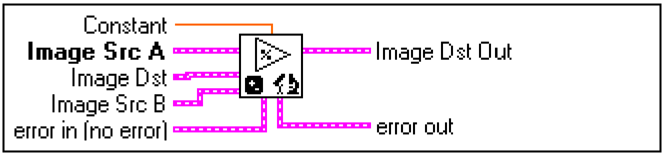
$$Dst(x, y) = (SrcA(x, y) \times Constant) \div SrcB(x, y)$$

All input images must of be the same image type.

Division by 0 is not allowed. If this value is found in **Image Src B**, the equivalent pixel value from **Image Src A** is directly applied to **Image Dst**. If one of the two source images is empty, the result is a copy of the other.

IMAQ Modulo

Executes *modulo division* (remainder) of one image by another or an image by a constant.



Constant. The input **Image Src A** is divided by the Constant value for image-constant operations. The default is 1.

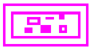
Image Src A is the reference to the source (input) image A.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src A**.

Image Src B is the reference to the source (input) image B.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src A**.



error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

An operation between an image and a constant occurs when the input **Image Src B** is not connected. The two possibilities are distinguished in the following equations:

$$Dst(x, y) = SrcA(x, y) \% SrcB(x, y), \text{ or}$$

$$Dst(x, y) = SrcA(x, y) \% Constant.$$

If **Image Src A** is a 32-bit floating-point image then the following operation is performed:

$$Dst(x, y) = SrcA(x, y) - SrcB(x, y) \times E(SrcA(x, y) \div SrcB(x, y)), \text{ or}$$

$$Dst(x, y) = SrcA(x, y) - Constant \times E(SrcA(x, y) \div Constant),$$

where $E(x)$ is the integer part of x.

The different image-type combinations supported by this VI are described in the following equations. The first symbol represents the image connected to **Image Src A** and the second symbol represents the image type connected to **Image Src B**. The third symbol represents the image type that should be connected to the output **Image Dst**.

8 % 8 = 8 16 % 8 = 16 R % 8 = R

16 % 16 = 16 R % 16 = R

R % R = R

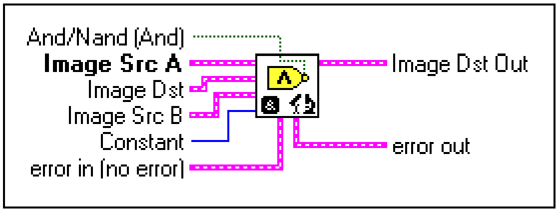
To modulo-divide an image by a constant, the output **Image Dst** must be connected to the same image type as the input **Image Src A**.

Division by 0 is not allowed. If 0 is found in the divider, it automatically is replaced by 1. If one of the two source images is empty, the result is a copy of the other.

Logic Operators

IMAQ And

Performs an AND or NAND operation on two images or an image and a constant.



And/Nand (And) is the result from a logic operation. If set to TRUE, the result of a logic operation is the negative of the performed logic operation (NAND instead of AND). The default is FALSE, which specifies a positive operation (AND).

Image Src A is the reference to the source (input) image A.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src A**.

Image Src B is the reference to the source (input) image B.

Constant is a binary constant used for image-constant operations. The default is 0.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

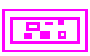


Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src A**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

All connected images must be the same image type. An operation between an image and a constant occurs when the input **Image Src B** is not connected.

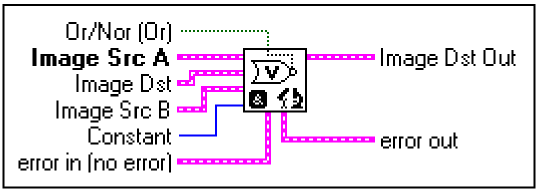
This VI is performed for each pixel (*x*, *y*) in the following manner.

If two images are connected on input, *then* $Dst(x, y) = SrcA(x, y)$ AND $SrcB(x, y)$.

If the input **Image Src B** is not connected, *then* $Dst(x, y) = SrcA(x, y)$ AND *Constant*.

IMAQ Or

Performs an OR or NOR operation on two images or an image and a constant.



Or/Nor (Or) is the result from a logic operation. If set to TRUE, the result of a logic operation is the negative of the performed logic operation (NOR instead of OR). The default is FALSE, which specifies a positive operation (OR).

Image Src A is the reference to the source (input) image A.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src A**.

Image Src B is the reference to the source (input) image B.

Constant is a binary constant used for image-constant operations. The default is 0.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src A**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

All connected images must be the same image type. An operation between an image and a constant occurs when the input **Image Src B** is not connected.

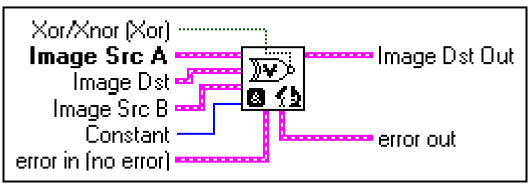
This VI is performed for each pixel (x, y) in the following manner.

If two images are connected on input, *then* $Dst(x, y) = SrcA(x, y)$ OR $SrcB(x, y)$.

If the input **Image Src B** is not connected, *then* $Dst(x, y) = SrcA(x, y)$ OR *Constant*.

IMAQ Xor

Performs an XOR or XNOR operation on two images or an image and a constant.



Xor/Xnor (Xor) is the result from a logic operation. If set to TRUE, the result of a logic operation is the negative of the performed logic operation (XNOR instead of XOR). The default is FALSE, which specifies a positive operation (XOR).

Image Src A is the reference to the source (input) image A.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src A**.

Image Src B is the reference to the source (input) image B.

Constant is a binary constant used for image-constant operations. The default is 0.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src A**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

All connected images must be the same image type. An operation between an image and a constant occurs when the input **Image Src B** is not connected.

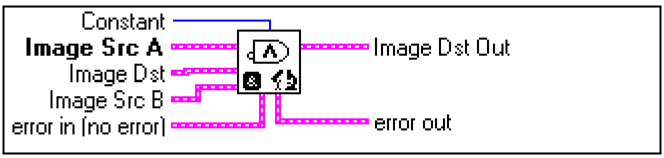
This VI is performed for each pixel (x, y) in the following manner.

If two images are connected on input, *then* $Dst(x, y) = SrcA(x, y)$ XOR $SrcB(x, y)$.

If the input **Image Src B** is not connected, *then* $Dst(x, y) = SrcA(x, y)$ XOR *Constant*.

IMAQ LogDiff

Keeps bits found in **Image Src A** that are absent from image **Image Src B.**



This VI is performed for each pixel (*x*, *y*) in the following manner.

If two images are connected on input, *then* $Dst(x, y) = SrcA(x, y)$ And Not ($SrcB(x, y)$).

If the input **Image Src B** is not connected, *then* $Dst(x, y) = SrcA(x, y)$ And Not (*Constant*).

Constant is a constant value that can replace **Image Src B** for image-constant operations. The default is 0.

Image Src A is the reference to the source (input) image A.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src A**.

Image Src B is the reference to the source (input) image B.

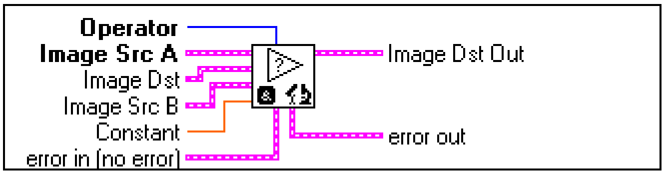
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src A**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ Compare

Regroups all comparison operations between two images or an image and a constant. An operation between an image and a constant occurs when the input **Image Src B** is not connected.



Operator specifies the comparison operator to use. The valid operators are described in the following table.

0	Average	Calculates the average.
1	Min	Extracts the smallest value.
2	Max	Extracts the largest value.
3	Clear if $<$	*If* $SrcA(x, y) < SrcB(x, y)$ or a constant, *then* $Dst\ (x, y) = 0$, *else* $Dst(x, y) = SrcA(x, y)$.
4	Clear if $<$ or $=$	*If* $SrcA(x, y) \le SrcB(x, y)$ or a constant, *then* $Dst\ (x, y) = 0$, *else* $Dst(x, y) = SrcA(x, y)$.
5	Clear if $=$	*If* $SrcA(x, y) = SrcB(x, y)$ or a constant, *then* $Dst\ (x, y) = 0$, *else* $Dst(x, y) = Src\ A(x, y)$.
6	Clear if $>$ or $=$	*If* $SrcA(x, y) \ge SrcB(x, y)$ or a constant, *then* $Dst\ (x, y) = 0$, *else* $Dst(x, y) = SrcA(x, y)$.
7	Clear if $>$	*If* $Src\ A(x, y) > SrcB(x, y)$ or a constant, *then* $Dst\ (x, y) = 0$, *else* $Dst(x, y) = SrcA(x, y)$.

Image Src A is the reference to the source (input) image A.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src A**.

Image Src B is the reference to the source (input) image B.

Constant is the value used in comparison with **Image Src A** for image-constant operations. The default is 0.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The different image-type combinations supported by this VI are described in the following equations. The first symbol represents the image connected to **Image Src A** and the second symbol represents the image type connected to **Image Src B**. The third symbol represents the image type that should be connected to the output **Image Dst**.

8 # 8 = 8　　16 # 8 = 16　　R # 8 = R

16 # 16 = 16　　R # 16 = R

R # R = R

For all comparison operations, the output **Image Dst** must be connected to the same image type as the input **Image Src A.**

If one of the two source images is empty, the result is a copy of the other.

IMAQ Mask

Recopies the **Image Src** into the **Image Dst**. If a pixel value is 0 (OFF) in the **Image Mask**, then all corresponding pixels in **Image Dst** are reset to 0.

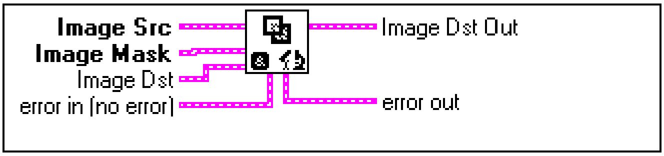


Image Src is the reference to the source (input) image.

Image Mask is an 8-bit image that specifies the region in the image to modify. Only pixels in the original image that correspond to the equivalent pixel in the mask are replaced by the values in the lookup table (provided that the value in the mask is not 0). All pixels not corresponding to this criteria keep their original value. The complete image is modified if **Image Mask** is not connected.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The **Image Mask** contents are considered to be binary. All pixel values other than zero are lit and all pixel values of 0 are turned off. **Image Mask** must be an 8-bit image if it is different than the **Image Src**. **Image Dst** must be the same image type as **Image Src**.

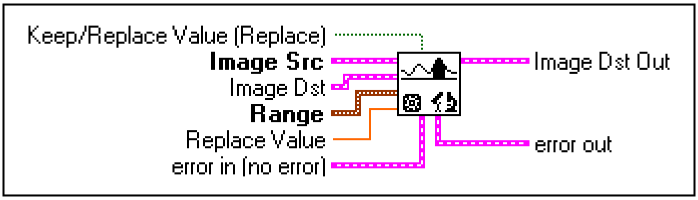
Chapter 16

Processing VIs

This chapter describes the Processing VIs in IMAQ Vision.

IMAQ Threshold

Applies a threshold to an image.



Keep/Replace Value (Replace) determines whether the pixels existing in the range between **Lower value** and **Upper value** are to be replaced by another value. The default TRUE replaces these pixel values and the status FALSE keeps the original values.

Image Src is the reference to the source (input) image.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

Range is a cluster specifying the threshold range. It is composed of the following elements:

Lower value is the lowest pixel value used during a threshold. The default is 128.

Upper value is the highest pixel value used during a threshold. The default is 255.

All pixels not contained between **Lower value** and **Upper value** are set to 0. All values found between this range are replaced by the value entered in **Replace Value**, if **Keep/Replace Value (Replace)** is set to TRUE.

Replace Value is the value used to replace pixels between the **Lower value** and **Upper value**. This operation requires that **Keep/Replace Value (Replace)** be set to TRUE.

Note: ***You should use a binary palette when you plan to visualize an image to which a threshold has been applied in Replace mode. However, which palette to use for visualization depends on the value of Replace Value. For example, the visualization of a threshold image could be performed with a gray palette. However, in this case it is advised that you use a replacement value of 255 (white) to see the threshold image better.***

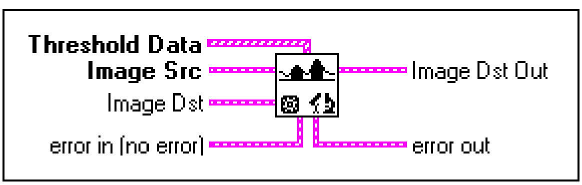
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ MultiThreshold

Applies a multi-threshold to an image.



Threshold Data is an array of clusters specifying the mode and threshold range. This operation is analogous to the process in IMAQ Threshold. Each cluster is composed of the following elements.

Lower value is the lowest pixel value to be taken into account during a threshold. The default is 128.

Upper value (default 255) is the highest pixel value to be taken into account during a threshold. The default is 128.

All pixels not contained between these the two values **Lower value** and **Upper value** are set to 0. All values found between this range are replaced by the value entered in **Replace**, if **Replace** is set to TRUE.

Image Src is the reference to the source (input) image.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The threshold operations are performed in the order that the data is received from **Threshold Data**. A pixel can be taken into account only once, even if the pixel is included in the threshold range of two different thresholds by **Threshold Data**.

For example, a VI contains two clusters on input:

Cluster 1 **Lower value** = 80, **Upper value** = 150, **Keep/Replace Value** = TRUE, **Replace Value** = 255.

Cluster 2 **Lower value** = 120, **Upper value** = 200, **Keep/Replace Value** = FALSE.

This example shows two threshold ranges with an overlap between 120 and 150. Therefore, the pixels between 120 and 150 are treated only by the first threshold. The following results occur after execution of this VI:

- Pixel values between 0 and 79 are replaced by 0
- Pixel values between 80 and 150 are replaced by 255
- Pixel values between 151 and 200 keep their original values
- Pixel values greater than 200 are set to 0

IMAQ AutoBThreshold

Applies an automatic binary threshold to an image that initially possesses 256 gray levels in two classes. Performs a statistical calculation to determine the optimal threshold.

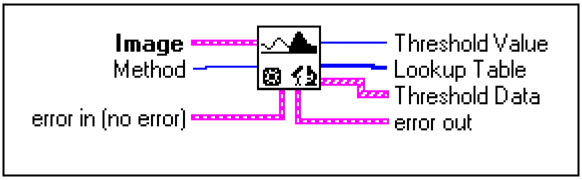
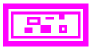


Image is the reference to the source (input) image.

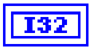
Method is the threshold method used. The following values are valid.

0	clustering
1	entropy
2	metric
3	moments
4	inter-class variance

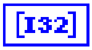
Note: ***See the Thresholding section of Chapter 7, Morphology Analysis, for more information about these methods.***



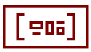
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.



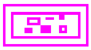
Threshold Value outputs the threshold value. This value can be directly connected to **Lower value** from IMAQ Threshold, provided that 255 is connected to **Upper value**.



Lookup Table outputs a lookup table containing 256 elements encoded in 0 and 1. If the threshold value is 160 then the values between 0 and 159 become zero and the values between 160 and 255 become 1. This array can be used directly by IMAQ UserLookup.



Threshold Data outputs an array containing two clusters compatible with IMAQ MultiThreshold. The elements in this array define a set of intervals equivalent to the LUT outputted by **Lookup Table**.



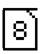
error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

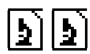
The VI outputs the threshold data in three forms:

- The threshold data directly (**Threshold Value**)
- An LUT directly usable by IMAQ UserLookup
- An array directly usable by IMAQ MultiThreshold (**Threshold Data**)

IMAQ AutoMThreshold

Applies an automatic multi-threshold by using a variant of the classification by clustering method. Starting from a random sort, the gray scale values are determined. This technique is rapid.





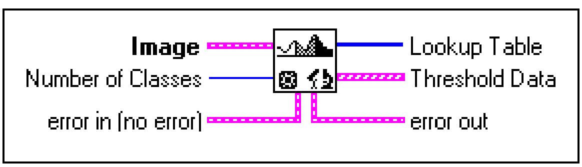


Image is the reference to the source (input) image.

Number of Classes is the number of desired phases. This algorithm uses a clustering method and can use any value between 2 and 256. The default is 2.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Lookup Table is an array containing the values of the 256 transformed elements encoded between 0 and the (*n* – 1), *where n* is the **Number of Classes**. This array can be connected directly to IMAQ UserLookup.

Threshold Data outputs an array containing the **Number of Classes** compatible with IMAQ MultiThreshold. The results range from 0 to (*n* – 1), *where n* is the **Number of Classes**.

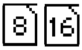
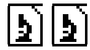
error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

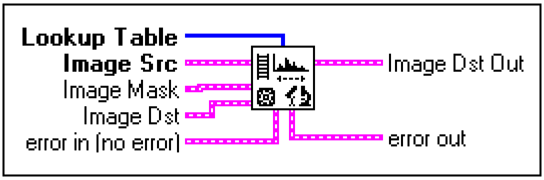
This method is based on a reiterated measurement of an histogram. After finding the best result (a very rapid process), the histogram is segmented into *n* groups. These groups are based on the fact that each point in a group is closer to the *barycenter* of its own group than the other group. The VI outputs the threshold data in two forms:

- A LUT directly usable by IMAQ UserLookup
- An array directly usable by IMAQ MultiThreshold (**Threshold Data**)

IMAQ UserLookup

Performs a user-chosen lookup table transformation by remapping the pixel values in an image.




Lookup Table is a color replacement table. This array can contain 256 elements (8-bit) or 65536 elements (16-bit) depending on the type of image. Individual pixels within the image are not modified in cases in which the lookup table is missing a corresponding value.

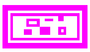


Image Src is the reference to the source (input) image.


Image Mask is an 8-bit image that specifies the region in the image to modify. Only pixels in the original image that correspond to the equivalent pixel in the mask are replaced by the values in the lookup table (provided that the value in the mask is not 0). All pixels not corresponding to this criteria keep their original value. The complete image is modified if **Image Mask** is not connected.


Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.


error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

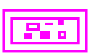
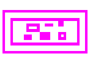
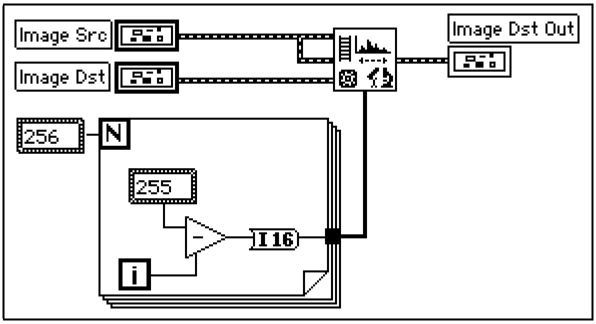


Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.


error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

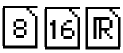
The following example creates a negative of an 8-bit image (256 values) by applying IMAQ UserLookup.

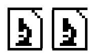


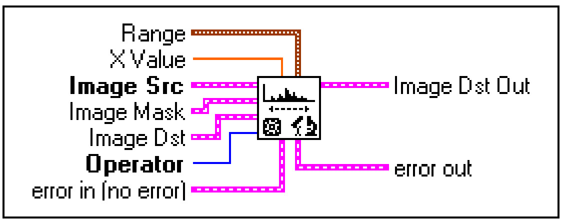
Each gray-level value is replaced by the value (255 – *n*). The result is a negative of the original image placed in **Image Dst**.

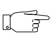
IMAQ MathLookup

Converts the pixel values of an image by replacing them with values from a defined lookup table. This VI modifies the dynamic range of either part of an image or the complete image, depending on the type of curve chosen.









Note: ***This VI is fundamental for many image processing procedures. You can use this VI with 8-bit and 16-bit images to create your own lookup table. You can then apply your new curve with the VI IMAQ UserLookup.***

Range is a cluster containing the minimum and maximum values for the range to modify. The dynamic range of the entire image is modified if this cluster is not connected (or the defaults 0 and 0 are used as input). The dynamic range of the destination image is dependent on the type of input image. The dynamic range for an 8-bit image is between 0 and 255. The dynamic range for 16-bit and 32-bit floating-point images is the smallest and largest pixel value contained in the original image prior to processing. The default is (0, 0).

Note: ***The dynamic range for 16-bit and 32-bit floating-point images is not modified. Only the distribution of the values is changed.***

The following elements are specified in the Range cluster.

Minimum is the smallest value used for processing. After processing, all pixel values that are less than or equal to the **Minimum** (in the original image) are set to 0 for an 8-bit image. In 16-bit and 32-bit floating-point images, these pixel values are set to the smallest pixel value found in the original image.

Maximum is the largest value used for processing. After processing, all pixel values that are greater than or equal to the **Maximum** (in the original image) are set to 255 for an 8-bit image. In 16-bit and 32-bit floating-point images, these pixel values are set to the largest pixel value found in the original image.

X value is a value used only for the operators Power X and Power 1/X.

Image Src is the reference to the source (input) image.

Image Mask is an 8-bit image that specifies the region in the image to modify. Only pixels in the original image that correspond to the equivalent pixel in the mask are replaced by the values in the lookup table (provided that the value in the mask is not 0). All pixels not corresponding to this criteria keep their original value. The complete image is modified if **Image Mask** is not connected.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

Operator specifies the remapping procedure used. The horizontal axis represents the pixel values before processing (between **Minimum** and **Maximum**) and the vertical axis represents the pixel values (between **Dynamic Minimum** and **Dynamic Maximum**) after processing. The default is 0, which specifies linear remapping.

0	Linear	Linear remapping.
1	Log	A logarithmic remapping operation that gives extended contrast for small pixel values and less contrast for large pixel values.
2	Exp	An exponential remapping operation that gives extended contrast for large pixel values and less contrast for small pixel values.
3	Square	Similar to Exponential but with a more gradual effect.
4	Square Root	Similar to Logarithmic but with a more gradual effect.
5	Power X	Gives variable effects depending on the value of *X*. The default value of *X* is 1.5.
6	Power 1/X	Gives variable effects depending on the value of *X*. The default value of *X* is 1.5.

Note: ***For an 8-bit image, the minimum is always 0 and the maximum is always 255. For 32-bit floating-point images, the minimum and maximum are the endpoint values found in the image prior to processing.***

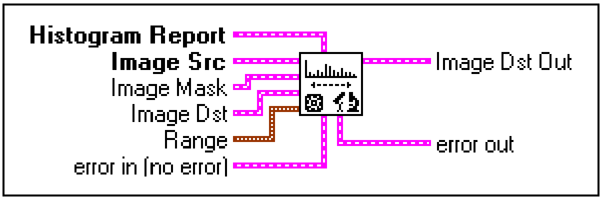
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ Equalize

Produces a histogram equalization of an image. This VI redistributes the pixel values of an image in order to provide an accumulated linear histogram. It is necessary to execute IMAQ Histogram prior to this VI in order to supply **Histogram Report** as input. The precision of the VI is dependent on the histogram precision, which in turn is dependent on the number of classes used in the histogram.



Histogram Report is the histogram from the source image. This histogram is supplied from the output of the VI IMAQ Histogram. No processing occurs if this input is not connected, therefore you need to connect the same image to both IMAQ Histogram and this VI.

Image Src is the reference to the source (input) image.

Image Mask is an 8-bit image that specifies the region in the image to modify. Only pixels in the original image that correspond to the equivalent pixel in the mask are replaced by the values in the lookup table (provided that the value in the mask is not 0). All pixels not corresponding to this criteria keep their original value. The complete image is modified if **Image Mask** is not connected.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

Range is a cluster containing the minimum and maximum values for the range to equalize. The equalization of the entire image occurs if this cluster is not connected (or the defaults 0 and 0 are used as input). In this case, the **Minimal Value** and **Maximal Value** contained in **Histogram Report** are considered to be the min and max. The default is (0, 0).

The following elements are specified in this cluster.

Minimum is the smallest value used for processing. After processing, all pixel values that are less than or equal to the **Minimum** (in the original image) are set to 0 for an 8-bit image. In 16-bit and 32-bit floating-point images, these pixel values are set to the smallest pixel value found in the original image.

Maximum is the largest value used for processing. After processing, all pixel values that are greater than or equal to the **Maximum** (in the original image) are set to 255 for an 8-bit image. In 16-bit and 32-bit floating-point images, these pixel values are set to the largest pixel value found in the original image.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

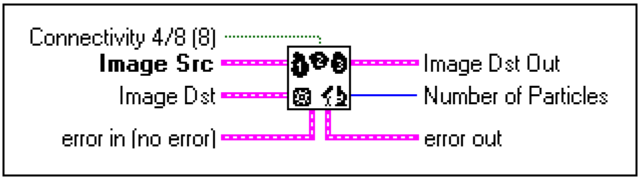
Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Note: ***The modification to the pixel value is dependent on the histogram contents, regardless of the image type used. All pixels entering into the same histogram class have an identical value after equalization.***

IMAQ Label

Labels the particles in a binary image.



Connectivity 4/8 (8) specifies the connectivity used for particle detection. The default is 8.

Image Src is the reference to the source (input) image.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

Number of Particles indicates the number of particles detected in the image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

This operation applies a color to all pixels composing the same group of pixels (a particle). This color level is encoded in 8 or 16 bits, depending on the image type. Therefore, 255 particles can be labeled in an 8-bit image and 65535 particles in a 16-bit image. If you want to label more than 255 particles in an 8-bit image, you need to perform a threshold operation with an interval of [255, 255] after processing the first 254 particles. The goal of this threshold operation is to eliminate the first 254 particles in order to visualize the next 254 particles.

Image Src is the input image and **Image Dst** is the resulting image. This operation requires that **Image Src** and **Image Dst** be the same image type and that the border for these images be greater or equal to 2.

Chapter 17

Filter VIs

This chapter describes the Filter VIs in IMAQ Vision. The filters are divided into two types: linear (also called convolution) and nonlinear.

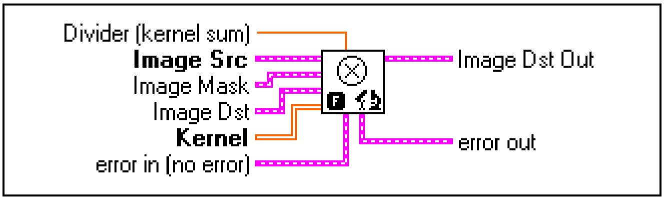
A *convolution* is a special algorithm that consists of recalculating the value of a pixel based on its own pixel value as well as the pixel values of its neighbors. The sum of this calculation is divided by the sum of the elements in the matrix in order to obtain a new pixel value. The size of the *convolution matrix* (or *kernel*) does not have a theoretical limit and can be either square or rectangular (3 × 3, 5 × 5, 5 × 7, 9 × 3, 127 × 127, and so forth). The convolutions are divided into four families: gradient, Laplacian, smoothing, and Gaussian. This grouping is determined by the convolution matrix contents or the weight assigned to each pixel depending on the geographical position of that pixel in relation to the central matrix pixel.

IMAQ Vision supplies a set of standard convolution kernels for each family and for the usual sizes (3 × 3, 5 × 5 and 7 × 7). These convolution kernels are accessible from the VI IMAQ GetKernel. You can also create your own kernels. The contents of these user-defined kernels are chosen by the user, and the size of the kernel is virtually unlimited. With this capability, you can create special effect filters.

The purpose of the nonlinear filters is to either extract the contours (edge detection) or remove the effect or the isolated pixels. The VI IMAQ EdgeDetection provides six different methods for contour extraction (Differentiation, Gradient, Prewitt, Roberts, Sigma, Sobel). The harmonization of pixel values can be performed with two VIs each using a different method: IMAQ NthOrder and IMAQ LowPass. These VIs require that a kernel size and order number (IMAQ NthOrder) or percentage (IMAQ LowPass) is specified on input.

IMAQ Convolute

Filters an image using a linear filter. The calculations are performed either with integers or floating points, depending on the image type and the contents of the kernel.



Divider (kernel sum) is a normalization factor that can be applied to the sum of the obtained products. Under normal conditions the divider should not be connected. If connected (and not equal to 0), the elements internal to the matrix are summed and then divided by this normalization factor.

Image Src is the image reference source. It must be an 8-bit or RGB image.

Image Mask is an 8-bit image that specifies the region in the image to modify. Only pixels in the original image that correspond to the equivalent pixel in the mask are replaced by the values in the lookup table (provided that the value in the mask is not 0). All pixels not corresponding to this criteria keep their original value. The complete image is modified if **Image Mask** is not connected.

Image Dst is the reference of the image destination. If it is connected, it must be the same type as the **Image Src**.

Kernel is a 2D array that contains the convolution matrix to be applied to the image. The size of the convolution is fixed by the size of this array. The array can be generated by using standard G programming techniques or the VIs IMAQ GetKernel or IMAQ BuildKernel. If the dimensions (*XY*) produced by this array are not greater than 3, the filter is considered null and the output image is identical to the input image.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Any image connected to the input **Image Dst** must be the same image type connected to **Image Src**. The image type connected to the input **Image Mask** must be an 8-bit image.

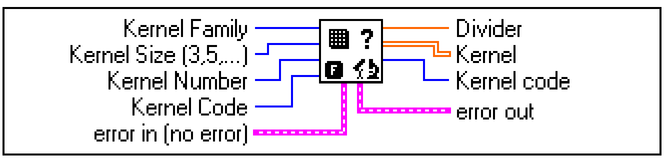
The connected source image must have been created with a border capable of supporting the size of the convolution matrix. A 3 × 3 matrix must have a minimum border of 1, a 5 x 5 matrix must have a minimum border of 2, and so forth. The border size of the destination image is not important.

A convolution matrix must have odd-sized dimensions so that it contains a central pixel. The function does not take into account the odd boundary, furthest out on the matrix, if one of the **Kernel** dimensions is even. For example, if the input **Kernel** is 6 × 4 ($X = 6$ and $Y = 4$), the actual convolution is 5 × 3. Both the sixth line and the fourth are ignored. Remember, the second dimension in a G array is the vertical direction (Y).

Calculations made with an 8-bit or 16-bit **Image Src** input are made in integer mode provided that the kernel contains only integers. Calculations made with a 32-bit floating-point **Image Src** input are made in floating-point mode. Note that the processing speed is correlated with the size of the kernel. A 3 × 3 convolution processes nine pixels while a 5 × 5 convolution processes 25 pixels.

IMAQ GetKernel

Reads a predefined kernel. This VI uses the contents of a convolution catalog (`imaqknl.txt`). This VI outputs a specified kernel after reading the kernel-associated code. This code consists of three separate units: **Kernel Family**, **Kernel Size**, and **Kernel Number**. If you already know the code, you can enter it directly with **Kernel Code**.



Kernel Family determines the type of matrix. The valid values are between 1 and 4, each associated with a particular type. This value corresponds to the thousandth unit in the researched code.

1	Gradient
2	Laplacian
3	Smoothing
4	Gaussian

Kernel Size (3,5,...) determines the horizontal and vertical matrix size. The values are 3, 5, and 7, corresponding to the convolutions 3 × 3, 5 × 5, and 7 × 7 supplied in the matrix catalog. This value corresponds to the hundredth unit in the researched code.

Kernel Number is the matrix family number. It is a two-digit number, between 0 and *n*, belonging to a family and a size. A number of predefined matrices are available for each type and size.

Kernel Code is a code that permits direct access to a convolution matrix cataloged in the file `imaqknl.txt`. Each code specifies a specific convolution matrix. This input is used under the conditions that it is connected and is not 0. The kernel located in the file then is transcribed into a 2D G array that is available from the output **Kernel**. The user can use the codes to specify a predefined kernel as well as to create new user-coded kernels. The coding syntax is simple to employ and is broken down in he following manner.

FSnn,

where F is the kernel family (1 to 4),
S is the kernel size (3,5, and so forth), and
nn is the kernel number (based on the family and size of the kernel).

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Divider is the normalization factor associated with the retrieved kernel.

Kernel is the resulting matrix. It corresponds to a kernel encoded by a code specified from the inputs **Kernel Family**, **Kernel Size**, and **Kernel Number** or a from a code directly passed through the input **Kernel Code**. This output can be connected directly to the input **Kernel** in IMAQ Convolute.

Kernel code indicates the code that was used to retrieve the kernel.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

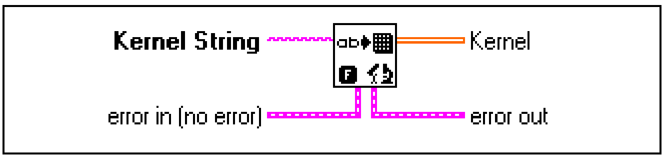
Example

For the kernel code 1300, the kernel family is gradient, the kernel size is 3 × 3, and the kernel number (*nn*) is 00. The matrix is

$$\begin{matrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{matrix}$$

IMAQ BuildKernel

Constructs a convolution matrix by converting a string. This string can represent either integers or floating-point values.



Kernel String is a string listing the coefficients forming the matrix.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

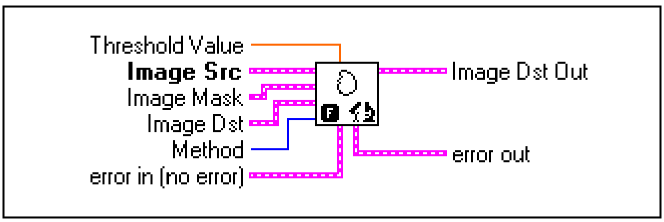
Kernel is the resulting matrix converted from the input string. This output can be connected directly to the input **Kernel** in IMAQ Convolute.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The column separator can be either a comma, a semi-colon, or a blank space. The line separator is a hard return. For example, the string `1 1 1 1 1 1 1 1 1` produces a 3 × 3 matrix with all coefficients set to `1`.

IMAQ EdgeDetection

Extracts the contours (detects edges) in gray-level values. Any image connected to the input **Image Dst** must be the same image type connected to **Image Src**. The image type connected to the input **Image Mask** must be an 8-bit image. The connected source image must have been created with a border capable of supporting the size of the processing matrix. For example, a 3 × 3 matrix has a minimum border size of 1. The border size of the destination image is not important.



Threshold Value is the minimum pixel value to appear in the resulting image. It is rare to use a value greater than 0 for this type of processing because the results from this processing are usually very dark and are not very dynamic. The default is 0.

Image Src is the image reference source.

Image Mask is an 8-bit image that specifies the region in the image to modify. Only pixels in the original image that correspond to the equivalent pixel in the mask are replaced by the values in the lookup table (provided that the value in the mask is not 0). All pixels not corresponding to this criteria keep their original value. The complete image is modified if **Image Mask** is not connected.

Image Dst is the reference of the image destination. If it is connected, it must be the same type as the **Image Src**.

Method specifies the type of edge-detection filter to use. The following table lists some of the available filters.

0	Differentiation	(Default) Processing with a 2 × 2 matrix
1	Gradient	Processing with a 2 × 2 matrix
2	Prewitt	Processing with a 3 × 3 matrix
3	Roberts	Processing with a 2 × 2 matrix
4	Sigma	Processing with a 3 × 3 matrix
5	Sobel	Processing with a 3 × 3 matrix

Note: ***See the** Nonlinear Filters **section of Chapter 5,** Spatial Filtering**, for more information about these filters.***

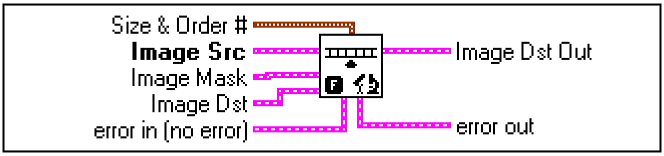
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ NthOrder

Orders (or classifies) the pixel values surrounding the pixel being processed. The data is placed into an array and the pixel being processed is set to the Nth pixel value, the Nth pixel being the ordered number.



Size & Order # is a cluster that specifies the following variables.

X Size is the size of the horizontal matrix axis. The default is 3.

Y Size is the size of the vertical matrix axis. The default is 3.

Order # is the order number chosen after classing the values. The default is 4.

Image Src is the image reference source.

Image Mask is an 8-bit image that specifies the region in the image to modify. Only pixels in the original image that correspond to the equivalent pixel in the mask are replaced by the values in the lookup table (provided that the value in the mask is not 0). All pixels not corresponding to this criteria keep their original value. The complete image is modified if **Image Mask** is not connected.

Image Dst is the reference of the image destination. If it is connected, it must be the same type as the **Image Src**.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Note: ***See the** Nonlinear Filters **section of Chapter 5,** Spatial Filtering**, for more information about the Nth order filter.***

Any image connected to the input **Image Dst** must be the same image type connected to **Image Src**. The image type connected to the input **Image Mask** must be an 8-bit image.

The connected source image must have been created with a border capable of supporting the size of the convolution matrix. A 3 × 3 matrix must have a minimum border of 1, a 5 x 5 matrix must have a minimum border of 2, and so forth. The border size of the destination image is not important.

The default for this VI is a 3 × 3 *Median operation* with *X* = 3, *Y* = 3, and *Order* = 4. To change to a 5 × 5 Median operation, the cluster must take the values *X* = 5, *Y* = 5, and *Order* = 12. In this last example, the order number is determined by calculating the central pixel number in the array. For a 5 × 5 convolution, *Order* = 12 (the thirteenth pixel) because that pixel is the center pixel number for a 2D array of 25 pixels.

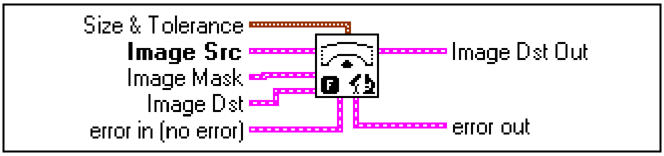
A lighter image results when using a higher order number (such as 7 in a 3 × 3 matrix). Darker images result when using a lower order number (such as 1 in a 3 × 3 matrix).

A median (center-pixel) operation is advantageous because it standardizes the gray-level values without significantly modifying the form of the objects or the overall brightness in the image.

If the order value that is entered is 0, then the image obtained is representative of the local minimum from the source image. If the order value that is passed is equal to [(*X Size* × *Y Size*) – 1], then the obtained image is representative of the local maximum from the source image.

IMAQ LowPass

Calculates the inter-pixel variation between the pixel being processed and those pixels surrounding it. If the pixel being processed has a variation greater than a specified percentage, it is set to the average pixel value as calculated from the neighboring pixels.



Size & Tolerance is a cluster that specifies the following variables.

X Size is the size of the horizontal matrix axis. The default is 3.

Y Size is the size of the vertical matrix axis. The default is 3.

% Tolerance is the maximum variation authorized. The default is 40%.

Image Src is the image reference source.

Image Mask is an 8-bit image that specifies the region in the image to modify. Only pixels in the original image that correspond to the equivalent pixel in the mask are replaced by the values in the lookup table (provided that the value in the mask is not 0). All pixels not corresponding to this criteria keep their original value. The complete image is modified if **Image Mask** is not connected.

Image Dst is the reference of the image destination. If it is connected, it must be the same type as the **Image Src**.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

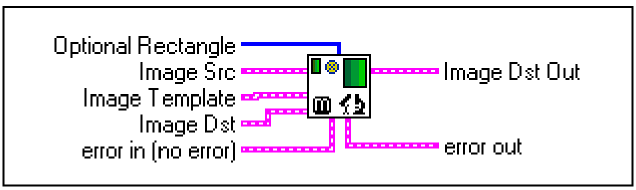
Note: ***See the* Nonlinear Filters *section of Chapter 5,* Spatial Filtering*, for more information about the lowpass filter.***

Any image connected to the input **Image Dst** must be the same image type connected to **Image Src**. The image type connected to the input **Image Mask** must be an 8-bit image.

The connected source image must have been created with a border capable of supporting the size of the convolution matrix. A 3 × 3 matrix must have a minimum border of 1, a 5 x 5 matrix must have a minimum border of 2, and so forth. The border size of the destination image is not important.

IMAQ Correlate

Computes the normalized cross correlation between the source image and the template image.



Optional Rectangle defines an array (four elements) containing the coordinates (Left / Top / Right / Bottom) of the region in the source image that is used for the correlation process. Correlation is applied to the entire image if the input is empty or not connected.

Image Src is a reference to the source image. The normalized cross correlation is performed between this image and the template image. This image must be an 8-bit image.

Image Template is a reference to a template image. This image must be an 8-bit image. For the correlation, the center of the template image is used as the origin.

Image Dst is the reference of the image destination. If it is connected, it must be the same type as the **Image Src**.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is an 8-bit image that contains the cross-correlation values normalized to lie in the range [0, 255]. A value of 255 indicates a very high correlation and a value of 0 indicates no correlation.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Note: ***Correlation is a time-intensive operation. You can reduce the time required to perform a correlation by keeping the template size small and reducing the search area in the source image by using the optional rectangle.***

Morphology VIs

Chapter 18

This chapter describes the Morphology VIs in IMAQ Vision. The morphological transformations are divided into two groups: binary morphology and gray-level morphology.

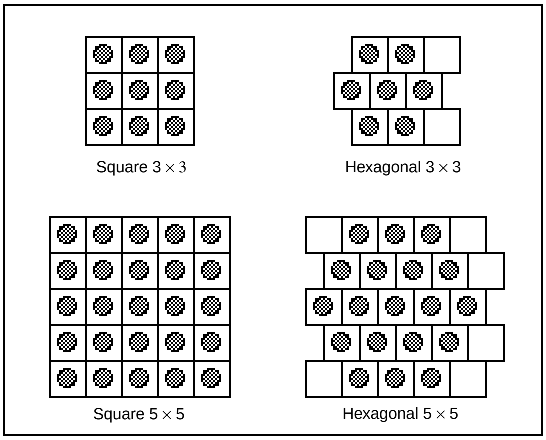
In binary morphology, the pixels are considered to exist in either of two states. The pixels are present (for pixel values other than 0) or absent (for pixel values equal to 0). The two types of binary processing available, primary and advanced, perform one of two actions: They activate and deactivate pixels. However, with gray-level morphology, a pixel is compared to those pixels surrounding it, to keep those pixel values that are the smallest (erosion) or the largest (dilation). VIs responsible for binary morphological transformations only accept an 8-bit image while the VI for gray-level morphological transformations (using IMAQ GrayMorphology) accepts 8-bit 16-bit, or 32-bit floating-point images.

An image is considered to be binary after it has undergone a threshold (IMAQ Threshold, IMAQ AutoBThreshold, and so forth). Binary morphology is divided into two groups in IMAQ Vision. The primary operations are all performed by a single VI (IMAQ Morphology). This VI performs erosions, dilations, openings, closings, and contour extractions. The advanced operations are performed by multiple VIs, each responsible for a single type of operation. These types of operations include the separation of particles, removing either small or large particles, filling holes in particles, removing particles that touch the boundary of the image border, and creating the skeleton of particles.

Morphological transformations are performed using an object known as a structuring element. This structuring element allows you to control the effect of the functions on the shape and the boundary of object. In IMAQ Vision, the structuring element is a 2D array that specifies, by its size and contents, which pixels are to be processed and which pixels are to be left unchanged. A structuring element must have a center pixel and therefore must contain an odd-sized axis. The contents of the structuring element are also considered to be binary (0 or not 0). The most often used structuring element is 3×3 and contains only values of 1. This is usually the default model for binary and gray-level morphological transformations. You need at least a basic understanding of structuring elements before experimenting with user-chosen sizes and contents. The majority of the VIs for advanced morphology do not possess an input for structuring element because only the standard 3 × 3 default is useful.

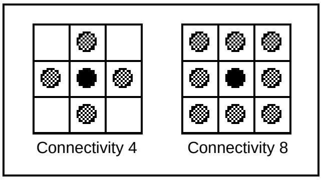
The connected source image for a morphological transformation must have been created with a border capable of supporting the size of the structuring element. A 3 × 3 structuring element requires a minimal border of 1, a 5 × 5 structuring element requires a minimal border of 2, and so forth.

The input **Square/Hexa** is available for certain VIs that perform morphological transformations. This concept introduces a variable for the perception of an *image frame* (aligned or shifted), which has an influence on the decision to include or not include pixels in the processing. The figure shown below illustrates the difference between a 3 × 3 and 5 × 5 structuring element in a square frame and a hexagonal frame.



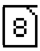
When processing in hexagonal mode, the elements [2, 0] and [2, 2] from the 3 × 3 structuring element are not used. The same holds true for the elements [0, 0], [4, 0], [4, 1], [4, 3], [0, 4] and [4, 4] if the transformation is made with a 5 × 5 structuring element.

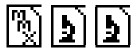
The input **Connectivity 4/8** (default is 8) is used for the advanced morphology VIs: IMAQ RemoveParticle, IMAQ RejectBorder, and IMAQ FillHole. These VIs use this input to determine whether or not a neighboring pixel is considered to be part of same particle. The difference is illustrated below.

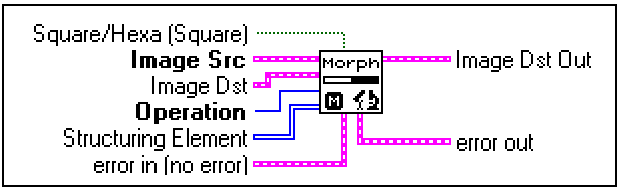


IMAQ Morphology

Performs primary morphological transformations. All source images must be 8-bit binary images. The connected source image for a morphological transformation must have been created with a border capable of supporting the size of the structuring element. A 3 × 3 structuring element requires a minimal border of 1, a 5 × 5 structuring element requires a minimal border of 2, and so forth. The border size of the destination image is not important.



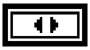




Square/Hexa (Square) specifies whether the pixel frame is treated as square or hexagonal during the transformation. The default is square.

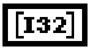
Image Src is the reference to the source (input) image.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

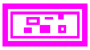


Operation specifies the type of morphological transformation procedure to use. The default is 0.

0	AutoM	(Default) Auto median
1	Close	Dilation followed by an erosion
2	Dilate	Dilation (the opposite of an erosion)
3	Erode	Erosion that eliminates isolated background pixels
4	Gradient	Extraction of internal and external contours of a particle
5	Gradient out	Extraction of exterior contours of a particle
6	Gradient in	Extraction of interior contours of a particle
7	Hit miss	Elimination of all pixels that do not have the same pattern as found in the structuring element
8	Open	Erosion followed by a dilation
9	PClose	A succession of 7 closings and openings
10	POpen	A succession of 7 openings and closings
11	Thick	Activation of all pixels matching the pattern in the structuring element
12	Thin	Activation of all pixels matching the pattern in the structuring element



Structuring Element is a 2D array that contains the structuring element to be applied to the image. The size of the structuring element (the size of this array) determines the processing size. A structuring element of 3 × 3 is used if this input is not connected.



error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

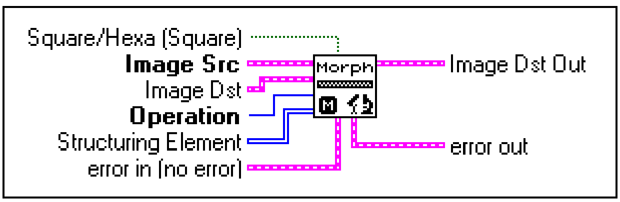
Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

A structuring element must have odd-sized dimensions so that it contains a central pixel. The function does not take into account the odd boundary, furthest out on the matrix, if one of the dimensions for the structuring element is even. For example, if the input structuring element is 6 × 4 (X = 6 and Y = 4), the actual processing is performed at 5 × 3. Both the sixth line and the fourth row are ignored. Recall that the second dimension in a G array is the vertical direction (Y). The processing speed is correlated with the size of the structuring element; for example, a 3 × 3 convolution processes nine pixels while a 5 × 5 convolution processes 25 pixels.

IMAQ GrayMorphology

Performs morphological transformations that can be directly applied to gray-level images. All source and destination image types must be the same. The connected source image for a morphological transformation must have been created with a border capable of supporting the size of the structuring element. A 3 × 3 structuring element requires a minimal border of 1, a 5 × 5 structuring element requires a minimal border of 2, and so forth. The border size of the destination image is not important.



Square/Hexa (Square) specifies whether the pixel frame is treated as square or hexagonal during the transformation. The default is square.

Image Src is the reference to the source (input) image.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

Operation specifies the type of morphological transformation procedure to use. The default is 0.

0	AutoM	(Default) Auto median
1	Close	Dilation followed by an erosion
2	Dilate	Dilation
3	Erode	Erosion
4	unused	
5	unused	
6	unused	
7	unused	
8	Open	Erosion followed by a dilation
9	PClose	A succession of 7 closings and openings
10	POpen	A succession of 7 openings and closings

Structuring Element is a 2D array that contains the structuring element to be applied to the image. The size of the structuring element (the size of this array) determines the processing size. A structuring element of 3 × 3 is used if this input is not connected.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

A structuring element must have odd-sized dimensions so that it contains a central pixel. The function does not take into account the odd boundary, farthest out on the matrix, if one of the dimensions for the structuring element is even. For example, if the input structuring element is 6 × 4 (X = 6 and Y = 4), the actual processing is performed at 5 × 3. Both the sixth line and the fourth row are ignored. Recall that the second dimension in a G array is the vertical direction (Y). The processing speed is correlated with the size of the structuring element. For example, a 3 × 3 convolution processes nine pixels while a 5 × 5 convolution processes 25 pixels.

IMAQ Distance

Encodes a pixel value of a particle as a function of the location of that pixel in relation to the distance to the border of the particle. The source image must have been created with a border size of at least 1 and must be an 8-bit binary image. This function requires the creation of a temporary memory space that is twice the size of the source image.

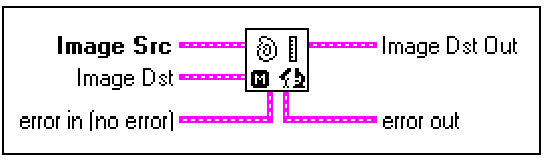


Image Src is the reference to the source (input) image.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ Danielsson

Returns a distance map based on the algorithms of Danielsson. The *Danielsson distance map* produces images and data that are similar to IMAQ Distance but are much more accurate. In most cases it is recommended that you use this function instead of IMAQ Distance.

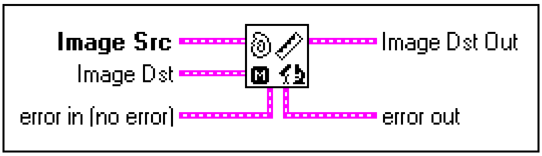


Image Src is the reference to the source (input) image.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

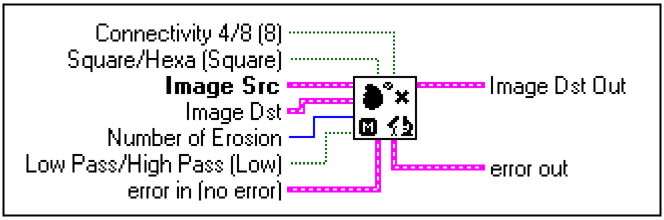
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ RemoveParticle

Eliminates or keeps particles resistant to a specified number of 3 × 3 erosions. The particles that are kept are exactly the same as those found in the original source image. The source image must be an 8-bit binary image. This function requires the creation of a temporary memory space that is twice the size of the source image.



Connectivity 4/8 (8) specifies how the algorithm determines whether an adjacent pixel is the same or different particle. The default is 8.

Square/Hexa (Square) specifies whether the pixel frame is treated as square or hexagonal during the transformation. The default is square.

Image Src is the reference to the source (input) image.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

Number of Erosion specifies the number of 3 × 3 erosions to apply to the image. The default is 2.

Low Pass/High Pass (Low) specifies whether the objects resistant to *n* erosions are discarded or kept (default).

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ FillHole

Fills the holes found in a particle. The holes are filled with a pixel value of 1. The source image must be an 8-bit binary image. This operation requires the creation of a temporary memory space that is equal to the size of the source image.

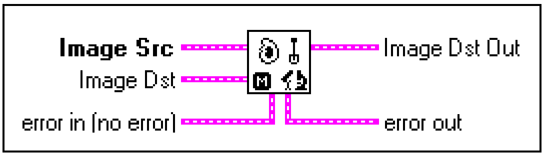


Image Src is the reference to the source (input) image.

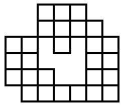
Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

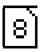
In the following example, the central empty portion is a hole and therefore is filled with a connectivity of 8. With a connectivity of 4, this function leaves the hole unchanged.

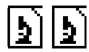


Note: ***The holes found in contact with the image border are never filled because it is impossible to determine whether these holes are part of a particle or not.***

IMAQ RejectBorder

Eliminates particles that touch the border of an image. The source image must be an 8-bit binary. This operation requires the creation of a temporary memory space that is equal to the size of the source image.





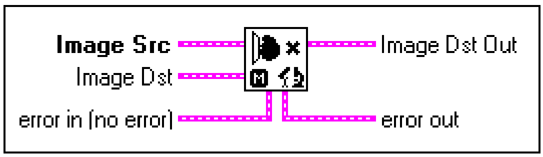


Image Src is the reference to the source (input) image.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ Convex

Calculates a convex envelope for particles that are labeled in an image. You need to execute IMAQ Label prior to this VI in order to label the objects in the image.

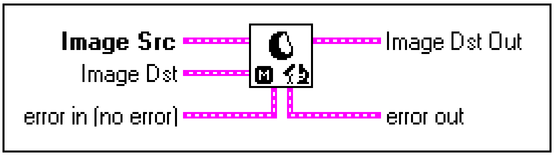


Image Src is the reference to the source (input) image.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

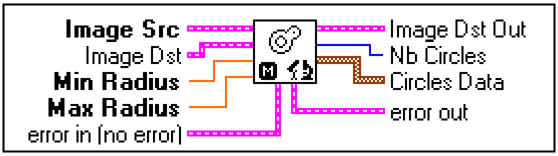
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ Circles

Separates overlapping circular objects and classifies them based on their radius, surface area, and perimeter. Starting from a binary image, it finds the radius and center of the circular objects even when multiple circular objects overlap. In addition, this VI can trace the circles in the destination image. It constructs and uses a Danielsson distance map to determine the radius of each object.



Note: ***IMAQ Circles works correctly only for circles that have a radius less than or equal to 256 pixels.***

Image Src is the reference to the source (input) image.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

Min Radius is the smallest radius (in pixels) that is detected. Circles possessing a radius smaller than this value do not appear in the destination image and have a negative radius value in the output **Circles Data**. The default is 1.

Max Radius (default 10) is the largest radius (in pixels) that is detected. Circles possessing a radius larger than this value do not appear in the destination image and have a negative radius value in the output **Circles Data**. The default is 10.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

Nb Circles returns the number of detected circles in the image

Note: ***Circles with a radius outside the limits of Min Radius or Max Radius also are included in this number.***

Circles Data returns an array of measurements for all detected circles. Each element in the array has a structure containing the following elements:

Pos. X is the horizontal position (in pixels) of the center of the circle.

Pos. Y is the vertical position (in pixels) of the center of the circle.

Radius is the radius of the circle (in pixels). Circles with a radius outside the limits of **Min Radius** or **Max Radius** contain negative radius values.

Core Area is the surface area (in pixels) of the nucleus of the circle as defined by the Danielsson distance map.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ Segmentation

Starting from a labeled image, calculates the zones of influence between particles. Each labeled particle grows until the particles reach their neighbors, at which time this growth is stopped. The source image must have a border greater than or equal to 1.

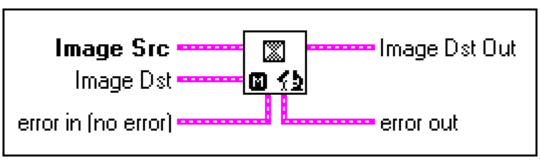


Image Src is the reference to the source (input) image.

Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.

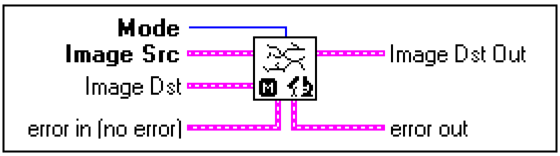
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ Skeleton

Starting from a binary image, calculates a skeleton from particles within an image or the lines delineating the zones of influence (skeleton of an inverse image). The source image must have a border greater than or equal to 1.



Mode specifies the type of skeleton to perform. The default is 0.

0 Skeleton L uses this type structuring element:

0	?	1
0	1	1
0	?	1

1 Skeleton M uses this type structuring element:

?	?	1
0	1	1
?	?	1

2 Skiz is an inverse skeleton (Skeleton L on an inverse image).

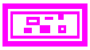


Image Src is the reference to the source (input) image.

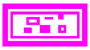
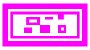


Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.



error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

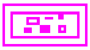
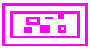


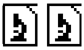
Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

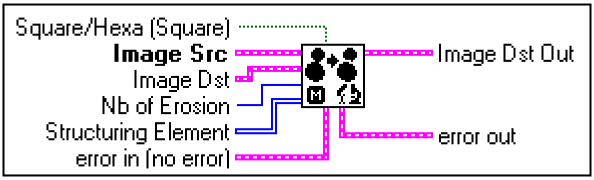


error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ Separation

Separates touching particles, particularly small isthmuses found between particles. It performs *n* erosions (*n* = **Nb of erosions**) and then reconstructs the final image based on the results of the erosion. If during the erosion process an existing isthmus has been broken or removed, then the particles are reconstructed without the isthmus. The reconstructed particles, however, have the same size as the initial particles except that they are separated. If during the erosion process no isthmus has been broken, then the particles are reconstructed as they were initially found (no changes are made). The source image must be an 8-bit binary image. The source image must have a border greater than or equal to 1.



Square/Hexa (Square) specifies whether the pixel frame is treated as square or hexagonal during the transformation. The default is square.

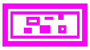


Image Src is the reference to the source (input) image.

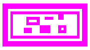
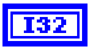
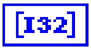


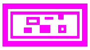
Image Dst is the reference to the destination image. If it is connected, it must be the same type as the **Image Src**.



Nb of Erosion specifies the number of erosions that are used to separate the particles. The default is 1.



Structuring Element is a 2D array that contains the structuring element to be applied to the image. The size of the structuring element (the size of this array) determines the processing size. A structuring element of 3 × 3 is used if this input is not connected.



error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

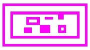
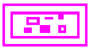
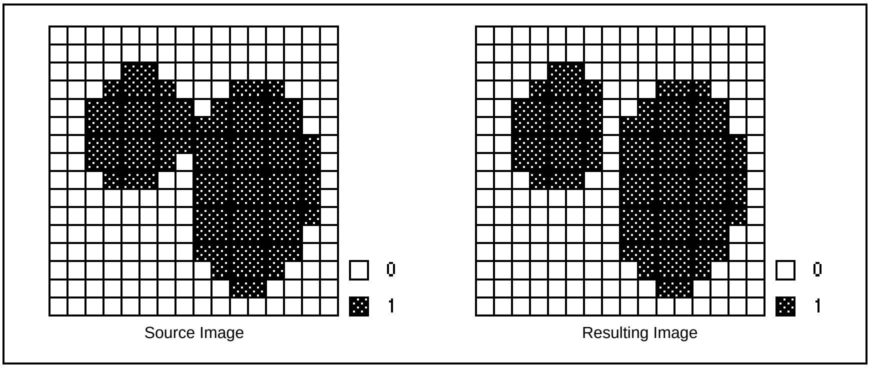


Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.



error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The following graphic illustrates the processing performed with this function.



Chapter 19

Analysis VIs

This chapter describes the Analysis VIs in IMAQ Vision.

IMAQ Histogram

Calculates the histogram of an image.

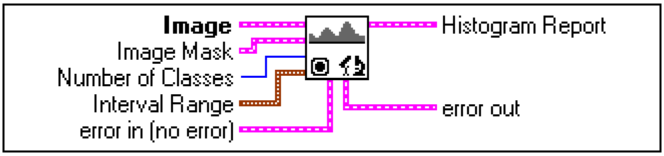


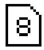
Image is the input source image used for calculating the histogram.

Image Mask is an 8-bit image specifying the region in the image to use for calculating a histogram. Only pixels in the original image that correspond to the equivalent pixel in the mask are used for calculating the histogram (provided that the value in the mask is not 0). A histogram on the complete image occurs if the **Image Mask** is not connected.

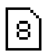
Number of Classes specifies the number of classes used to classify the pixels. The number of obtained classes differs from the specified amount in a case in which the minimum and maximum boundaries are overshot in the **Interval Range.** It is advised to specify an even number of classes (for example, 2, 4, or 8) for 8-bit or 16-bit images. The default value is 256, which is designed for 8-bit images. This value gives a uniform class distribution or one class for each pixel in a 8-bit image.

Interval Range is a cluster specifying the minimum and maximum boundaries for the histogram calculation. Only pixels having a value that falls in this range are taken into account by the histogram calculation. This cluster is composed of the following elements.

Minimum is the minimum interval value. The default value of (0, 0) insures that the real minimum value is determined by the source image, as described in the following table.

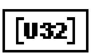
Image Type	Minimum Value Used
	(0, 0)
	Minimum pixel value found in the image
	Minimum pixel value found in the image

Maximum is the maximum interval value. The default value of (0, 0) insures that the real maximum value is determined by the source image, as described in the following table.

Image Type	Maximum Value Used
	255
	Maximum pixel value found in the image
	Maximum pixel value found in the image

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Histogram Report is a cluster that returns the histogram values. This cluster contains the following elements.



Histogram returns the histogram values in an array. The elements found in this array are the number of pixels per class. The *n*th class contains all pixel values belonging to the interval $[(Starting\ Value + (n - 1) \times Interval\ Width),$ $(Starting\ Value + n \times (Interval\ Width - 1))]$.

Minimal Value returns the smallest pixel value used in calculating the histogram.

Maximal Value returns the largest pixel value used in calculating the histogram.

Starting Value returns the smallest pixel value from the first class calculated in the histogram. It can be equal to the **Minimal** value from the **Interval Range** or the smallest value found for the image type connected.

Interval Width returns the length of each class.

Mean Value returns the mean value of the pixels used in calculating the histogram.

Standard Deviation returns the standard deviation from the histogram A higher value corresponds to a better distribution of the values in the histogram and the image.

Area (pixels) returns the number of pixels used in the histogram calculation. This is influenced by the values specified in **Interval Range** and the contents of **Image Mask**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ Histograph

Calculates the histogram from an image. This VI returns a data type (cluster) compatible with a LabVIEW or BridgeVIEW graph.

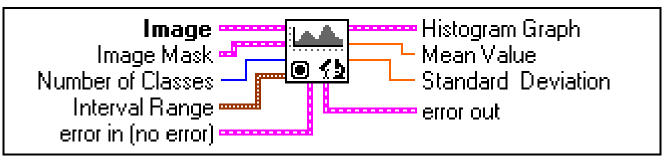


Image is the input source image used for calculating the histogram.

Image Mask is an 8-bit image specifying the region in the image to use for calculating a histogram. Only pixels in the original image that correspond to the equivalent pixel in the mask are used for calculating the histogram (provided that the value in the mask is not 0). A histogram on the complete image occurs if the **Image Mask** is not connected.

Number of Classes specifies the number of classes used to classify the pixels. The number of obtained classes differs from the specified amount in a case in which the minimum and maximum boundaries are overshot in the **Interval Range**. You are advised to specify an even number of classes (for example, 2, 4, or 8) for 8-bit or 16-bit images. The default value is 256, which is designed for 8-bit images. This value gives a uniform class distribution or one class for each pixel in a 8-bit image.

Interval Range is a cluster specifying the minimum and maximum boundaries for the histogram calculation. Only pixels having a value that falls in this range are taken into account by the histogram calculation. This cluster is composed of the following elements.

Minimum is the minimum interval value. The default value of (0, 0) insures that the real minimum value is determined by the source image, as described in the following table.

Image Type	Minimum Value Used
8	0
16	Minimum pixel value found in the image
R	Minimum pixel value found in the image

Maximum is the maximum interval value. The default value of (0, 0) insures that the real maximum value is determined by the source image, as described in the following table.

Image Type	Maximum Value Used
8	255
16	Maximum pixel value found in the image
R	Maximum pixel value found in the image

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Histogram Graph is a cluster that returns the histogram values. This cluster contains the following elements.

Starting Value returns the smallest pixel value from the first class calculated in the histogram. It can be equal to the **Minimal** value from the **Interval Range** or the smallest value found for the image type connected.

Incremental Value returns the incrementing value that specifies how much to add to **Starting Value** in calculating the median value of each class from the histogram. The median value x_n from the nth class is

$$x_n = \mathit{Starting\ Value} + n \times \mathit{Incremental\ Value}.$$

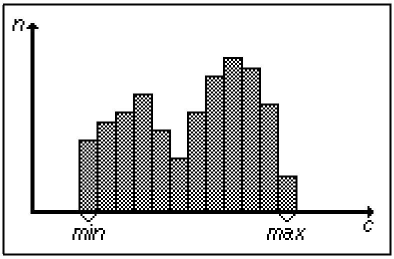
Histogram returns the histogram values in an array. The elements found in this array are the number of pixels per class. The nth class contains all pixel values belonging to the interval $[(\mathit{Starting\ Value} + (n-1) \times \mathit{Interval\ Width}), (\mathit{Starting\ Value} + n \times (\mathit{Interval\ Width} - 1))]$.

Mean Value returns the mean value of the pixels used in calculating the histogram.

Standard Deviation returns the standard deviation from the histogram. The higher this value, the better the distribution of the values in the histogram and the image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The following figure shows the interval for calculating a histogram, *where n* is the number of pixels and *c* is the indexing number.



IMAQ LineProfile

Calculates the profile of a line of pixels. This VI returns a data type (cluster) compatible with a LabVIEW or BridgeVIEW graph. The relevant pixel information is taken from the specified vector (line).

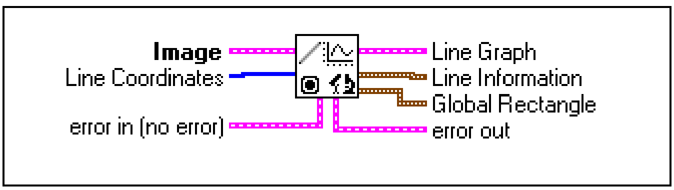


Image is the input source image used for calculating the line profile.

Line Coordinates are an array specifying the pixel coordinates that form the end-points of the line.

Note: ***A line with the coordinates [0, 0, 0, 255] is formed from 256 pixels. Any pixels designated by the Line Coordinates found outside the actual image are set to 0 in Line Graph.***

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Line Graph is a cluster that contains the line profile with an X origin at 0 and an increment of 1. The cluster contains the following elements.

x0 always returns 0.

dx always returns 1.

Pixels Line returns the line profile calculated in an array in which elements represent the pixel values belonging to the specified vector.

Line Information is a cluster containing relevant information about the pixels found in the specified vector. This cluster contains the following elements.

Min returns the smallest pixel value found in the line profile.

Max returns the largest pixel value found in the line profile.

Mean returns the mean value of the pixels found in the line profile.

Var returns the standard deviation from the line profile.

Count found in the line profile.

Global Rectangle is a cluster that contains the coordinates of a bounding rectangle for the line in the image. The following elements are included in the cluster.

x1Left indicates the coordinates for the upper-left corner of the rectangle.

y1Top indicates the coordinates for the top-left corner of the rectangle.

x2Right indicates the coordinates for the lower-right corner of the rectangle.

y2Bottom indicates the coordinates for the bottom-right corner of the rectangle.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ LinearAverages

Computes the average pixel intensity (mean line profile) on whole or part of the image.

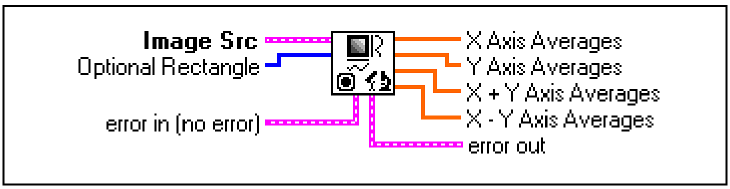


Image Src is the reference to the source (input) image.

Optional Rectangle defines an array (four elements) containing the coordinates (Left / Top / Right / Bottom) of the region to extract. The operation is applied to the entire image if the input is empty or not connected.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

X Axis Averages is the linear average along each column in the image.

Y Axis Averages is the linear average along each row in the image.

X + Y Axis Averages is the linear average along each diagonal running from bottom-left to top-right.

X - Y Axis Averages is the linear average along each diagonal running from top-left to bottom-right.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ Quantify

Quantifies the contents of an image or the regions within an image. The region definition is performed with a labeled image mask. Each mask has a single unique value.

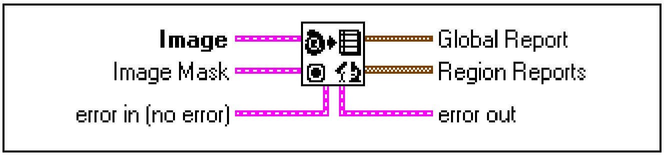


Image is the input source image.

Image Mask is an 8-bit image specifying the regions to quantify in the image. Only pixels in the original image that correspond to the equivalent pixel in the mask are used for the quantification. Each pixel in this image (mask) indicates, by its value, which region belongs the corresponding pixel in **Image**. 255 different regions can be quantified directly from the **Image**. A quantification is performed on the complete image if the **Image Mask** is not connected.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Global Report is a cluster containing the quantification data relative to all the regions within an image (or the entire image if the **Image Mask** is not connected). The following elements are contained in this cluster.

Mean Value of the pixels is returned.

Standard Deviation of the pixel values is returned. It indicates the distribution of the values in relation to the average. The higher this value, the better the distribution of the pixel values.

Minimal Value returns the smallest pixel value.

Maximal Value returns the largest pixel value.

Area (calibrated) returns the analyzed surface area in user-units.

Area (pixels) returns the analyzed surface area in pixels.

% returns the percentage of the analyzed surface in relation to the complete image.

Region Reports is a cluster containing the quantification data relative to each region within an image (or the entire image if the **Image Mask** is not connected). The *n*th element in this array contains the data regarding the *n*th region. The size of this array is equal to the largest pixel value in **Image Mask**. The returned data is identical to the data in **Global Report**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ Centroid

Computes the energy center of the image.

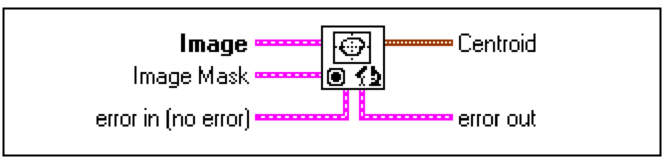


Image is the reference to the image whose centroid has to be calculated.

Image Mask is an 8-bit image specifying the region in the image to use for calculating a centroid. Only pixels in the original image that correspond to the equivalent pixel in the mask are used for calculating the centroid (provided that the value in the mask is not 0). A centroid on the complete image occurs if the **Image Mask** is not connected.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Centroid is a cluster containing the X and Y coordinates of the centroid of the image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ BasicParticle

Detects and measures particles. This VI returns the area and position of particles in a binary image.

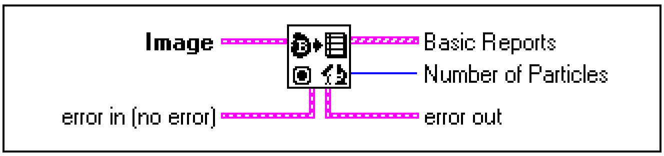


Image is the input source image used for calculating the matrices. The image must be binary. A particle is considered to consist of pixels that do not contain a null (0) value. The source image must have been created with a border size of at least 2.

Connectivity 4/8 specifies the type of connectivity used by the algorithm for particle detection. The connectivity mode directly determines whether an adjacent pixel belongs to the same particle or a different particle. The default is 8. The following values are possible:

TRUE	Connectivity 8	(Default) Particle detection is performed in connectivity mode 8.
FALSE	Connectivity 4	Particle detection is performed in connectivity mode 4.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Basic Reports is an array that returns a set of measurements from the detected particles. This cluster contains the following elements.

Area (pixels) indicates the surface area of a particle in number of pixels.

Area (calibrated) indicates the surface area of a particle in user-defined units.

Global Rectangle is a cluster that contains the coordinates of a bounding rectangle for a particle. The following elements are included in the cluster.

x1Left indicates the coordinates for the upper-left corner of the rectangle.

y1Top indicates the coordinates for the top-left corner of the rectangle.

x2Right indicates the coordinates for the lower-right corner of the rectangle.

y2Bottom indicates the coordinates for the bottom-right corner of the rectangle.

Number of Particles returns the number of pixels detected in a particle.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ComplexParticle

Detects and measures particles. This VI returns a set of measurements made from particles in a binary image.

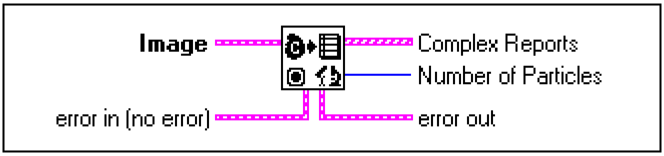


Image is the input source image used for calculating the matrices. The image must be binary. A particle is considered to consist of pixels that do not contain a null (0) value. The source image must have been created with a border size of at least 2.

Connectivity 4/8 specifies the type of connectivity used by the algorithm for particle detection. The connectivity mode directly determines whether an adjacent pixel belongs to the same particle or a different particle. The default is 8. The following values are possible.

TRUE	Connectivity 8	(Default) Particle detection is performed in connectivity mode 8.
FALSE	Connectivity 4	Particle detection is performed in connectivity mode 4.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Complex Reports is an array that returns a set of measurements from the detected particles. This cluster contains the following elements.

I32 **Area (pixels)** indicates the surface area of a particle in number of pixels.

SGL **Area (calibrated)** indicates the surface area of a particle in user-defined units.

SGL **Perimeter** is the perimeter size in user units.

I32 **Number of Holes** is the number of holes in the particle.

I32 **Hole's Area (pixels)** is the total surface area of all the holes in a particle (in pixels).

SGL **Hole's Perimeter** is the total perimeter size calculated from all the holes in a particle (in user units).

Global Rectangle is a cluster that contains the coordinates of a bounding rectangle for a particle. The following elements are included in the cluster.

- I32 **x1Left** indicates the coordinates for the upper-left corner of the rectangle.
- I32 **y1Top** indicates the coordinates for the top-left corner of the rectangle.
- I32 **x2Right** indicates the coordinates for the lower-right corner of the rectangle.
- I32 **y2Bottom** indicates the coordinates for the bottom-right corner of the rectangle

SGL $\sum$ **x** is the sum of the X-axis for each pixel of the particle.

SGL $\sum$ **y** is the sum of the Y-axis for each pixel of the particle.

SGL $\sum$ **xx** is the sum of the X-axis squared for each pixel of the particle.

SGL $\sum$ **xy** is the sum of the X-axis and Y-axis for each pixel of the particle.

SGL $\sum$ **yy** is the sum of the Y-axis squared for each pixel of the particle.

Longest Segment Length is the longest segment length of the particle.

Longest Segment Coordinates are the coordinates of the left most pixel in the **Longest Segment Length** of the particle. The top-most segment coordinates are used in a case in which more than one **Longest Segment Length** exist. This cluster contains the following parameters.

x is the x-axis (coordinate) of the pixel the furthest left in the **Longest Segment Length** in the particle.

y is the y-axis (coordinate) of the pixel the furthest left in the **Longest Segment Length** in the particle.

Projection x is half the sum of the horizontal segments in a particle that do not overlap another adjacent horizontal segment.

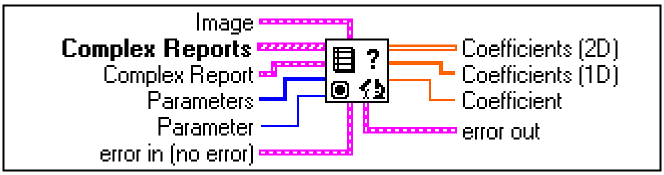
Projection y is half the sum of the vertical segments in a particle that do not overlap another adjacent vertical segment.

Number of Particles returns the number of detected particles.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ComplexMeasure

Calculates the coefficients of all detected particles. This VI returns an array of coefficients whose measurements are based on the results sent from IMAQ ComplexParticle.



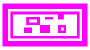
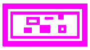
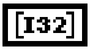


Image is the same input source image that is used to measure the particle coefficients by IMAQ ComplexParticle.

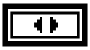
Complex Reports is the output array of measurements from IMAQ ComplexParticle. The measurements stored in each element of this array are described in the *IMAQ ComplexParticle* section.



Complex Report is an extraction of the output array of measurements from IMAQ ComplexParticle. The measurements stored in each element of this array are described in the *IMAQ ComplexParticle* section. This input is used only in a case in which **Complex Reports** is not connected, thereby specifying that the measurements are to be made on a single particle.



Parameters is an array specifying a descriptor list of the coefficients that the user wants to calculate. The user can calculate one or more coefficients for one or more particles. The descriptor list is described in the table for the **Parameter** control.



Parameter is an array specifying a descriptor list of the coefficients that the user wants to calculate. The user can calculate one or more coefficients for one or more particles. This input is used only in a situation in which the input **Parameters** is not connected. The descriptor list is described in the following table.

0	Area (pixels)	surface area of particle in pixels
1	Area (calibrated)	surface area of particle in user units
2	Number of holes	number of holes
3	Hole's Area	surface area of the holes in user units
4	Total area	total surface area (holes and particles) in user units
5	Scanned Area	surface area of the entire image in user units
6	Ratio Area/ Scanned Area %	percentage of the surface area of a particle in relation to the Scanned Area
7	Ratio Area/ Total Area %	percentage of a particle's surface area in relation to the Total Area

8	Center of mass (X)	X coordinate of the center of gravity
9	Center of mass (Y)	Y coordinate of the center of gravity
10	Left column (X)	left X coordinate of bounding rectangle
11	Upper row (Y)	top Y coordinate of bounding rectangle
12	Right column (X)	right hand X coordinate of bounding rectangle
13	Lower Row (Y)	bottom Y coordinate of bounding rectangle
14	Width	width of bounding rectangle in user units
15	Height	height of bounding rectangle in user units
16	Longest segment length	length of longest horizontal line segment
17	Longest segment left column(X)	left-most X coordinate of longest horizontal line segment
18	Longest segment row (Y)	Y coordinate of longest horizontal line segment
19	Perimeter	length of outer contour of particle in user units
20	Hole's Perimeter	perimeter of all holes in user units
21	SumX	sum of the X-axis for each pixel of the particle
22	SumY	sum of the Y-axis for each pixel of the particle
23	SumXX	sum of the X-axis squared, for each pixel of the particle
24	SumYY	sum of the Y-axis squared, for each pixel of the particle
25	SumXY	sum of the X-axis and Y-axis for each pixel of the particle

26	Corrected projection X	projection corrected in *x*
27	Corrected projection Y	projection corrected in *y*
28	Moment of inertia Ixx	inertia matrix coefficient in *xx*
29	Moment of inertia Iyy	inertia matrix coefficient in *yy*
30	Moment of inertia Ixy	inertia matrix coefficient in *xy*
31	Mean chord X	mean length of horizontal segments
32	Mean chord Y	mean length of vertical segments
33	Max intercept	length of longest segment
34	Mean intercept perpendicular	mean length of the chords in an object perpendicular to its max intercept
35	Particle orientation	direction of the longest segment
36	Equivalent ellipse minor axis	total length of the axis of the ellipse having the same area as the particle and a major axis equal to half the max intercept.
37	Ellipse major axis	total length of major axis having the same area and perimeter as the particle in user units
38	Ellipse minor axis	total length of minor axis having the same area and perimeter as the particle in user units
39	Ratio of equivalent ellipse axis	fraction of major axis to minor axis
40	Rectangle big side	length of the large side of a rectangle having the same area and perimeter as the particle in user units
41	Rectangle small side	length of the small side of a rectangle having the same area and perimeter as the particle in user units

42	Ratio of equivalent rectangle sides	ratio of rectangle big side to rectangle small side
43	Elongation factor	max intercept / mean perpendicular intercept
44	Compactness factor	particle area (breadth × width)
45	Heywood circularity factor	particle perimeter / perimeter of circle having same area as particle
46	Type Factor	a complex factor relating the surface area to the moment of inertia.
47	Hydraulic Radius	particle area / particle perimeter
48	Waddel disk diameter	diameter of the disk having the same area as the particle in user units
49	Diagonal	diagonal of an equivalent rectangle in user units

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Coefficients (2D) is a 2D array containing the specified measurements. This array is used only when the user has specified multiple coefficients (measurements) for each particle. The data is stored by particle followed by the coefficients.

Coefficients (1D) is a 1D array containing the specified measurements. This array is used only when the user has specified either multiple coefficients (measurements) for a single particle or a single coefficient for multiple particles.

Coefficient is the measurement specified for a single particle.

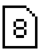
error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

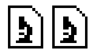
The output from this VI can be in one of three forms: **Coefficients (2D)**, **Coefficients (1D)**, or **Coefficient**. The final type of output is dependent on the connected inputs, as shown in the following table.

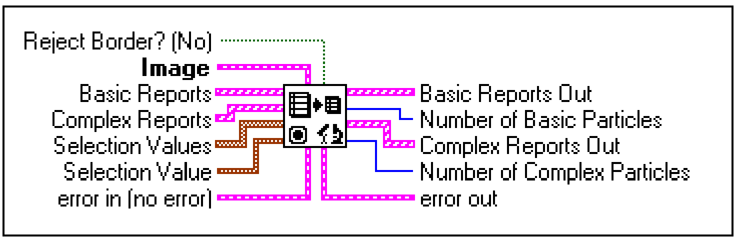
Possible Inputs	Resulting Type of Output
Complex Reports and Parameters	Coefficients (2D)
Complex Reports and Parameter	Coefficients (1D)
Complex Report and Parameters	Coefficients (1D)
Complex Report and Parameter	Coefficient

IMAQ ChooseMeasurements

Returns a selection of particle measurements that are sent from IMAQ BasicParticle or IMAQ ComplexParticle based on a minimum and maximum criteria. With this VI, you choose which measurements you want to obtain from a particle detection process.







Reject Border? (No) determines whether particles touching the border should be measured. If set to TRUE, the measurements for particles touching the border are rejected. In this case the input image source must be connected to the input **Image**. The default is FALSE.

Image is the same input source image that is used to measure the particle coefficients by IMAQ BasicParticle or IMAQ ComplexParticle. This input is used only in a case in which particles touching the border are discarded for measurement calculations (**Reject Border?** is set to TRUE).

Basic Reports is the output array of measurements from IMAQ BasicParticle. The measurements stored in each element of this array are described in the *IMAQ BasicParticle* section.

Complex Reports is the output array of measurements from IMAQ ComplexParticle. The measurements stored in each element of this array are described in the *IMAQ ComplexParticle* section.

Selection Values is an array of selection criteria. Each criteria is composed of the following elements.

Parameter is an indicator that determines the coefficient (measurement) to be selected. **Parameter** can have values compatible to those described in IMAQ ComplexMeasure. The validity of these values depends on the type of measurements passed as input (for example, through **Basic Reports** or **Complex Reports**).

Note: ***Only the particle measurements that respond to the selection criteria are selected. The coefficient values must be contained in the interval between*** Lower Value ***and*** Upper Value**.**

The following values are possible for selecting basic measurements (from **Basic Reports**).

0	Area (pixels)	surface area of particle in pixels
1	Area (calibrated)	surface area of particle in user units
2 – 9	unused	
10	Left column (X)	left X coordinate of bounding rectangle
11	Upper row (Y)	top Y coordinate of bounding rectangle
12	Right column (X)	right X coordinate of bounding rectangle
13	Lower row (Y)	bottom Y coordinate of bounding rectangle
14 – 27	unused	

The following values are possible for selecting complex measurements (from **Complex Reports**).

0	Area (pixels)	surface area of particle in pixels
1	Area (calibrated)	surface area of particle in user units
2	Number of holes	number of holes
3	Hole’s area (pixels)	surface area of the holes in pixels
4 – 9	unused	
10	Left column (X)	left X coordinate of bounding rectangle
11	Upper row (Y)	top Y coordinate of bounding rectangle
12	Right column (X)	right X coordinate of bounding rectangle
13	Lower row (Y)	bottom Y coordinate of bounding rectangle
14 – 15	unused	
16	Longest segment length	length of longest horizontal line segment
17	Longest segment left column (X)	left-most X coordinate of longest horizontal line
18	Longest segment top row (Y)	Y coordinate of longest horizontal line segment
19	Perimeter	length of outer contour of particle
20	Hole's Perimeter	perimeter of all holes
21	SumX	sum of the X-axis for each pixel of the particle
22	SumY	sum of the Y-axis for each pixel of the particle
23	SumXX	sum of the X-axis squared for each pixel of the particle
24	SumYY	sum of the Y-axis squared for each pixel of the particle
25	SumXY	sum of the X-axis and Y-axis for each pixel of the particle

26	Corrected projection x	projection corrected in x
27	Corrected projection y	projection corrected in y

Lower Value is the minimum value (boundary) for the values to be selected.

Upper Value is the maximum value (boundary) for the values to be selected.

Selection Value is a selection criteria. This value is used only if the array of selection criteria is not connected to **Selection Values**. The selection criteria possess the same structure as each element in the array **Selection Values**. The default value for **Parameter** is –1, which specifies that all measurements are made (no selection).

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Basic Reports Out is an output containing an array of the basic measurements selected.

Number of Basic Particles is an output containing the number of basic measurements selected.

Complex Reports Out is an output containing an array of the complex measurements selected.

Number of Complex Particles is an output containing the number of complex measurements selected.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

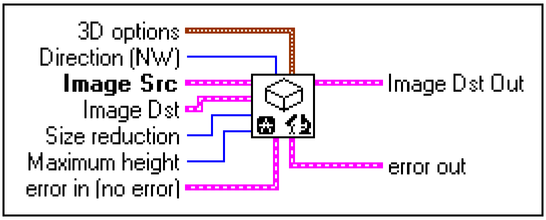
Chapter 20

Geometry VIs

This chapter describes the Geometry VIs in IMAQ Vision.

IMAQ 3DView

Displays an image using an isometric view. Each pixel from the image source is represented as a column of pixels in the 3D view. The pixel value corresponds to the altitude.



3D Options is a cluster containing the elements **alpha**, **beta**, **border**, **background**, and **plane**.

alpha defines the angle between the horizontal and the base line (see figure). The value can be between 0° and 45°. The default value is 30°.

beta defines the angle between, the horizontal and the second baseline. The value can be between 0° and 45°. The default value is 30°.

border defines the border size in the 3D view. The default value is 20.

background defines the background color for the 3D view. The default is 85.

plane specifies the view to display if the image is complex. There are four possible planes that can be visualized from a complex image. For complex images, the default is the magnitude.

0 real

1 imaginary

2 (Default) magnitude

3 phase

Direction (NW) defines the viewing orientation shown for the 3D view. Four viewing angles are possible. The default is North-West.

0 (Default) North-West

1 South-West

2 South-East

3 North-East

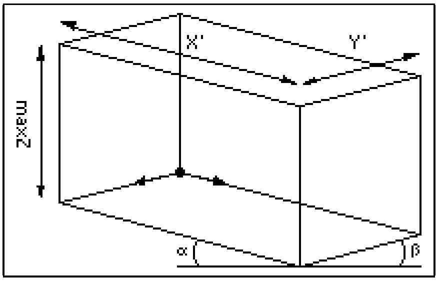
Image Src is the reference to the source (input) image.

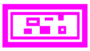
Image Dst must be an 8-bit image.

Size reduction is a factor applied to the source image to calculate the final dimensions of the 3D view image. This factor is a divisor that is applied to the source image when determining the final height and width of the 3D view image. A factor of 1 uses all of the pixels of the source image when determining the 3D view image. A factor of 2 uses every other line and every other column of the pixels of the source image to determine the 3D view image. The default is 2.

Maximum height defines the maximum height of a pixel from the image source that is drawn in 3D. This value is mapped from a maximum of 255 (from the source image) in relation to the baseline in the 3D view. A value of 255, therefore, gives a one-to-one correspondence between the intensity value in the source image and the display in 3D view. The default value of 64 results in a reduction of

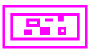
4-fold between the original intensity value of the pixel in the source image and the final displayed 3D image.





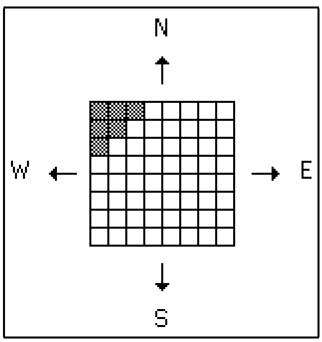
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

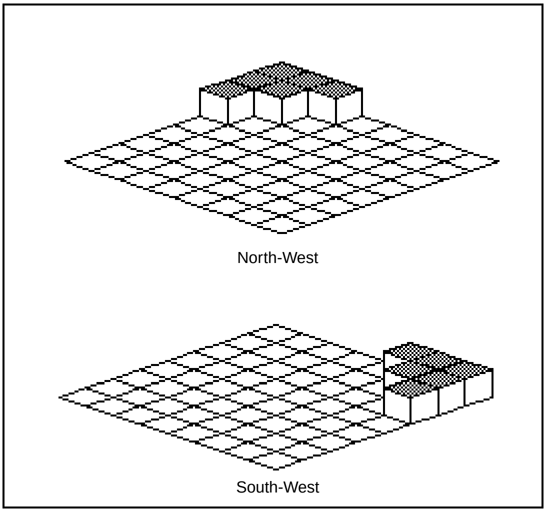


error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The following graphic illustrates the cardinal coordinates of an image.

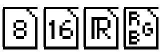


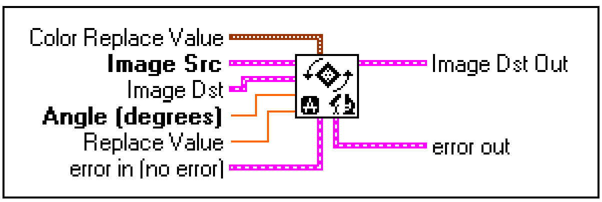
The North-West direction and the South-West direction are depicted in the following graphic.



IMAQ Rotate

Rotates an image.





Color Replace Value is a cluster containing the **Alpha, Red, Green,** and **Blue** channel values used for filling a color image. The default is 0.

Image Src is the reference to the source (input) image.

Image Dst is the reference of the image destination. If it is connected, it must be the same type as the **Image Src**.

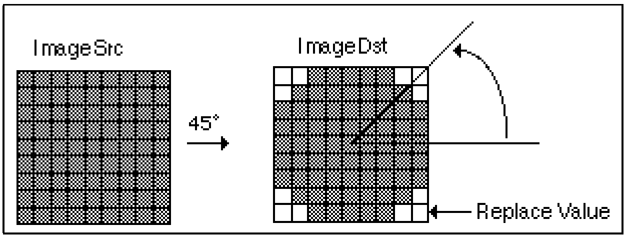
Angle (degrees) defines the angle (in degrees) to rotate. The default is 0.

Replace Value defines the filling value created by the rotation. The default is 0.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

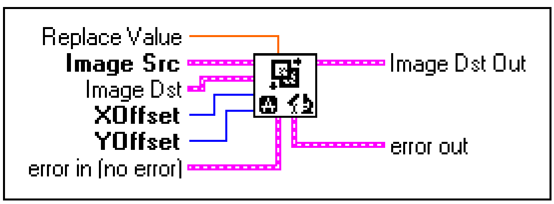
Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.



IMAQ Shift

Translates an image based on a horizontal and vertical offset.



Replace Value defines the filling value created by the shift. The default is 0.

Image Src is the reference to the source (input) image.

Image Dst is the reference of the image destination. If it is connected, it must be the same type as the **Image Src**.

XOffset is the horizontal offset added to the image. The default is 0.

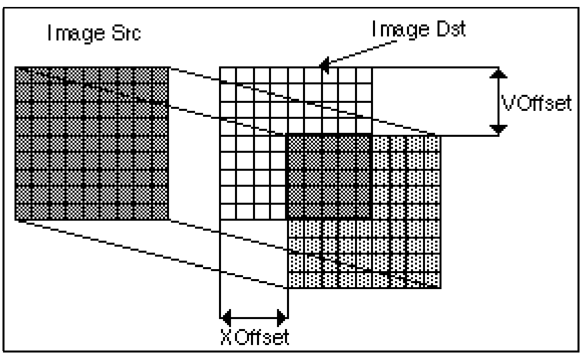
YOffset is the vertical offset added to an image. The default is 0.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

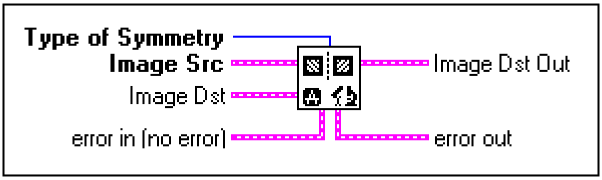
error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The following graphic illustrates the functionality of this VI.



IMAQ Symmetry

Transforms an image through its symmetry.



Type of Symmetry specifies the symmetry used. The default is 0.

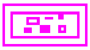
0	Horizontal	(Default) Based on the horizontal axis of the image
1	Vertical	Based on the vertical axis of the image
2	Central	Based on the center of the image
3	1st Diagonal	Based on the first diagonal of the image (the image must be square)
4	2nd Diagonal	Based on the second diagonal of the image (the image must be square)

Image Src is the reference to the source (input) image.

Image Dst is the reference of the image destination. If it is connected, it must be the same type as the **Image Src**.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.



error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Complex VIs

Chapter 21

This chapter describes the Complex VIs.

Frequency processing is another technique for extracting information from an image. Instead of using the location and direction of light intensity variations, frequency processing allows you to manipulate the frequency of the occurrence of these variations in the spatial domain. This new component is called the *spatial frequency*, which is the frequency with which the light intensity in an image varies as a function of spatial coordinates.

Spatial frequencies of an image are computed with the Fast Fourier Transform (FFT). The FFT is calculated in two steps: a one-dimensional transform of the rows, followed by a one-dimensional transform of the columns of the previous results. The complex numbers that compose the FFT plane are encoded in a 64-bit floating-point image (called a complex image): 32 bits for the real part and 32 bits for the imaginary part. IMAQ Vision can read and write complex images through IMAQ ReadFile and IMAQ WriteFile.

In an image, details and sharp edges are associated with high spatial frequencies because they introduce significant gray-level variations over short distances. Gradually varying patterns are associated with low spatial frequencies. Filtering spatial frequencies allows you to remove, attenuate, or highlight the spatial components to which they relate.

You can use a lowpass frequency filter to attenuate or remove (truncate) high frequencies present in the FFT plane. This filter suppresses information related to rapid variations of light intensities in the spatial image. An inverse FFT after a lowpass frequency filter produces an image in which noise, details, texture, and sharp edges are smoothed (IMAQ ComplexAttenuate or IMAQ ComplexTruncate).

A highpass frequency filter attenuates or remove (truncates) low frequencies present in the FFT plane. This filter suppresses information related to slow variations of light intensities in the spatial image. In this case, an inverse FFT after a highpass frequency filter produces an image in which overall patterns are sharpened and details are emphasized (IMAQ ComplexAttenuate or IMAQ ComplexTruncate).

A *mask frequency filter* removes frequencies contained in a mask specified by the user (IMAQ Mask).

The display of complex images is handled by IMAQ WindDraw. This VI displays an image by inverting the high and low frequencies and then dividing their values by a size factor.

This size factor *m* is calculated from the following formula.

$$m = f\,(w + h) = f\,(32.2n) = 2.4n,$$

where w is the width of the image and *h* is the height.

IMAQ FFT

Computes the FFT of an image.

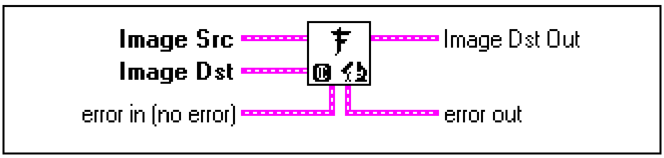


Image Src is the handle of the source image. The image must have a resolution of $2^n \times 2^m$.

Image Dst is the handle of the complex image that contains the resulting FFT image. This input can accept only a complex image (2 × 32-bit floating point), which is an image created with IMAQ Create using type 3. The complex image is resized to the **Image Src**.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Note: ***The FFT that is calculated is not normalized; you can use IMAQ Complex Divide to normalize the complex image.***

The FFT is a complex image in which high frequencies are grouped at the center, while low frequencies are located at the edges.

IMAQ InverseFFT

Computes the inverse FFT of a complex image (2 × 32-bit floating point).

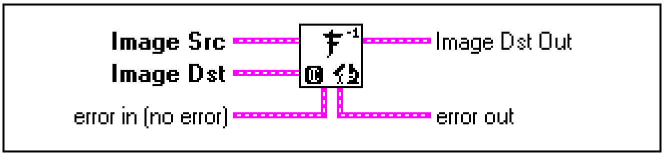


Image Src is the handle of the source image. This input can accept only a complex image. The image must have a resolution of $2^n \times 2^m$.

Image Dst is the handle of the 8-bit, 16-bit, or 32-bit floating-point image that contains the resulting spatial image.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Note: ***This VI uses a buffer equal to the size of the complex image. An 8-bit image with a resolution of 256 × 256 pixels uses 64 KB of memory. The FFT associated with this image requires eight times the memory, or 64 × 8 = 512KB. The calculation of the inverse FFT also requires a temporary buffer of 512 KB. Therefore, the total memory necessary for this operation is 1080 KB.***

IMAQ ComplexFlipFrequency

Transposes the complex components of an FFT image of a complex image. The high and low frequency components of an FFT image are inverted to produce a central symmetric representation of the spatial frequencies.

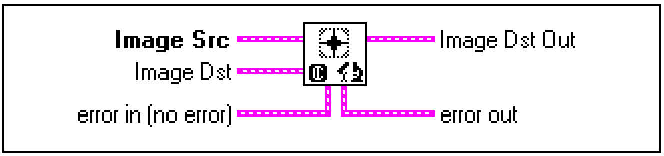


Image Src is the handle of the source image for the image to be transposed. This input can accept only a complex image.

Image Dst is the handle of the complex image that contains the resulting FFT image. This input can accept only a complex image.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ComplexConjugate

Computes the conjugate of a complex image. This VI converts the complex pixel data $z = a + ib$ of an FFT image into $z' = a - ib$.

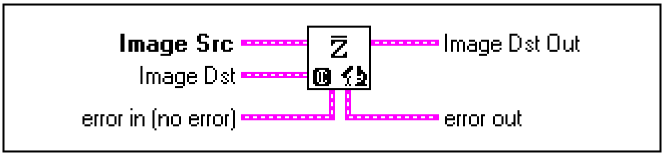


Image Src is the handle of the source image for the image that is used to measure the conjugate. This input can accept only a complex image.

Image Dst is the handle of the complex image that contains the resulting FFT image. This input can accept only a complex image.

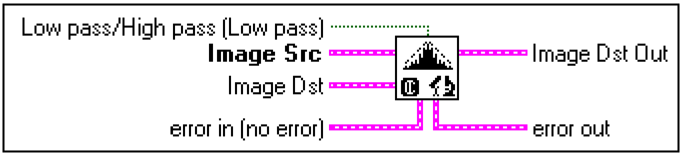
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ComplexAttenuate

Attenuates the frequencies of a complex image.



Low pass/High pass (Low pass) determines which frequencies are attenuated. Choose low pass (F) to attenuate the high frequencies or high pass (T) to attenuate the low frequencies. The default is FALSE, which specifies lowpass.

Image Src is the image reference source.

Image Dst is the reference of the image destination.

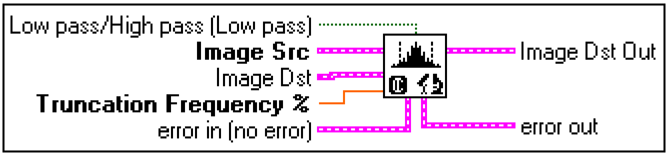
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ComplexTruncate

Truncates the frequencies of a complex image.



Low pass/High pass (Low pass) determines which frequencies are truncated. Choose low pass (F) to remove the high frequencies or high pass (T) to remove the low frequencies. The default is FALSE, which specifies lowpass.

Image Src is the image reference source. It must be an 8-bit or RGB image.

Image Dst is the reference of the image destination. If it is connected, it must be the same type as the **Image Src**.

Truncation Frequency % is the percentage of the frequencies that are retained within a Fourier-transformed image. This percentage is expressed with respect to the length of the diagonal of the FFT image and the Boolean **Low pass/High pass (Low pass)**. The default value is 10.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

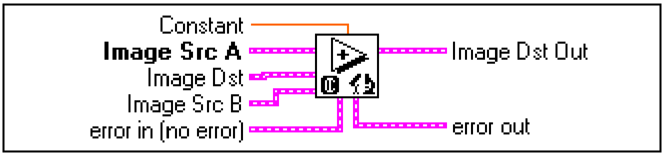
Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

For example, the defaults Low pass (F) and 10 result in retaining 10 percent of the frequencies starting from the center (low frequencies). The selection of High pass (T) and 10 results in retaining 10 percent of the frequencies starting from the outer periphery.

IMAQ ComplexAdd

Adds two images where the first is a complex image, or adds a complex image and a complex constant.



Constant is the complex constant added to the input **Image Src A** for image-constant operations. The default is 0.

Image Src A is the handle of the first source image and must be a complex image.

Image Dst is the handle of the complex image that contains the resulting FFT image. This input can accept only a complex image.

Image Src B is the handle of the second source image. This input can accept an 8-bit, 16-bit, 32-bit floating-point, or complex image. If the image is not a complex image, then the imaginary part of the **Image Dst** is equal to **Image Src A**.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src A**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

An operation between an image and a constant occurs when the input **Image Src B** is not connected. The two possibilities are distinguished in the following equations.

$$Dst(x, y) = SrcA(x, y) + SrcB(x, y), \text{ or}$$

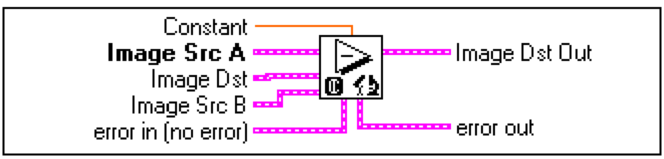
$$Dst(x, y) = SrcA(x, y) + Constant.$$

The different image type combinations supported by this VI are described in the following table, where *I* is the resulting image that is connected to the output **Image Dst**.

Image Connected to Image Src A	Image Connected to Image Src B	Equations
a complex image: I_c	an 8-bit, 16-bit, or 32-bit floating-point image: $I_{8\text{-bit}}$, $I_{16\text{-bit}}$, or $I_{32\text{-bit}}$	$\text{Real}(I) = \text{Real}(I_c) + (I_{8\text{-bit}}, I_{16\text{-bit}}, \text{ or } I_{32\text{-bit}})$ $\text{Imaginary}(I) = \text{Imaginary}(I_c)$
a complex image: I_{c1}	another complex image: I_{c2}.	$\text{Real}(I) = \text{Real}(I_{c1}) + \text{Real}(I_{c2})$ $\text{Imaginary}(I) = \text{Imaginary}(I_{c1}) + \text{Imaginary}(I_{c2})$

IMAQ ComplexSubtract

Subtracts two images where the first is a complex image, or subtracts a complex constant from a complex image.



Constant is the complex constant subtracted from the input **Image Src A** for image-constant operations. The default is 0.

Image Src A is the handle of the first source image and must be a complex image.

Image Dst is the handle of the complex image that contains the resulting FFT image. This input can accept only a complex image.

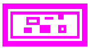
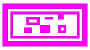


Image Src B is the handle of the second source image. This input can accept an 8-bit, 16-bit, 32-bit floating-point, or complex image. If the image is not a complex image, then the imaginary part of the **Image Dst** is equal to **Image Src A**.



error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

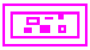
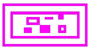


Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src A**.



error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

An operation between an image and a constant occurs when the input **Image Src B** is not connected. The two possibilities are distinguished in the following equations.

$$Dst(x, y) = SrcA(x, y) - SrcB(x, y), \text{ or}$$

$$Dst(x, y) = SrcA(x, y) - Constant.$$

The different image type combinations supported by this VI are described below. The first column describes the image connected to **Image Src A** and the second column describes the image type connected to **Image Src B.** The third column describes the image type that should be connected to the output **Image Dst.**

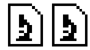
The different image type combinations supported by this VI are described in the following table, where I is the resulting image that is connected to the output Image Dst.

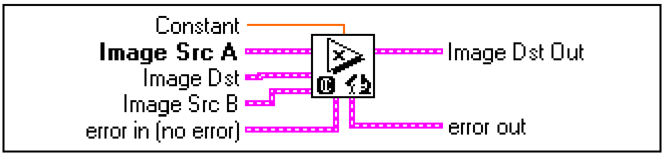
Image Connected to Image Src A	Image Connected to Image Src B	Equations
a complex image: I_c	an 8-bit, 16-bit, or 32-bit floating-point image: $I_{8\text{-bit}}$, $I_{16\text{-bit}}$, or $I_{32\text{-bit}}$	$\text{Real}(I) = \text{Real}(I_c) - (I_{8\text{-bit}}, I_{16\text{-bit}}, \text{ or } I_{32\text{-bit}})$ $\text{Imaginary}(I) = \text{Imaginary}(I_c)$

Image Connected to Image Src A	Image Connected to Image Src B	Equations
a complex image: I_{c1}	another complex image: I_{c2}.	$\text{Real}(I) = \text{Real}(I_{c1}) - \text{Real}(I_{c2})$ $\text{Imaginary}(I) = \text{Imaginary}(I_{c1}) - \text{Imaginary}(I_{c2})$

IMAQ ComplexMultiply

Multiplies two images where the first is a complex image, or multiples a complex image and a complex constant.





Constant. The input **Image Src A** is multiplied by this complex constant for image-constant operations. The default is 0.

Image Src A is the handle of the first source image and must be a complex image.

Image Dst is the handle of the complex image that contains the resulting FFT image. This input can accept only a complex image.

Image Src B is the handle of the second source image. This input can accept an 8-bit, 16-bit, 32-bit floating-point, or complex image.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

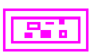
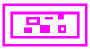


Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src A**.



error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

An operation between an image and a constant occurs when the input **Image Src B** is not connected. The two possibilities are distinguished in the following equations.

$$Dst(x, y) = SrcA(x, y) \times SrcB(x, y), \text{ or}$$

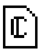
$$Dst(x, y) = SrcA(x, y) \times Constant.$$

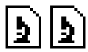
The different image type combinations supported by this VI are described in the following table, *where I* is the resulting image that is connected to the output Image Dst.

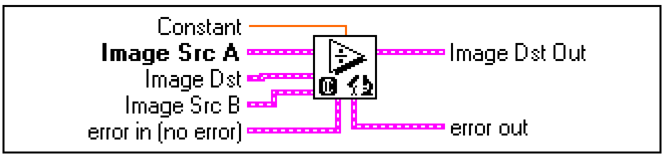
Image Connected to Image Src A	Image Connected to Image Src B	Equations
a complex image: I_c	an 8-bit, 16-bit, or 32-bit floating-point image: $I_{8\text{-bit}}$, $I_{16\text{-bit}}$, or $I_{32\text{-bit}}$	$\text{Real}(I) = \text{Real}(I_c) \times (I_{8\text{-bit}}, I_{16\text{-bit}}, \text{ or } I_{32\text{-bit}})$ $\text{Imaginary}(I) = \text{Imaginary}(I_c) \times (I_{8\text{-bit}}, I_{16\text{-bit}}, \text{ or } I_{32\text{-bit}})$
a complex image: I_{c1}	another complex image: I_{c2}.	$\text{Real}(I) = \text{Real}(I_{c1}) \times \text{Real}(I_{c2}) - \text{Imaginary}(I_{c1}) \times \text{Imaginary}(I_{c2})$ $\text{Imaginary}(I) = \text{Imaginary}(I_{c1}) \times \text{Real}(I_{c2}) + \text{Real}(I_{c1}) \times \text{Imaginary}(I_{c2})$

IMAQ ComplexDivide

Divides one image by another where the first is a complex image, or divides a complex image by a complex constant.







Constant. The input **Image Src A** is divided by this complex constant for image-constant operations. The default is 0.

Note: ***Division by 0 is not allowed. If the constant is 0 it automatically is replaced by 1. If one of the two source images is empty, the result is a copy of the other.***

Image Src A is the handle of the first source image and must be a complex image.

Image Dst is the handle of the complex image that contains the resulting FFT image. This input can accept only a complex image.

Image Src B is the handle of the second source image. This input can accept an 8-bit, 16-bit, 32-bit floating-point, or complex image.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src A**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

An operation between an image and a constant occurs when the input **Image Src B** is not connected. The two possibilities are distinguished in the following equations.

$$Dst(x, y) = SrcA(x, y) \div SrcB(x, y), \text{ or}$$

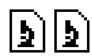
$$Dst(x, y) = SrcA(x, y) \div Constant.$$

The different image type combinations supported by this VI are described in the following table, *where I* is the resulting image that is connected to the output **Image Dst**.

Image Connected to Image Src A	Image Connected to Image Src B	Equations
a complex image: I_c	an 8-bit, 16-bit, or 32-bit floating-point image: $I_{8\text{-bit}}$, $I_{16\text{-bit}}$, or $I_{32\text{-bit}}$	$\text{Real}(I) = \text{Real}(I_c) \div (I_{8\text{-bit}}, I_{16\text{-bit}}, \text{ or } I_{32\text{-bit}})$ $\text{Imaginary}(I) = \text{Imaginary}(I_c) \div (I_{8\text{-bit}}, I_{16\text{-bit}}, \text{ or } I_{32\text{-bit}})$
a complex image: I_{c1}	another complex image: I_{c2}.	$\text{Real}(I) = \frac{\text{Real}(I_{c1}) \times \text{Real}(I_{c2}) + \text{Imaginary}(I_{c1}) \times \text{Imaginary}(I_{c2})}{\text{Real}(I_{c2})^2 + \text{Imaginary}(I_{c2})^2}$ $\text{Imaginary}(I) = \frac{\text{Imaginary}(I_{c1}) \times \text{Real}(I_{c2}) + \text{Real}(I_{c1}) \times \text{Imaginary}(I_{c2})}{\text{Real}(I_{c2})^2 + \text{Imaginary}(I_{c2})^2}$

IMAQ ComplexImageToArray

Extracts the pixels from a complex image (2 × 32-bit floating point) into a 2D complex array ([CSG]).



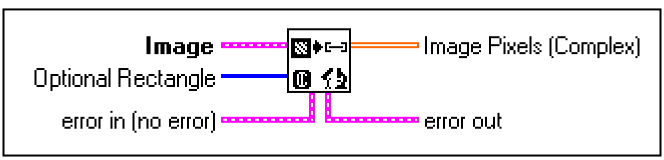


Image is the reference to the complex image.

Optional Rectangle specifies a rectangular region of the complex image to be extracted. The operation is applied to the entire image if the input is empty or not connected.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Pixels (Complex) is a 2D array (Line, Column) containing all the pixel values that comprise the image. The first index corresponds to the vertical axis and the second to the horizontal index. The final size of the array is equal to the size of the image or to the size of the optional rectangle.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ArrayToComplexImage

Creates a complex image, starting from a complex 2D array ([CSG]).

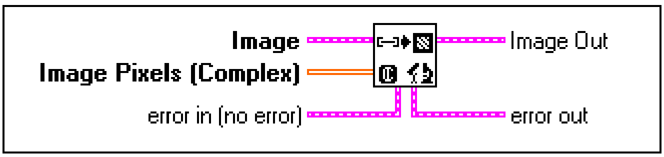


Image is the reference to the complex image to be created.

Image Pixels (Complex) is the complex 2D array (Line, Column) containing all the pixel values that form the image. The first index corresponds to the vertical axis and the second to the horizontal index. The final size of the image is equal to the size of the array. The image passed in the input **Image** is forced to the same size as the complex 2D array encoded by **Input Pixels**.

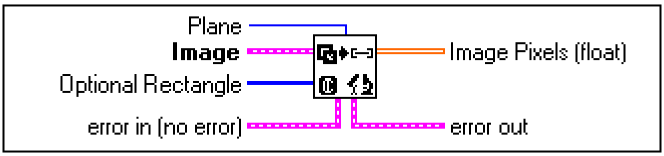
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Out is the reference to the destination (output) image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ComplexPlaneToArray

Extracts the pixels from the real part, imaginary part, magnitude, or phase from a complex image into a floating-point 2D array.



Plane indicates which component of the complex image is extracted into an array. The following values are valid:

0 (Default) Real

1 Imaginary

2 Magnitude

3 Phase

Image is the reference to the input complex image.

Optional Rectangle specifies a rectangular region of the complex image to be extracted. The operation is applied to the entire image if the input is empty or not connected.

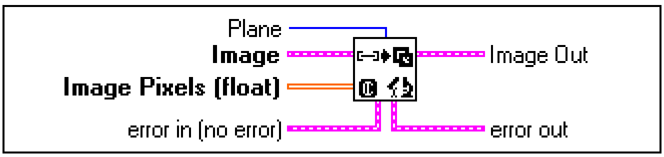
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Pixels (float) is a 2D floating-point array (Line, Column) containing all the pixel values that comprise the image. The first index corresponds to the vertical axis and the second to the horizontal index. The final size of the array is equal to the size of the image or to the size of the optional rectangle.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ArrayToComplexPlane

Replaces the real part or the imaginary part of a complex image, starting from a 2D array of floating-point values.



Plane specifies which component of the complex image is replaced with the values encoded in the array of floating points **Image Pixels.** The following values are valid:

0	(Default) Real
1	Imaginary

Image is the reference to the input complex image.

Image Pixels (Float) is a 2D floating-point array (Line, Column) containing all the pixel values that form the image. The first index corresponds to the vertical axis and the second to the horizontal index.

The final size of the image is equal to the size of the array. The image passed in the input **Image** is forced to the same size as the array encoded by **Input Pixels**.

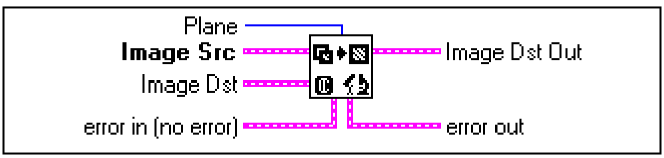
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Out is the reference to the destination (output) image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ComplexPlaneToImage

Extracts the pixels from the real part, imaginary part, magnitude, or phase from a complex image (2 × 32-bit floating point) into an 8-bit, 16-bit, or 32-bit floating-point image.



Plane indicates which component of the complex image is extracted. The following values are valid:

0	(Default) Real
1	Imaginary
2	Magnitude
3	Phase

Image Src must be a complex image.

Image Dst must be an 8-bit, 16-bit, or 32-bit floating-point image.

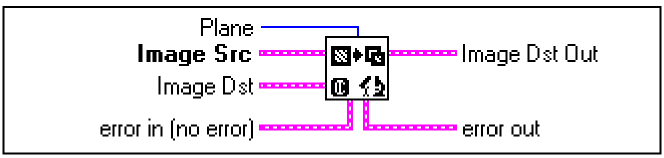
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. It is the same as **Image Dst**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ImageToComplexPlane

Extracts the pixels from an 8-bit, 16-bit, or 32-bit floating-point image into the real part or imaginary part of a complex image (2 × 32-bit floating point).



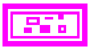
Plane specifies which component of the complex image is replaced. The following values are valid:

0 (Default) Real

0 Imaginary

Image Src must be an 8-bit, 16-bit, or 32-bit floating-point image.

Image Dst must be a complex image.



error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

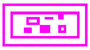
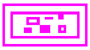


Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. If the **Image Dst** is connected, then **Image Dst Out** is the same as **Image Dst**. Otherwise, **Image Dst Out** refers to the image referenced by **Image Src**.



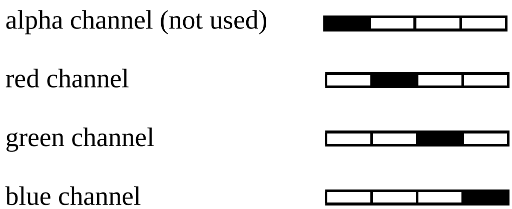
error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Chapter 22

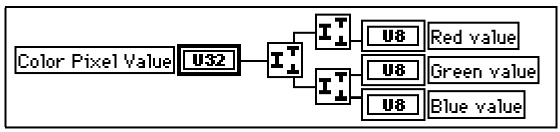
Color VIs

This chapter describes the Color VIs in IMAQ Vision.

An RGB-chunky image (standard color) is a color image coded in three parts: red, green, and blue. A pixel encoded in 32 bits is actually four channels:



A color pixel encoded as an unsigned 32-bit integer control can be decomposed as shown in the following graphic.



A color image always is encoded in memory in the form (R, G, B). However, there are a number of other coding models such as (H, S, L) and (H, S, V). The (H, S, L) model is composed as hue, saturation, and lightness, and the (H, S, V) model as hue, saturation, and value.

To recuperate the values for hue, saturation, lightness, or value a measurement is made from the red, green, and blue components. Note that these measurements require time, depending on the values to extract. These extractions are not completely objective. In effect, a color converted between two of the different color models (for instance, RGB to HSL) and then reconverted back to the original color model, does not have exactly the same values as the original image. This difference is because of the 8-bit encoding of the image planes, which causes some loss of data.

The principal operations that can be performed on color images are:

- Extraction or replacement of a color image plane (R, G, B, H, S, L, V)
- Application of a threshold to a color image based on one of the three color models (RGB, HSL, or HSV)
- Performance of a histogram on a color image based on one of the three color models (RGB, HSL, or HSV)

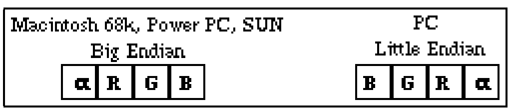
The other VIs are auxiliary VIs that enable the user to extract or replace a pixel, a line, or a part of an image, convert the image from one color model to another, and convert the image to and from an array of data.

Color Planes Inversion [PC]

Prior to version 4.0, color pixels (RGB_CHUNKY) were organized the same way across all platforms:

All Platforms	
[0]	Alpha
[1]	Red
[2]	Green
[3]	Blue

When processing the pixels as 32 bits with the `Color.llb` library, there was a difference in the 32 bits value depending on the host machine:

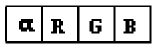


From the 4.0 version on, a new memory organization is used. The pixel bytes are stored according to the CPU logic, but the 32-bit access register order is constant across all platforms:

Macintosh 68k, Power PC, and SUN	
[0]	Alpha
[1]	Red
[2]	Green
[3]	Blue

Windows	
[0]	Blue
[1]	Green
[2]	Red
[3]	Alpha

The following graphic describes a color pixel for all platforms:



This solution offers many advantages, including the ability to write real multi-platform applications using the `Color.llb` library.

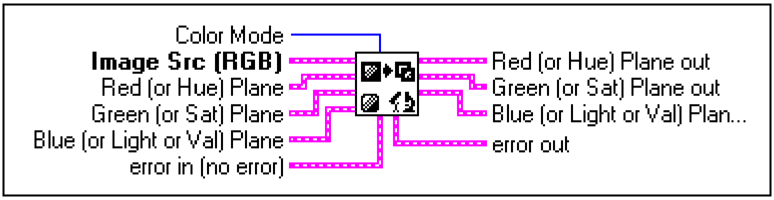
For color image transfer from an image grabber to the host memory, use DMA direct or BlockMove instructions can be used for better performance.

Note that this change does not improve color images display speed under LabVIEW or BridgeVIEW because of overhead processing needed to organize display data as 24-bit triplets.

[0]	Red
[1]	Green
[2]	Blue

IMAQ ExtractColorPlanes

Extracts the three planes (RGB, HSV, or HSL) from an image.



Color Mode defines the image color format to use for the operation. The default is 0, which specifies RGB.

0	(Default) RGB
1	HSL
2	HSV

Image Src (RGB) is the reference to an image that has its three planes extracted: RGB, HSV or HSL. It must be an RGB-chunky image.

Red (or Hue) Plane is the reference to the destination image. It contains the first color plane. This plane can be either the red plane (**Color Mode** 0) or the hue plane (**Color Mode** 1 or 2). It must be an 8-bit image. The color plane is not extracted if the input is not connected.

Green (or Sat) Plane is the reference to the destination image. It contains the second color plane. This plane can be either the green plane (**Color Mode** 0) or the saturation plane (**Color Mode** 1 or 2). It must be an 8-bit image. The color plane is not extracted if the input is not connected.

Blue (or Light or Val) Plane is the reference to the destination image. It contains the third color plane. This plane can be either the blue plane (**Color Mode** 0), the lightness plane (**Color Mode** 1), or the value plane (**Color Mode** 2). It must be an 8-bit image. The input must be connected for the color plane to be extracted.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Red (or Hue) Plane out is the reference to the image containing the red (or hue) plane of the source (input) image.

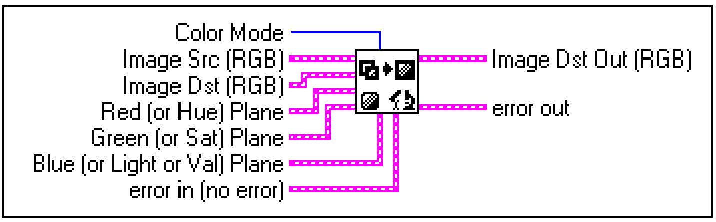
Green (or Sat) Plane out is the reference to the image containing the green (or saturation) plane of the source (input) image.

Blue (or Light or Val) Plane out is the reference to the image containing the blue (or lightness or value) plane of the source (input) image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ReplaceColorPlane

Replaces one or more image planes from a color image (RGB, HSL, or HSV). Only the planes connected at the input are replaced. If all three planes are connected then the input **Image Src** is not necessary and only the **Image Dst** is used. The image is resized to the dimensions of the planes passed on input; therefore their size must be identical. If one or two planes are connected, then the planes must have the same dimension as the source image.



Color Mode defines the image color format to use for the operation. The default is 0, which specifies RGB.

0	(Default) RGB
1	HSL
2	HSV

Image Src (RGB) is the reference to an image that has its three color planes replaced. It must be an RGB-chunky image. This image is not necessary if the destination image and the three color planes are connected.

Image Dst (RGB) is the reference to the destination image. It must be an RGB-chunky image.

Red (or Hue) Plane is the reference to the first color plane. This plane can be either the red plane (**Color Mode** 0) or the hue plane (**Color Mode** 1 or 2). It must be an 8-bit image. The color plane is not replaced if the input is not connected.

Green (or Sat) Plane is the reference to the second color plane. This plane can be either the green plane (**Color Mode** 0) or the saturation plane (**Color Mode** 1 or 2). It must be an 8-bit image. The color plane is not replaced if the input is not connected.

Blue (or Light or Val) Plane is the reference to the third color plane. This plane can be either the blue plane (**Color Mode** 0), the lightness plane (**Color Mode** 1), or the value plane (**Color Mode** 2). It must be an 8-bit image. The color plane is not replaced if the input is not connected.

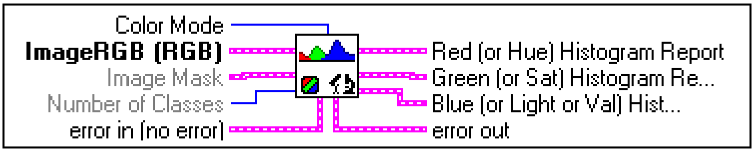
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out (RGB) is the reference to the output RGB image that is obtained by replacing one or more planes of the source color image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ColorHistogram

Calculates the histograms extracted from the three planes of an image. This VI can function in one of three modes corresponding to the three color models (RGB, HSL, or HSV). IMAQ ColorHistograph, a variant of the IMAQ ColorHistogram VI, has the advantage that its output data is directly compatible with a LabVIEW or BridgeVIEW graph.



Color Mode defines the image color format to use for the operation. The default is 0, which specifies RGB.

0	(Default) RGB
1	HSL
2	HSV

ImageRGB (RGB) is the input source image used for calculating the histogram. It must be an RGB-chunky image.

Image Mask, if connected, must be an 8-bit image.

Number of Classes specifies the number of classes used to classify the pixels. The default is 256.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Red (or Hue) Histogram Report is a cluster that returns the detailed results from a histogram calculated on a red or hue plane (depending on the **Color Mode**). This cluster is the same as the cluster used by IMAQ Histogram. It contains the following elements.

Histogram returns the histogram values in an array. The elements found in this array are the number of pixels per class. The *n*th class contains all pixel values belonging to the interval [*Starting Value* + (*n* – 1) × *Interval Width*, *Starting Value* + *n* × *Interval Width* – 1].

Minimal Value returns the smallest pixel value used in calculating the histogram.

Maximal Value returns the largest pixel value used in calculating the histogram.

Starting Value is always equal to 0 here. It returns the smallest pixel value from the first class calculated in the histogram. It can be equal to the **Minimal** value from the **Interval Range** or the smallest value found for the image type connected.

Interval Width returns the length of each class.

Mean Value returns the mean value of the pixels used in calculating the histogram.

Standard Deviation returns the standard deviation from the histogram. A higher value corresponds to a better distribution of the values in the histogram and the image.

Area (pixels) returns the number of pixels used in the histogram calculation. This is influenced by the contents of **Image Mask**.

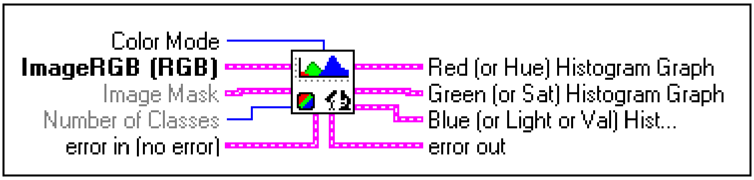
Green (or Sat) Histogram Report is a cluster that returns the detailed results from a histogram calculated on the green or saturation plane (depending on the **Color Mode**). It has the same elements as found in **Red (or Hue) Histogram Report**.

Blue (or Light or Val) Histogram Report is a cluster that returns the detailed results from a histogram calculated on the blue, lightness, or value planes (depending on the **Color Mode**). It has the same elements as found in **Red (or Hue) Histogram Report**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ColorHistograph

Calculates the histograms extracted from the three planes of an image. This VI can function in one of three modes corresponding to the three color models (RGB, HSL, or HSV). The output from this VI is directly compatible with a LabVIEW or BridgeVIEW graph.



Color Mode defines the image color format to use for the operation. The default is 0, which specifies RGB.

0	RGB (default)
1	HSL
2	HSV

ImageRGB (RGB) is the RGB-chunky input source image used for calculating the histogram.

Image Mask, if connected, must be an 8-bit image.

Number of Classes specifies the number of classes used to class the pixels. The default is 256.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Red (or Hue) Histogram Graph is a cluster that returns the detailed results from a histogram calculated on a red or hue plane (depending on the **Color Mode**). This cluster is the same as the cluster used by IMAQ Histograph. It contains the following elements.

Starting Value is always equal to 0 here. This parameter is returned in the type Histogram Report, as in the VI IMAQ Histograph.

Incremental Value returns the incrementing value that specifies how much to add to **Starting Value** in calculating the median value of each class from the histogram. The median value x_n from the nth class is x_n = *Starting Value* + n × *Incremental Value*.

Histogram returns the histogram values in an array. The elements found in this array are the number of pixels per class. the nth class contains all pixel values belonging to the interval [*Starting Value* + (n – 1) × *Interval Width*, *Starting Value* + n × *Interval Width* – 1].

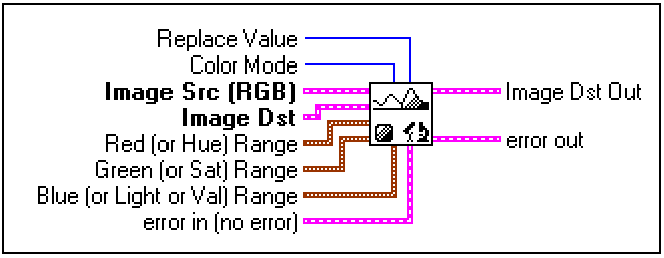
Green (or Sat) Histogram Graph is a cluster that returns the detailed results from a histogram calculated on the green or saturation plane (depending on the **Color Mode**). It has the same elements as found in **Red (or Hue) Histogram Graph**.

Blue (or Light or Val) Histogram Graph is a cluster that returns the detailed results from a histogram calculated on the blue, lightness, or value planes (depending on the **Color Mode**). It has the same elements as found in **Red (or Hue) Histogram Graph**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ColorThreshold

Applies a threshold to the three planes of an RGB-chunky image and places the result into an 8-bit image. A test is performed with each range (**Red (or Hue) Range**, **Green (or Sat) Range**, and **Blue (or Light or Val) Range)**, to determine whether the corresponding pixel from the **Image Src** is set to the value specified in **Replace Value**. If a pixel from the **Image Src** does not have corresponding pixel values specified in all three ranges, then the corresponding pixel in **Image Dst Out** is set to 0.



Note: ***By default the pixels in the Image Dst Out take the new value specified by ReplaceValue as all three ranges are set for 0 to 255. Therefore you easily can apply a threshold to one of the three ranges without having to set the values of the other two ranges.***

Replace Value specifies the value applied to the destination image when the corresponding pixel from the **Image Src** is found in all three ranges. The default is 1.

Color Mode defines the image color format to use for the operation. The default is 0, which specifies RGB.

0 (Default) RGB

1 HSL

2 HSV

Image Src (RGB) is the reference to the image to threshold. It must be an RGB-chunky image.

Image Dst must be connected and must be an 8-bit image.

Red (or Hue) Range is a cluster used to determine the thresholding range for the red or hue plane (depending on the **Color Mode**). Any pixel values not included in this range are reset to zero in the destination image. The pixel values included in this range are altered depending on the status of the **Replace** input. By default, all pixel values are included (0, 255).

Lower Value is the minimal pixel value in the red or hue plane that is used for the threshold. The default is 0.

Upper Value is the maximal pixel value in the red or hue plane that is used for the threshold. The default is 255.

Green (or Sat) Range is a cluster used to determine the thresholding range for the green or saturation plane (depending on the **Color Mode**). Any pixel values not included in this range are reset to zero in the destination image. The pixel values included in this range are altered depending on the status of the **Replace** input. By default, all pixel values are included (0, 255). **Green (or Sat) Range** has the same elements as found in **Red (or Hue) Range**.

Blue (or Light or Val) Range is a cluster used to determine the thresholding range for the blue, lightness, or value plane (depending on the **Color Mode**). Any pixel values not included in this range are reset to zero in the destination image. The pixel values included in this range are altered depending on the status of the **Replace** input. By default, all pixel values are included (0, 255). **Blue (or Light or Val) Range** has the same elements as found in **Red (or Hue) Range**.

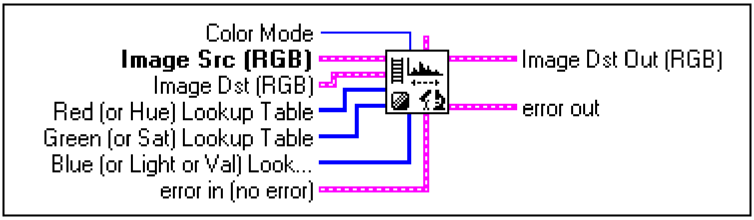
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out is the reference to the destination (output) image which receives the processing results of the VI. **Image Dst Out** is the same as **Image Dst**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ColorUserLookup

Applies a lookup table (LUT) to each color plane.

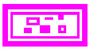
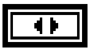


Image Mask, if connected, must be an 8-bit image.



Color Mode defines the image color format to use for the operation. The default is 0, which specifies RGB.

0	(Default) RGB
1	HSL
2	HSV

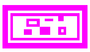
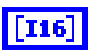


Image Src (RGB) is the reference to the source image. It must be an RGB-chunky image.

Image Dst (RGB) is the reference to the destination image. If connected, it must be an RGB-chunky image.



Red (or Hue) Lookup Table is the LUT applied to the first color plane (depending on the **Color Mode**). This array can contain a maximum of 256 elements. The array is filled automatically when less than 256 elements are specified. This procedure does not change pixel values that are not explicitly specified from the values of the LUT given by the user on input. By default this array is empty and no replacement occurs on this plane.

Green (or Sat) Lookup Table is the LUT applied to the second color plane (depending on the **Color Mode**). This array can contain a maximum of 256 elements. The array is filled automatically when less than 256 elements are specified. This procedure does not change pixel values that are not explicitly specified from the values of the LUT given by the user on input. By default this array is empty and no replacement occurs on this plane.

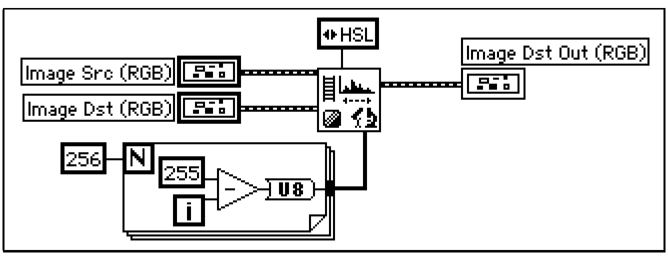
Blue (or Light or Val) Lookup Table is the LUT applied to the third color plane (depending on the **Color Mode**). This array can contain a maximum of 256 elements. The array is filled automatically when less than 256 elements are specified. This procedure does not change pixel values that are not explicitly specified from the values of the LUT given by the user on input. By default this array is empty and no replacement occurs on this plane.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out (RGB) is the reference to the output RGB image that is obtained by applying the color LUT to the source image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

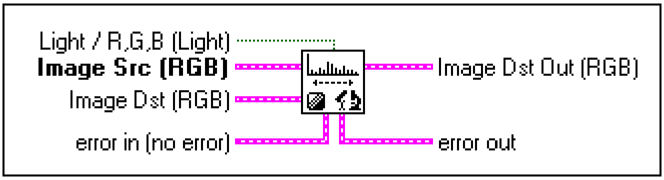
For example, you can use IMAQ ColorUserLookup to inverse the lightness plane for an RGB-chunky image.



Each level *n* is replaced by the value (255 – *n*), resulting in an inverse of the lightness plane.

IMAQ ColorEqualize

Equalizes a color image. This VI equalizes either the lightness plane (default) or all three planes (red, green, and blue).



Light / R,G,B (Light) specifies whether the operation is performed on the lightness plane or on all three planes (red, green, blue). An equalization on the lightness plane conserves the hue and saturation from the color image. An equalization of the three planes (red, green, blue), gives a stronger contrast but changes the hue and saturation of the color image. The default is FALSE.

Image Src (RGB) is the reference to the source image. It must be an RGB-chunky image.

Image Dst (RGB) is the reference to the destination image. If connected, it must be an RGB-chunky image.

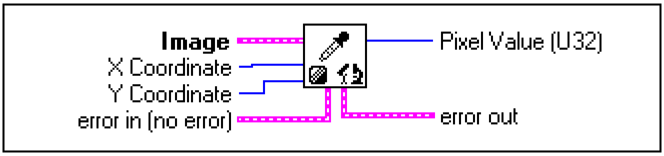
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Dst Out (RGB) is the reference to the output RGB image that is obtained after equalization of the source color image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ GetColorPixelValue

Reads the pixel values from a color image. This VI returns the pixel value as an unsigned 32-bit integer indicator. This indicator can be converted into a cluster containing three elements possessing either (R, G, B), (H, S, L), or (H, S, V) using the VI IMAQ IntegerToColorValue.



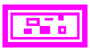
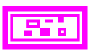


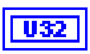
Image must be an RGB-chunky image.

X Coordinate is the horizontal position of the pixel.

Y Coordinate is the vertical position of the pixel



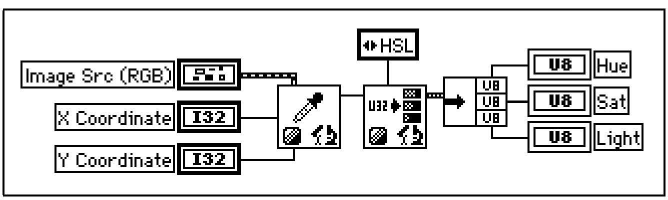
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.



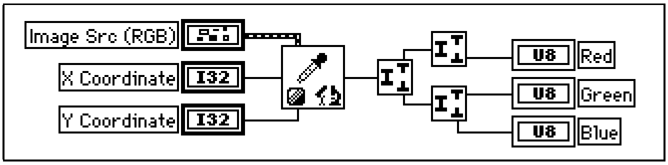
Pixel Value (U32) returns the pixel value as an unsigned 32-bit integer indicator.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The following graphic illustrates the use of this VI.

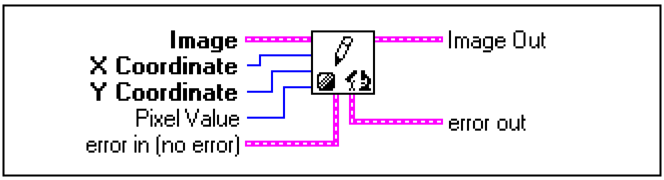


The red, green, and blue values also can be manipulated with the following sequence.



IMAQ SetColorPixelValue

Changes the pixel value for a color image. This VI receives the pixel value as an unsigned 32-bit integer control. The values (R, G, B), (H, S, L), or (H, S, V) can be converted into an unsigned 32-bit integer control using the VI IMAQ ColorValueToInteger.



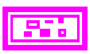


Image must be an RGB-chunky image.

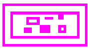
X Coordinate is the horizontal position of the pixel.

Y Coordinate is the vertical position of the pixel.

Pixel Value (U32) contains the pixel value as an unsigned 32-bit integer control.

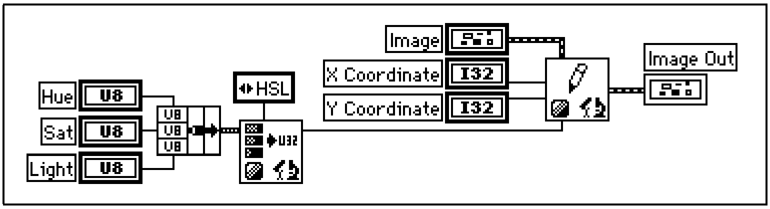
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Out is the reference to the destination (output) image.

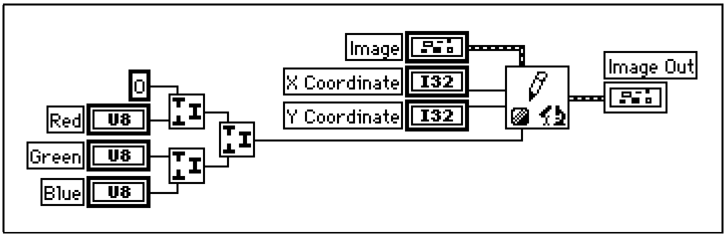


error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The following graphic illustrates the use of this VI.



The red, green, and blue values also can be manipulated with the following sequence.



IMAQ GetColorPixelLine

Extracts a line of pixels from a color image. This VI returns an array of unsigned 32-bit integer indicators. This array can be converted into an array of clusters coding the three color values as either (R, G, B), (H, S, L), or (H, S, V) using the VI IMAQ IntegerToColorValue.

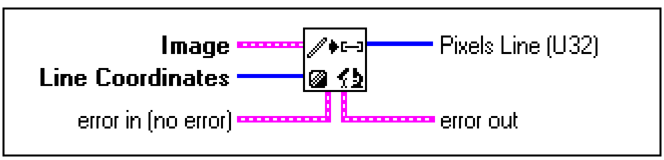


Image must be an RGB-chunky image.

Line Coordinates is an array specifying the two endpoints of the line to extract.

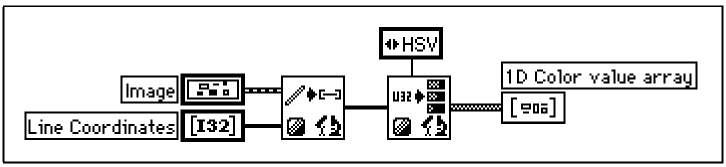
Note: ***A line designated by the coordinates [0, 0, 0, 255] consists of 256 pixels. The output Pixels Line contains the values specified by this line. Any pixel values outside the image automatically is set to 0 in Pixels Line.***

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

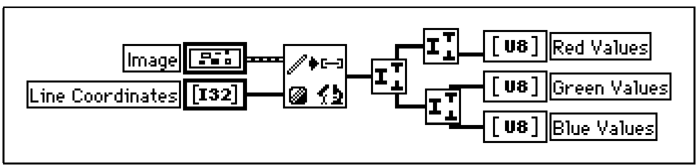
Pixels Line (U32) returns the pixel values as a 1D array of unsigned 32-bit integer indicators.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The following graphic illustrates the use of this VI.

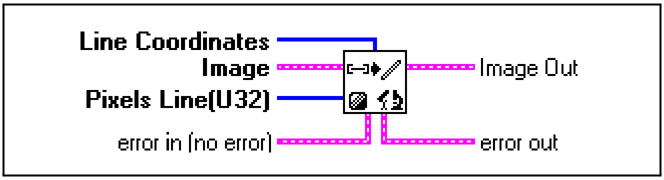


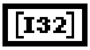
An array of red, green, and blue values also can be modified with the following sequence.



IMAQ SetColorPixelLine

Changes a line of pixels from a color image. This VI receives an array of unsigned 32-bit integer controls. An array of clusters coding the color three values (R, G, B), (H, S, L), or (H, S, V) can be converted into an array of pixels (unsigned 32-bit integer controls) using the VI IMAQ IntegerToColorValue.





Line Coordinates is an array specifying the two endpoints of the line to modify. Any pixels designated by the **Line Coordinates** found outside the actual image are not replaced.

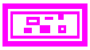
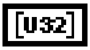
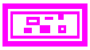


Image must be an RGB-chunky image.



Pixels Line(U32) contains the pixel values as a 1D array of unsigned 32-bit integer controls.



error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

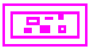
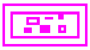
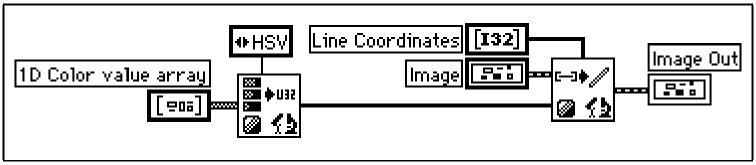


Image Out is the reference to the destination (output) image.

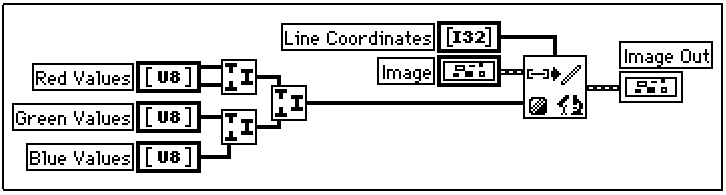


error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The following graphic illustrates the use of this VI.

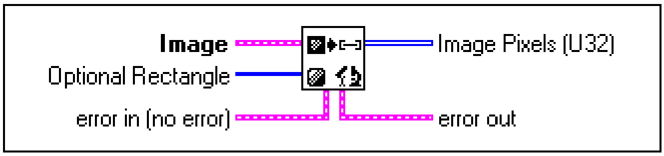


An array of red, green, and blue values also can be modified with the following sequence.



IMAQ ColorImageToArray

Extracts the pixels from a color image, or from part of a color image, into a 2D array. This VI returns the values as a 2D array of unsigned 32-bit integer indicators. This 2D array can be converted into a 2D array of clusters coding the three color values as either (R, G, B), (H, S, L), or (H, S, V) using the VI IMAQ IntegerToColorValue.

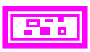
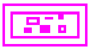


Image must be an RGB-chunky image.

Optional Rectangle designates a rectangular region (Left / Top / Right / Bottom) within an image in which the pixels are to be changed. If this array is empty the entire image is changed.

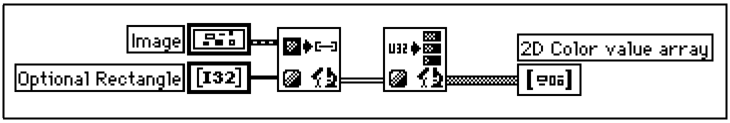

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Pixels (U32) returns the pixel values as a 2D array of unsigned 32-bit integer indicators.

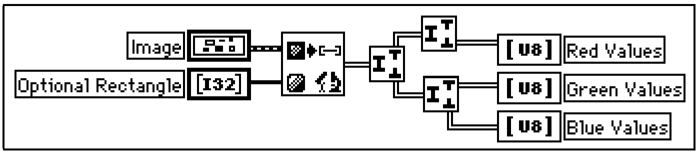


error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The following graphic illustrates the use of this VI.



An array of red, green, and blue values also can be modified with the following sequence.



IMAQ ArrayToColorImage

Creates a color image from a 2D array. This VI receives the values as a 2D array of unsigned 32-bit integer controls. A 2D array of clusters coding the three color values as either (R, G, B), (H, S, L), or (H, S, V) can be converted into a 2D array of pixels (unsigned 32-bit integer controls) using the VI IMAQ ColorValueToInteger.

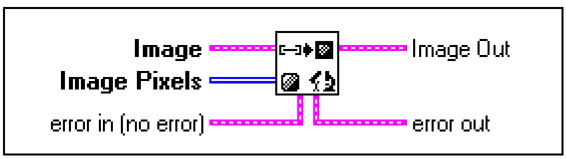


Image must be an RGB-chunky image.

Image Pixels (U32) contains the pixel values as a 2D array of unsigned 32-bit integer controls.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

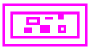
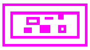
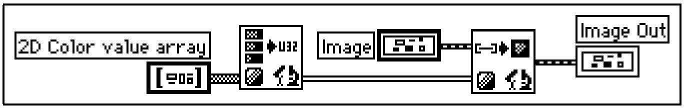


Image Out is the reference to the destination (output) image.

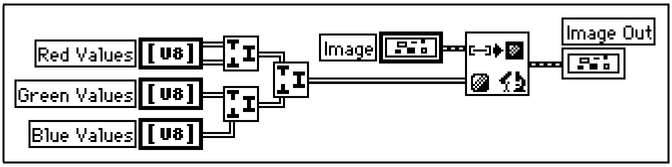


error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The following graphic illustrates the use of this VI.

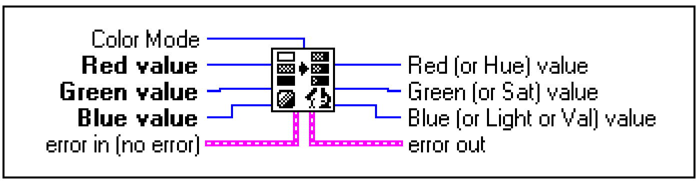


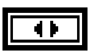
A 2D array of red, green, and blue values also can be modified with the following sequence.



IMAQ RGBToColor

Converts an RGB color value into another format (HSL or HSV).



Color Mode defines the image color format conversion to perform. The default is 0, which specifies no change.

0	RGB	(Default) no change
1	HSL	Convert to HSL
2	HSV	Convert to HSV

Red value is the input red value.

Green value is the input green value.

Blue value is the input blue value.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Red (or Hue) value is the output value for the first color plane (depending on the **Color Mode)** chosen.

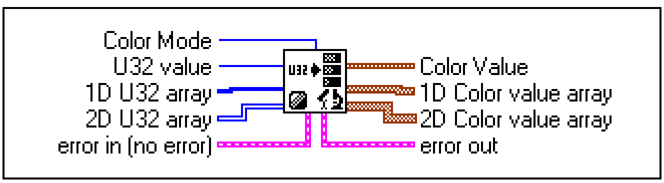
Green (or Sat) value is the output value for the second color plane (depending on the **Color Mode)** chosen.

Blue (or Light or Val) value is the output value for the third color plane (depending on the **Color Mode)** chosen.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ IntegerToColorValue

Converts colors in the form of an unsigned 32-bit integer control into a cluster composed of the three colors in mode (R, G, B), (H, S, L), or (H, S, V). These colors can be entered as a single value, a 1D array, a 2D array, or a combination of the above.



Color Mode defines the image color format to use for the output. The default is 0, which specifies that the input and output values are the same.

0	RGB	(Default) no change
1	HSL	Convert to HSL
2	HSV	Convert to HSV

U32 value a color value encoded as an unsigned 32-bit integer control.

1D U32 array a set of color values encoded as a 1D array of unsigned 32-bit integer controls.

2D U32 array a set of color values encoded as a 2D array of unsigned 32-bit integer controls.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Color Value is a cluster containing the color value resulting from the input **U32 Value.** This cluster can contain the values (R, G, B), (H, S, L), or (H, S, V), depending on the status of the set **Color Mode**. The cluster is composed of the following elements.

Red (or Hue) Value is the first color plane value (depending on the **Color Mode**).

Green (or Sat) Value is the second color plane value (depending on the **Color Mode**).

Blue (or Light or Val) Value is the third color plane value (depending on the **Color Mode**).

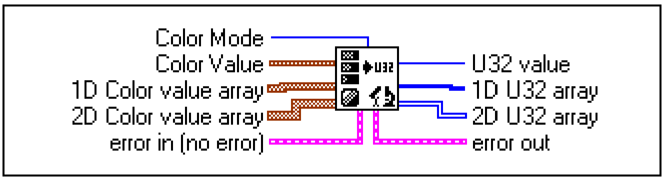
1D Color value array is a 1D array containing the color value resulting from the input **1D U32 Array.** This array can contain the values (R, G, B), (H, S, L), or (H, S, V), depending on the status of the set **Color Mode**.

2D Color value array is a 2D array containing the color value resulting from the input **2D U32 Array.** This array can contain the values (R, G, B), (H, S, L), or (H, S, V), depending on the status of the set **Color Mode**.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ColorValueToInteger

Converts clusters composed of three colors in mode (R, G, B), (H, S, L), or (H, S, V) into colors encoded in the form of an unsigned 32-bit integer control. The elements of these clusters can contain single values, 1D arrays, 2D arrays, or a combination of the above.



Color Mode defines the image color format to use for the output. The default is 0, which specifies that the input and output values are the same.

0	RGB	(Default) no change
1	HSL	Convert to HSL
2	HSV	Convert to HSV

Color Value is a cluster containing a color in (R, G, B), (H, S, L), or (H, S, V) (depending on the **Color Mode**).

Red (Hue) Value is the first color plane value (depending on the **Color Mode**).

Green (Sat) Value is the second color plane value (depending on the **Color Mode**).

Blue (Light,Val) Value is the third color plane value (depending on the **Color Mode**).

1D Color value array is a 1D array of clusters containing the color values. The values are in (R, G, B), (H, S, L), or (H, S, V) depending on the status of the set **Color Mode**. These clusters are the same type as **Color Value**.

2D Color value array is a 2D array of clusters containing the color values. The values are in (R, G, B), (H, S, L), or (H, S, V) depending on the status of the set **Color Mode**. These clusters are the same type as **Color Value**.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

U32 value receives the color value resulting from the input **Color Value** and it is encoded as an unsigned 32-bit integer control.

1D U32 array receives the color value resulting from the input **1D Color Value Array** and it is encoded as a 1D array of unsigned 32-bit integer controls.

2D U32 array receives the color value resulting from the input **2D Color Value Array** and it is encoded as a 2D array of unsigned 32-bit integer controls.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Chapter 23

External Library Support VIs

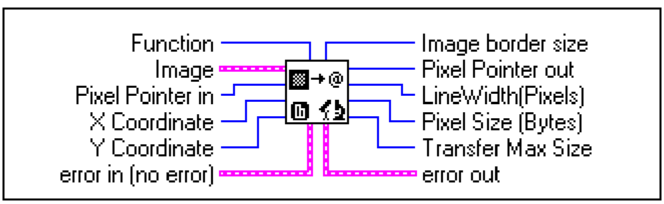
This chapter describes the External Library Support VIs in IMAQ Vision. This set of VIs allows G programmers who have a good understanding of DLLs (Windows) or Shared Libraries (Macintosh) to write their own image grabber device VIs.

These VIs give you additional functionalities that are not provided by LabVIEW or BridgeVIEW when using an external library. These VIs allow you to do the following actions:

- Get a pointer in the pixel space of an image
- Copy the data of a char* type pointer to a G programming language string
- Copy a memory block addressed by a pointer to a G programming language string
- Change the border size of an image
- Modify the pixel values at the border of an image
- Interlace or separate images

IMAQ GetImagePixelPtr

Obtains a pointer on the pixels of an image. This VI also returns information on the organization of the image pixels in memory.



Function has three modes:

0	Map Pixel Pointer	Obtains the pointer on a pixel of an image and obtains information related to the organization of the pixels of this image in memory.
1	Unmap Pixel Pointer	Frees the pointer and related information previously obtained using Map Pixel Pointer.
2	Get Pixel Info	Obtains information related to the organization of the pixels of an image in memory without mapping a pointer.

Image is the reference of the image on which the pointer is obtained.

Pixel Pointer in is only used in the Unmap Pixel Pointer mode (see the **Function** description). When the VI is executed to obtain a pointer (using the Map Pixel Pointer function), some information regarding the pointer that is required to unmap the pixel pointer is recorded.

Note: ***You need to give this pointer to the VI to retrieve this information when executing the Unmap Pixel Pointer function.***

X Coordinate allows you to select the X coordinate of the pixel in the image on which the pointer is required. This parameter is not used in the mode Unmap Pixel Pointer mode. The default is 0.

Y Coordinate allows you to select the Y coordinate of the pixel in the image on which the pointer is required. This parameter is not used in the mode Unmap Pixel Pointer mode. The default is 0.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image border size is the border size of the image.

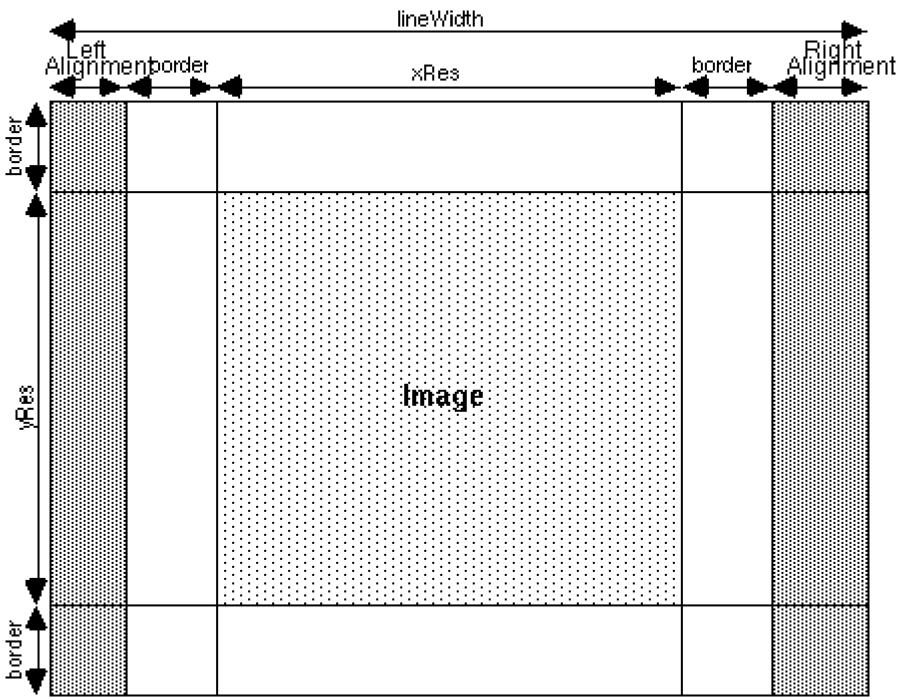
U32

Pixel Pointer Out is the pointer on the pixels of the image. This pointer is obtained only in the Map Pixel Pointer mode. The following table gives the pointer type for different platforms.

Platform	Pointer Type
IMAQ Vision for LabVIEW 4 for Windows 3.1	16-bit FAR
Other platforms	32-bit flat

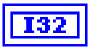
I32

LineWidth (Pixels) returns the total number of pixels in a horizontal line in the image. This is the sum of the X size of the image, the borders of the image, and the left and right alignments of the image, as shown in the following image. This number may not match the horizontal size of the image.

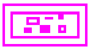


I32

Pixel Size (Bytes) returns the size in bytes of each pixel in the image. This value multiplied with the **LineWidth** gives the number of bytes occupied by a line of the image in memory.



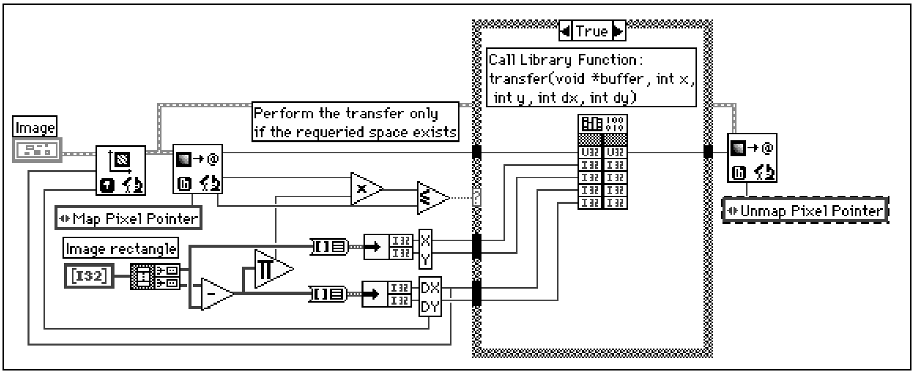
Transfer Max Size returns the number of bytes from the pixel pointer to the end of the image. This size represents the maximum size of bytes that can be transferred. For example, for an 8-bit image of size 256 × 256 and border 1, the line width is 272 and the maximum transfer size from pixel (0, 0) is 69632 bytes.



error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Example

The following graphic illustrates a typical implementation scheme for IMAQ GetImagePixelPtr.



This VI receives an image and a rectangle. The transfer call needs five parameters: destination address, X and Y start coordinates, and the X and Y size of the transfer. This VI uses the following steps:

- From the image rectangle, computes the image size.
- Resizes the image and obtains a pixel pointer on the coordinates [0, 0] of the image.
- Verifies that the maximum transfer size is compatible with the parameters needed by the called library.
- If everything is correct, begins transferring.
- Unmaps the pixel pointer.

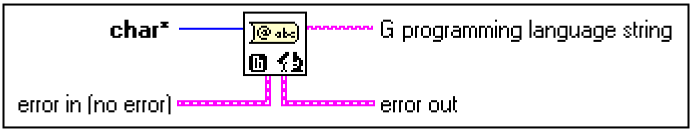
Note: ***The transfer call, as it is shown above, only supports images with a border width of zero that have a horizontal size aligned on a multiple of 8. This restriction exists because no passed parameter discriminates between the number of pixels per line and the memory address increment to the next line.***

The following code uses IMAQ GetImagePixelPtr to apply a function *f* on the pixels of a floating-point image. The pointer on the pixel (0, 0) of the image (**FirstPixelPtr**) has been retrieved from the VI. In the following C code, `xSize`, `ySize`, and `LineWidth` have been obtained from other VIs.

```
int xSize; // is the x size of the image.

int ySize; // is the y size of the image (Given by IMAQ GetImageSize
or IMAQ GetImageInfo)

int LineWidth; // is the line width of the image (Given by IMAQ
GetImagePixelPtr)

float *FirstPixelPtr; // Given by IMAQ GetImagePixelPtr


float *TempPixelPtr;

int i, j;


for (j = 0; j < ySize; j++) // for each line of the image
      {
      TempPixelPtr = FirstPixelPtr;

      for (i = 0; i < xSize; i++)// for each pixel of the line
            {
            *TempPixelPtr = f (*TempPixelPtr);// apply the function
            TempPixelPtr++;// pixel increment
            }
      FirstPixelPtr += LineWidth;// line increment
      }
```

IMAQ CharPtrToString

Copies a C character string to a G programming language string. In LabVIEW 4.0 and BridgeVIEW 1.0, the Call Library function does not directly support entry points returning a character pointer (char*). This VI allows the use of a char* pointer to get the associated string.



char* is the C character string pointer. The end of the character string is marked with a 0 (\00) value. The following table gives the pointer type for different platforms.

Platform	Pointer Type
IMAQ Vision for LabVIEW 4 for Windows 3.1	16-bit FAR
Other platforms	32-bit flat (universal type)

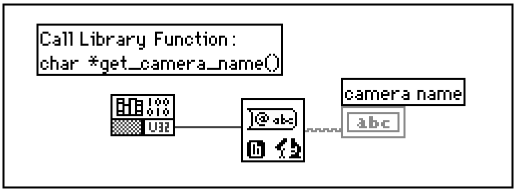
The copied string size is limited to 65536 bytes.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

G programming language string is a G programming language string containing all characters before `\00` (end of string mark in C).

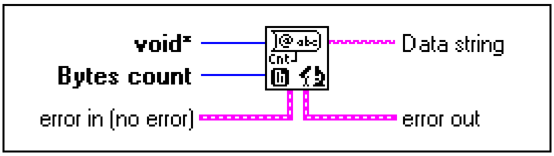
error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

The following graphic illustrates a typical implementation scheme for IMAQ CharPtrToString.



IMAQ MemPeek

Copies a memory zone in a G programming language string. In LabVIEW 4.0 and BridgeVIEW 1.0 the Call Library function does not directly manipulate a C structure; this VI provides this function.



void* is the pointer on the memory zone to be copied. The following table gives the pointer type for different platforms.

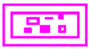
Platform	Pointer Type
IMAQ Vision for LabVIEW 4 for Windows 3.1	16-bit FAR
Other platforms	32-bit flat (universal type)

The size of the memory zone is not limited.

Bytes count is the number of bytes to be copied in the G programming language string.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Data string is the G programming language string containing the bytes of the specified memory zone.



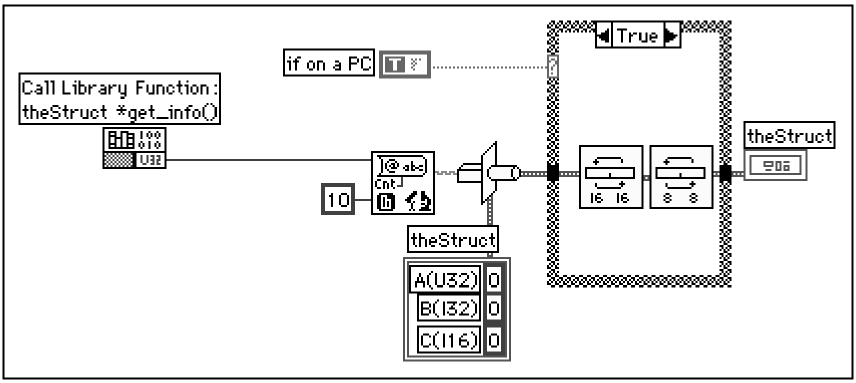
error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Example

In this example, a function returning a pointer on a structure has the following description:

```
typedef struct theStruct{
unsigned long a;
long b;
short c;
} theStruct;
```

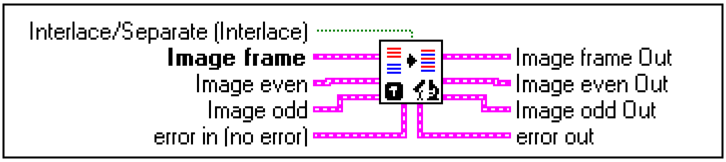
It is possible to find this structure using the following diagram:



LabVIEW and BridgeVIEW map flat data in BigEndian mode, so the bytes need to be inverted when using Windows.

IMAQ Interlace

Extracts odd and even fields from an interlaced image or builds an image using two field images.



Interlace/Separate (Interlace). The default is the interlace mode, which specifies that an interlaced image is built using two field images (**Image even** and **Image odd**). In the separate mode, the odd and even fields from an interlaced image (**Image frame**) are extracted.

Image frame is the reference to the image in which odd and even fields have to be extracted.

Image even is the reference to the image that forms the even lines of the interlaced image.

Image odd is the reference to the image that forms the odd lines of the interlaced image.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Frame Out contains the interlaced image.

Image even Out contains the even lines of the input image.

Image odd Out contains the odd lines of the input image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Note: ***When two fields are interlaced, the first line in the resulting frame comes from the even field and the second comes from the odd field.***

IMAQ ImageBorderOperation

Fills the border of an image.

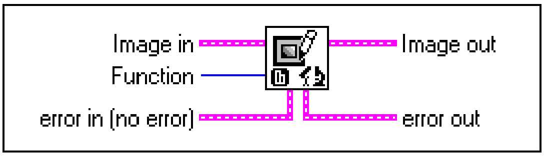


Image in is the reference to the image that has to be modified.

Function indicates the method used to fill the border of the image. This parameter has three possible values:

0	Border Mirror	Repeats the pixel values of the image near the border into the border by symmetry.
1	Border Copy	Sets the value of the border pixels to the value of the image pixel near the border.
2	Border Clear	Sets all border pixels to 0.

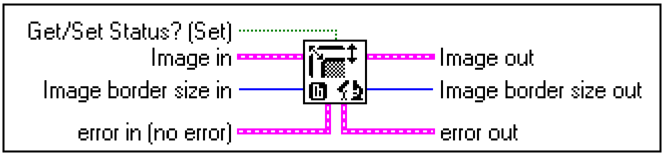
error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Out is the reference to the destination (output) image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

IMAQ ImageBorderSize

Sets the border size of the image and determines the current border size of the image.



Get/Set Status (Get) determines whether the image border size is changed to the Image border size value (Set) or the current image border size value is retrieved (Get).

Image in is the reference to the image that has to be modified.

Image border size in determines the new border size of the image.

error in (no error) is a cluster that describes the error status before this VI executes. For more information about this control, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Image Out is the reference to the destination (output) image.

Image border size out is the border size of the image.

error out is a cluster that describes the error status after this VI executes. For more information about this indicator, see the section *IMAQ VI Error Clusters* in Chapter 9, *VI Overview and Programming Concepts*.

Appendix A

Customer Communication

For your convenience, this appendix contains forms to help you gather the information necessary to help us solve your technical problems and a form you can use to comment on the product documentation. When you contact us, we need the information on the Technical Support Form and the configuration form, if your manual contains one, about your system configuration to answer your questions as quickly as possible.

National Instruments has technical assistance through electronic, fax, and telephone systems to quickly provide the information you need. Our electronic services include a bulletin board service, an FTP site, a fax-on-demand system, and e-mail support. If you have a hardware or software problem, first try the electronic support systems. If the information available on these systems does not answer your questions, we offer fax and telephone support through our technical support centers, which are staffed by applications engineers.

Electronic Services

Bulletin Board

National Instruments has BBS and FTP sites dedicated for 24-hour support with a collection of files and documents to answer most common customer questions. From these sites, you can also download the latest instrument drivers, updates, and example programs. For recorded instructions on how to use the bulletin board and FTP services and for BBS automated information, call (512) 795-6990. You can access these services at:

United States: (512) 794-5422
Up to 14,400 baud, 8 data bits, 1 stop bit, no parity

United Kingdom: 01635 551422
Up to 9,600 baud, 8 data bits, 1 stop bit, no parity

France: 01 48 65 15 59
Up to 9,600 baud, 8 data bits, 1 stop bit, no parity

FTP Support

To access our FTP site, log on to our Internet host, `ftp.natinst.com`, as `anonymous` and use your Internet address, such as `joesmith@anywhere.com`, as your password. The support files and documents are located in the `/support` directories.

Fax-on-Demand Support

Fax-on-Demand is a 24-hour information retrieval system containing a library of documents on a wide range of technical information. You can access Fax-on-Demand from a touch-tone telephone at (512) 418-1111.

E-Mail Support (currently U.S. only)

You can submit technical support questions to the applications engineering team through e-mail at the Internet address listed below. Remember to include your name, address, and phone number so we can contact you with solutions and suggestions.

`support@natinst.com`

Telephone and Fax Support

National Instruments has branch offices all over the world. Use the list below to find the technical support number for your country. If there is no National Instruments office in your country, contact the source from which you purchased your software to obtain support.

	Telephone	Fax
Australia	03 9879 5166	02 9874 4455
Austria	0662 45 79 90 0	0662 45 79 90 19
Belgium	02 757 00 20	02 757 03 11
Canada (Ontario)	905 785 0085	905 785 0086
Canada (Quebec)	514 694 8521	514 694 4399
Denmark	45 76 26 00	45 76 26 02
Finland	09 725 725 11	09 725 725 55
France	01 48 14 24 24	01 48 14 24 14
Germany	089 741 31 30	089 714 60 35
Hong Kong	2645 3186	2686 8505
Israel	03 5734815	03 5734816
Italy	02 413091	06 57284309
Japan	03 5472 2970	03 5472 2977
Korea	02 596 7456	02 596 7455
Mexico	5 520 2635	5 520 3282
Netherlands	0348 433466	0348 430673
Norway	32 84 84 00	32 84 86 00
Singapore	2265886	2265887
Spain	91 640 0085	91 640 0533
Sweden	08 730 49 70	08 730 43 70
Switzerland	056 200 51 51	056 200 51 55
Taiwan	02 377 1200	02 737 4644
United States	512 794 0100	512 794 8411
U.K.	01635 523545	01635 523154

Technical Support Form

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Clock speed ______MHz RAM _____MB Display adapter ___________________________

Mouse ___yes ___no Other adapters installed____

Hard disk capacity _____MB Brand _______________________________________

Instruments used ____

____

National Instruments hardware product model ___________ Revision ______________________

Configuration ____

National Instruments software product ______________________________Version ____________

Configuration ____

The problem is: ____

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List any error messages: ____

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The following steps reproduce the problem:_______________________________________

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IMAQ Vision for G
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Part Number: 321379B-01

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Glossary

Numbers/Symbols

1D	One-dimensional.
2D	Two-dimensional.
3D	Three-dimensional.
3D view	Displays the light intensity of an image in a three-dimensional coordinate system, where the spatial coordinates of the image form two dimensions and the light intensity forms the third dimension.

A

AIPD	National Instruments' internal image format used for saving calibration information associated with an image and for saving complex images.
area threshold	Detects objects based on their size, which can fall within a user-specified range.
arithmetic operators	The image operations multiply, divide, add, subtract, and remainder.
auto-median function	A function that uses dual combinations of opening and closing operations to smooth the boundaries of objects.

B

binary image	An image containing objects usually represented with a pixel intensity of 1 (or 255) and the background of 0.
binary morphology	Functions that perform morphological operations on a binary image.

BMP	Image format commonly used for 8-bit images on PCs.
border function	Removes objects (or particles) in a binary image that touch the image border.

C

circle function	Detects circular objects in a binary image.
closing	A dilation followed by an erosion. A closing fills small holes in objects and smooths the boundaries of objects.
color images	Images containing color information, usually encoded in the RGB form.
color lookup table	Table for converting the value of a pixel in an image into a red, green, and blue (RGB) intensity.
complex images	Save information obtained from the FFT of an image. The complex numbers which compose the FFT plane are encoded in 64-bit floating-point values: 32 bits for the real part and 32 bits for the imaginary part.
connectivity	Defines which of the surrounding pixels of a given pixel constitute its neighborhood.
connectivity-4	Only pixels adjacent in the horizontal and vertical directions are considered as neighbors.
connectivity-8	All adjacent pixels are considered as neighbors.
convex function	Computes the convex regions of objects in a binary image.
convolution	*See* linear filter.
convolution kernel	Simple 3×3, 5×5, or 7×7 matrices (or templates) used to represent the filter in the filtering process. The contents of these kernels are a discrete two-dimensional representation of the impulse response of the filter that they represent.

D

Danielsson function	Similar to the distance functions, but with more accurate results.

density function — For each gray level in a linear histogram, it gives the number of pixels in the image that have the same gray level.

differentiation filter — Extracts the contours (edge detection) in gray level.

digital image — An image $f(x, y)$ that has been converted into a discrete number of pixels. Both spatial coordinates and brightness are specified.

dilation — Increases the size of an object along its boundary and removes tiny holes in the object.

distance calibration — Determination of the physical dimensions of a pixel by defining the physical dimensions of a line in the image.

distance function — Assigns to each pixel in an object a gray-level value equal to its shortest Euclidean distance from the border of the object.

E

Equalize function — *See* histogram equalization.

erosion — Reduces the size of an object along its boundary and eliminates isolated points in the image.

exponential and gamma corrections — Expand the high gray-level information in an image while suppressing low gray-level information.

Exponential function — Decreases the brightness and increases the contrast in bright regions of an image, and decreases contrast in dark regions.

F

Fast Fourier Transform — A method used to compute the Fourier transform of an image.

FFT — Fast Fourier Transform.

Fourier spectrum — The magnitude information of the Fourier transform of an image.

Fourier Transform — Transforms an image from the spatial domain to the frequency domain.

frequency filters — Counterparts of spatial filters in the frequency domain. For images, frequency information is in the form of spatial frequency.

G

G	The graphical programming language used to develop LabVIEW and BridgeVIEW applications.
Gaussian filter	A filter similar to the smoothing filter, but using a Gaussian kernel in the filter operation. The blurring in a Gaussian filter is more gentle than a smoothing filter.
gradient convolution filter	*See* gradient filter.
gradient filter	Extracts the contours (edge detection) in gray-level values. Gradient filters include the Prewitt and Sobel filters.
gray level	The brightness of a point (pixel) in an image.
gray-level dilation	Increases the brightness of pixels in an image that are surrounded by other pixels with a higher intensity.
gray-level erosion	Reduces the brightness of pixels in an image that are surrounded by other pixels with a lower intensity.
gray-level images	Images with monochrome information.
gray-level morphology	Functions that perform morphological operations on a gray-level image.

H

highpass attenuation	Inverse of lowpass attenuation.
highpass FFT filter	Removes or attenuates low frequencies present in the FFT domain of an image.
highpass filter	Emphasizes the intensity variations in an image, detects edges (or object boundaries), and enhances fine details in an image.
highpass frequency filter	Attenuates or removes (truncates) low frequencies present in the frequency domain of the image. A highpass frequency filter suppresses information related to slow variations of light intensities in the spatial image.
highpass truncation	Inverse of lowpass truncations.

histogram	Indicates the quantitative distribution of the pixels of an image per gray-level value.
histogram equalization	Transforms the gray-level values of the pixels of an image to occupy the entire range (0 to 255 in an 8-bit image) of the histogram, increasing the contrast of the image.
hit-miss function	Locates objects in the image similar to the pattern defined in the structuring element.
hole filling function	Fills all holes in objects that are present in a binary image.
HSL	Color encoding scheme in Hue, Saturation, and Lightness.
HSV	Color encoding scheme in Hue, Saturation, and Value.

I

image	A two-dimensional light intensity function $f(x, y)$, where, x and y denote spatial coordinates and the value f at any point (x, y) is proportional to the brightness at that point.
image file	A file containing image information and data.
image processing	Encompasses various processes and analysis functions which you can apply to an image.
image visualization	The presentation (display) of an image (image data) to the user.
inner gradient	Finds the inner boundary of objects.
intensity calibration	Assigning user-defined quantities such as optical densities or concentrations to the gray-level values in an image.
intensity range	Defines the range of gray-level values in an object of an image.
intensity threshold	Characterizes an object based on the range of gray-level values in the object. If the intensity range of the object falls within the user specified range, it is considered as an object; otherwise it is considered as part of the background.

L

labeling	The process by which each object in a binary image is assigned a unique value. This process is useful for identifying the number of objects in the image and giving each object a unique identity.
Laplacian filter	Extracts the contours of objects in the image by highlighting the variation of light intensity surrounding a pixel.
line profile	Represents the gray-level distribution along a line of pixels in an image.
linear filter	A special algorithm that calculates the value of a pixel based on its own pixel value as well as the pixel values of its neighbors. The sum of this calculation is divided by the sum of the elements in the matrix to obtain a new pixel value.
logarithmic and inverse gamma corrections	Expand low gray-level information in an image while compressing information from the high gray-level ranges.
Logarithmic function	Increases the brightness and contrast in dark regions of an image, and decreases the contrast in bright regions of the image.
Logic operators	The image operations AND, NAND, OR, XOR, NOR, difference, mask, mean, max, and min.
lookup table	Table containing values used to transform the gray-level values of an image. For each gray-level value in the image, the corresponding new value is obtained from the lookup table.
lowpass attenuation	Applies a linear attenuation to the frequencies in an image, with no attenuation at the lowest frequency and full attenuation at the highest frequency.
lowpass FFT filter	Removes or attenuates high frequencies present in the FFT domain of an image.
lowpass filter	Attenuates intensity variations in an image. You can use these filters to smooth an image by eliminating fine details and blurring edges.
lowpass frequency filter	Attenuates high frequencies present in the frequency domain of the image. A lowpass frequency filter suppresses information related to fast variations of light intensities in the spatial image.

lowpass truncation	Removes all frequency information above a certain frequency.
L-skeleton function	Uses an L-shaped structuring element in the Skeleton function.

M

mask	Isolates parts of an image for further processing.
mask filter	Removes frequencies contained in a mask (range) specified by the user.
mask image	An image containing a value of 1 and values of 0. Pixels in the source image with a corresponding mask image value of 1 are processed, while the others are left unchanged.
mechanical action	Specifies how a zone is activated. In the **Switch** mode, the first click on a zone turns the zone to TRUE and a second click turns it to FALSE. In the **Latch** mode, a click causes the zone to be temporarily TRUE.
median filter	A low pass filter that assigns to each pixel the median value of its neighbors. This filter effectively removes isolated pixels without blurring the contours of objects.
morphological transformations	Extract and alter the structure of objects in an image. You can use these transformations for expanding (dilating) or reducing (eroding) objects, filling holes, closing inclusions, or smoothing borders. They mainly are used to delineate objects and prepare them for quantitative inspection analysis.
M-skeleton	Uses an M-shaped structuring element in the skeleton function.

N

neighborhood operations	Operations on a point in an image that take into consideration the values of the pixels neighboring that point.
nonlinear filter	Replaces each pixel value with a nonlinear function of its surrounding pixels.
nonlinear gradient filter	A highpass edge-extraction filter that favors vertical edges.

nonlinear Prewitt filter	A highpass edge-extraction filter that favors horizontal and vertical edges in an image.
nonlinear Sobel filter	A highpass edge-extraction filter that favors horizontal and vertical edges in an image.
Nth order filter	Filters an image using a nonlinear filter. This filter orders (or classifies) the pixel values surrounding the pixel being processed. The pixel being processed is set to the *N*th pixel value, *where N* is the order of the filter.

O

opening	An erosion followed by a dilation. An opening removes small objects and smoothes boundaries of objects in the image.
operators	Allow masking, combination, and comparison of images. You can use arithmetic and logic operators in IMAQ Vision.
optical representation	Contains the low-frequency information at the center and the high-frequency information at the corners of an FFT-transformed image.
outer gradient	Finds the outer boundary of objects.

P

palette	The gradation of colors used to display an image on screen, usually defined by a color lookup table.
PICT	Image format commonly used for 8-bit images on Macintosh and Power Macintosh platforms.
picture element	An element of a digital image.
pixel	Picture element.
pixel calibration	Directly calibrating the physical dimensions of a pixel in an image.
pixel depth	The number of bits used to represent the gray level of a pixel.
Power 1/Y function	Similar to a logarithmic function but with a weaker effect.
Power Y function	*See* exponential function.

Prewitt filter	Extracts the contours (edge detection) in gray-level values using a 3 × 3 filter kernel.
probability function	Defines the probability that a pixel in an image has a certain gray-level value.
proper-closing	A finite combination of successive closing and opening operations that you can use to fill small holes and smooth the boundaries of objects.
proper-opening	A finite combination of successive opening and closing operations that you can use to remove small particles and smooth the boundaries of objects.

Q

quantitative analysis	Obtaining various measurements of objects in an image.

R

region of interest	An area of the image that is graphically selected from a window displaying the image. This area can be used focus further processing.
Reverse function	Inverts the pixel values in an image, producing a photometric negative of the image.
RGB	Color image encoding using red, green, and blue colors.
RGB chunky	Color encoding scheme using red, green and blue (RGB) color information where each pixel in the color image is encoded using 32 bits: 8 bits for red, 8 bits for green, 8 bits for blue, and 8 bits for the alpha value (unused).
Roberts filter	Extracts the contours (edge detection) in gray level, favoring diagonal edges.
ROI	Region of interest.

S

segmentation function	Fully partitions a labeled binary image into non-overlapping segments, with each segment containing a unique object.
separation function	Separates objects that touch each other by narrow isthmuses.
Sigma filter	A highpass filter that outlines edges.
skeleton function	Applies a succession of thinning operations to an object until its width becomes one pixel.
skiz	Obtains lines in an image that separate each object from the others and are equidistant from the objects that they separate.
smoothing filter	Blurs an image by attenuating variations of light intensity in the neighborhood of a pixel.
Sobel filter	Extracts the contours (edge detection) in gray-level values using a 3×3 filter kernel.
spatial calibration	Assigning physical dimensions to the area of a pixel in an image.
spatial filters	Alter the intensity of a pixel with respect to variations in intensities of its neighboring pixels. You can use these filters for edge detection, image enhancement, noise reduction, smoothing, and so forth.
spatial resolution	The number of pixels in an image, in terms of the number of rows and columns in the image.
Square function	*See* exponential function.
Square Root function	*See* logarithmic function.
standard representation	Contains the low-frequency information at the corners and high-frequency information at the center of an FFT-transformed image.
structuring element	A binary mask used in most morphological operations. A structuring element is used to determine which neighboring pixels contribute in the operation.

T

thickening — Alters the shape of objects by adding parts to the object that match the pattern specified in the structuring element.

thinning — Alters the shape of objects by eliminating parts of the object that match the pattern specified in the structuring element.

threshold — Separates objects from the background by assigning all pixels with intensities within a specified range to the object and the rest of the pixels to the background. In the resulting binary image, objects are represented with a pixel intensity of 255 and the background is set to 0.

threshold interval — Two parameters, the lower threshold gray-level value and the upper threshold gray-level value.

TIFF — Image format commonly used for encoding 8-bit and 16-bit images and color images on both Macintosh and PC platforms.

truth table — A table associated with a logic operator which describes the rules used for that operation.

Z

zones — Areas in a displayed image that respond to user clicks. You can use these zones to control events which can then be interpreted within LabVIEW or BridgeVIEW.

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