IMAQ™

IMAQ™ Vision Builder Tutorial

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Conventions

The following conventions are used in this manual:

»	The **»** symbol leads you through nested menu items and dialog box options to a final action. The sequence **File»Page Setup»Options** directs you to pull down the **File** menu, select the **Page Setup** item, and select **Options** from the last dialog box.
	This icon denotes a tip, which alerts you to advisory information.
	This icon denotes a note, which alerts you to important information.
bold	Bold text denotes items that you must select or click on in the software, such as menu items and dialog box options. Bold text also denotes parameter names.
italic	Italic text denotes variables, emphasis, a cross reference, or an introduction to a key concept. This font also denotes text that is a placeholder for a word or value that you must supply.
`monospace`	Text in this font denotes text or characters that you should enter from the keyboard, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, operations, variables, filenames and extensions, and code excerpts.

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1

System Requirements and Installation

This chapter lists system requirements and installation instructions and introduces the IMAQ Vision Builder environment.

System Requirements

To run IMAQ Vision Builder, you must have the following minimum system requirements:

- Personal computer using at least a 133 MHz Pentium or higher microprocessor (233 MHz Pentium MMX or higher microprocessor recommended)
- Microsoft Windows 2000/NT/9*x*
- 800 × 600 resolution (or higher) video adapter, 65,536 colors (16-bit) or higher
- National Instruments image acquisition (IMAQ) hardware and NI-IMAQ 2.2 or higher for Windows 2000/NT/9*x* (if you are acquiring images)
- Minimum of 32 MB RAM (64 MB recommended)
- Minimum of 30 MB of free hard disk space

Note You need Excel 97 or higher installed on your computer to complete a few steps in the second tutorial.

Installing IMAQ Vision Builder

Note To install IMAQ Vision Builder on a Windows NT or Windows 2000 system, you must be logged in with Administrator privileges.

1. Insert the IMAQ Vision Builder CD into your CD-ROM drive.

   If the CD startup screen does not appear, use the Windows Explorer to run the `SETUP.EXE` program in the `\Setup` directory on the CD.
2. Follow the setup instructions you see on your screen.

By default, the IMAQ Vision Builder installation program creates a new folder, `\Program Files\National Instruments\IMAQ Vision Builder\`, that contains the following items:

- `Program` folder—`IMAQ Vision Builder.exe`, the online help file, function libraries, and other related program files
- `Readme.txt`—Late-breaking information about IMAQ Vision Builder
- `Examples` folder—Images and scripts that you need to complete the example tutorials in this manual
- `Manuals` folder—Portable Document Format (PDF) versions of the *IMAQ Vision User Manual* and this manual

Note You must have Adobe Acrobat Reader installed to access these documents.

- `Solutions` folder—Example images and scripts

Launching and Exiting IMAQ Vision Builder

To launch IMAQ Vision Builder in Windows, point to **Start»Programs»National Instruments IMAQ Vision Builder» IMAQ Vision Builder**.

To quit IMAQ Vision Builder, follow these steps:

1. Close open parameter windows.
2. Save your script and images if you want to keep them.
3. Select **File»Exit**.

IMAQ Vision Builder Environment

IMAQ Vision Builder is a tool that you can use to prototype and test image processing applications. To prototype your image processing application, you build custom algorithms with the IMAQ Vision Builder scripting feature. The scripting feature records every step of your processing algorithm. After completing the algorithm, you can test it on other images to make sure it works.

The algorithm is recorded in a *Builder file*. Builder files are ASCII text files that list the processing functions and relevant parameters for an algorithm that you create in IMAQ Vision Builder. You can implement the algorithm defined by the Builder file in any development environment, such as LabVIEW, LabWindows/CVI, or Visual Basic using the IMAQ Vision machine vision and image processing library. Refer to *Implementing the Algorithm in LabVIEW* in Chapter 3, *Using Blob Analysis to Analyze the Structure of a Metal*, for an example of a Builder file and its LabVIEW implementation.

Features

IMAQ Vision Builder offers the following features:

- Script window—Records a series of image processing steps and the settings you use for each of those steps. You can run scripts on single images or image collections (batch processing). You can modify and save scripts. See Figure 2-6 to view a script in the Script window.
- Image Browser—Contains all of the images currently loaded in IMAQ Vision Builder. Through the Image Browser, you can select an image that you want to process by double clicking on it. See Figure 2-3 to view images loaded into the Image Browser.
- Acquisition window—Displays the Interfaces window (IMAQ hardware and channels available) and the property pages for the IMAQ hardware device. See Figure 2-7 to view all the elements of the Acquisition window.
- Processing window—Updates the image as you change parameters. Because this view immediately reflects the changes you have made in the parameters window, you can continue modifying parameters until you get the desired result. See Figure 2-4 to view an image loaded into the Processing window.
- Parameter window—Displays parameters that you can set for an image processing function. Each IMAQ Vision function available through the menus has a parameter window where you set the parameters for that

function. See Figure 2-5 to view an example of the threshold Parameter window.

- Reference window—Displays the original version of the image (image source) as you manipulate it in the processing window. See Figure 2-4 to view an image in the Reference window.
- Tools palette—Displays a collection of tools for selecting regions of interest (ROI), zooming in and out, and changing the Image palette. See Figure 2-6 to view the Tools palette.
- Solution Wizard—Displays a list of industries and corresponding quality-assurance tasks that those industries perform. Based on the task the user selects, the wizard loads an IMAQ Vision-based solution to the task.
- Performance Meter—Estimates how long your script will take to run in IMAQ Vision on a given image. The Performance Meter gives you estimates on both how long the entire script will take to run on the current image and how long each function of the script will take to execute.

Image Analysis Functions

IMAQ Vision Builder also offers several image analysis functions, including the following:

- Histogram—Counts the total number of pixels in each grayscale value and graphs it.
- Line Profile—Returns the grayscale values of the pixels along a line that you draw with the **Line Tool** from the Tools palette and graphs it.
- Particle Analysis—Computes more than 40 measurements on objects in an image, including the area and perimeter of the objects.
- 3D View—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.
- Centroid—Computes the energy center of a grayscale image or area of interest.

Image Processing Functions

IMAQ Vision Builder includes a comprehensive set of functions for image processing, including the following:

- Filtering—Functions for smoothing, edge detection, and convolution.
- Morphology—Functions (including erosion, dilation, opening, and closing) that modify the shape of objects in grayscale or binary images.

- Thresholding—Functions that enable you to select ranges of pixel values in grayscale and color images, separating the objects under consideration from the background.
- Particle Filtering—Functions to filter objects based on shape measurements.

Machine Vision Functions

IMAQ Vision Builder also offers several machine vision functions, including the following:

- Edge Detection—Finds edges along a line that you draw with the **Line Tool** from the Tools palette.
- Pattern Matching—Locates regions of a grayscale image that match a predetermined template. Pattern Matching can find template matches regardless of poor lighting, blur, noise, shifting of the template, and rotation of the template.
- Shape Matching—Searches for the presence of a shape in a binary image and specifies the location of each matching shape. The shape can be detected even if rotated or scaled.
- Circle Detection—Finds the center and radius of circular objects in an image.
- Caliper—Computes measurements such as distances, areas, and angles based on results returned from other machine vision and image processing functions.
- Color Matching—Quantifies which colors and how much of each color exist in a region of an image and uses this information to check if another image contains the same colors in the same ratio.

Getting Help

As you work with IMAQ Vision Builder, you might need to consult other sources if you have questions. The following sources can provide you with more specific information about IMAQ Vision, IMAQ hardware, and imaging.

IMAQ Vision Builder Online Help

IMAQ Vision Builder offers tooltips and online help that you can access in the following ways:

- Access the IMAQ Vision Builder online help by selecting **Online Help** from the **Help** menu. There you can find information not available in this manual, such as function descriptions and directions for performing image processing functions.

- Tooltips appear when you move the mouse cursor over a button in the Processing toolbar, Tools palette, Script window, Reference window, Acquisition window, or Image Browser.
- Press the **Help** button in any function parameter window to get information about that function and its parameters.

IMAQ Vision Manuals

If you have purchased IMAQ Vision software from National Instruments, you also have one of the following manuals, depending on the development environment you use. The following manuals provide information about image processing and the IMAQ Vision functions:

- *IMAQ Vision for G Reference Manual*
- *IMAQ Vision for LabWindows/CVI*
- *Getting Results with ComponentWorks IMAQ Vision*

For detailed information about the concepts and algorithms used by IMAQ Vision Builder, launch the *IMAQ Vision User Manual* from the **Start** menu (**Start»Programs»National Instruments IMAQ Vision Builder»IMAQ Vision User Manual**).

National Instruments Web Site

The National Instruments Web site provides information about IMAQ hardware and software. Visit the site at `www.ni.com/imaq`.

From the IMAQ site, you can locate information about new IMAQ Vision features, machine vision problems and solutions, using MMX technology on machine vision applications, and selecting the appropriate IMAQ hardware, cameras, lenses, and lighting equipment for your application.

IMAQ Vision Builder Scripts

You installed several example scripts when you installed IMAQ Vision Builder. You can run these scripts to learn more about IMAQ Vision Builder scripting capabilities. You also can customize these scripts for your own applications. By default, the scripts are installed at `\Program Files\National Instruments\IMAQ Vision Builder\Examples`.

2

Introduction to Image Processing with IMAQ Vision Builder

This chapter describes how you can use IMAQ Vision Builder to create and test your own image processing algorithms. It explains the types of images IMAQ Vision Builder can load and process and how to get started in IMAQ Vision Builder.

Images

For the purposes of image processing, the term image refers to a digital image. 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 convention, the spatial reference of the pixel with the coordinates (0, 0) is located at the upper-left corner of the image. Notice in the following representation that the value of x increases moving from left to right, and y increases in the downward direction.

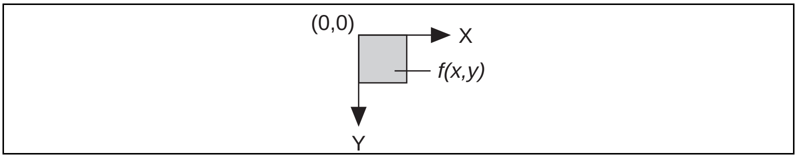


Figure 2-1. Spatial Reference of the (0, 0) Pixel

Properties

A digitized image has three basic properties: resolution, 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 $m \times n$. This image has n pixels along its horizontal axis and m pixels along its vertical axis.
- Image Definition—The definition of an image indicates the number of shades that you can see in the image. The *bit depth* of an image is the number of bits used to encode the value of a pixel. For a given bit depth of n, the image has an image definition of 2^n, meaning a pixel can have 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 from –32,768 to 32,767.
- Number of Planes—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 Figure 2-2. For a color version of this figure, see the PDF version of this document, which you can find in **Start»Programs»National Instruments IMAQ Vision Builder»IMAQ Vision Builder Tutorial**.

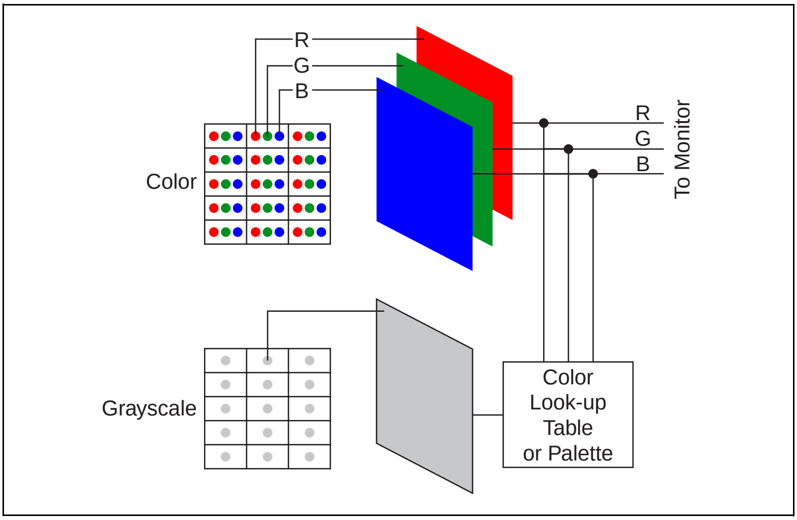


Figure 2-2. Number of Planes in an Image

In gray-level images, there is a single intensity value per pixel. In three-plane or true-color images, the RGB intensities of a pixel are coded into three different values, corresponding to the red, green, and blue components.

Image Types and File 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 image file formats are 8-bit BMP, TIFF, PNG, JPEG, and AIPD. Standard 16-bit gray-level formats are PNG and AIPD. AIPD is an internal file format that offers the advantage of storing the spatial calibration of an image.
- Color Images—Color images are composed of pixels that are a composite of four values. In the RGB color model, each color is encoded with an 8-bit red, green, and blue value. In the HSL color model, each color is encoded with an 8-bit hue, saturation, and luminance value. In both color models, an additional 8-bit value goes unused. This representation is called both 4×8 bit and 32 bit. Standard color file formats for RGB images are BMP, TIFF, PNG, JPEG, 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.

Getting Started in IMAQ Vision Builder

This section describes the software-specific terminology that you need to complete the tutorials in this manual and understand the online help. The best way to understand how IMAQ Vision Builder works and what you can accomplish with IMAQ Vision Builder is by using it.

In this short example, you load images into IMAQ Vision Builder and perform one image processing function—a *threshold*. Thresholding isolates objects so that you can keep those that interest you and remove those that do not. Thresholding also converts the image from a grayscale image, with pixel values ranging from 0 to 255, to a binary image, with pixel values of 0 or 1.

Follow these steps to get started in IMAQ Vision Builder:

1. Launch IMAQ Vision Builder from the **Start** menu (**Start»Programs»National Instruments IMAQ Vision Builder»IMAQ Vision Builder**).

2. To load images, select the **Open Image** button from the Welcome Screen.
3. Navigate to `Program Files\National Instruments\IMAQ Vision Builder\Examples\Metal` and check the **Select All Files** option. IMAQ Vision Builder previews the images in the Preview Image window and displays information about the file type and image depth.
4. Click **OK**.

   IMAQ Vision Builder loads those image files into the Image Browser, as shown in Figure 2-3. The Image Browser provides information about the selected image, such as image size, location, depth, and type.

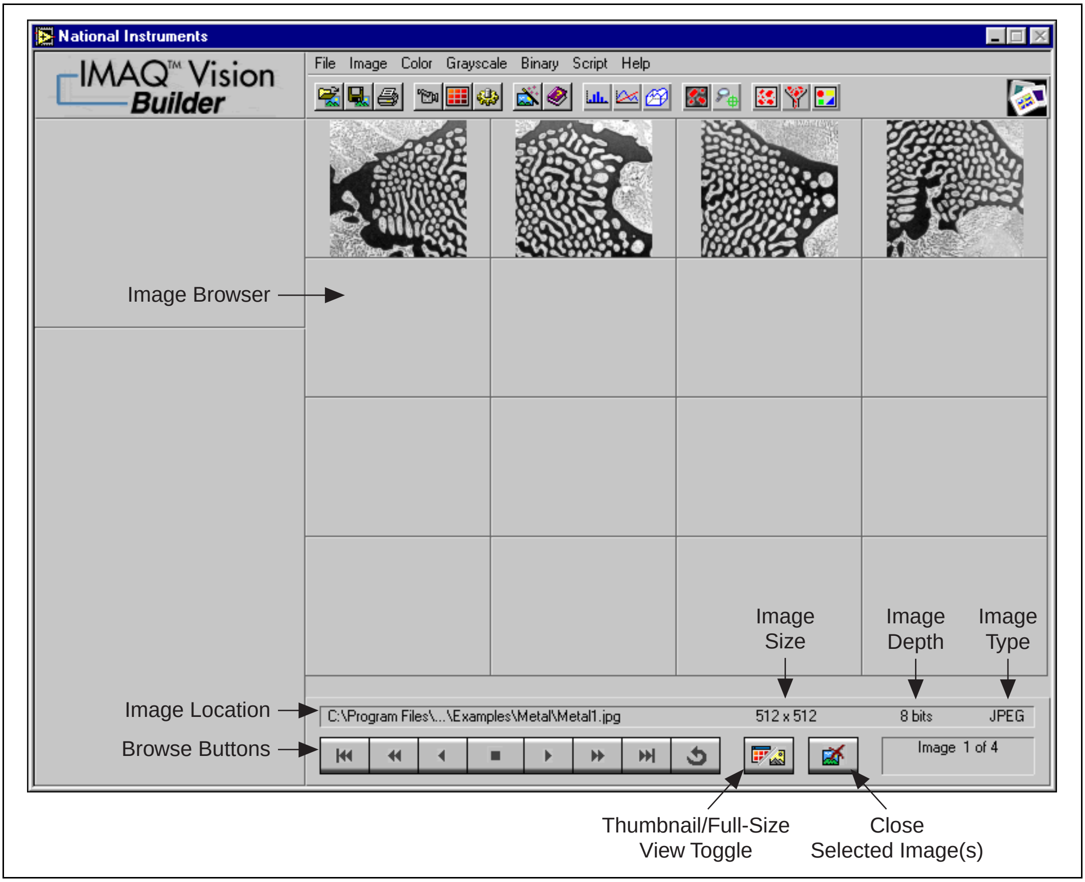


Figure 2-3. Image Browser

You can view new images in either thumbnail view, as shown in Figure 2-3, or in full-size view, which shows a single full-size view of the selected image.

5. Click the **Thumbnail/Full-Size View toggle** to view the first image in full size.
6. To enter processing mode, double click the image `Metal1.jpg`. IMAQ Vision Builder loads the image into the processing window, as shown in Figure 2-4.

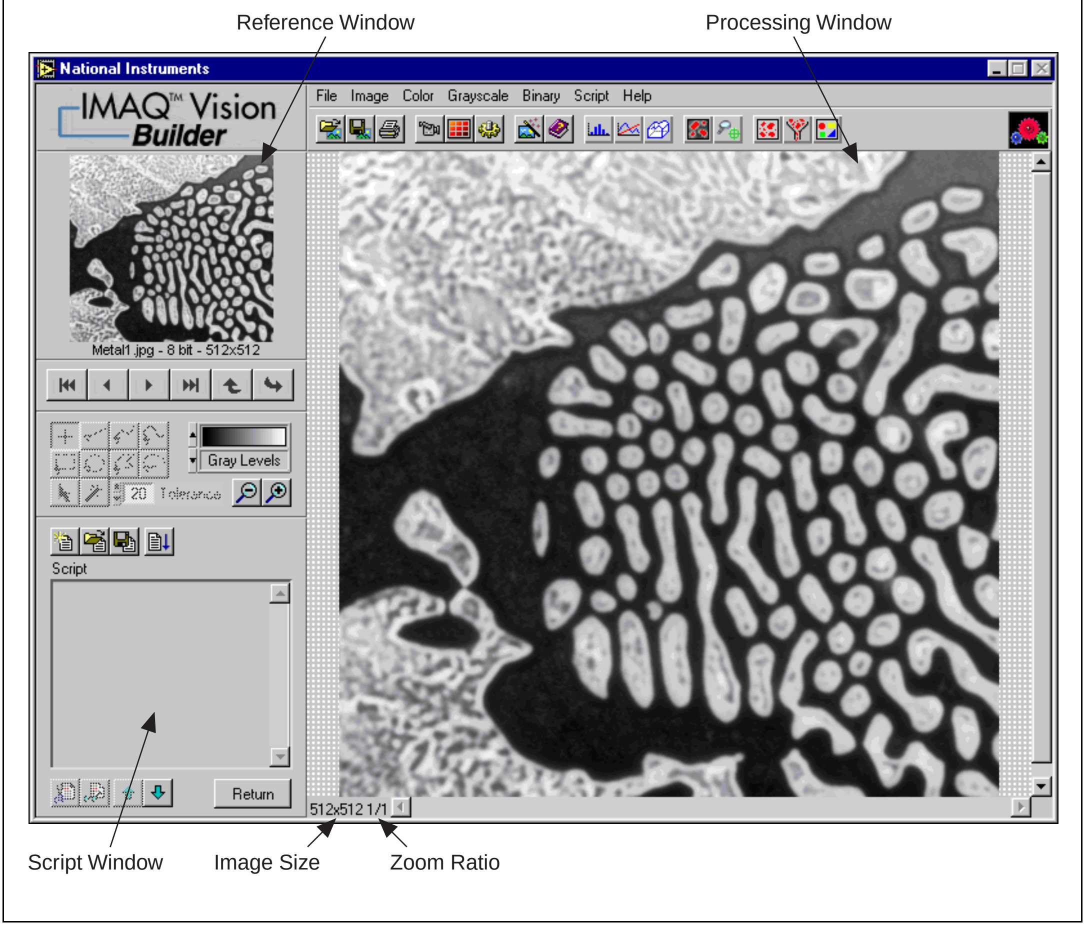


Figure 2-4. Processing an Image

Tip The Reference window displays the original version of the image as you manipulate it in the Processing window.

7. Select **Grayscale»Threshold**. The Threshold parameter window appears in the lower right corner of the IMAQ Vision Builder window, as shown in Figure 2-5.

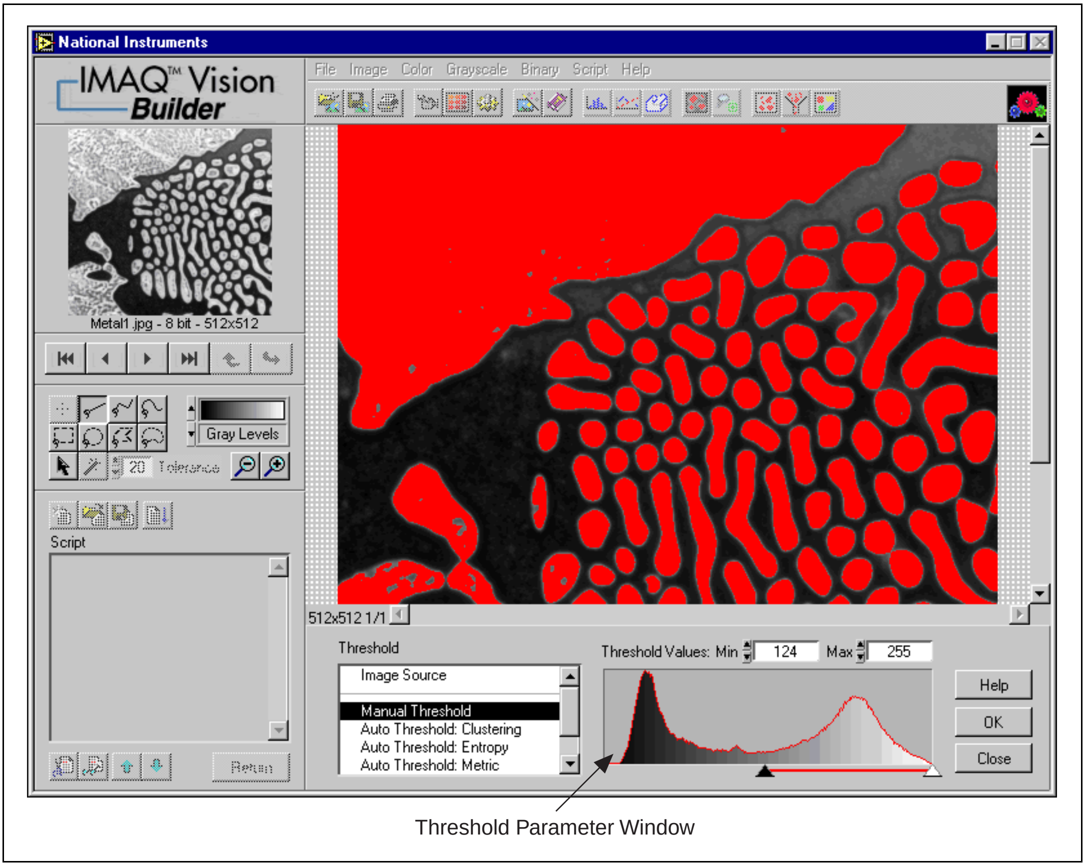


Figure 2-5. Thresholding an Image

The Threshold parameter window displays a histogram. A histogram counts the total number of pixels at each grayscale value and graphs it. From the graph, you can tell whether the image contains distinct regions of a certain gray-level value, and you can select pixel regions of the image. For example, if the background of an image is black and you want to remove it, you can select a range with values close to 255 (white).

The Processing window displays a preview of the threshold operation using the current set of parameters. The pixels depicted in red have intensities that fall inside the threshold range. The threshold operator will set their values to 1. The pixels depicted in gray have values outside the threshold range. The threshold operator will set their values to 0.

8. From the Threshold parameter window, specify settings that work best for your application. To threshold this image, set the **Min** value to 130 and **Max** value to 255 to select all of the objects.

Tip Often you will need to manipulate the parameters several times to find the values that work best. Rather than entering numbers in the **Min** and **Max** fields, you can select the range using the pointers on the histogram. Adjust the pointers until all of the objects you want to select are red. The black pointer marks the minimum value, and the white pointer marks the maximum value.

9. Click **OK** to apply the manual threshold to the image. The image is converted to a binary image where all of the selected pixels in the threshold range are set to 255 (white) and all other pixels are set to 0 (black).

   Refer to Figure 2-6 to see what the image looks like after the threshold has been applied.

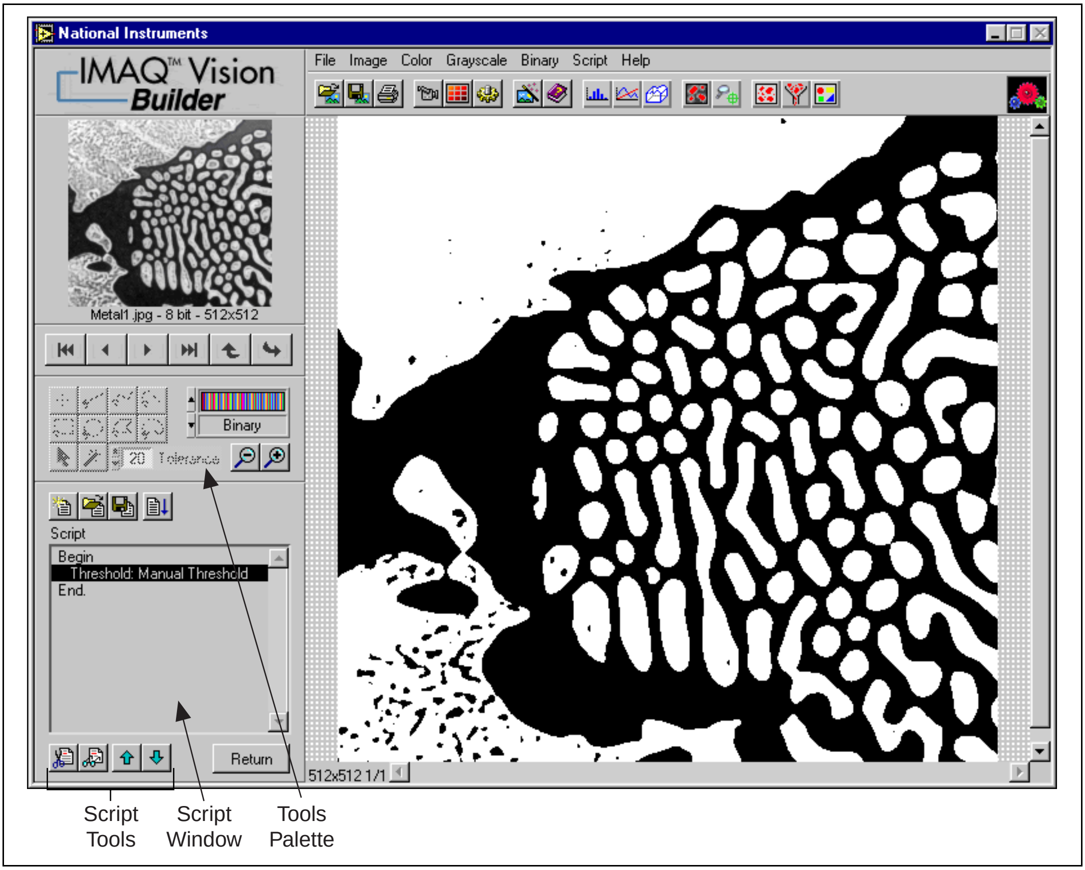


Figure 2-6. Thresholded Image

The thresholding step is recorded in the Script window. The script records the processing operation and all of its parameters. If you need to run the same operation on other images, you can save the script and use it again.

10. Select **Script»Save Script** and name the script `threshold.scr`.

    If you find another image that you need to threshold similarly, run this script on a different image using the following steps:

    a. Load the image.

    b. Select **Script»Open Script** to open `threshold.scr`.

    c. Click the **Run Script** button in the script window.

    Try experimenting with different options and images. For example, you can perform a particle analysis to find the area that each object in this image occupies. If you need help with any specific image processing operation, click the **Help** button in the parameter window.

11. Select **File»Exit** to close IMAQ Vision Builder.

Acquiring Images in IMAQ Vision Builder

If you have National Instruments IMAQ hardware and NI-IMAQ installed, you can acquire live images in IMAQ Vision Builder.

Tip If you do *not* have IMAQ hardware and NI-IMAQ 2.2 or later, IMAQ Vision Builder automatically simulates the acquisition process by displaying a sequence of images. You can stop the sequence at any frame, capture the image, and send the image to the Image Browser for processing.

IMAQ Vision Builder offers three types of acquisitions: snap, grab, and sequence. A *snap* acquires and displays a single image. A *grab* acquires and displays a continuous sequence, which is useful, for example, when you need to focus your camera. A *sequence* acquires images according to settings that you specify and sends the images to the Image Browser.

Opening the Acquisition Window

If IMAQ Vision Builder is not loaded, launch the application from the **Start** menu (**Start»Programs»National Instruments IMAQ Vision Builder»IMAQ Vision Builder**). Press the **Acquire Image** button from the Welcome Screen to view the Acquisition window, as shown in Figure 2-7.

If you already have IMAQ Vision Builder running, press the **Acquire Image** button in the toolbar. IMAQ Vision Builder displays the Acquisition window, as shown in Figure 2-7.

The Interfaces window displays all IMAQ hardware and channels available for your computer. Figure 2-7 shows that two IMAQ hardware devices are available—the IMAQ PCI-1408 and the IMAQ PCI-1424.

Note The hardware devices listed in your Interfaces window will vary according to the devices plugged into your computer.

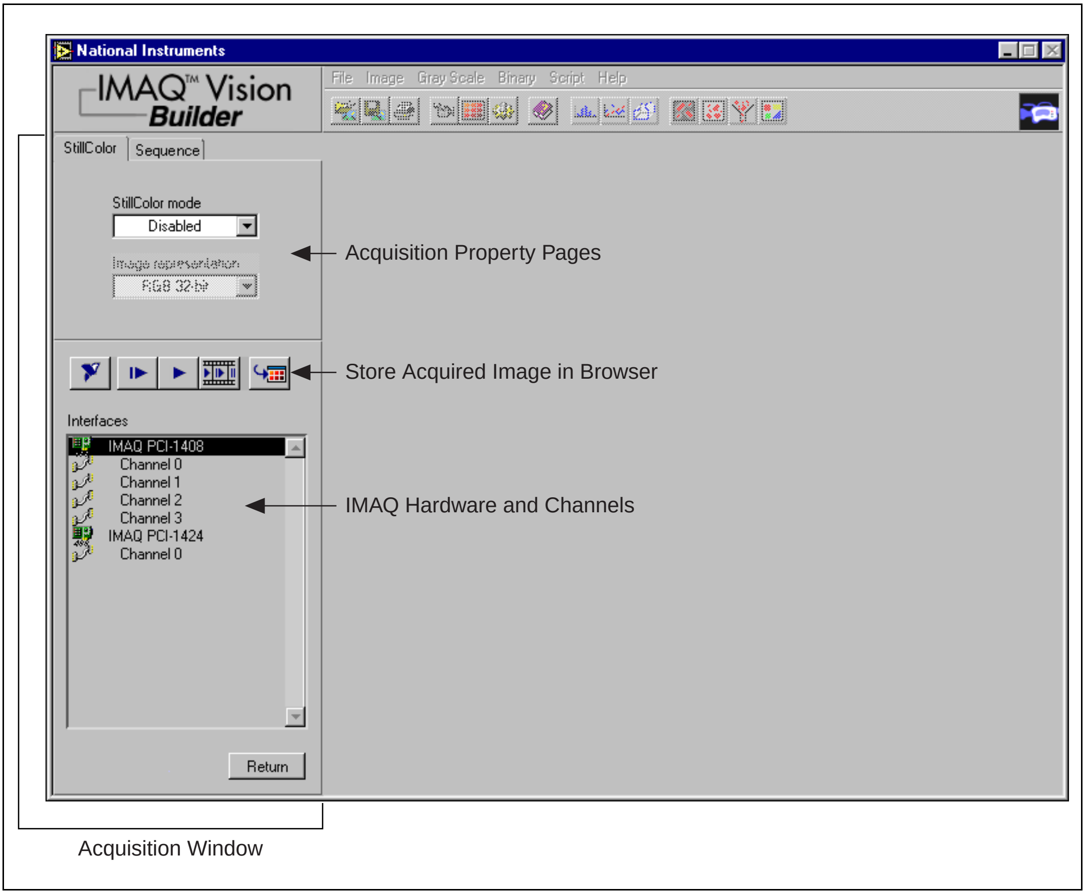


Figure 2-7. Acquiring Images in IMAQ Vision Builder

The property pages above the Interfaces window list properties available for the selected device. In Figure 2-7, the IMAQ PCI-1408 is selected. Because the PCI-1408 can acquire a sequence of images, you can set the following properties for Sequence acquisition. For information about the properties of other IMAQ devices, see your hardware manual and the Measurement & Automation Explorer online help.

- **Number of Frames**—Number of frames you want to acquire.
- **Skip Count**—Number of frames you want to skip between acquisitions.
- **Line**—Physical trigger line.
- **Action**—Triggering action.
  - **Disabled**—Disables triggering

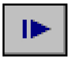
- **Trigger start of acquisition**
- **Trigger each image**
- **Timeout**—Time, in milliseconds, within which the trigger must occur.

Note A *trigger* is any event that causes or starts some form of data capture.

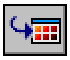
Note Your computer must have a National Instruments IMAQ board and NI-IMAQ 2.2 or higher installed before you can acquire live images in IMAQ Vision Builder.

Snapping an Image (Single Acquisition)

1. Make sure the Acquisition window is open.



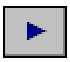
2. Click the **Acquire Single Image** button to acquire a single image with the IMAQ device and display it. This operation is also known as a *snap*.



3. Press the **Store Acquired Image in Browser** button to send the image to the Image Browser.
4. Press **Return** to return to the Image Browser.
5. Process the image as you would any other image in IMAQ Vision Builder. See Chapter 3, *Using Blob Analysis to Analyze the Structure of a Metal*, and Chapter 4, *Using Gauging for Part Inspection* for examples of processing images in IMAQ Vision Builder.

Grabbing an Image (Continuous Acquisition)

1. Make sure the Acquisition window is open.

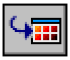


2. Click the **Acquire Continuous Images** button to acquire and display images in continuous mode at the maximum rate. This operation is also known as a *grab.*

Note If your computer does *not* have an IMAQ board, IMAQ Vision Builder simulates the live acquisition process. You can interact with the simulation module as you would with a live acquisition.

3. Click the **Acquire Continuous Images** button again to stop the acquisition and display the last acquired image.

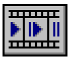
Tip You can acquire a region of interest within the full-sized image. Draw a region of interest in your image while grabbing it, and the image reduces to that area. You can refine the acquired area again by selecting another region of interest or return to the full-sized image by clicking on the image.



4. Press the **Store Acquired Image in Browser** button to send the image to the Image Browser.
5. Press **Return** to return to the Image Browser.
6. Process the image as you would any other image in IMAQ Vision Builder. See Chapter 3, *Using Blob Analysis to Analyze the Structure of a Metal*, and Chapter 4, *Using Gauging for Part Inspection*, for examples of processing images in IMAQ Vision Builder.

Acquiring a Sequence of Images

1. Make sure the Acquisition window is open.
2. Set the properties for the Sequence property page.



3. Click the **Sequence Acquisition** button to acquire a sequence of live images. A panel describing the status of sequence acquisition appears.

   If you set the triggering action property to Disabled, press the **Start Acquisition** button to begin acquiring a sequence of images.

   Images acquired are automatically sent to the Image Browser.
4. Press **Return** to return to the Image Browser.
5. Process the image as you would any other image in IMAQ Vision Builder. See Chapter 3, *Using Blob Analysis to Analyze the Structure of a Metal*, and Chapter 4, *Using Gauging for Part Inspection*, for examples of processing images in IMAQ Vision Builder.

3

Using Blob Analysis to Analyze the Structure of a Metal

This chapter describes blob analysis and provides step-by-step directions for completing a blob analysis tutorial in IMAQ Vision Builder.

What Is Blob Analysis?

Blob analysis consists of a series of processing operations and analysis functions to produce some information about the blobs in an image. A blob (*b*inary *l*arge *ob*ject) is defined as a connected region or grouping of pixels in an image in which all pixels have the same intensity level. In a binary image, the background is zero, and every non-zero pixel is part of a binary object.

You perform a blob analysis to find statistical information—such as the size of the blobs or the number, location, and presence of blob regions. With this information, you can detect flaws on silicon wafers, detect soldering defects on electronic boards, or locate objects in motion control applications when there is significant variance in part shape or orientation.

Tutorial

In this tutorial, you find the area of circular particles in a metal. As you perform this analysis, IMAQ Vision Builder records all of the processing operations and parameters in a script. You will run that script on other images to test your blob analysis script.

To find the total area of circular particles, you will perform the following image processing steps:

- Filter the image to sharpen edges and ease the separation of the particles from the background.
- Threshold the image to isolate pixels that interest you (the particles) and remove all other pixels (the background).
- Fill holes that appear in the particles after thresholding.

- Remove all objects touching the border so that you remove partial particles.
- Use a particle filter to find all circular blobs and remove non-circular blobs.
- Perform a particle analysis to find the total area occupied by circular blobs.

Loading Images into IMAQ Vision Builder

1. If IMAQ Vision Builder is not loaded, launch the application from the **Start** menu (**Start»Programs»National Instruments IMAQ Vision Builder»IMAQ Vision Builder**). Press the **Open Image** button from the Welcome Screen.

   If you already have IMAQ Vision Builder running, press the **Open Image** button in the toolbar.
2. Navigate to `Program Files\National Instruments\IMAQ Vision Builder\Examples\Metal` and check the **Select All Files** option. IMAQ Vision Builder previews the images in the Preview Image window and displays information about the file format and size and pixel depth.

Tip The Preview Image window displays all selected images in a sequence. To view the images at a different rate, adjust the slide to the right of the Preview Image window.

3. Click **OK**.

   IMAQ Vision Builder loads the image files, which represent microscopic views of pieces of metal, into the Image Browser. From this collection of images in the Image Browser, you can select the image that you want to process.
4. Double click the first image, `Metal1.jpg`. The image is loaded into the processing window.

Preparing an Image for Blob Analysis

Before you can separate circular particles from non-circular particles, you need to prepare the image. To isolate particles of interest, verify that individual particles are distinct from other particles (that is, there is a gap between particles) and that the borders of those particles are sharp.

Examining the Image

Examine the image in the processing window. The image is slightly blurred. Also, the edges of particles are not sharp. Although you can see these problems from just looking at this image, you might need to use a *line profile* in other cases. A line profile returns the grayscale values along a line that you draw with the **Line Tool** from the Tools palette. Follow these steps to examine edges using a line profile:

1. Select **Image»Line Profile**. The parameter window appears and the **Line Tool** from the Tools palette is automatically selected and active.
2. Draw a short segment across a particle, as shown in Figure 3-1.

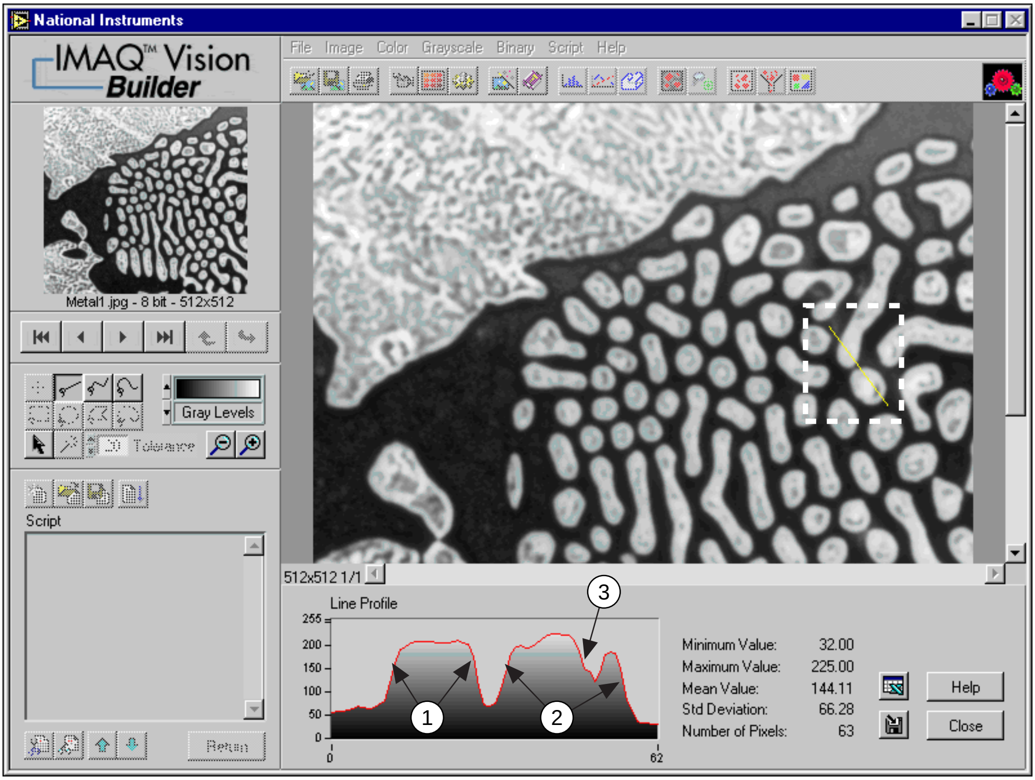


Figure 3-1. Using a Line Profile to Examine Edges

In Figure 3-1, the areas labeled 1 and 2 represent the edges of the particles. Notice that the edges of both particles have a slope. The more shallow the slope, the greater variation you will have in detecting the exact location of the edge. As you change the threshold level in images with shallow-sloped particle edges, you could inadvertently change the shape or size of the particle. In the *Filtering the Image* section, you will use the Convolution-Highlight Details filter under **Grayscale»Filters** to define the edges of the particles and increase the slope.

The area labeled 3 is a fluctuation in pixel values, which might be caused by brighter and darker pixels in the center of the particles or it could be edges of a hole in the particle. Later, you will threshold the image to make all pixels in the objects the same pixel value and perform a morphological operation on the image to fill any holes left in the object.

3. Click **Close**.

Filtering the Image

Filters can smooth, sharpen, transform, and remove noise from an image so that you can extract the information you need. To sharpen edges, including the edges of any holes inside a particle, and create contrast between the particles and the background, follow these steps:

1. Select **Grayscale»Filters**.
2. Select **Convolution-Highlight Details** from the Filters list. This function looks for sharp transitions and highlights edge pixels according to a *kernel* to make gaps more prominent. A kernel is a structure that represents a pixel and its relationship to its neighbors.
3. Click **Apply** to add this step to the script.
4. Click **Close**.

Examining the Results of the Filtering

To confirm that the filtering helped sharpen edges and separate particles, perform another line profile using the following steps:

1. Select **Image»Line Profile**.
2. Click and drag to draw a short segment across a particle to examine the line profile of a particle and its border, as shown in Figure 3-2. The line profile indicates more defined edges.
3. Click **Close**.

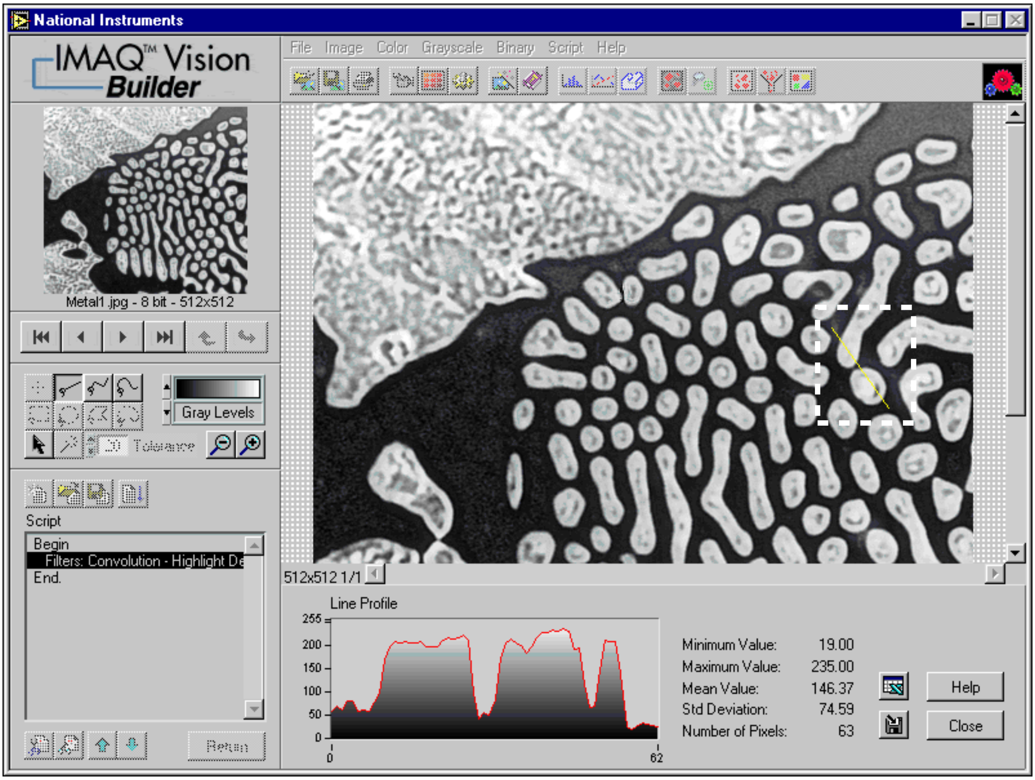


Figure 3-2. Using a Line Profile to Examine Particle Edges

Separating Particles from the Background with Thresholding

Thresholding isolates pixels so that you can keep those that interest you and remove the remaining pixels. Thresholding also converts the image from grayscale to binary.

The Threshold parameter window displays a histogram. A histogram counts the total number of pixels in each grayscale value and graphs it. From the graph, you can tell whether the image contains distinct regions of a certain gray-level value, and you can select pixel regions of the image.

Follow these steps to select a range of brighter pixels to analyze:

1. Select **Grayscale»Threshold**.
2. Select **Manual Threshold** from the Threshold list.

3. Select a range of **130** to **255**.

   Notice that the particles of interest (circular and non-circular) are highlighted in red. When you apply this threshold, everything highlighted in red is set to white (255) and all other pixels are set to 0 (black).

Tip You can adjust the pointers until all of the particles of interest are red. The black pointer marks the minimum value, and the white pointer marks the maximum value.

4. Click **OK** to add this step to the script. Figure 3-3 shows the thresholded image. The pixels that you want to process are white. Unselected pixels are set to black.

   The image is now a binary image, which is an image composed of black and white pixels with values of 0 and 255. The white particles are now referred to as blobs.

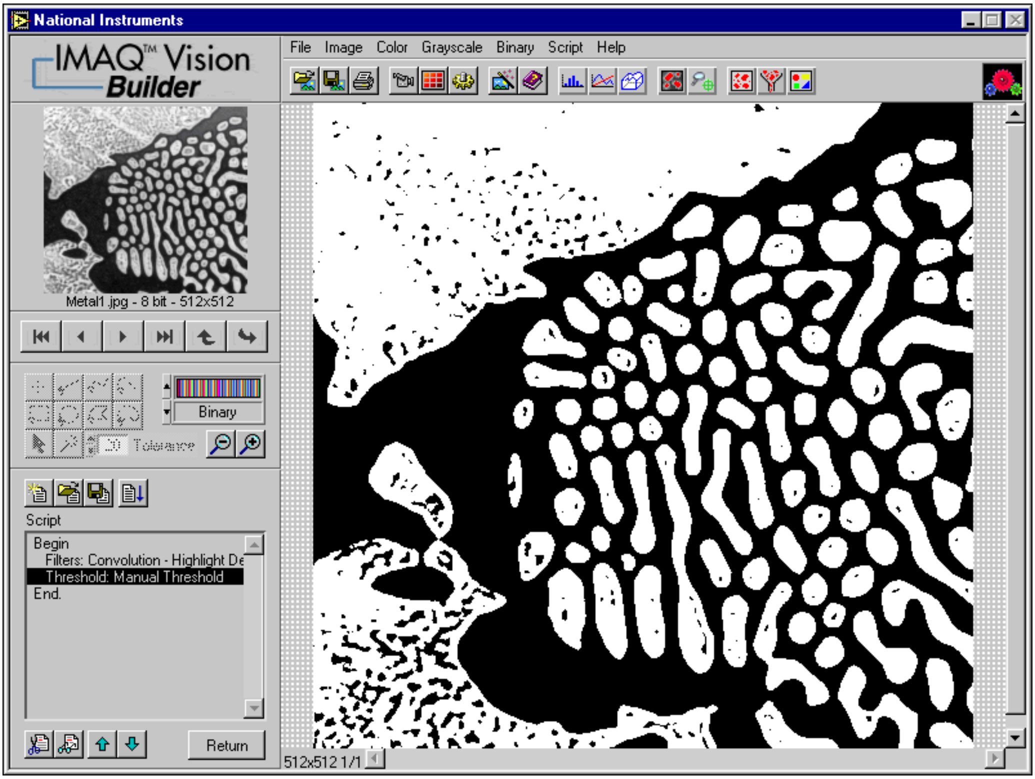


Figure 3-3. Separating Particles from the Background with Thresholding

Modifying Blobs with Morphological Functions

Morphological functions affect the shape of blobs. Each blob or region in the binary image is affected on an individual basis. Morphological operations prepare blobs in the image for quantitative analysis such as finding the area, perimeter, or orientation. Use the following steps to apply two morphological functions to the image. The first function fills holes in the particles and the second removes objects that touch the border of the image.

1. Select **Binary»Adv. Morphology**.
2. Select **Fill holes** from the Morphology-Advanced function list.
3. Click **Apply** to add this step to the script.
4. Select **Remove border objects** to remove any objects that touch the border of the image, as shown in Figure 3-4.
5. Click **Apply** and **Close** to add this step to the script and close the Advanced Morphology window.

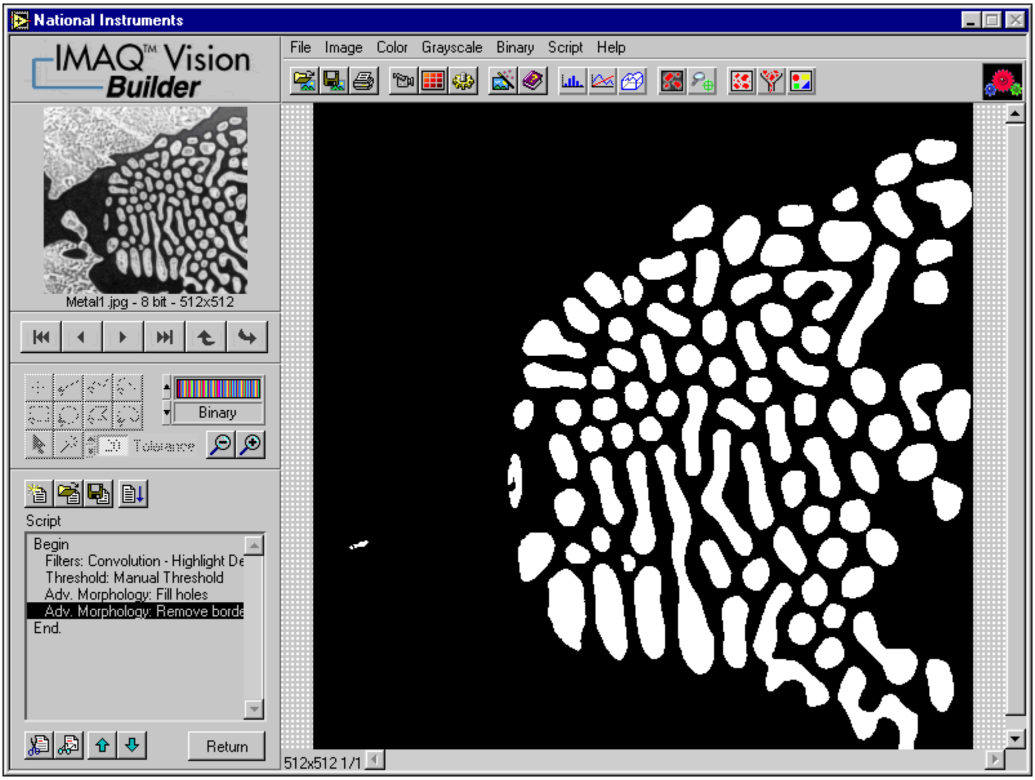


Figure 3-4. Modifying Blobs with Morphological Functions

Isolating Circular Blobs

Use the following steps to define a particle filter that isolates and keeps the circular blobs and removes the non-circular blobs from the image.

1. Select **Binary»Particle Filter**.
2. Select **Heywood circularity factor** from the list of particle filters. This function calculates the ratio of the perimeter of the blob to the area of the particle. The more circular the blob, the closer the ratio to 1.
3. To find more circular and less oblong blobs, enter a minimum value of **0** and a maximum value of **1.06** for the parameter range.
4. Select the **Keep Objects** option to keep the circular blobs (and remove the blobs that do not fit in this range).
5. Click **OK** to add this step to the script. The image now contains only the circular blobs, as shown in Figure 3-5.

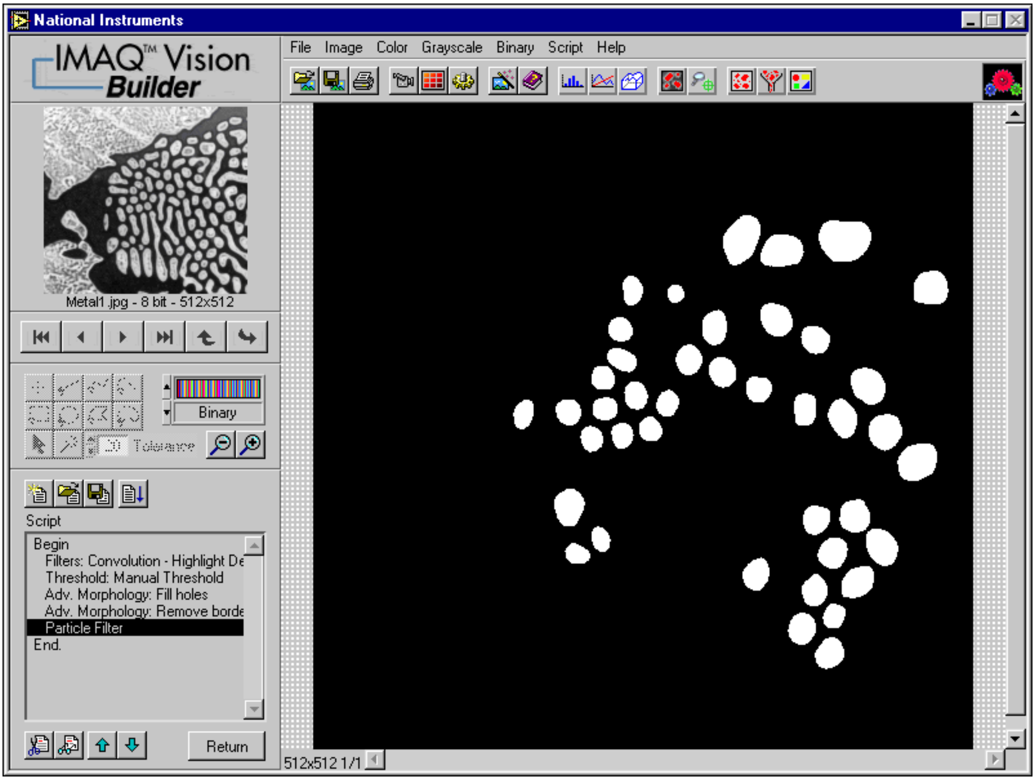


Figure 3-5. Isolating Circular Blobs

Analyzing Circular Blobs

Now that you have isolated the circular blobs, follow these steps to find the area occupied by them:

1. Select **Binary»Particle Analysis**. A results table is displayed with all of the measurement results.

   IMAQ Vision Builder assign numerical labels to each blob. The first row of the results table lists the numerical label associated with each blob.

2. Click the **Show/Hide Labels** button to view the labels.

Tip When you click on a blob, the measurement results for that blob are highlighted in blue. When you click on the results for a blob, the blob is highlighted in yellow in the processing view.

3. To show only the area measurement, click the **Choose Measurements** button.
4. Click **None** to deselect all of the measurements.
5. Double click **Area (unit)**.
6. Click **OK**.
7. Click **Apply** to record the particle analysis in the script.
8. Click **Close**.

You now have all of the information you need to analyze the structure of the metal. Remember to include the analysis as part of your LabVIEW, LabWindows/CVI, or Visual Basic solution. You also can use Microsoft Excel to analyze the data generated by IMAQ Vision Builder.

Tip To send the data to Microsoft Excel, click the **Send Data to Excel** button in the Particle Analysis results window.

Testing the Blob Analysis Script

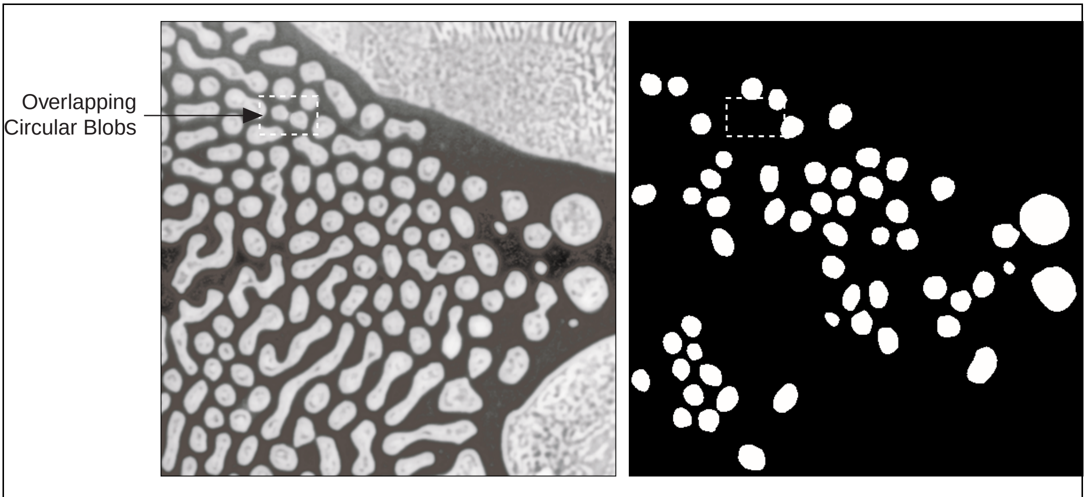
The script that you created as you processed this image is a custom algorithm. To test this algorithm, run it on another image in the collection using the following steps:

1. Click the **Image Browser** button in the Standard toolbar.
2. Double click the third image, `Metal3.jpg`.

Tip Rather than returning to the Image Browser, you can navigate through the images in the Image Browser from the Reference window. Click the next and back buttons until you see the image you want to process and then click the **Make Image Active** button to move that image into the Processing window.

3. Click the **Run Script** button.

   Figure 3-6 shows the original image, `Metal3.jpg`, on the left and the image after the blob analysis processing on the right. Notice that two circular blobs are removed from the image during processing because they are touching each other. To separate particles from each other, you can adjust the thresholding step.



Original Image (Metal3.jpg) Image after Processing

Figure 3-6. Comparing the Original Image to the Processed Image

4. Click **Done** to close the Particle Analysis window.
5. Double click the Threshold step in the script window to open the threshold parameters. Figure 3-7 shows `Metal3.jpg` at the thresholding step of the script.

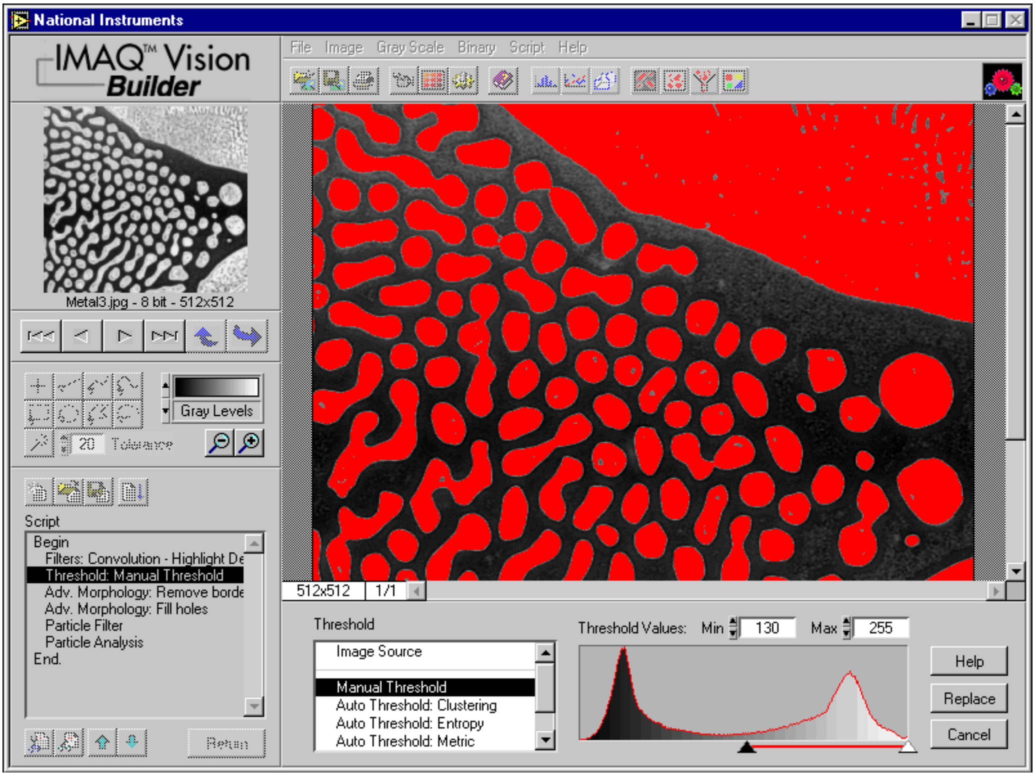


Figure 3-7. Testing the Blob Analysis Script

6. Adjust the minimum threshold value until the blobs are clearly separated. A minimum value of **150** works well.
7. Click **Replace**.

8. Click the **Run Script** button to rerun the script. Notice that only the circular blobs now appear in the final processed image.
9. Click **Done** to close the Particle Analysis window.

Saving the Blob Analysis Script

Now that you have written a blob analysis algorithm and tested it on another image, you can save the script to use on similar images. You also can perform batch processing with this script. See the *Analyzing a Collection of Images with Batch Processing* section in Chapter 4, *Using Gauging for Part Inspection*, for an example of batch processing in IMAQ Vision Builder.

1. Select **Script»Save Script**.
2. Save the script as `blob analysis.scr`.

Estimating Processing Time

IMAQ Vision Builder can estimate the time, in milliseconds, that IMAQ Vision will take to process the active image with the open script. The Performance Meter gives both an estimate of the total time IMAQ Vision will take to process the image and an estimate of the time each function within the script will require. Follow these steps to estimate how many milliseconds IMAQ Vision will use to process `Metal3.jpg` with `blob analysis.scr`:

1. Select **Script»Performance Meter**. The Performance Meter gives an estimate of the total time IMAQ Vision will take to run the script.
2. Click **Expand** to view an itemized list of the time IMAQ Vision will take to perform each function in the script.
3. Click **OK** to close the Performance Meter.

Implementing the Algorithm in LabVIEW

You have prototyped, tested, and refined an IMAQ Vision processing algorithm. Now you can use that script to implement the algorithm in development environments such as LabVIEW, LabWindows/CVI, and Visual Basic using the IMAQ Vision library. Follow these steps to implement the blob analysis algorithm in LabVIEW:

1. Select **Script»Builder File**. The Builder Information window lists all of the processing steps and the parameters for each.
2. Select **File»Save**.
3. Save the file as `blob analysis.txt`.
4. Close the Builder Information window.
5. Use **File»Exit** to close IMAQ Vision Builder.
6. Open the file in a text editor or word processor and print the file.

7. Launch LabVIEW and use the step descriptions to build the blob analysis block diagram with IMAQ Vision VIs. The block diagram should look similar to Figure 3-8.

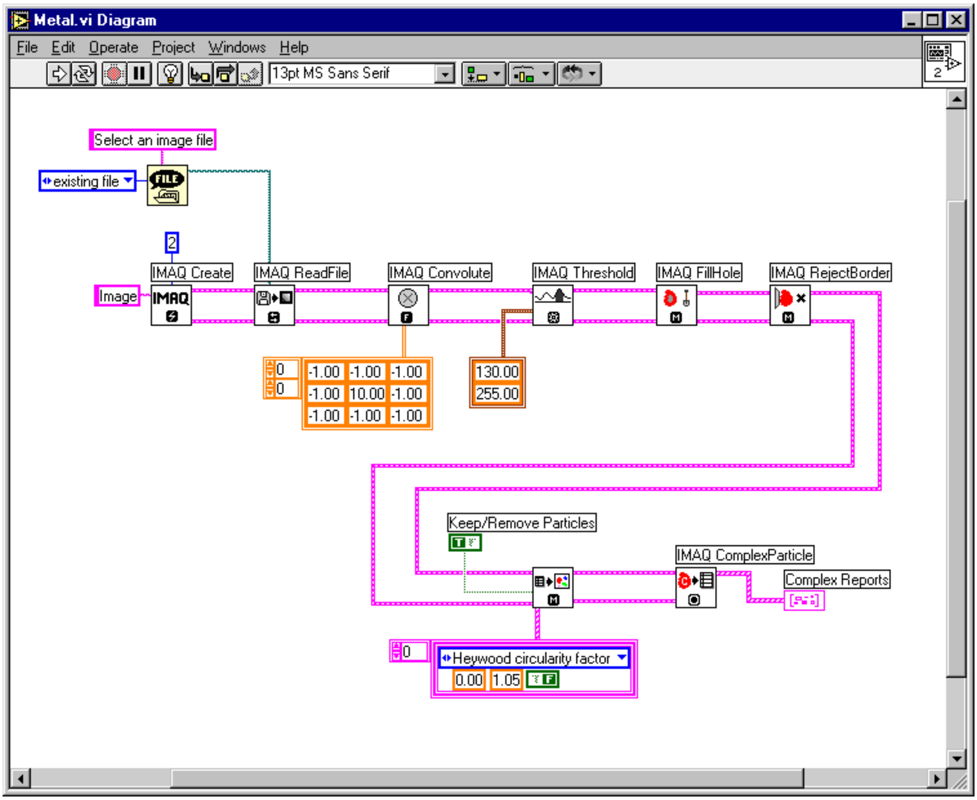


Figure 3-8. Blob Analysis Block Diagram

4

Using Gauging for Part Inspection

This chapter describes gauging and provides step-by-step directions for completing a part inspection tutorial in IMAQ Vision Builder.

What Is Gauging?

Components such as connectors, switches, and relays are small and manufactured in high quantity. Human inspection of these components is tedious and time consuming. Vision systems can quickly and consistently measure certain features on a component and generate a report with the results. From the results, you can determine whether a part meets its specifications.

Gauging consists of making critical distance measurements—such as lengths, diameters, angles, and counts—to determine if the product is manufactured correctly. If the gauged distance or count does not fall within tolerance limits, the component or part does not meet specifications and should be rejected. Gauging inspection is used often in mechanical assembly verification, electronic packaging inspection, container inspection, glass vile inspection, and electronic connector inspection.

Tutorial

In this tutorial, you analyze images of pipe brackets to see if the brackets meet their physical specifications. A pipe bracket is a metal piece of hardware used to bolt down long, slender parts, such as a tube of bundled wires.

Your goal is to measure angles and distances between features on the brackets and determine if those measurements fall within a tolerance range. Figure 4-1 illustrates the measurements and the acceptable values for those measurements.

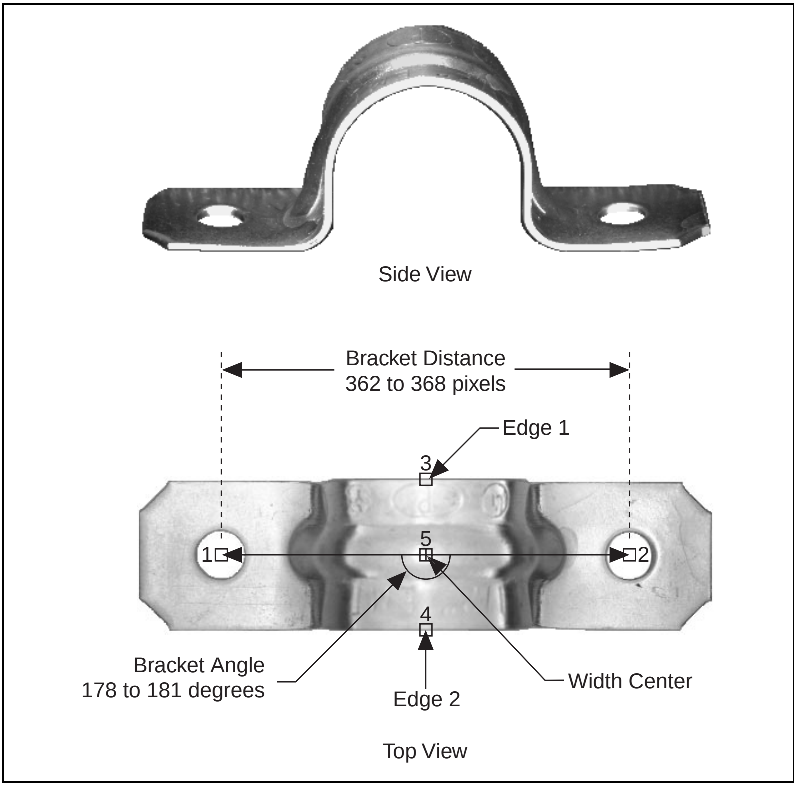


Figure 4-1. Bracket Specifications

Width Center is the center of the bracket's width. Width Center will become the vertex of Bracket Angle. Bracket Distance measures the length in pixels between two manufactured holes in the bracket. Bracket Distance determines whether the bracket's arch is the appropriate height and curvature. Bracket Angle measures the angle of the arms of the bracket and determines if the bracket's arms are aligned properly.

As you perform this analysis, IMAQ Vision Builder records all of the processing operations and parameters in a script. You will run that script on other bracket images to determine which are good and which are defective.

Loading Images into IMAQ Vision Builder

Perform the following steps to load an image:

1. Launch IMAQ Vision Builder from the **Start** menu (**Start»Programs»National Instruments IMAQ Vision Builder»IMAQ Vision Builder**).
2. Select **File»Open Image** to load images.
3. Navigate to `Program Files\National Instruments\IMAQ Vision Builder\Examples\Bracket` and check the **Select All Files** option. IMAQ Vision Builder previews the images in the Preview Image window and displays information about the file format and size and pixel depth.

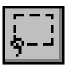
Tip The Preview Image window displays all selected images in a sequence. To view the images at a different rate, adjust the slide to the right of the Preview Image window.

4. Click **OK** to load the image files into IMAQ Vision Builder. From this collection of images in the Image Browser, you can select the image that you want to process.
5. Double click the first image, `Bracket1.jpg`, to load it into the processing window.

Finding Measurement Points Using Pattern Matching

Before you can compute the measurements, you need to locate features on which you can base the measurements. In this example, you will use pattern matching to find manufactured holes in a bracket. These holes will serve as points of measurement from which you will determine whether the bracket's arch is the appropriate height and curvature.

1. Select **Grayscale»Pattern Matching**. Make sure the Learn Template tab is selected.



2. With the **Rectangle Tool**, click and drag a box around the left hole in the image, as shown in Figure 4-2. The selected area, or region of interest (ROI), will become the template pattern.

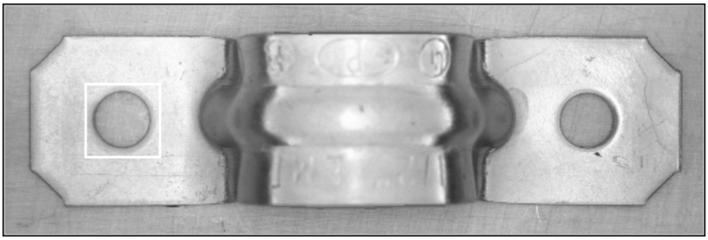


Figure 4-2. Selecting a Template Pattern

3. Click **Create from ROI** to learn the selected area as the template pattern. This will take a few seconds. After IMAQ Vision Builder learns the template, a save dialog box appears.
4. Navigate to `Program Files\National Instruments\IMAQ Vision Builder\Examples\Bracket`.
5. Save the template as `template.png`. The Pattern Matching parameter window displays the template image and its path.
6. Select the **Search Template** tab.
7. Set **Search Mode** to Shift Invariant. Use shift-invariant matching when you do not expect the matches you locate to be rotated in their images. If you expect your matches to be rotated, use rotation-invariant matching.
8. Uncheck the **Sub-Pixel Accuracy** checkbox.
9. Set the **Minimum Score** to 600. A minimum score of 600 ensures that IMAQ Vision Builder will find matches similar, but not identical, to the template.
10. Set **Number of Matches** to 1.
11. With the **Rectangle Tool**, draw an ROI around the left side of the bracket, as shown in Figure 4-3. Be sure that the region you draw is larger than the template image and big enough to encompass all possible locations of the template in the other images you will analyze.

    Drawing a region of interest in which you expect to locate a template match is a significant step in pattern matching. It reduces the risk of finding a mismatch. It also allows you to specify the order in which you want to locate multiple instances of a template in an image.

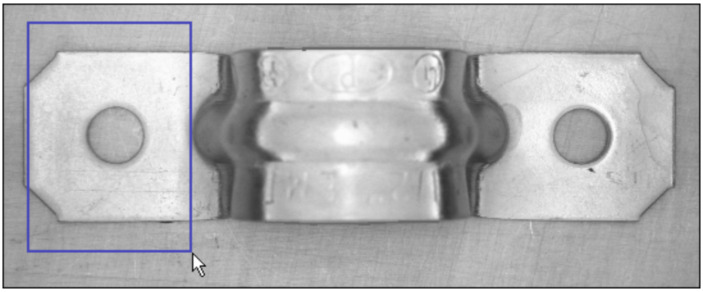


Figure 4-3. Selecting the First Search Area

Once you draw the region of interest, IMAQ Vision Builder automatically locates the template in the region and displays the score and location of the match. Notice that the score for the match is 1000. The score for this match is perfect because you made the template from the same region of the image.

12. Click **Apply** to add this step to the script.
13. With the **Rectangle Tool**, draw a region of interest around the right side of the bracket, as shown in Figure 4-4. IMAQ Vision Builder automatically locates the template in the region bound by the rectangle and displays the score and location of the match.

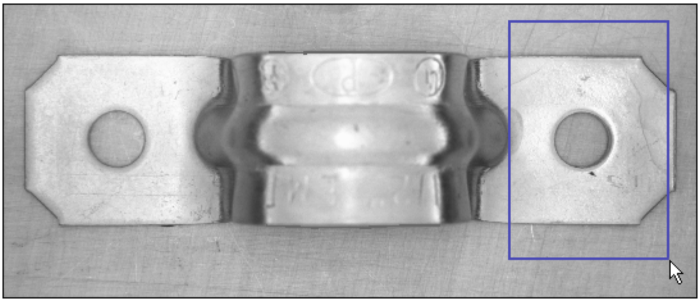


Figure 4-4. Selecting the Second Search Area

The score of the second match is not a perfect 1000, but it is high enough for you to consider it a match to the template.

14. Click **Apply** to add this step to the script.
15. Click **Close**.

Finding Edges in the Image

Before you can compute measurements to determine whether a bracket meets specifications, you need to detect edges on which you can base the measurements. The Edge Detector finds edges along a line that you draw with the **Line Tool** from the Tools palette.

1. Select **Grayscale»Edge Detector**.
2. Select the **Simple Edge Tool**. The Simple Edge Tool is effective on images with sharp contrast between the background and objects.
3. Select **First & Last Edge** so that IMAQ Vision Builder finds and labels only the first and last edges along the line you draw.
4. Select **Absolute Value**. Absolute Value indicates that you want to use pixel values to specify the threshold level. **Relative Value** indicates that you are specifying the threshold level as a percentage.
5. Set **Threshold Level** to 128. The threshold level specifies the difference in pixel values that you expect to constitute an edge in the image. Absolute detection considers a threshold level of 128 or greater as an edge.
6. Click and drag to draw a vertical line across the middle of the bracket to find the edges that you will use to calculate Width Center, as shown in Figure 4-5. IMAQ Vision Builder labels the edges 1and 2.

Tip To draw a straight line, press and hold the <Shift> key as you draw the line.

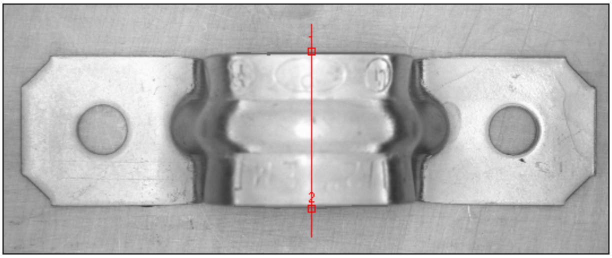


Figure 4-5. Finding the Edges for Bracket Distance

Look at the line profile. The sharp transitions in the line profile indicate edges. Notice that the number of edges found is displayed under the line profile.

7. Click **Apply** to add this edge detection step to the script.
8. Click **Close** to close the Edge Detector window.

Making the Measurements

Now that you have found the bracket's holes and the necessary edges, you can calculate the center of the bracket's width, distance between the bracket's holes, and angle of the bracket's arms with the Caliper function. The Caliper function is a tool that uses points on the image to calculate measurements, such as distances, angles, the center of a segment, or the area, depending on the number of points you have selected on the image. These points are results of earlier processing steps, such as edge detections and pattern matching.

Follow these steps to make the measurements:

1. Select **Grayscale»Caliper**.
2. In the image, click on points **3** and **4** to obtain the first measurement—Width Center, which specifies the center of the bracket's width.

Tip If you have trouble finding the points, click the **Zoom In** tool in the Tools palette to magnify the image. Magnification factors are displayed in the lower, left corner of the processing window. 1/1 specifies 100% magnification (default). 2/1 specifies a slightly magnified view, and 1/2 specifies a slightly demagnified view.

Tip Instead of clicking on the points in the image, you can double click on the points in the **Points** list box to select them. When you select a point, IMAQ Vision Builder places a check mark next to it.

3. Select **Center** from the **Type of Measure** list.
4. Click the **Measure** button to compute the center of the bracket's width and add the Width Center measurement to the results table, as shown in Figure 4-6.

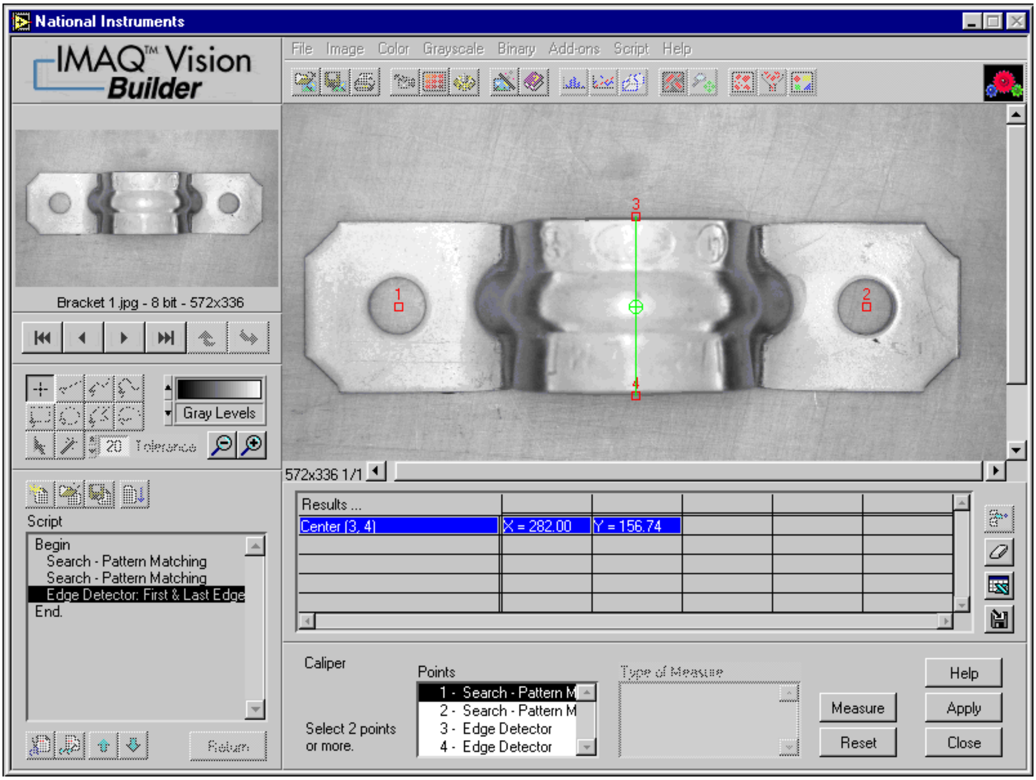


Figure 4-6. Using the Caliper Function to Find Width Center

5. Click **Apply** to add this step to the script.
6. Select **Grayscale»Caliper** again. The center of the bracket's width appears as point 5.
7. Click on points **1** and **2** in the image to find the second measurement—Bracket Distance, which measures the length between the manufactured holes in the bracket and determines whether the bracket's arch is the appropriate height.
8. Select **Distance** from the Type of Measure list.
9. Click the **Measure** button to compute the distance between the bracket's holes and add the measurement to the results table.
10. Click on points **1**, **5**, and **2** (in that order) to find the third measurement—Bracket Angle, which measures the angle of the bracket's arms with respect to a vertex at point 5, as shown in Figure 4-7.
11. Select **Angle** from the Type of Measure list.

12. Click the **Measure** button to compute the angle of the bracket’s arms and add the measurement to the results table.

Figure 4-7 shows the image with Bracket Distance and Bracket Angle selected on the image and displayed in the results table.

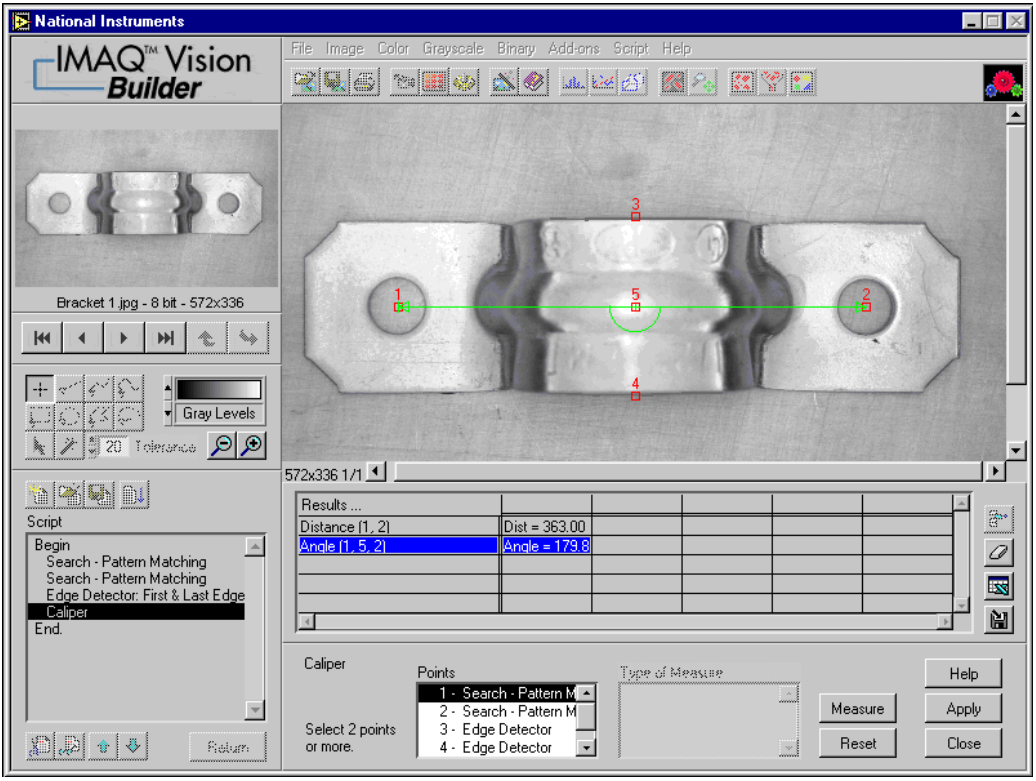


Figure 4-7. Using the Caliper Tool to Collect Measurements

13. Click **Apply** to add these caliper measurements to the script and close the Caliper window.
14. Select **Script»Save Script** and save the script as `bracket.scr`.

Analyzing a Collection of Images with Batch Processing

Perform the following steps to run the script as a batch process on the bracket images and generate a text file containing all of the measurement data:

1. Select **Script»Batch Processing**.
2. Select **Browser** from Image Source to process the images stored in the Image Browser.

The listbox contains all of the steps in the script. You can select any step in the script and choose options, such as saving that step's results to file, displaying results, or opening the parameter window to adjust the settings on each iteration. For this example, open the Caliper parameter window and save the caliper results to a file.

3. Select the last Caliper entry in the list box.
4. Check **Open Results Panel** and **Save Results** under Analysis Mode.
5. Click the **Setup** button and set the following options:
   a. Select **One file for all results**.
   b. Press the **Browse** button, navigate to the directory where you want the file saved, and click **Select Cur Dir**.
   c. In the File Name Prefix box, type `bracket.txt` to give the results files a consistent name.
6. Click **OK** to close the Setup options.
7. Click **Run!** to start the batch process.

   As batch processing runs, a progress window appears on the left side of the IMAQ Vision Builder window. The progress window displays the current process (acquiring an image or processing an image), the number of times the process has been completed, the starting time, and an estimation of the time remaining. If you ever need to stop a batch process, click the **Cancel** button.

Note Because you checked **Open Results Panel** when setting up the batch processing parameters, you must click the **Done** button after the script runs on each image.

8. When the batch processing completes, click **OK**.
9. Click **Return** to exit the Batch Processing window.

The bracket images have been processed and the caliper results stored in a text file.

Analyzing the Results

As you implement this algorithm in your development environment using the Builder file, remember to include your analysis. For this example, you can use Excel to quickly analyze the results.

Note To complete this part of the tutorial, you must have Microsoft Excel 97 or higher installed on your computer.

1. Launch Microsoft Excel.
2. Open `bracket.txt` from within Excel to view the results.

The results are labeled and listed in the order in which they appear in the Image Browser. In this case, images are listed from `Bracket1.jpg` to `Bracket6.jpg`.

Table 4-1 lists the acceptable ranges for the bracket measurements and the actual values you might see for the bracket images. Notice that `Bracket1`, `Bracket2`, and `Bracket3` are the only ones that meet the specifications. The **bold** values for the other brackets indicate which measurements caused them to fail.

Note The values you see may not match the values in Table 4-1 exactly. However, the values you obtain should be close enough to the values in Table 4-1 so that `Bracket1`, `Bracket2`, and `Bracket3` pass inspection, and `Bracket4`, `Bracket5`, and `Bracket6` do not pass.

Table 4-1. Bracket Measurement Results

Bracket Number	Bracket Distance (acceptable range: 362–368 pixels)	Bracket Angle (acceptable range: 178°–181°)
Bracket 1	363.00	179.8
Bracket 2	364.00	180.3
Bracket 3	363.00	179.7
Bracket 4	**349.00**	178.5
Bracket 5	**339.01**	178.4
Bracket 6	**359.03**	**174.8**

A

Technical Support Resources

This appendix describes the comprehensive resources available to you in the Technical Support section of the National Instruments Web site and provides technical support telephone numbers for you to use if you have trouble connecting to our Web site or if you do not have internet access.

NI Web Support

To provide you with immediate answers and solutions 24 hours a day, 365 days a year, National Instruments maintains extensive online technical support resources. They are available to you at no cost, are updated daily, and can be found in the Technical Support section of our Web site at `www.ni.com/support`.

Online Problem-Solving and Diagnostic Resources

- **KnowledgeBase**—A searchable database containing thousands of frequently asked questions (FAQs) and their corresponding answers or solutions, including special sections devoted to our newest products. The database is updated daily in response to new customer experiences and feedback.
- **Troubleshooting Wizards**—Step-by-step guides lead you through common problems and answer questions about our entire product line. Wizards include screen shots that illustrate the steps being described and provide detailed information ranging from simple getting started instructions to advanced topics.
- **Product Manuals**—A comprehensive, searchable library of the latest editions of National Instruments hardware and software product manuals.
- **Hardware Reference Database**—A searchable database containing brief hardware descriptions, mechanical drawings, and helpful images of jumper settings and connector pinouts.
- **Application Notes**—A library with more than 100 short papers addressing specific topics such as creating and calling DLLs, developing your own instrument driver software, and porting applications between platforms and operating systems.

Software-Related Resources

- **Instrument Driver Network**—A library with hundreds of instrument drivers for control of standalone instruments via GPIB, VXI, or serial interfaces. You also can submit a request for a particular instrument driver if it does not already appear in the library.
- **Example Programs Database**—A database with numerous, non-shipping example programs for National Instruments programming environments. You can use them to complement the example programs that are already included with National Instruments products.
- **Software Library**—A library with updates and patches to application software, links to the latest versions of driver software for National Instruments hardware products, and utility routines.

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Glossary

Prefix	Meaning	Value
p-	pico-	10^{-12}
n-	nano-	10^{-9}
μ-	micro-	10^{-6}
m-	milli-	10^{-3}
k-	kilo-	10^{3}
M-	mega-	10^{6}
G-	giga-	10^{9}
t-	tera-	10^{12}

Numbers

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 all image types and for saving calibration information associated with the image (extension .APD).
alpha channel	Channel used to code extra information, such as gamma correction, about a color image. The alpha channel is stored as the first byte in the four-byte representation of an RGB pixel.

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.
bit depth	The number of bits (*n*) used to encode the value of a pixel. For a given *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.
blob	Binary large object. A connected region or grouping of pixels in an image in which all pixels have the same intensity level.
blob analysis	A series of processing operations and analysis functions that produce some information about the blobs in an image.
BMP	Bitmap. Image file format commonly used for 8-bit and color images (extension .BMP).
border function	Removes objects (or particles) in a binary image that touch the image border.
Builder file	IMAQ Vision Builder script file. Builder files are ASCII text files that list the processing functions and relevant parameters for an image processing algorithm that you created in IMAQ Vision Builder.

C

caliper	(1) A function in IMAQ Vision Builder that calculates distances, angles, circular fits, and the center of mass based on positions given by edge detection, particle analysis, centroid, and search functions; (2) A measurement function that finds edge pairs along a specified path in the image. This function performs an edge extraction and then finds edge pairs based on specified criteria such as the distance between the leading and trailing edges, edge contrasts, and so forth.
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.
CLUT	Color look-up 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 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.
definition	The number of values a pixel can take on, which is the number of colors or shades that you can see in the image.
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.
device	Plug-in data acquisition board that can contain multiple channels and conversion devices.
differentiation filter	Extracts the contours (edge detection) in gray level.
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.
driver	Software that controls a specific hardware device, such as a data acquisition board.

E

edge	Defined by a sharp change (transition) in the pixel intensities in an image or along an array of pixels.
edge contrast	The difference between the average pixel intensity before and the average pixel intensity after the edge.
edge hysteresis	The difference in threshold level between a rising and a falling edge.
edge steepness	The number of pixels that corresponds to the slope or transition area of an edge.
Euclidean distance	The shortest distance between two points in a cartesian system.
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

FFT	Fast Fourier Transform. A method used to compute the Fourier transform of an image.
fiducial	A reference pattern on a part that helps a machine vision application find the part's location and orientation in an image.
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

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.
grab	Acquisition technique that acquires and displays a continuous sequence of images using an IMAQ device. Use this acquisition technique when you need to focus your camera.
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.
grayscale	The range of shades of black in an 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.
hole filling function	Fills all holes in objects that are present in a binary image.
HSI	Color encoding scheme in Hue, Saturation, and Intensity.
HSL	A color space where a color image is represented as hue, saturation, and luminance.
HSV	A color space where a color image is represented as 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 Browser	IMAQ Vision Builder feature that displays all of the images currently loaded. Through the Image Browser, you can select an image that you want to process by double clicking it.
image buffer	Memory location used to store images.
image file	A file containing image information and data.
image palette	The gradation of colors used to display an image on screen, usually defined by a color look-up table.
image processing	Encompasses various processes and analysis functions which you can apply to an image.
image source	Original input image.
image visualization	The presentation (display) of an image (image data) to the user.
inner gradient	Finds the inner boundary of objects.
inspection function	Detects specific features in an image. The features detected include edges, peaks, and rotational shifts.
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 an object; otherwise it is considered part of the background.
interpolation	Is the technique used to find values in between known values when resampling an image or array of pixels.

J

JPEG	Joint Photographic Experts Group. Image file format for storing 8-bit and color images with lossy compression (extension .JPG).

K

kernel	Structure that represents a pixel and its relationship to its neighbors. The relationship is specified by weighted coefficients of each neighbor.

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.
LabVIEW	Laboratory Virtual Instrument Engineering Workbench. Program development environment application based on the programming language G used commonly for test and measurement applications.
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.
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.
LUT	Look-up 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 look-up table.

M

mask	Isolates parts of an image for further processing.
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.
median filter	A lowpass 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 function	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.
*N*th 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.
number of planes (in an image)	The number of arrays of pixels that compose the image. A gray-level or pseudo-color image is composed of one plane, while an RGB image is composed of three planes (one for the red component, one for the blue, and one for the green).

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.
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 look-up table.
Parameter window	Displays parameters that you can set for an image processing function. Each IMAQ Vision function available through the menus has a parameter window where you set the parameters for that function.
pattern matching	The technique used to locate quickly a grayscale template within a grayscale image
picture element	An element of a digital image. Also called *pixel*.
pixel	Picture element. The smallest division that makes up the video scan line; for display on a computer monitor, a pixel's optimum dimension is square (aspect ratio of 1:1, or the width equal to the height).

pixel calibration	Directly calibrating the physical dimensions of a pixel in an image.
PNG	Portable Network Graphic. An image file format for storing 8-bit, 16-bit, and color images with lossless compression (extension .PNG).
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.
Processing window	IMAQ Vision Builder feature that updates the image as you change parameters. The Processing window is located on the right side of the IMAQ Vision Builder window.
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

Reference window	IMAQ Vision Builder feature that displays the original version of the image (image source) as you manipulate it in the processing window. The Reference window appears in the upper left corner of the IMAQ Vision Builder window.
resolution	The number of rows and columns of pixels. An image composed of *m* rows and *n* columns has a resolution of $m \times n$. This image has *n* pixels along its horizontal axis and *m* pixels along its vertical axis.
reverse function	Inverts the pixel values in an image, producing a photometric negative of the image.

RGB	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. An area of the image that is graphically selected from a window displaying the image. This area can be used to focus further processing.
ROI tools	Collection of tools from the Tools palette that enable you to select a region of interest from an image. These tools let you select a point or line; polygon, rectangle, and oval regions; and freehand lines and areas.
rotation-invariant pattern matching	A pattern matching technique in which the reference pattern can be located anywhere in the test image as well as rotated at any degree.

S

script	List of image processing and analysis functions and the parameters for each of those functions. IMAQ Vision Builder records each function and relevant parameters as you prototype your image processing application.
Script window	The window in which IMAQ Vision Builder displays a script. From the scripting window, you can edit, remove, or add steps and run scripts. The Script window appears in the lower left corner of the IMAQ Vision Builder window.
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.
sequence	Acquisition technique that acquires images according to settings that you specify in the acquisition property pages.
shape matching	Finds objects in an image whose shape matches the shape of the object specified by a shape template. The matching process is invariant to rotation and can be set to be invariant to the scale of the objects.
shift-invariant matching	A pattern matching technique in which the reference pattern can be located anywhere in the test image but cannot be rotated or scaled.

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 function	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.
snap	Acquisition technique that acquires and displays a single image.
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*.
structuring element	A binary mask used in most morphological operations. A structuring element is used to determine which neighboring pixels contribute in the operation.
sub-pixel analysis	Used to find the location of the edge coordinates in terms of fractions of a pixel.

T

template	Color, shape, or pattern that you are trying to match in an image using the color matching. shape matching, or pattern matching functions. A template can be a region selected from an image or it can be an entire image.
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	Tagged Image File Format. Tagged Image File Format. Image format commonly used for encoding 8-bit, 16-bit, and color images (extension .TIF).
Tools palette	Collection of tools that enable you to select regions of interest, zoom in and out, and change the image palette.
trigger	Any event that causes or starts some form of data capture.

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