

IMAQ™

NI Vision Assistant Tutorial

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National Instruments Corporate Headquarters

11500 North Mopac Expressway Austin, Texas 78759-3504 USA Tel: 512 683 0100

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About This Manual

The *NI Vision Assistant Tutorial* provides step-by-step instructions for prototyping a vision application with Vision Assistant. This tutorial is designed for Windows users with varied levels of vision experience.

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 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.

Related Documentation

The following list includes additional documents that you might find helpful as you work through this tutorial:

- *IMAQ Vision Concepts Manual*—Installs with Vision Assistant and contains vision conceptual information. Refer to this document if you are new to vision.
- *Vision Assistant Help*—Details each of the Vision Assistant functions and how to use them.

If you have purchased IMAQ Vision software from National Instruments, you also have one of the following sets of documentation, which might be helpful as you work through this tutorial.

- LabVIEW
 - *IMAQ Vision for LabVIEW User Manual*—Contains information about how to build a Vision application using IMAQ Vision for LabVIEW
 - *NI-IMAQ VI Reference Help*—Contains reference information about IMAQ Vision VIs. To open this help file, click **Help»IMAQ Vision** in LabVIEW.
- LabWindows/CVI
 - *IMAQ Vision for LabVIEW User Manual: LabWindows/CVI*—Contains information about how to build a vision application using IMAQ Vision for LabWindows™/CVI™.
 - *IMAQ Vision for LabWindows/CVI function reference*—Contains reference information about IMAQ Vision for LabWindows/CVI
- Measurement Studio
 - *IMAQ Vision for Measurement Studio User Manual: Visual Basic*—Contains information about how to build a Vision application using IMAQ Vision for Measurement Studio
 - *IMAQ Vision for Visual Basic function reference*—Contains reference information about IMAQ Vision for Measurement Studio

System Requirements and Installation

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

System Requirements

To run Vision Assistant, the system must meet the following minimum requirements:

- Personal computer using a 233 MHz Pentium-class processor
- Microsoft Windows 2000/NT/XP/Me/98. If you are using Windows NT 4.0, you must have Service Pack 6 or later installed.
- 1024 × 768 resolution or higher video adapter; 65,536 colors—16-bit—or higher
- If you are acquiring images, the system must have National Instruments image acquisition (IMAQ) hardware and NI-IMAQ 2.5 or later or NI-IMAQ for IEEE-1394 1.5 or later installed
- Minimum of 128 MB RAM; 256 MB recommended
- Minimum of 200 MB of free hard disk space



Note You must have Microsoft Excel 97 or later installed to complete some steps in the second tutorial.

Installing Vision Assistant



Note To install Vision Assistant on a Windows 2000/NT/XP system, you must be logged in with Administrator privileges.

1. Insert the Vision Assistant CD into the CD-ROM drive.
2. If you do not have autorun enabled, double-click `autorun.exe`. If you have autorun enabled, `autorun.exe` runs automatically.
3. Follow the setup instructions that appear.

By default, the Vision Assistant installation program creates a new folder, `\Program Files\National Instruments\Vision Assistant 7.0`, that contains the following items:

- `examples` folder—Images and scripts that you must complete the example tutorials in this manual
- `Help` folder—Online help files
- `LV` folder—LabVIEW VI Creation support files
- `manuals` folder—*Vision Assistant Tutorial* and *IMAQ Vision Concepts Manual* in PDF format
- `plugins` folder—Image processing functions
- `readme.wri`—Late-breaking information about Vision Assistant
- `solutions` folder—Example images and scripts
- `Vision Assistant.exe`, function libraries, and other related program files

Launching and Exiting Vision Assistant

To launch Vision Assistant on Windows, select **Start»Programs»National Instruments Vision Assistant 7.0**.

To quit Vision Assistant, complete the following steps:

1. Close the Parameter window.
2. Save the open script and images, if necessary.
3. Click **File»Exit**.

Vision Assistant Environment

Vision Assistant is a tool for prototyping and testing image processing applications. To prototype an image processing application, build custom algorithms with the Vision Assistant scripting feature. The scripting feature records every step of the 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, which is an ASCII text file that lists the processing functions and relevant parameters for an algorithm that you prototype in Vision Assistant. Using the LabVIEW VI Creation Wizard, you can create a LabVIEW VI that performs the prototype that you created in Vision Assistant.



Note You must have LabVIEW 6.1 or later and IMAQ Vision 6.1 for LabVIEW or later installed to use the LabVIEW VI Creation Wizard.

For more information about LabVIEW VI creation, refer to the *Creating a LabVIEW VI* section of Chapter 3, *Using Blob Analysis to Analyze the Structure of a Metal*.

You also can implement the algorithm defined by the Builder file into any development environment, such as LabWindows/CVI or Visual Basic, using the IMAQ Vision machine vision and image processing libraries.

Features

Vision Assistant 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 in a batch to analyze a collection of images. You can modify and save scripts. Refer to Figure 2-2, *Processing an Image*, for an example of the Script window.
- **Image Browser**—Contains all of the images currently loaded in Vision Assistant. Through the Image Browser, you can select an image to process by double-clicking it. Refer to Figure 2-1, *Image Browser*, to view images loaded into the Image Browser.
- **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 result you want. Refer to Figure 2-2, *Processing an Image*, to view an image loaded into the Processing window.
- **Functions window/Parameter window**—Displays a list of image processing functions you can use to develop an algorithm or displays parameters that you can set for an image processing function. Each function available through the menus has a Parameter window in which you set the parameters for that function. Refer to Figure 2-3, *Thresholding an Image*, to view an example of the threshold Parameter window.

- Reference window/Embedded Help window—The **Image** tab displays the image source as you manipulate it in the Processing window. The other tabs contain context help for the function you are using. Refer to Figure 2-2, *Processing an Image*, to view an image in the Reference window.
- Solution Wizard—Displays a list of industries and corresponding quality-assurance tasks that those industries perform. Based on the task you select, the wizard loads an IMAQ Vision-based solution for the task.
- Performance Meter—Estimates how long a script will take to complete on a given image.
- LabVIEW VI Creation—Creates a LabVIEW and IMAQ Vision VI corresponding to the algorithm you prototype in Vision Assistant. Based on the options you select, the LabVIEW VI Creation Wizard creates a new VI that implements the image processing steps of the current script or of a saved script file.
- Builder File—ASCII text file that lists the C and Microsoft Visual Basic functions and parameters for the algorithm you prototyped in Vision Assistant.

Image Analysis Functions

Vision Assistant provides the following image analysis functions:

- Histogram—Counts the total number of pixels in each grayscale value and graphs the result
- 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 the result
- Measure—Calculates measurement statistics associated with a region of interest in the image
- 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.
- Image Mask—Builds a mask from an entire image or region of interest
- Geometry—Modifies the geometrical representation of an image
- Image Buffer—Stores and retrieves images from buffers
- Get Image—Opens a new image from a file
- Calibrate Image—Calibrates an image to perform measurements in real-world units

- **Calibrate from Image**—Applies the calibration information saved in an image to another image
- **Image Correction**—Transforms a distorted image acquired in a calibrated setup into an image where perspective errors and lens deformations are corrected

Color Image Processing Functions

Vision Assistant provides the following set of functions for processing and analyzing color images:

- **Color Operators**—Applies an arithmetic operation between two images or between an image and a constant
- **Extract Color Planes**—Extracts the Red, Green, or Blue plane or the Hue, Saturation, or Luminance plane of a color image
- **Color Threshold**—Applies a threshold to the three planes of an RGB or HSL image
- **Color Location**—Locates colors in an image
- **Color Matching**—Compares the color content of one or multiple regions in an image to a reference color set
- **Color Pattern Matching**—Searches for a color template in an image

Grayscale Image Processing and Analysis Functions

Vision Assistant provides the following functions for grayscale image processing and analysis:

- **Lookup Table**—Applies predefined lookup table transformations to the image to modify the dynamic intensity of regions in the image with poor contrast
- **Filters**—Includes functions for smoothing, edge detection, and convolution
- **Gray Morphology**—Modifies the shape of objects in grayscale images using erosion, dilation, opening, and closing functions
- **FFT Filters**—Applies a frequency filter to the image
- **Threshold**—Isolates the pixels you specify and sets the remaining pixels as background pixels
- **Operators**—Performs basic arithmetic and logical operations between two images or between an image and a constant
- **Conversion**—Converts the current image to the specified image type

- Quantify—Measures the intensity statistics of one or multiple regions in an image
- Centroid—Computes the energy center of a grayscale image or an area of interest on a grayscale image

Binary Processing and Analysis Functions

Vision Assistant provides the following functions for binary processing and analysis:

- Basic Morphology—Performs morphology transformations that modify the shape of objects in binary images
- Adv. Morphology—Performs high-level operations on blobs in binary images
- Particle Filter—Filters objects based on shape measurements
- Invert Binary Image—Reverses the dynamic of an image that contains two different grayscale populations
- Shape Matching—Finds image objects that are shaped like the object specified by the template
- Particle Analysis—Computes more than 80 measurements on objects in an image, including the area and perimeter of the objects
- Circle Detection—Separates overlapping circular objects and classifies them according to their radii

Machine Vision Functions

Vision Assistant provides the following machine vision functions:

- Edge Detection—Finds edges along a line that you draw with the **Line Tool**
- Find Straight Edge—Finds points along the edge of an object and then finds a line describing the edge
- Find Circular Edge—Locates the intersection points between a set of search lines within a circular area, or annulus, and then finds the best fit circle
- Clamp—Finds edges within a rectangular ROI drawn in the image and measures the distance between the first and last edge
- 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

- Caliper—Computes measurements—such as distances, areas, and angles—based on results returned from other machine vision and image processing functions
- Barcode Reading—Reads 1D barcodes
- OCR—Performs optical character recognition on a region of an image

Vision Assistant Calibration Functions

Vision Assistant provides the following calibration functions:

- Simple Calibration—Sets a simple calibration for an image. This function sets the horizontal and vertical scaling factor, as well as the origin and orientation of the coordinate system for the image.
- User-Specified Points Calibration—Uses a set of known mapping points in the image and the corresponding locations in the real world. The calibration algorithm uses these known mappings to compute the pixel-to-real-world mapping for the entire image.
- Grid Calibration—Learns a calibration based on the image of a grid template acquired with the imaging setup you are calibrating
- Calibration from Image—Applies the calibration information saved in an image file to the current image
- Image Correction—Transforms a distorted image acquired in a calibrated setup into an image where perspective errors and lens distortion are corrected

Getting Help

As you work with Vision Assistant, you may must consult other sources if you have questions. The following sources can provide you with more specific information about IMAQ Vision, IMAQ hardware, and imaging.

Vision Assistant Embedded Help Window

Vision Assistant displays context-sensitive help in the Embedded Help window when you call any image processing function. The Embedded Help window contains several tabs that describe when to use image processing functions, how to perform an image processing function, and descriptions of the controls that appear in the Parameter window for the function.

Vision Assistant Online Help

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

- The *Vision Assistant Help* details each of the Vision Assistant functions and how to use them. To open the help in Vision Assistant, select **Help»Online Help**.
- Move the cursor over a button to see tooltips on buttons in the toolbar, Script window, Reference window, or Image Browser.

Vision Assistant Documentation

Vision Assistant offers the following documentation:

- *Vision Assistant Tutorial*—Step-by-step instructions for prototyping a vision application with Vision Assistant.
- *IMAQ Vision Concepts Manual*—Detailed information about the concepts and algorithms used by Vision Assistant. Launch the *IMAQ Vision Concepts Manual* by selecting **Start»Programs»National Instruments»Vision Documentation»IMAQ Vision Concepts Manual**.

National Instruments Web Site

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

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

The NI Developer Zone, at ni.com/zone, is the essential resource for building measurement and automation systems. The NI Developer Zone includes the latest example programs, system configurators, tutorials, and technical news, as well as a community of developers ready to share their own techniques.

Vision Assistant Scripts

The Vision Assistant installation program installs several example scripts. You can run these scripts to learn more about Vision Assistant scripting capabilities. You also can customize these scripts for your applications. By default, the scripts are installed at `\Program Files\National Instruments\Vision Assistant 7.0\Examples` and at `\Program Files\National Instruments\Vision Assistant 7.0\Solutions`.

Introduction to Image Processing with Vision Assistant

This chapter describes how you can use Vision Assistant to create and test image processing algorithms. For detailed information about digital images, refer to Chapter 1, *Digital Images*, of the *IMAQ Vision Concepts Manual*.

Getting Started in Vision Assistant

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 Vision Assistant works and what you can accomplish with Vision Assistant is to use it.

In this short example, you load images into Vision Assistant and perform a *threshold* on them. Thresholding isolates objects, keeping those that interest you and removing 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.

Complete the following steps to get started in Vision Assistant.

1. Select **Start»Programs»National Instruments Vision Assistant 7.0**.
2. To load images, click **Open Image** on the Welcome screen.
3. Navigate to `Program Files\National Instruments\Vision Assistant 7.0\Examples\Metal` and select **Select All Files**. Vision Assistant previews the images in the Preview Image window and displays information about the file type and image depth.
4. Click **OK**.

Vision Assistant loads the image files into the Image Browser, as shown in Figure 2-1. The Image Browser provides information about the selected image, such as image size, location, and type.

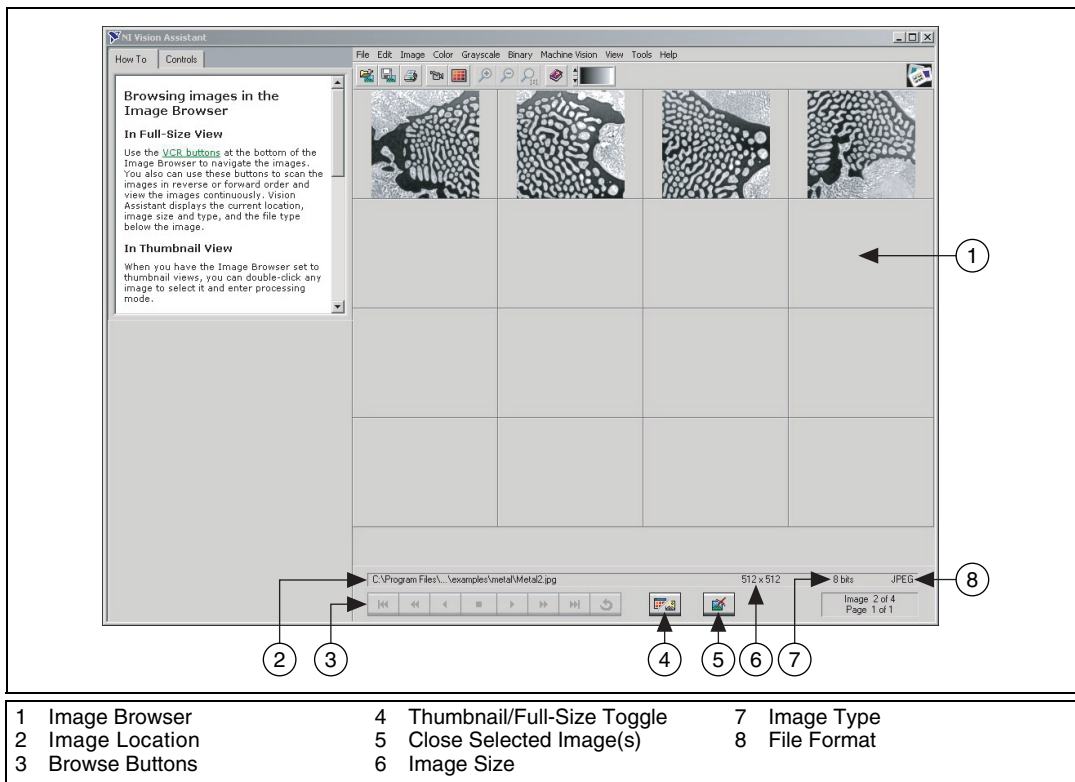


Figure 2-1. Image Browser

You can view new images in either thumbnail view, as shown in Figure 2-1, or in full-size view, which shows a single full-size view of the selected image.



5. Click the **Thumbnail/Full-Size View Toggle** button to view the first image in full size.
6. Double-click the `Metal1.jpg` image to begin processing it. Vision Assistant loads the image into the Processing window, as shown in Figure 2-2.

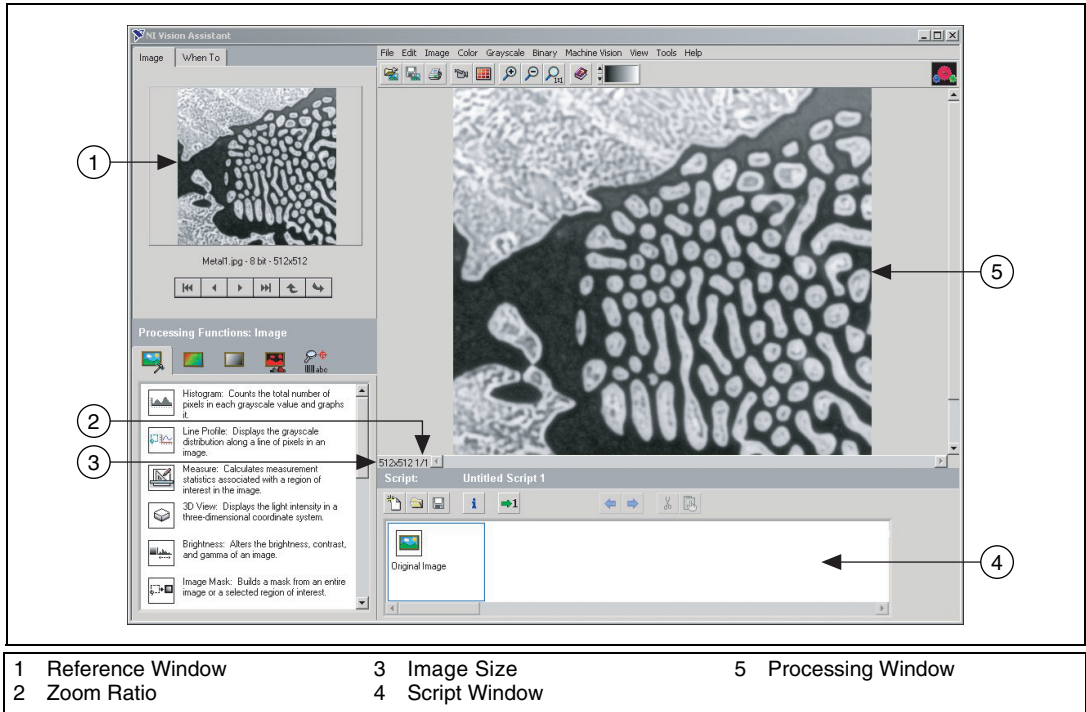


Figure 2-2. Processing an Image



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

- Click the **Grayscale** tab of the Processing Functions palette and click **Threshold**, or select **Grayscale»Threshold**. The Threshold Parameter window appears in the lower left corner of the Vision Assistant window, as shown in Figure 2-3.

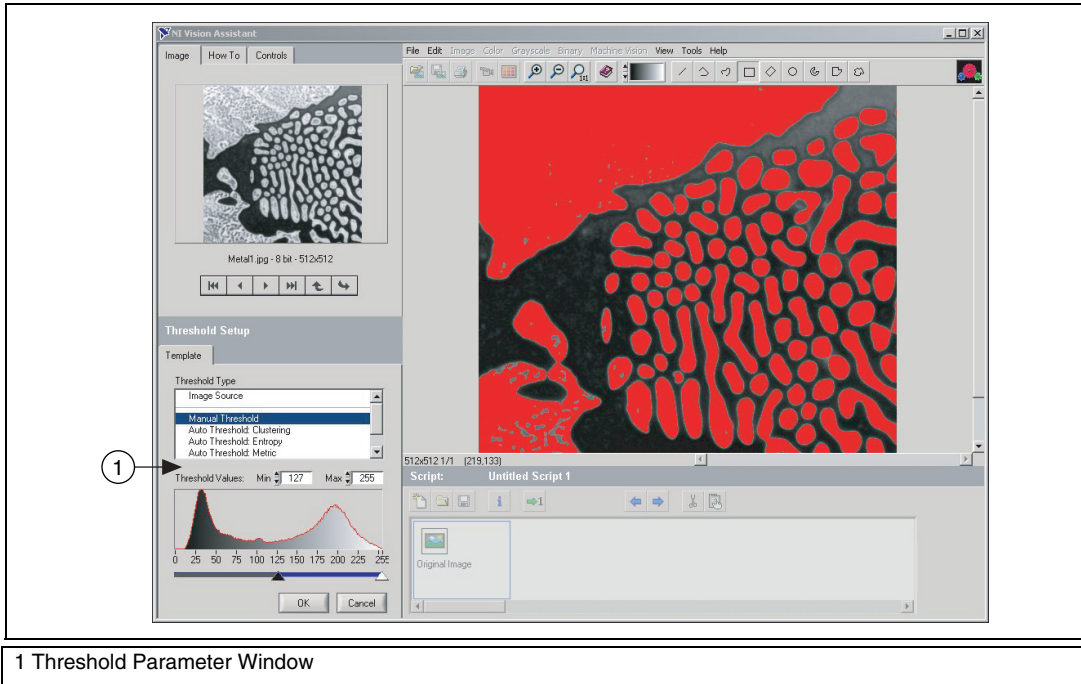


Figure 2-3. Thresholding an Image

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 if the image contains distinct regions of a certain grayscale 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 sets their values to 1. The pixels depicted in gray have values outside the threshold range. The threshold operator sets their values to 0.

8. To threshold this image, set the **Min** value to 130 and **Max** value to 255 to select all of the objects.



Tip You may 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 1 (red) and all other pixels are set to 0 (black).

Refer to Figure 2-4 to see what the image looks like after applying the threshold.

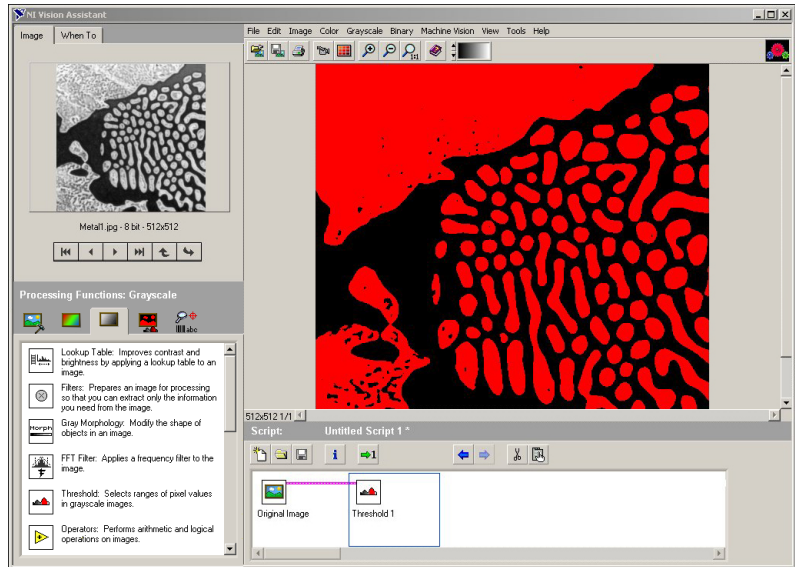


Figure 2-4. Thresholded Image

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

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

If you find another image that you must threshold similarly, run this script on the image using the following steps:

- a. Load the image.
- b. Select **File»Open Script**, select `threshold.scr`, and click **Open**.
- c. Click the **Run Once** 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 **How To** tab or the **Controls** tab in the Embedded Help window.

11. Select **File»Exit** to close Vision Assistant.

Acquiring Images in Vision Assistant

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

Using Vision Assistant, you can acquire images with various National Instruments digital and analog IMAQ devices, such as the PCI-1428, PXI/PCI-1409, PXI/PCI-1411, and so on. Vision Assistant provides specific support for several Sony, JAI, and IEEE 1394 cameras. You also can simulate acquiring an image if you do not have an IMAQ device. You configure IMAQ devices in National Instruments Measurement & Automation Explorer (MAX). For information about setting up IMAQ devices and channels in MAX, refer to the *Measurement & Automation Explorer Help for IMAQ*.

If you do *not* have IMAQ devices and NI-IMAQ 2.5 or later or NI-IMAQ for IEEE 1394 1.5 or later installed, Vision Assistant allows you to simulate 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.

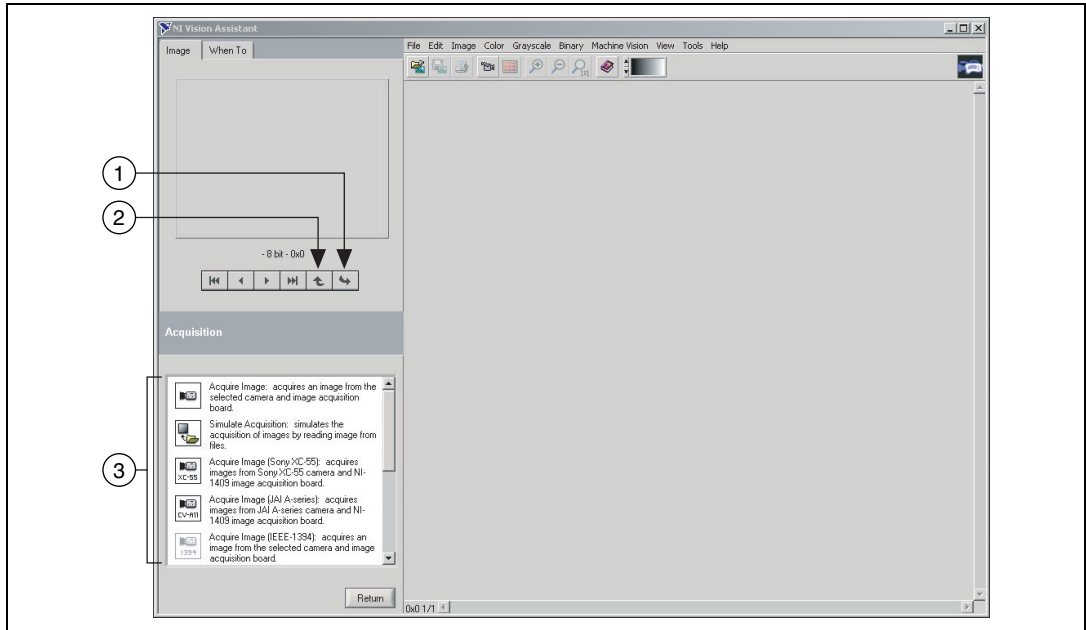
Opening the Acquisition Window

Complete the following steps to acquire images.

1. Click **Start»Programs»National Instruments Vision Assistant 7.0**. Click **Acquire Image** in the Welcome screen to view the Acquisition functions, as shown in Figure 2-5.



If you already have Vision Assistant running, click the **Acquire Image** button in the toolbar. Vision Assistant displays the Acquisition functions, as shown in Figure 2-5.



1 Make Image Active

2 Store Acquired Image in Browser Button

3 Acquisition Functions

Figure 2-5. Acquiring Images in Vision Assistant



Note You must have one of the following device and driver software combinations to acquire live images in Vision Assistant.

- National Instruments IMAQ device and NI-IMAQ 2.5 or later
- IEEE 1394 industrial camera and NI-IMAQ for IEEE-1394 1.5 or later



Note If the computer does not have an IMAQ device, you can simulate a live acquisition with the Simulate Acquisition function. You can interact with the simulation module as you would with a live acquisition.

2. Click **Acquire Image**. The Parameter window displays the IMAQ devices and channels installed on the computer. Figure 2-6 shows that the IMAQ PCI-1409 is installed.

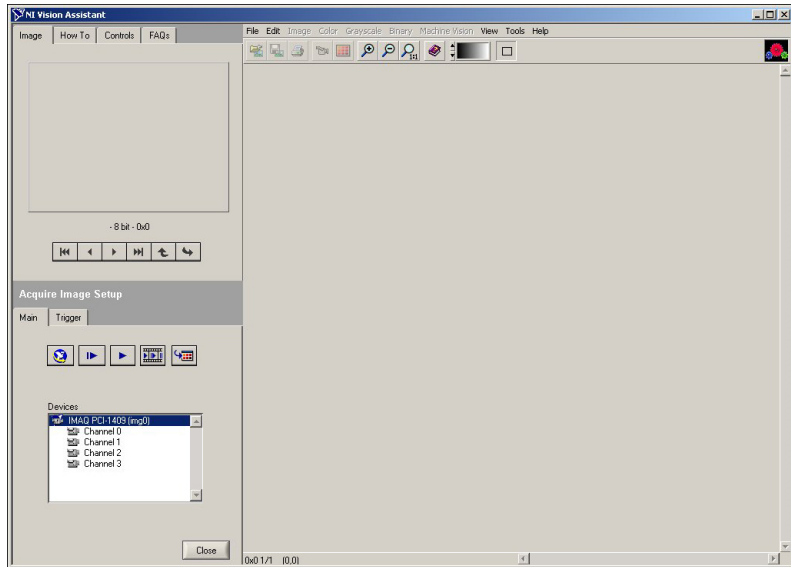


Figure 2-6. IMAQ Devices and Channels



Note The hardware devices listed in the Parameter window vary according to the devices installed.

Snapping an Image



1. Click **File»Acquire Image**.
2. Click **Acquire Image** in the Acquisition function list.
3. Select the appropriate device and channel.
4. Click the **Acquire Single Image** button to acquire a single image with the IMAQ device and display it.
5. Click the **Store Acquired Image in Browser** button to send the image to the Image Browser.
6. Click **Close** to exit the Parameter window.
7. Process the image as you would any other image in Vision Assistant. Refer to 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 Vision Assistant.

Grabbing an Image



1. Select **File»Acquire Image**.
2. Click **Acquire Image** in the Acquisition function list.
3. Select the appropriate device and channel.
4. Click the **Acquire Continuous Images** button to acquire and display images in continuous mode at the maximum rate.
5. 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 (ROI) within the full-sized image. If you draw an ROI on an image while grabbing it, the image reduces to the ROI. You can refine the acquired area again by selecting another region of interest, or you can return to the full-sized image by clicking the image.



6. Click the **Store Acquired Image in Browser** button to send the image to the Image Browser.
7. Click **Close** to exit the Parameter window.
8. Process the image as you would any other image in Vision Assistant. Refer to 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 Vision Assistant.

Acquiring a Sequence of Images



1. Click **File»Acquire Image**.
2. Click **Acquire Image** in the Acquisition function list.
3. Select the appropriate device and channel.
4. Click the **Sequence Acquisition** button.
5. Set the properties on the Sequence Acquisition Wizard.
 - **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. Valid values include Disabled, Trigger start of acquisition, and Trigger each image.

- **Timeout**—Time, in milliseconds, within which the trigger must occur
 - **Polarity**—Determines if the acquisition is triggered on the rising edge or the falling edge
6. Click **Next**, **Next**, and **Finish** to complete the acquisition.
If you set the triggering action property to **Disabled**, click **Next** to begin acquiring a sequence of images.
Images acquired are automatically sent to the Image Browser.
 7. Click **Close** to exit the Parameter window.
 8. Process the image as you would any other image in Vision Assistant. Refer to 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 Vision Assistant.

Using Blob Analysis to Analyze the Structure of a Metal

This chapter describes blob analysis and provides step-by-step directions for prototyping a blob analysis application in Vision Assistant.

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 (*binary large object*) is 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 pixels are 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

This tutorial demonstrates finding the area of circular particles in a metal. As you perform this analysis, Vision Assistant records all of the processing operations and parameters in a script. You run the script on other images to test the blob analysis algorithm.

To find the total area of circular particles, you 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 the appropriate particles.
- 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 Vision Assistant

1. Select **Start»Programs»National Instruments Vision Assistant 7.0**. Click **Open Image** on the Welcome Screen.



If you already have Vision Assistant running, click the **Open Image** button in the toolbar.

2. Navigate to `Program Files\National Instruments\Vision Assistant 7.0\Examples\Metal` and select **Select All Files**.



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**.

Vision Assistant 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`, to load the image into the Processing window.

Preparing an Image for Blob Analysis

Before you can separate circular particles from non-circular particles, you must prepare the image. To isolate particles of interest, verify that individual particles are separated by a gap and that the borders of those particles are distinct.

Examining the Image

Examine the image in the Processing window. The image is slightly blurred. Also, the edges of particles are not distinct. Although you can see these problems from just looking at the image, you may need to use a *line profile* in similar cases. A line profile returns the grayscale values along a line that you draw with the **Line Tool**.

Complete the following steps to examine edges using a line profile.

1. Click **Line Profile** in the **Image** tab of the Processing Functions palette or 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.



Tip ROIs are context sensitive, and you easily can adjust their location in the image or the position of their center points. You also can adjust the position of the ROI in the image by using the arrow keys on the keyboard.

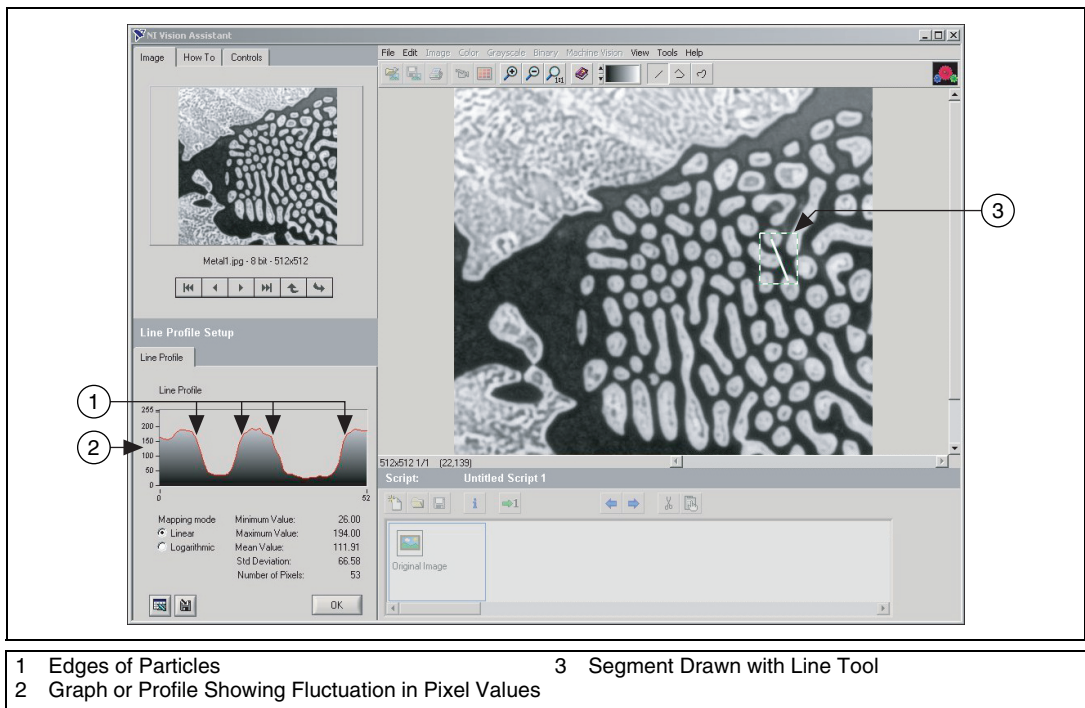


Figure 3-1. Using a Line Profile to Examine Edges

3. Click **OK**.

In Figure 3-1, the areas labeled **1** 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 have in detecting the exact location of the edge. As you change the threshold level in images with shallow-sloped particle edges, you might inadvertently change the

shape or size of the particle. In the *Filtering the Image* section, you use the Convolution-Highlight Details filter under **Filters** in the **Grayscale** tab of the Processing Functions palette to define the edges of the particles and increase the slope.

The area labeled **2** in Figure 3-1 is a fluctuation in pixel values, which might be caused by brighter and darker pixels in the center of the particles or it might also be edges of a hole in the particle. Later, you threshold the image to make all of the pixels in the particles the same pixel value and perform a morphological operation on the image to fill any holes left in the particles.

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, complete the following steps:

1. Select **Filters** in the **Grayscale** tab of the Inspection steps, or select **Grayscale»Filters**.
2. Select **Convolution-Highlight Details** from the Filters list. This function detects 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. For more information about kernels, refer to Chapter 5, *Image Processing*, of the *IMAQ Vision Concepts Manual*.
3. Click **OK** to add this step to the script.

Examining the Results of the Filtering

To confirm that the filter sharpened edges and separated particles, perform another line profile using the following steps:

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

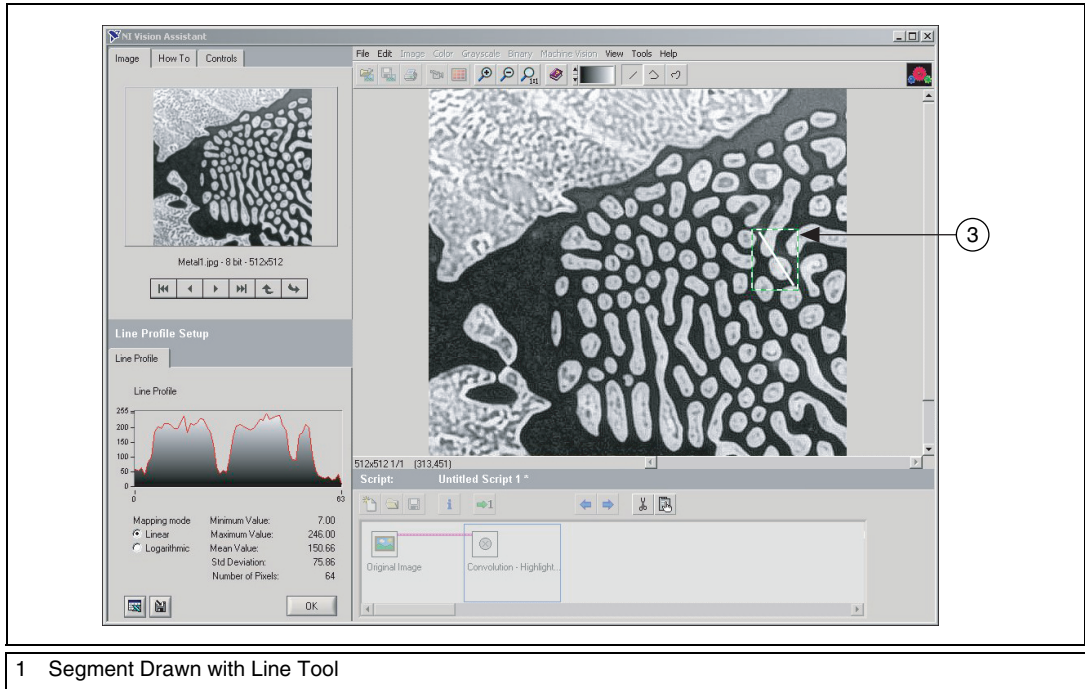


Figure 3-2. Using a Line Profile to Examine Particle Edges

Separating Particles from the Background with Thresholding

Thresholding isolates pixels that interest you and sets the remaining pixels as background pixels. Thresholding also converts the image from grayscale to binary.

Complete the following steps to select a range of brighter pixels to analyze.

1. Select **Threshold** in the **Grayscale** tab of the Processing Functions palette or select **Grayscale»Threshold**.

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 if the image contains distinct regions of a certain grayscale value, and you can select pixel regions of the image.

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 the threshold, everything highlighted is set to 1, and all other pixels are set to 0.



Tip 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.

4. Click **OK** to apply the threshold and add this step to the script. Figure 3-3 shows the thresholded image. The pixels that you selected for processing appear red. Unselected pixels appear black.

The image is now a binary image, which is an image composed of pixels with values of 0 and 1. This image is displayed using a binary palette, which displays the pixel intensities of an image with unique colors. All pixels with a value of 0 appear black and pixels set to 1 appear red. The red pixels are now referred to as blobs or particles.

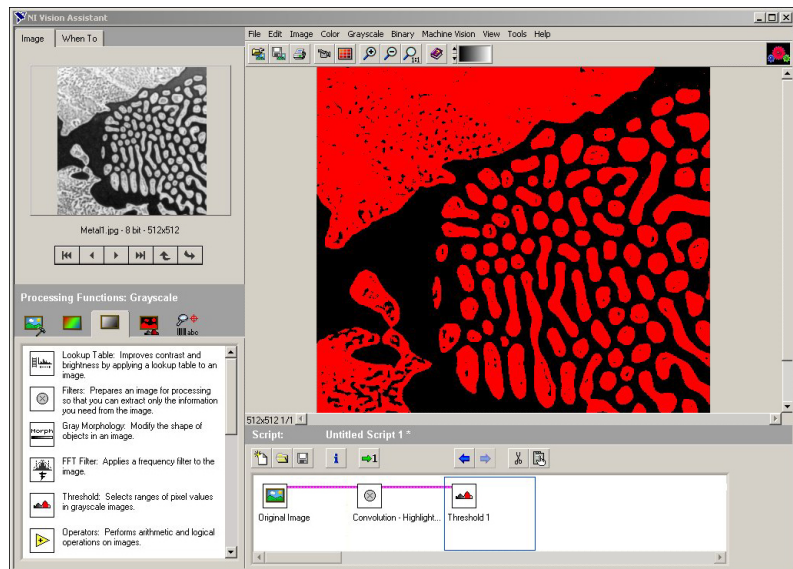


Figure 3-3. Separating Particles from the Background with Thresholding

Modifying Blobs with Morphological Functions

Morphological functions affect the shape of blobs 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 **Adv. Morphology** in the **Binary** tab of the Processing Functions palette or select **Binary»Adv. Morphology**.
2. Select **Fill holes** from the Morphology-Advanced function list.
3. Click **OK** to add this step to the script.
4. Select **Adv. Morphology** in the **Binary** tab of the Processing Functions palette or select **Binary»Adv. Morphology**.
5. Select **Remove border objects** to remove any objects that touch the border of the image, as shown in Figure 3-4.
6. Click **OK** to add this step to the script and close the Parameters window.

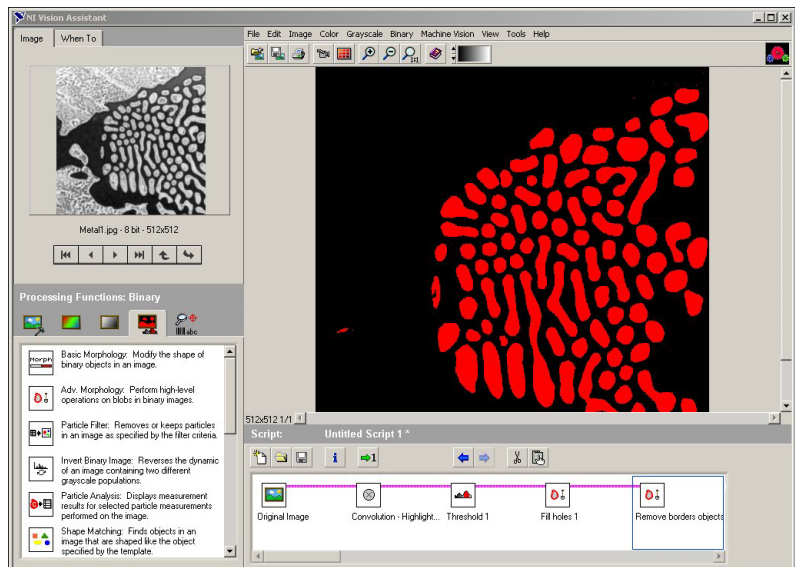


Figure 3-4. Modifying Blobs with Morphological Functions

Isolating Circular Blobs

Complete 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 **Particle Filter** from the **Binary** tab of the Processing Functions palette, or 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 perimeter of the circle with the same area. 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** option to keep circular blobs (and remove blobs that do not fit in this range).
5. Click **OK** to add this step to the script. The image now contains only circular blobs, as shown in Figure 3-5.

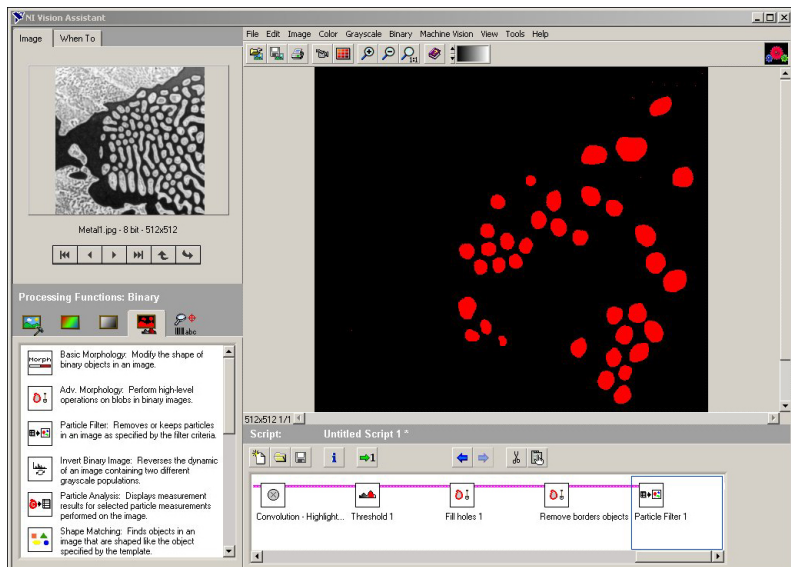


Figure 3-5. Isolating Circular Blobs

Analyzing Circular Blobs

Now that you have isolated circular blobs, complete the following steps to find the area occupied by them.

1. Select **Particle Analysis** from the **Binary** tab of the Processing Functions palette, or select **Binary»Particle Analysis**. A results table displays all of the measurement results.

Vision Assistant assigns numerical labels to each blob. The first row of the results table lists the numerical label associated with each blob.

2. Select **Show Labels** to view the labels.



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



3. To show only the area measurement, click **Select Measurements**.
4. Click the **None** button for both the pixels and real-world measurements to deselect all of the measurements.
5. Select **pixels** and **real-world** for **Area**.
6. Click **OK**.
7. Click **OK** to record the particle analysis and add the step to the script.

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



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, `Meta13.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 Image** and **Previous**



Image 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 Once** button.

Figure 3-6a shows the original image, `Meta13.jpg`. Figure 3-6b shows the image after the blob analysis processing. Notice that two circular blobs are removed from the image during processing because they are touching each other. Adjust the thresholding step to separate particles.

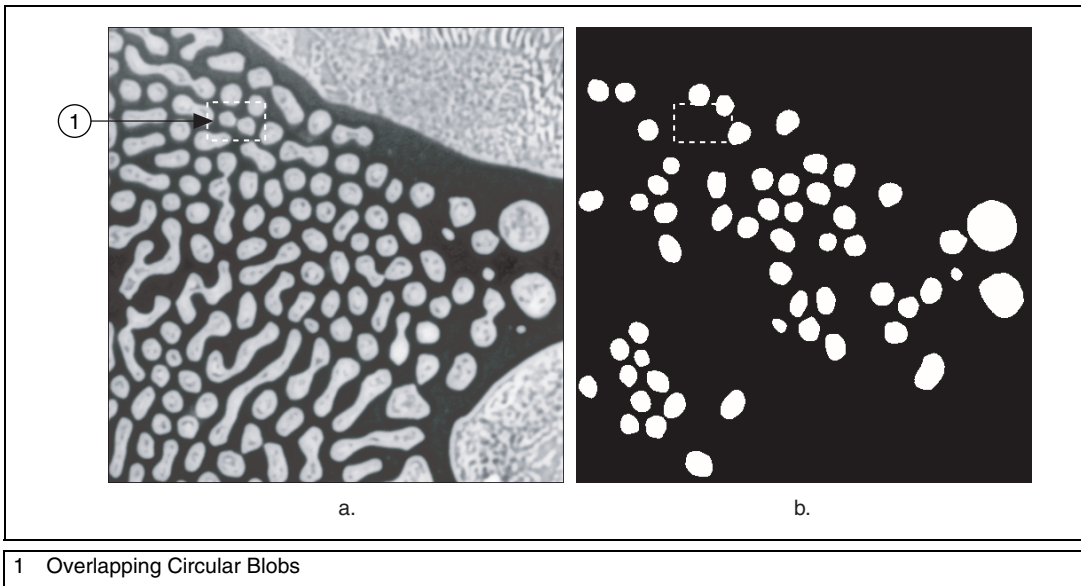


Figure 3-6. Comparing the Original Image to the Processed Image

4. Click **OK** 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 `Meta13.jpg` at the thresholding step of the script.

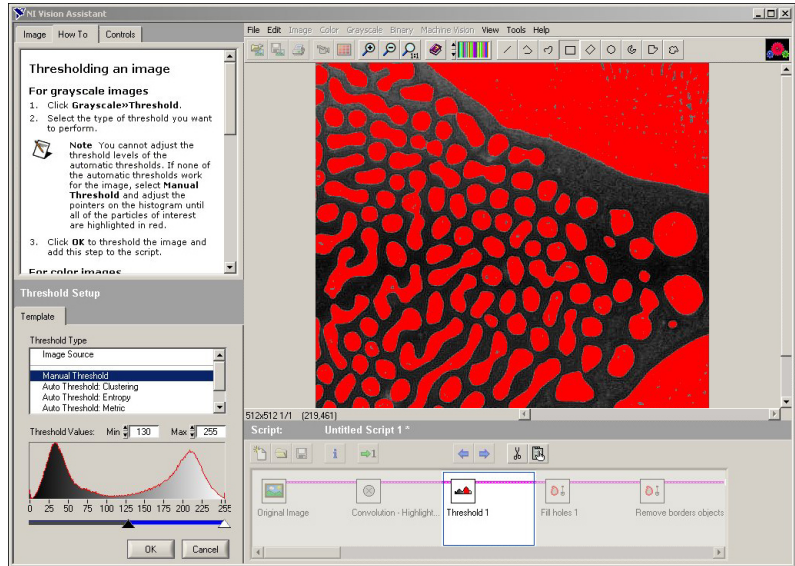


Figure 3-7. Testing the Blob Analysis Script

6. Adjust the minimum threshold value until the blobs are clearly separated. A minimum value of 150 works well.
7. Click **OK**.
8. Click **Run Once** to rerun the script. Notice that only the circular blobs now appear in the final processed image.



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. Refer to the [Analyzing the Results](#) section of Chapter 4, [Using Gauging for Part Inspection](#), for an example of batch processing in Vision Assistant.

1. Select **File»Save Script**.
2. Save the script as `blob_analysis.scr`.

Estimating Processing Time

Vision Assistant 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. Complete the following steps to estimate how many milliseconds IMAQ Vision will use to process `Meta13.jpg` with `blob analysis.scr`.

1. Select **Tools»Performance Meter**. The Performance Meter estimates of the total time IMAQ Vision will take to run the script.
2. Click **Details** 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.

Creating a LabVIEW VI

Vision Assistant features a wizard that creates a LabVIEW and IMAQ Vision VI for implementing the different steps of the script. Figure 3-8 shows the VI Creation Wizard.

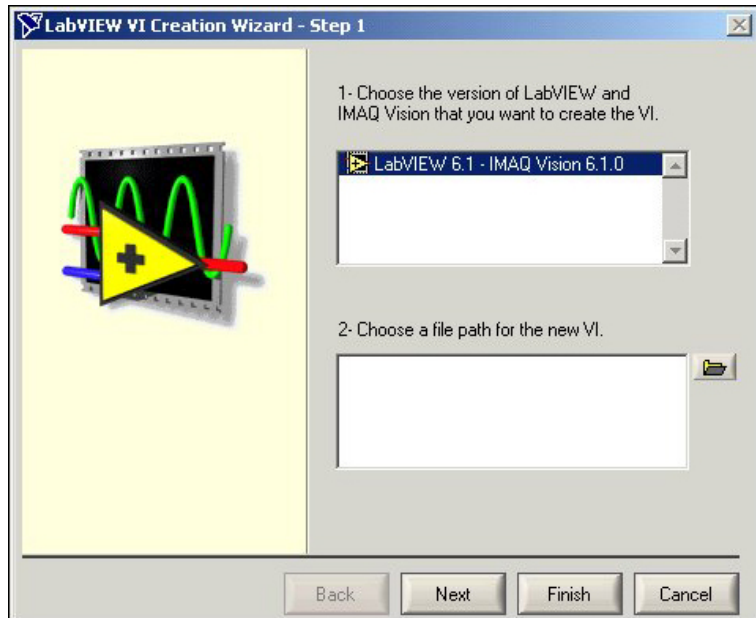


Figure 3-8. LabVIEW VI Creation Wizard

Complete the following steps to create a LabVIEW VI.

1. Select **Tools»Create LabVIEW VI**.



Note If several versions of LabVIEW and IMAQ Vision are installed on the computer, the wizard searches the machine and displays a list of the available LabVIEW and IMAQ Vision versions you can use to create the VI.

2. Select the version of LabVIEW in which you want to create a VI.
3. Select the location to which you want to save the VI, enter a **File name**, and click **Save**.
4. Click **Next**.
5. Select the appropriate Vision Assistant script option and click **Next**.
6. Select the image source.

Select **Image File** as the image source to create a VI that opens an image from the hard disk.

7. Click **Finish** to create the VI.



Note If you have LabVIEW open, you cannot create a VI for a different version of LabVIEW. For example, if you have LabVIEW 6.1 open and you select LabVIEW 7.0 in the LabVIEW VI Creation Wizard, the wizard returns an error when you click **Finish**.



Note You must have LabVIEW 6.1 or later and IMAQ Vision 6.1 for LabVIEW or later installed to use the Vision Assistant LabVIEW VI Creation Wizard.

Using Gauging for Part Inspection

This chapter describes gauging and provides step-by-step directions for prototyping a part inspection application in Vision Assistant.

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 if 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. Gauging inspection is used often in mechanical assembly verification, electronic packaging inspection, container inspection, glass vial inspection, and electronic connector inspection.

Tutorial

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

The 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 them.

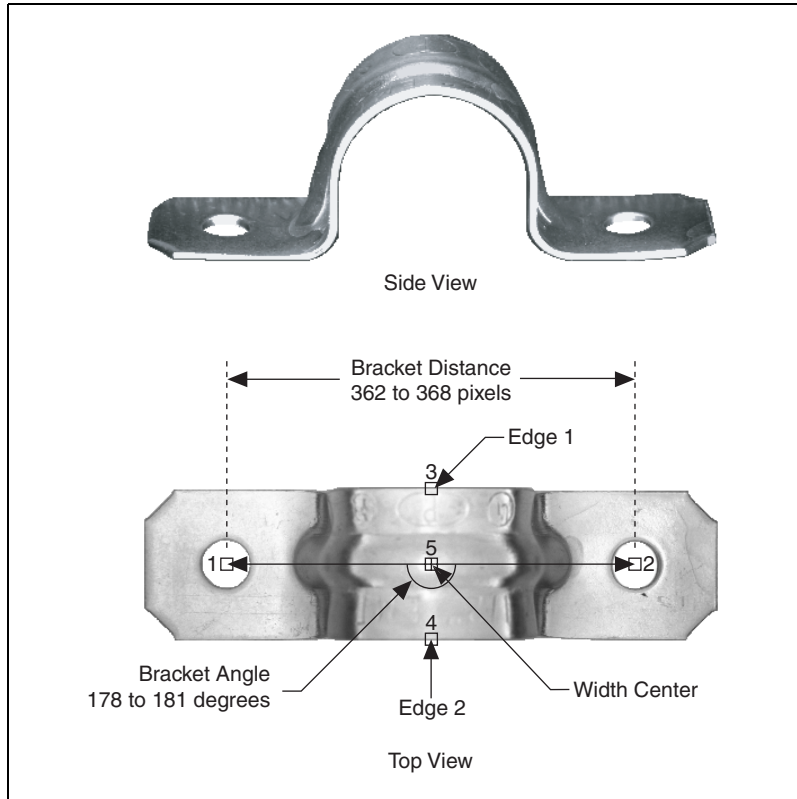


Figure 4-1. Bracket Specifications

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

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

Loading Images into Vision Assistant

Complete the following steps to load an image.

1. Select **Start»Programs»National Instruments Vision Assistant 7.0**.
2. Click **Open Image** in the Welcome screen or select **File»Open Image** to load images.
3. Navigate to Program Files\National Instruments\Vision Assistant 7.0\Examples\Bracket and select **Select All Files**.



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 Vision Assistant.
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 must locate features on which you can base the measurements. In this example, you use pattern matching to find manufactured holes in a bracket. These holes serve as measurement points from which you can determine if the bracket arch is the appropriate height and curvature.

1. Select **Pattern Matching** in the **Machine Vision** tab of the Inspection steps, or select **Machine Vision»Pattern Matching**.
2. Click **Create Template**.
3. With the **Rectangle Tool**, click and drag a box around the left hole in the image, as shown in Figure 4-2. The ROI becomes the template pattern.

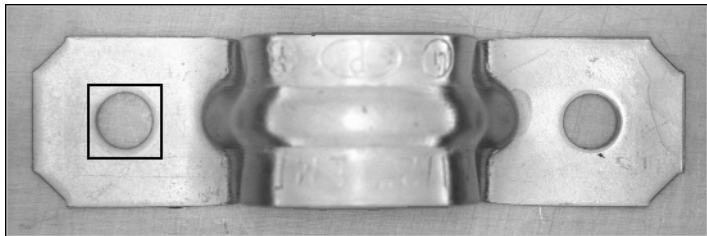


Figure 4-2. Selecting a Template Pattern

4. Click **OK** to learn the selected area as the template pattern. Learning the template takes a few seconds. After Vision Assistant learns the template, a save dialog box appears.
5. Navigate to Program Files\National Instruments\Vision Assistant 7.0\Examples\Bracket.
6. Save the template as `template.png`. The Pattern Matching Parameter window displays the template image and its path.
7. Click the **Settings** tab.
8. Set **Number of Matches to Find** to 1.
9. Set the **Minimum Score** to 600 to ensure that Vision Assistant finds matches similar, but not identical, to the template.
10. Click **Sub-pixel Accuracy**.
11. Make sure **Search for Rotated Patterns** is unselected to set the 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 the matches to be rotated, use rotation-invariant matching.
12. 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 analyze.

Drawing an ROI 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.

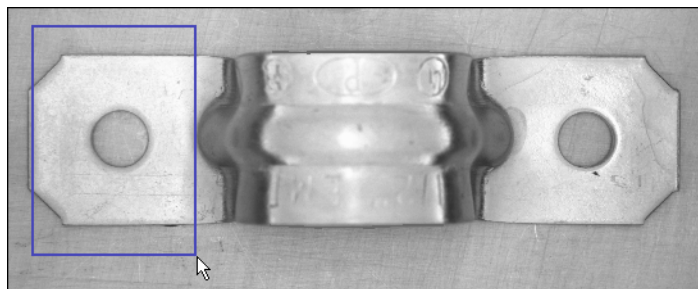


Figure 4-3. Selecting the First Search Area

When you draw the region of interest, Vision Assistant 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.

13. Click **OK** to save this step to the script.
14. Select **Pattern Matching** in the **Machine Vision** tab of the Inspection steps, or select **Machine Vision»Pattern Matching**.
15. Click **Load from File** and open the template you just saved.
16. Click the **Settings** tab.
17. Set **Number of Matches to Find** to 1.
18. Set the **Minimum Score** to 600 to ensure that Vision Assistant finds matches similar, but not identical, to the template.
19. Click **Sub-pixel Accuracy**.
20. With the **Rectangle Tool**, draw a region of interest around the right side of the bracket, as shown in Figure 4-4. Vision Assistant automatically locates the template in the region bound by the rectangle and displays the score and location of the match.

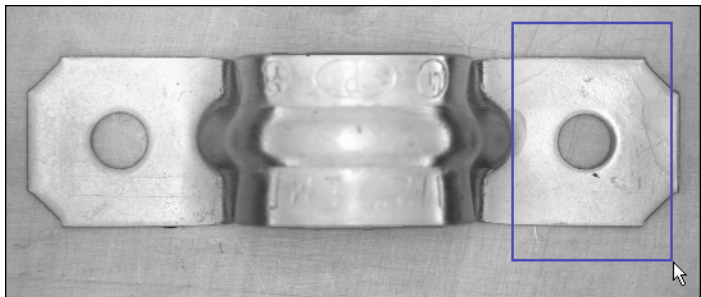


Figure 4-4. Selecting the Second Search Area

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.

21. Click **OK** to add this step to the script.

Finding Edges in the Image

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

1. Select **Edge Detector** in the **Machine Vision** tab of the Inspection steps, or select **Machine Vision»Edge Detector**.
2. Select the **Advanced Edge Tool**. The Advanced Edge Tool is effective on images with poor contrast between the background and objects.
3. Select **First & Last Edge** so that Vision Assistant finds and labels only the first and last edges along the line you draw.
4. Set the **Contrast** to 40. The detection process returns only the first and last edge whose contrast is greater than 40.
5. Click and drag to draw a vertical line across the middle of the bracket to find the edges that you can use to calculate Width Center, as shown in Figure 4-5. Vision Assistant labels the edges 1 and 2.



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

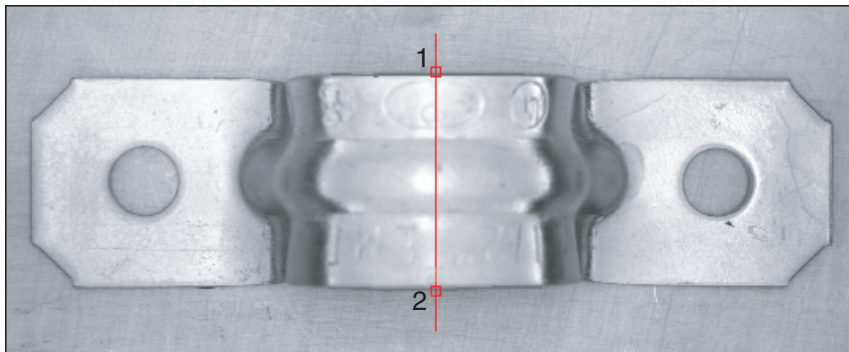


Figure 4-5. Finding the Edges for Bracket Distance

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.

6. Click **OK** to add this edge detection step to the script.

Taking the Measurements

Now that you have found the bracket holes and the necessary edges, you can calculate the center of the bracket width, distance between the bracket holes, and angle of the bracket 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.

Complete the following steps to make the measurements.

1. Select **Caliper** in the **Machine Vision** tab, or select **Machine Vision»Caliper**.
2. Select **Mid Point** in **Geometric Feature**.
3. In the image, click points **3** and **4** to obtain the first measurement—Width Center—which specifies the center of the bracket 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.

Also, you can double-click points in the **Points** list box to select them instead of clicking the points in the image. When you select a point, Vision Assistant places a check mark next to it.

4. Click the **Measure** button to compute the center of the bracket width and add the Width Center measurement to the results table, as shown in Figure 4-6.

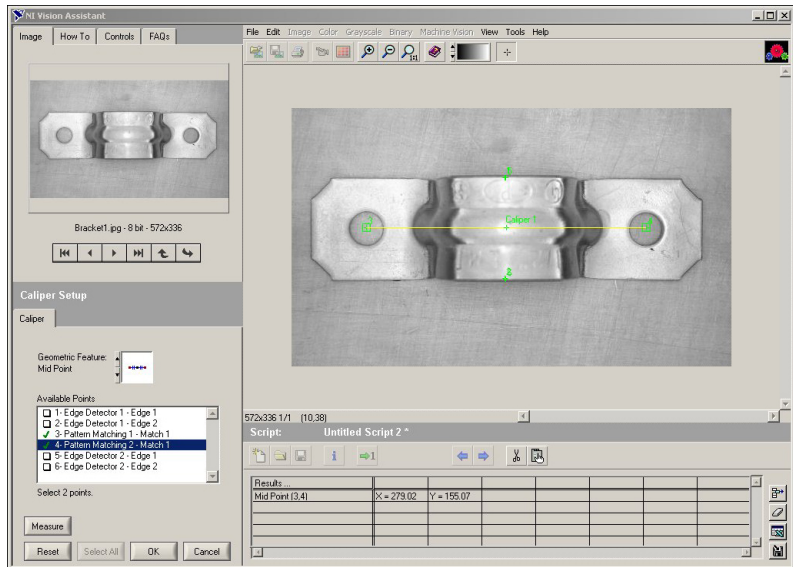


Figure 4-6. Using the Caliper Function to Find Width Center

5. Click **OK** to add this step to the script.
6. Select **Caliper** in the **Machine Vision** tab, or select **Machine Vision»Caliper** again. The center of the bracket width appears as point 5.
7. Select **Distance** in **Geometric Feature**.
8. Click 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 if the bracket arch is the appropriate height.
9. Click **Measure** to compute the distance between the bracket holes and add the measurement to the results table.
10. Select **Angle Defined by 3 Points** in **Geometric Feature**.

11. Click points **1**, **5**, and **2**, in this order, to find the third measurement—Bracket Angle—which measures the angle of the bracket arms with respect to a vertex at point 5, as shown in Figure 4-7.
12. Click **Measure** to compute the angle of the bracket 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.

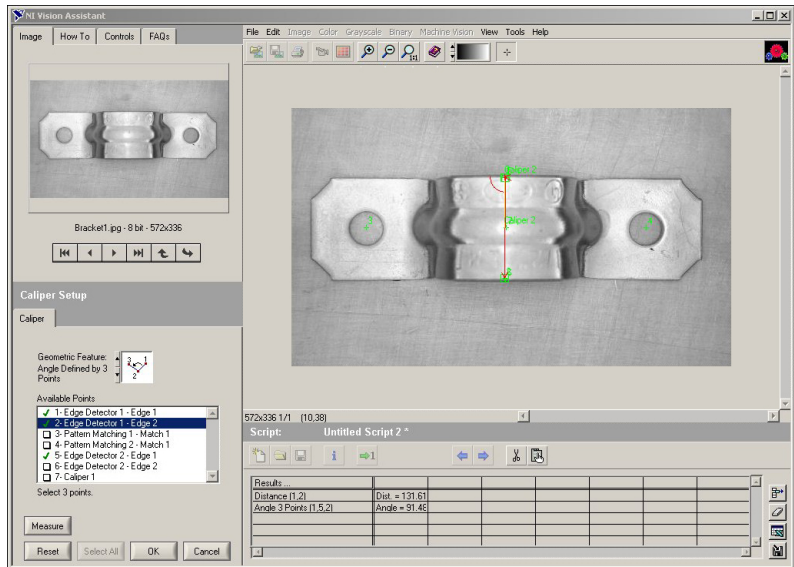


Figure 4-7. Using the Caliper Tool to Collect Measurements

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

Analyzing the Results

Complete the following steps to use a script to analyze another similar image.



1. Using the navigation buttons in the Reference Window, select the next bracket image and click the **Make Image Active** button.
2. Click **Run Once**.
3. Double-click the last step in the script, which uses the Caliper function. Table 4-1 shows the actual measurement results you might see for the bracket image.

You can use batch processing to analyze multiple images and save the resulting analysis information in a tab-delimited text file. Table 4-1 displays analysis information for multiple images, including the acceptable ranges for the bracket measurements and the actual values you might see for the bracket image. 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. Refer to the *Vision Assistant Help* for information about the Vision Assistant batch processing functionality.

Table 4-1. Bracket Measurement Results

Bracket Number	Bracket Distance (acceptable range: 362 to 368 pixels)	Bracket Angle (acceptable range: 178° to 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

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Glossary

Symbol	Prefix	Value
M	mega	10^6
G	giga	10^9

Numbers/Symbols

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

area A rectangular portion of an acquisition window or frame that is controlled and defined by software.

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.

B

b Bit. One binary digit, either 0 or 1.

B Byte. Eight related bits of data, an 8-bit binary number. Also denotes the amount of memory required to store 1 byte of data.

binary image An image in which the objects usually have a pixel intensity of 1 (or 255) and the background has a pixel intensity of 0.

binary morphology Functions that perform morphological operations on a binary image.

binary threshold	Separation of an image into objects of interest (assigned a pixel value of 1) and background (assigned pixel values of 0) based on the intensities of the image pixels.
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.
blurring	Reduces the amount of detail in an image. Blurring commonly occurs because the camera is out of focus. You can blur an image intentionally by applying a lowpass frequency filter.
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.
brightness	(1) A constant added to the red, green, and blue components of a color pixel during the color decoding process; (2) The perception by which white objects are distinguished from gray and light objects from dark objects.

C

caliper	(1) A function in Vision Assistant 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.
chroma	The color information in a video signal.
chrominance	<i>See</i> chroma.

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.
contrast	A constant multiplication factor applied to the luma and chroma components of a color pixel in the color decoding process.
convolution kernel	2D 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

default setting	A default parameter value recorded in the driver. In many cases, the default input of a control is a certain value (often 0).
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.
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.
driver	Software that controls a specific hardware device, such as an IMAQ or DAQ device.

E

edge	Defined by a sharp change (transition) in the pixel intensities in an image or along an array of pixels.
edge contrast/ edge strength	The difference between the average pixel intensity before and the average pixel intensity after the edge.
edge detection	Any of several techniques to identify the edges of objects in an image.

edge steepness	The number of pixels that corresponds to the slope or transition area of an edge.
erosion	Reduces the size of an object along its boundary and eliminates isolated points in the image.

F

fiducial	A reference pattern on a part that helps a machine vision application find the part's location and orientation in an image.
function	A set of software instructions executed by a single line of code that may have input and/or output parameters and returns a value when executed.

G

gauging	Measurement of an object or distances between objects.
grayscale image	An image with monochrome information.
grayscale morphology	Functions that perform morphological operations on a grayscale image.

H

histogram	Indicates the quantitative distribution of the pixels of an image per gray-level value.
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	Color encoding scheme using Hue, Saturation, and Luminance information where each image in the pixel is encoded using 32 bits: 8 bits for hue, 8 bits for saturation, 8 bits for luminance, and 8 unused bits.
HSV	Color encoding scheme in Hue, Saturation, and Value.
hue	Represents the dominant color of a pixel. The hue function is a continuous function that covers all the possible colors generated using the R, G, and B primaries. <i>See also</i> RGB .

I

I/O	Input/output. The transfer of data to/from a computer system involving communications channels, operator interface devices, and/or data acquisition and control interfaces.
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 border	A user-defined region of pixels surrounding an image. Functions that process pixels based on the value of the pixel neighbors require image borders.
Image Browser	An image that contains thumbnails of images to analyze or process in a vision application.
image definition	See pixel depth .
image enhancement	The process of improving the quality of an image that you acquire from a sensor in terms of signal-to-noise ratio, image contrast, edge definition, and so on.
image file	A file containing pixel data and additional information about the image.
image format	Defines how an image is stored in a file. Usually composed of a header followed by the pixel data.
image palette	The gradation of colors used to display an image on screen, usually defined by a color lookup table.
image processing	Encompasses various processes and analysis functions that you can apply to an image.
image source	Original input image.
image visualization	The presentation (display) of an image (image data) to the user.
imaging	Any process of acquiring and displaying images and analyzing image data.
IMAQ	Image Acquisition.
inspection	The process by which parts are tested for simple defects such as missing parts or cracks on part surfaces.

inspection function	Analyzes groups of pixels within an image and returns information about the size, shape, position, and pixel connectivity. Typical applications include quality of parts, analyzing defects, locating objects, and sorting objects.
instrument driver	A set of high-level software functions, such as NI-IMAQ, that control specific plug-in computer boards. Instrument drivers are available in several forms, ranging from a function callable from a programming language to a virtual instrument (VI) in LabVIEW.
intensity	The sum of the Red, Green, and Blue primary colors divided by three. $(Red + Green + Blue)/3$
intensity profile	The gray-level distribution of the pixels along an ROI 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 an object. Otherwise it is considered part of the background.

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.

line profile	Represents the gray-level distribution along a line of pixels in an image.
logic operators	The image operations AND, NAND, OR, XOR, NOR, XNOR, difference, mask, mean, max, and min.
luma	The brightness information in the video picture. The luma signal amplitude varies in proportion to the brightness of the video signal and corresponds exactly to the monochrome picture.
luminance	<i>See</i> luma.

M

M	(1) Mega, the standard metric prefix for 1 million or 10^6 , when used with units of measure such as volts and hertz; (2) Mega, the prefix for 1,048,576, or 2^{20} , when used with B to quantify data or computer memory.
machine vision	An automated application that performs a set of visual inspection tasks.
match score	A number ranging from 0 to 1000 that indicates how closely an acquired image matches the template image. A match score of 1000 indicates a perfect match. A match score of 0 indicates no match.
MB	Megabyte of memory.
MMX	Multimedia Extensions. Intel chip-based technology that allows parallel operations on integers, which results in accelerated processing of 8-bit images.
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 are used primarily to delineate objects and prepare them for quantitative inspection analysis.

N

neighbor	A pixel whose value affects the value of a nearby pixel when an image is processed. The neighbors of a pixel are usually defined by a kernel or a structuring element.
neighborhood operations	Operations on a point in an image that take into consideration the values of the pixels neighboring that point.
NI-IMAQ	Driver software for National Instruments IMAQ hardware.

O

opening	An erosion followed by a dilation. An opening removes small objects and smooths boundaries of objects in the image.
operators	Allow masking, combination, and comparison of images. You can use arithmetic and logic operators in IMAQ Vision.

P

palette	The gradation of colors used to display an image on screen, usually defined by a color lookup table.
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 aspect ratio	The ratio between the physical horizontal size and the vertical size of the region covered by the pixel. An acquired pixel should optimally be square, thus the optimal value is 1.0, but typically it falls between 0.95 and 1.05, depending on camera quality.
pixel depth	The number of bits used to represent the gray level of a pixel.
PNG	Portable Network Graphic. Image file format for storing 8-bit, 16-bit, and color images with lossless compression (extension PNG).

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.

pts Points.

Q

quantitative analysis Obtaining various measurements of objects in an image.

R

resolution The number of rows and columns of pixels. An image composed of m rows and n columns has a resolution of $m \times n$.

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).

ROI Region of interest. (1) An area of the image that is graphically selected from a window displaying the image. This area can be used focus further processing; (2) A hardware-programmable rectangular portion of the acquisition window.

ROI tools Collection of tools from the LabVIEW 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 matching A pattern matching technique in which the reference pattern can be located at any orientation in the test image as well as rotated at any degree.

S

saturation The amount of white added to a pure color. Saturation relates to the richness of a color. A saturation of zero corresponds to a pure color with no white added. Pink is a red with low saturation.

scale-invariant matching A pattern matching technique in which the reference pattern can be any size in the test image.

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.
smoothing filter	Blurs an image by attenuating variations of light intensity in the neighborhood of a pixel.
sub-pixel analysis	Finds 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.
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. Image format commonly used for encoding 8-bit, 16-bit, and color images.
Tools palette	Collection of tools that enable you to select regions of interest, zoom in and out, and change the image palette.

V

value	The grayscale intensity of a color pixel computed as the average of the maximum and minimum red, green, and blue values of that pixel.
VI	Virtual Instrument. (1) A combination of hardware and/or software elements, typically used with a PC, that has the functionality of a classic stand-alone instrument; (2) A LabVIEW software module (VI), which consists of a front panel user interface and a block diagram program.

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