

LabVIEW™ Machine Vision and Image Processing Online Course Manual

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ni.com

National Instruments Corporate Headquarters

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

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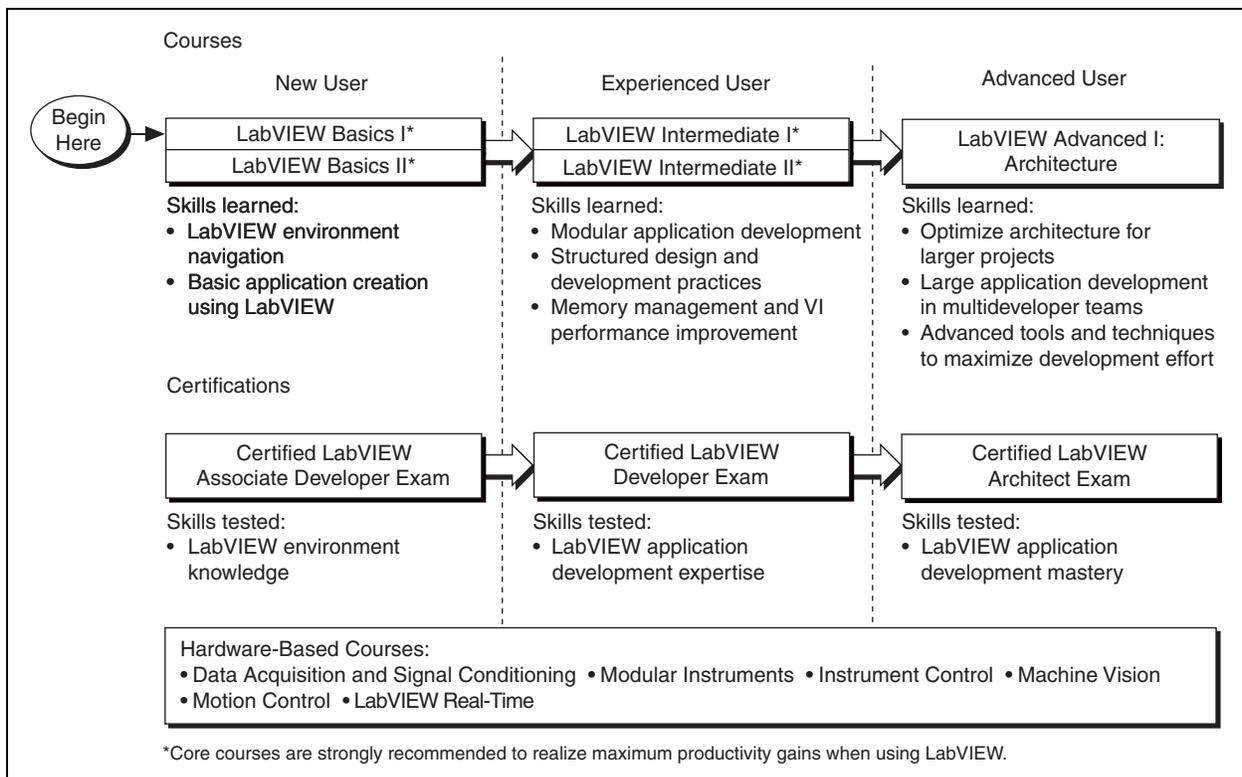
Course Evaluation

Student Guide

This exercise manual and the accompanying software are used in the 8-hour, online *LabVIEW Machine Vision and Image Processing* course.

A. NI Certification

The *LabVIEW Machine Vision and Image Processing* course is part of a series of courses designed to build your proficiency with LabVIEW and help you prepare for exams to become an NI Certified LabVIEW Developer and NI Certified LabVIEW Architect. The following illustration shows the courses that are part of the LabVIEW training series. Refer to ni.com/training for more information about NI Certification.



B. Course Description

The LabVIEW Machine Vision and Image Processing course teaches you to use National Instruments Vision products to build your machine vision application. By the end of this course, you should understand the fundamentals of machine vision, the components that make up a machine

vision system, and the various resources for locating appropriate cameras, lenses, and lighting equipment.

This course assumes that you have a basic knowledge of LabVIEW, including the concepts of front panels, block diagrams, While Loops, controls, and indicators. The course does not cover LabVIEW basics, so National Instruments encourages prior LabVIEW experience to fully understand the content of the course. If you are new to LabVIEW, you may want to consider taking the *LabVIEW Basics I: Introduction* course from National Instruments before starting this course.

The course is divided into lessons, each covering a topic or a set of topics. Each lesson consists of the following parts:

- An introduction that describes what you will learn.
- A discussion of the topics.
- A set of exercises to reinforce the topics presented in the discussion.

In this course you will use an analog image acquisition device, commonly called a frame grabber, and the NI Vision Development Module to complete the exercises.

C. What You Need to Get Started

When you attend the online course, you will connect to a remote computer for your hands-on exercises. All of the software, hardware and files you need are installed on the remote computer.

Before attending the course, check that you can use the remote computers by running the system check at <http://onlinecourses.ni.com/test/>.

If you use this exercise manual to complete the exercises using your own computer, make sure you have the following items:

- NI PCI-1407, NI PCI-1409, NI PCI-1410, or NI PCI-1411 image acquisition device
- Monochrome analog video camera
- BNC cable to connect your camera to your image acquisition device
- Power supply
- Lens
- LabVIEW 8.0 or later

- NI-IMAQ 3.5 or later
- NI Vision 8.0 Development Module
- The following files:

Filename	Description
Exercises	Folder for saving VIs and scripts created during the course
Solutions	Folder containing the solutions to all of the course exercises

D. Course Goals

The goals of this course are:

- To teach the fundamentals of building a complete machine vision system
- To introduce the basics of National Instruments image acquisition hardware and NI Vision software
- To accelerate the machine vision learning curve

This course does not describe any of the following topics:

- Basic principles of LabVIEW covered in the *LabVIEW Basics I: Introduction* course.
- Every machine vision function or the algorithms behind the NI Vision VIs
- How to build a complete machine vision application

The NI-IMAQ and NI Vision libraries contain many VIs that this course does not cover due to time constraints. This course covers the VIs that are the most commonly used by NI customers. If you have questions about other NI-IMAQ and NI Vision VIs, refer to the *NI-IMAQ VI Reference Help* and the *NI Vision for LabVIEW VI Reference Help*.

E. Course Conventions

The following conventions are used in this course 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. Italic text 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 enter from the keyboard, sections of code, programming examples, and syntax examples. This font also is used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, operations, variables, filenames, and extensions.

LabVIEW Machine Vision Online Course Exercises

Use this manual to complete the exercises for concepts introduced during the instructor-led portions of the course.

Exercise 1 Concept: Measure a Bracket

Goal

Open a solution and familiarize yourself with the NI Vision Assistant environment, then see how a Vision Assistant script can be turned into a LabVIEW VI.

1. Launch Vision Assistant 8.0 and open the Bracket Inspection solution.

Select **Start»All Programs»National Instruments Vision Assistant 8.0**.



Click **Solution Wizard**.



Figure 1. NI Vision Assistant Welcome Screen



2. Select **Tutorial»Bracket Inspection** and then click **Load Solution**.

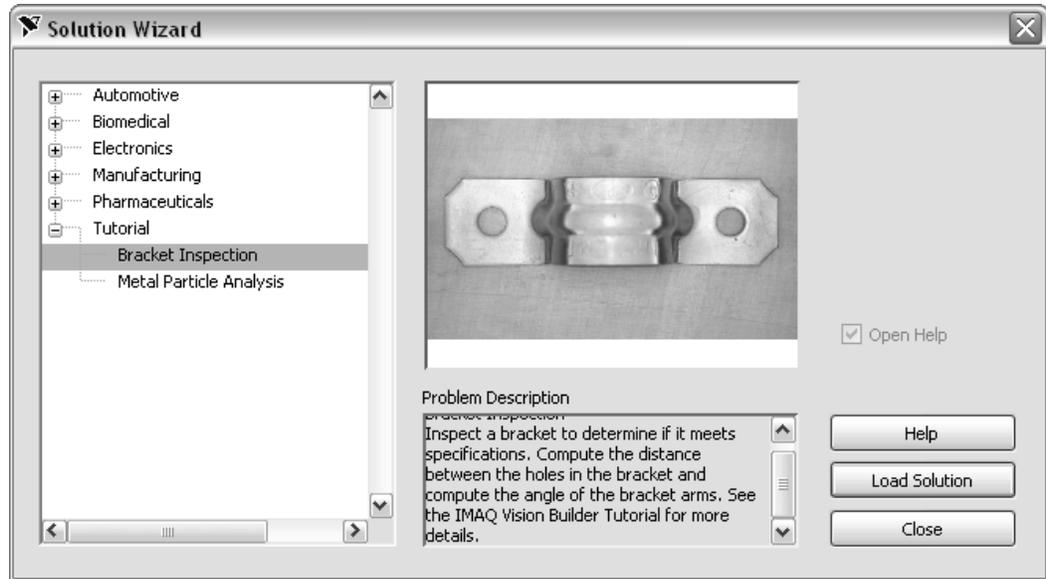


Figure 2. NI Vision Assistant Solution Wizard

3. On the bottom of the screen there are steps recorded in a script. The steps comprise an image-processing algorithm created with Vision Assistant. Examine how each step is configured.



4. Double-click the step in the script called **Pattern Matching 1**. This step looks for the predefined template pattern, which you can view in the **Template** tab. Notice that the results of the search are shown in the table in the middle of the window, and the location of the pattern is highlighted by a red square.

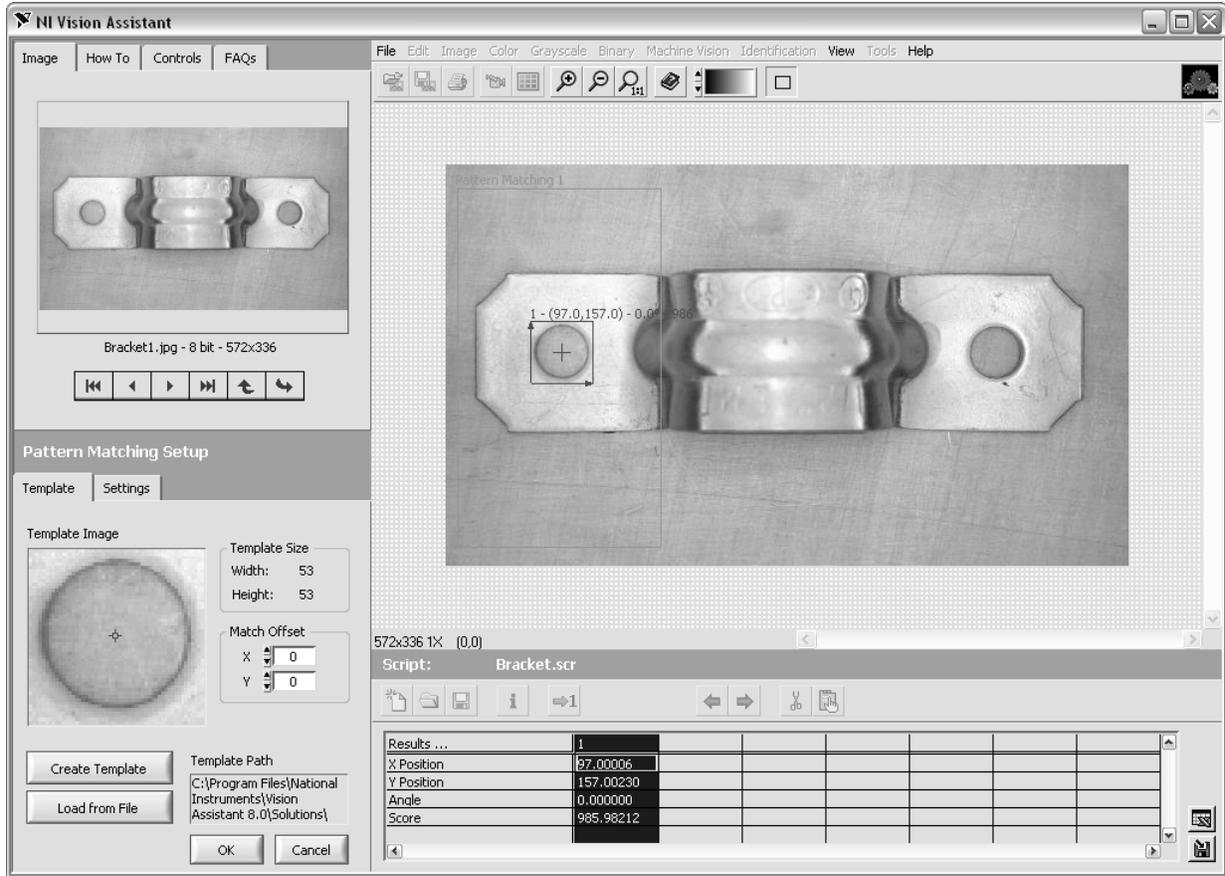


Figure 3. Pattern Matching Step

5. Click **OK**.



6. Double-click the **Pattern Matching 2** step. Notice that the step matched the same pattern on the right side of the bracket. Click **OK**.



7. Double-click the **Edge Detector 1** step. Notice the vertical line drawn through the center of the bracket. The step located the top and bottom edges of the bracket. In a moment, you will use these edges to find the center of the bracket.

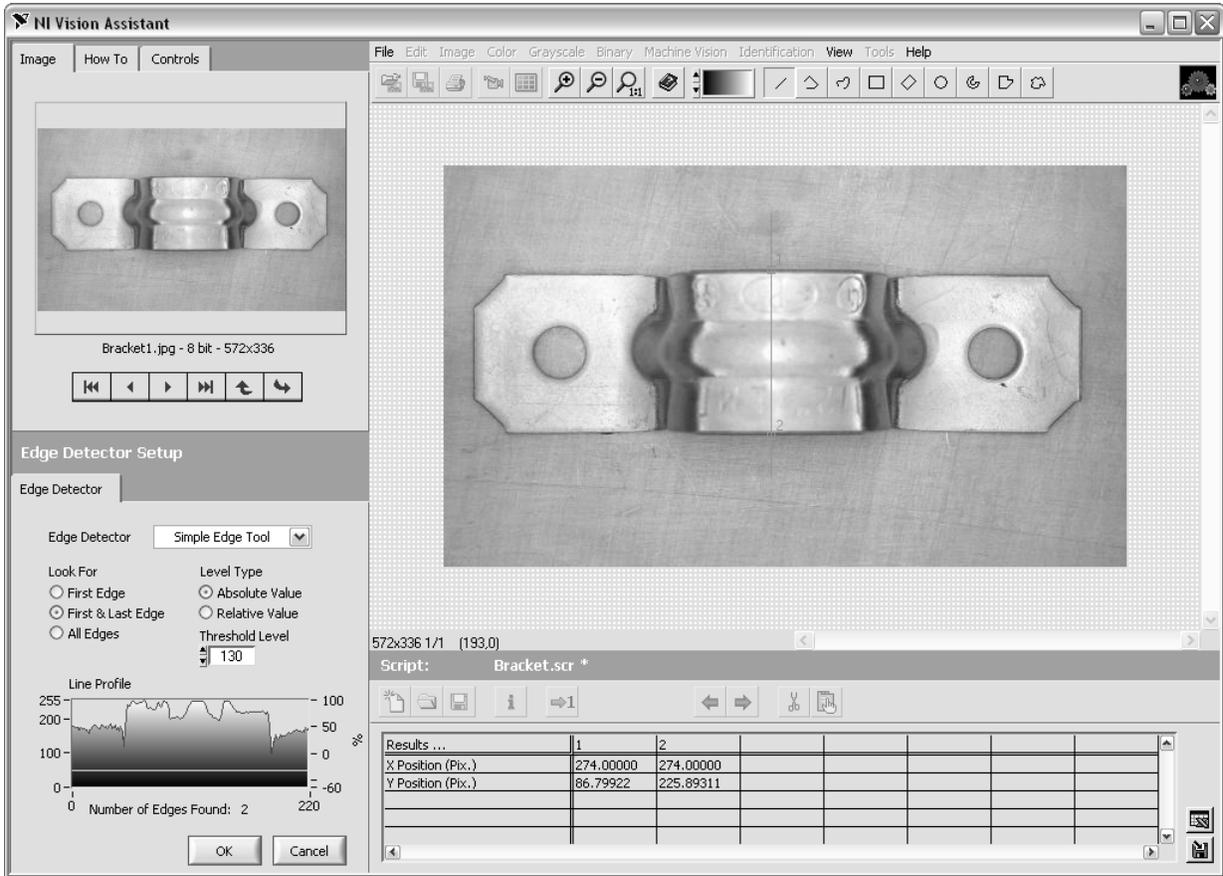


Figure 4. Edge Detector Step

8. Click **OK**.



9. Double-click the **Caliper 1** step. This step finds the midpoint of the two edges that the Edge Detector 1 step found.



Note A point labeled Caliper 1 has been added at the center of the bracket. The table displays the coordinates of Caliper 1.

10. Click **OK**.



11. Double-click the **Caliper 2** step. This step determines the angle by which the bracket is bent between point 1, the center, and point 2.

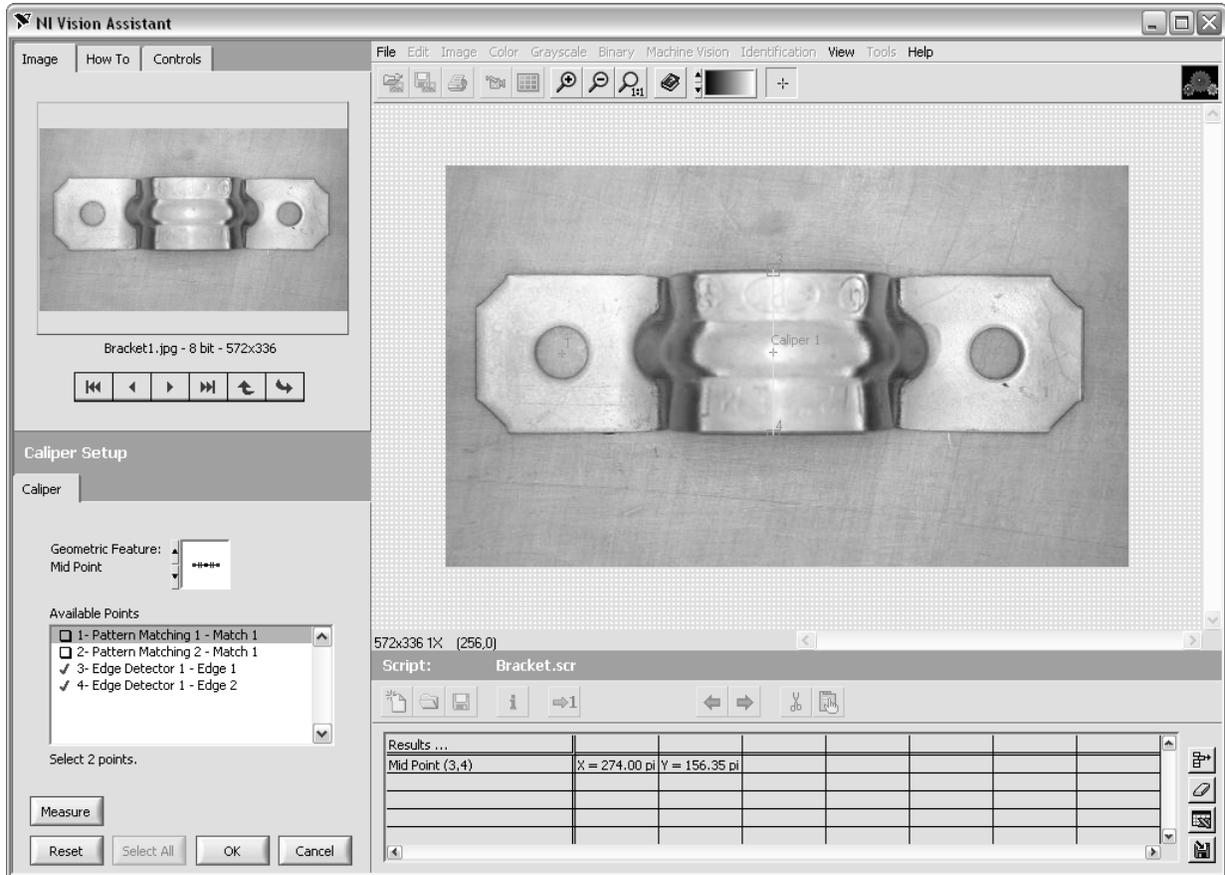


Figure 5. Caliper Step

12. Click **OK** when you are finished.

13. Create a LabVIEW VI from the script.

- Select **Tools»Create LabVIEW VI**. The LabVIEW VI Creation Wizard opens. Use this wizard to create a LabVIEW VI based on this script.
- Select the version of LabVIEW in which you want to create your VI.



Note If there are multiple versions of LabVIEW installed on the computer, close all versions first.

- Enter `C:\Exercises\LabVIEW Machine Vision\Measure a Bracket\Measuring a Bracket.vi` as the path to save the VI.
- Click **Next**.
- Select **Current Script** as the script from which to create your VI.

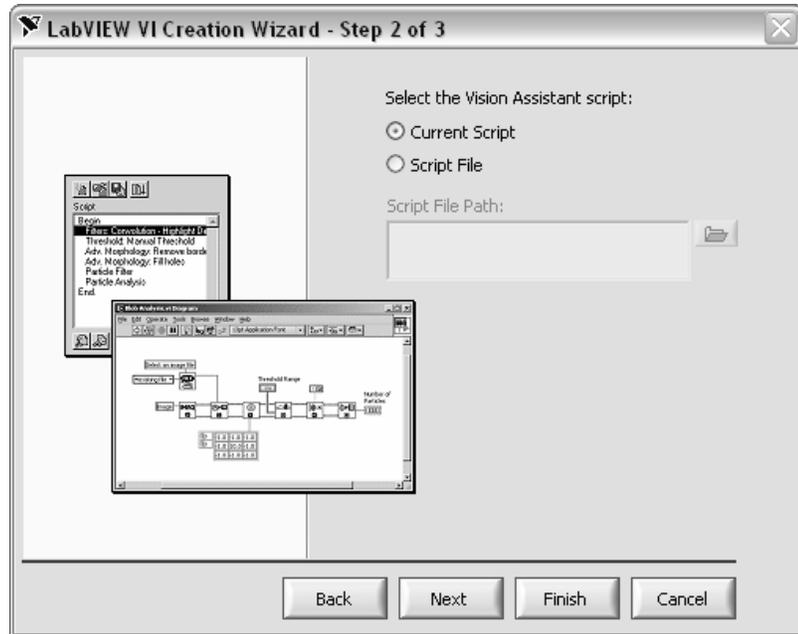


Figure 6. LabVIEW VI Creation Wizard

- Click **Next**.
- Select **Image File** as your image source.

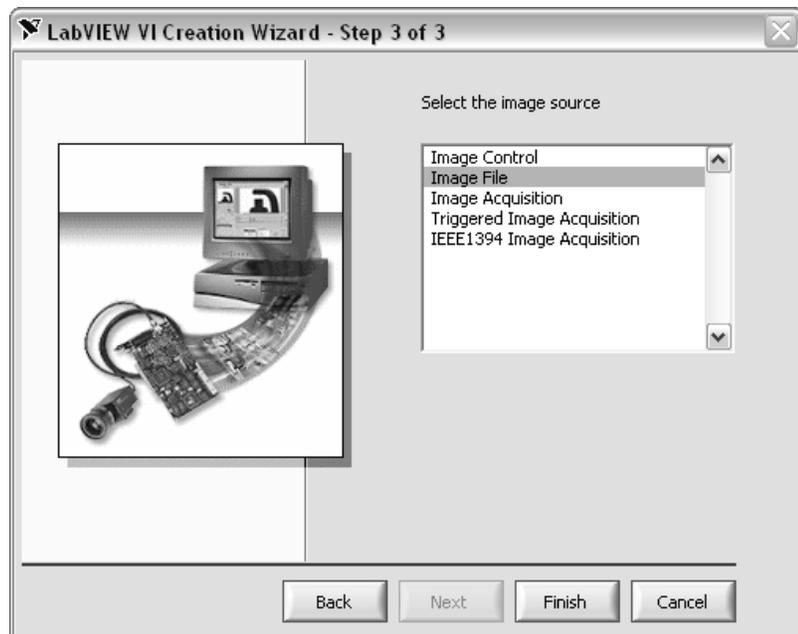


Figure 7. LabVIEW VI Creation Wizard

- Click **Finish**. LabVIEW launches and displays the front panel and block diagram of the VI you created in Vision Assistant.



14. Add the IMAQ Dispose VI (**Vision and Motion»Vision Utilities»Image Management**) as the final step to the block diagram. IMAQ Dispose will deallocate system memory.
15. On the front panel, right-click the Image Display control and select **Snapshot**.
16. Run the VI and open one of the bracket images from `C:\Program Files\National Instruments\Vision Assistant 8.0\Examples\bracket`.
17. Examine the generated code.

Challenge

When pattern matching was performed in Vision Assistant, the overlay was automatically displayed to help you locate objects. The overlay is not displayed by default in the code generated for LabVIEW. Add the code in LabVIEW to show overlays for the matched patterns on the image display.

End of Exercise 1

Exercise 2 Concept: Region of Interest

Goal

Select a region of interest and display it.

Scenario

Regions of interest (ROIs) are frequently used in machine vision applications to specify which part of an image is being inspected. For instance, it is inefficient and cumbersome to search an entire image for a part if you already know a smaller region where the part will exist.

Description

You will enhance a VI you previously created. The code you will add is the same regardless of whether you acquire images with a frame grabber or an IEEE 1394 camera.

You will create an enhanced block diagram, similar to the following figure.

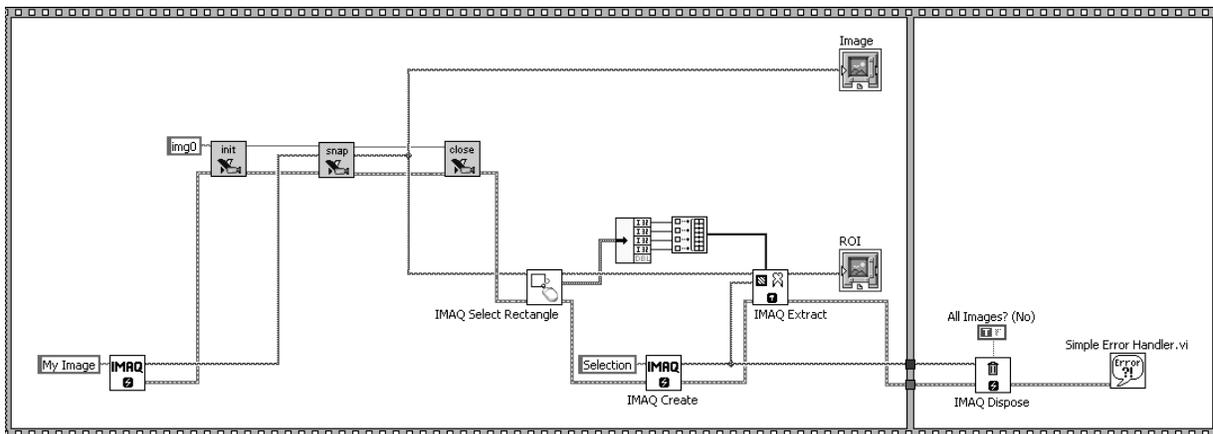


Figure 1-1. Block Diagram of Extract Region of Interest VI

1. Launch LabVIEW.
2. Open Snap and Display.vi, located in the C:\Exercises\LabVIEW Machine Vision\Snap and Display directory. Open the Snap and Display.vi block diagram.
3. Add the code to extract a region of interest and display on a second Image Display.
 - Expand the first frame of the sequence.
 - Add the IMAQ Select Rectangle VI (**Vision and Motion»Machine Vision»Select Region of Interest»IMAQ Select Rectangle**).





- Add the IMAQ Extract VI (**Vision and Motion»Vision Utilities»Image Manipulation»IMAQ Extract**).



- Unbundle the Rectangle output cluster and build the first four elements into an array for the Optional Rectangle input. (Use the Build Array function found on the **Programming»Array** palette.)



- Create a destination buffer for the IMAQ Extract VI. Add a new IMAQ Create VI and call the input `Selection`.



- Add a second Image Display (**Controls»Vision»Image Display**) to the front panel.
- Right-click the Image Display and select **Snapshot**.
- Connect the image and error cluster wires among the new VIs.
- Create a constant for the All Images? (No) input of IMAQ Dispose and set the constant to TRUE. This will clear both of the image buffers from memory when the program completes.

Testing

4. Run the VI.
 5. Draw a region of interest in the WindDraw window that opens.
- You must use the Rectangle tool to draw your ROI. The Rotated Rectangle tool will not work in this exercise.
6. Click **OK**. Your ROI is displayed in the second Image Display indicator.
 7. Save the VI as `Extract Region of Interest.vi` in the `C:\Exercises\LabVIEW Machine Vision\Region of Interest` directory.

End of Exercise 2

Exercise 3 Pattern Matching VI

Goal

Learn how to use pattern matching to locate objects in an image.

Scenario

Pattern matching is heavily used in semiconductor inspections. Pattern matching can help verify part placement and product yield. In this exercise, you will locate a text for a jumper on a printed circuit board so the part can be placed.

Design

The image processing functions for this VI will be scripted using Vision Assistant and the remainder of the code will be written by hand.

Flowchart

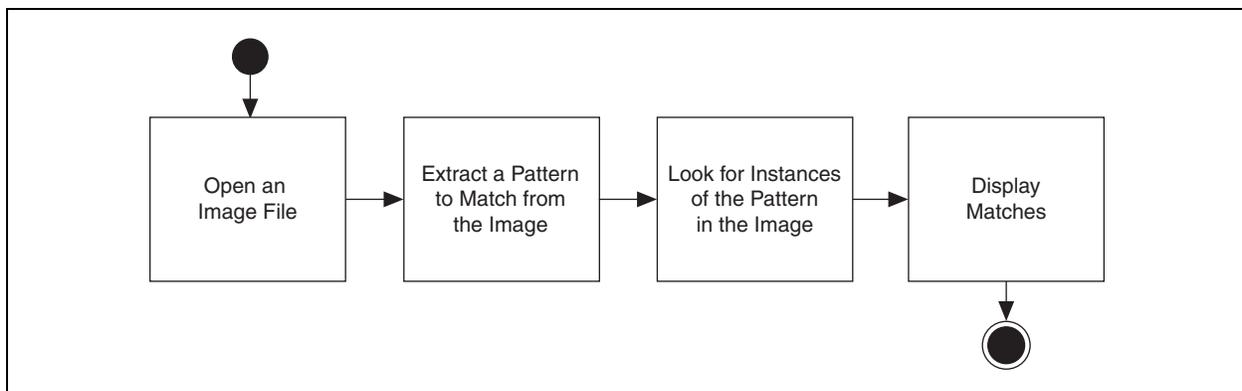


Figure 8. Flowchart of Pattern Matching VI

Description

Open sample images that ship with NI Vision. Create a pattern to find. Display the matches. Create a LabVIEW VI that will find the pattern.

1. Launch Vision Assistant.
 - Click **Open Image** on the splash screen. If Vision Assistant is already open, click **File»Open Image**.
 - Navigate to `C:\Program Files\National Instruments\LabVIEW 8.0\examples\Vision\Images\Pcb03`. **Enable the Select All Files** checkbox and click **Open**.

2. Create a pattern template and find it in the image.
 - Double-click the first image in the image browser.
 - Select **Processing Functions: Machine Vision»Pattern Matching**.
 - Click **Create Template**. The **Select a template in the image** window opens.
 - Draw a rectangular ROI around the inverted J3.

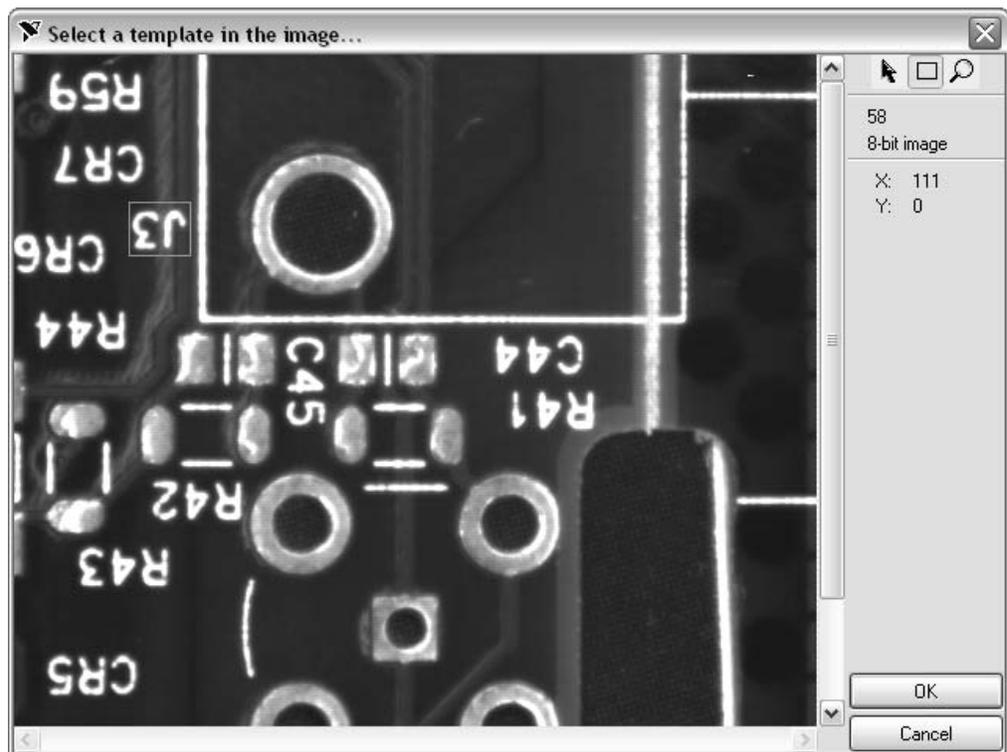
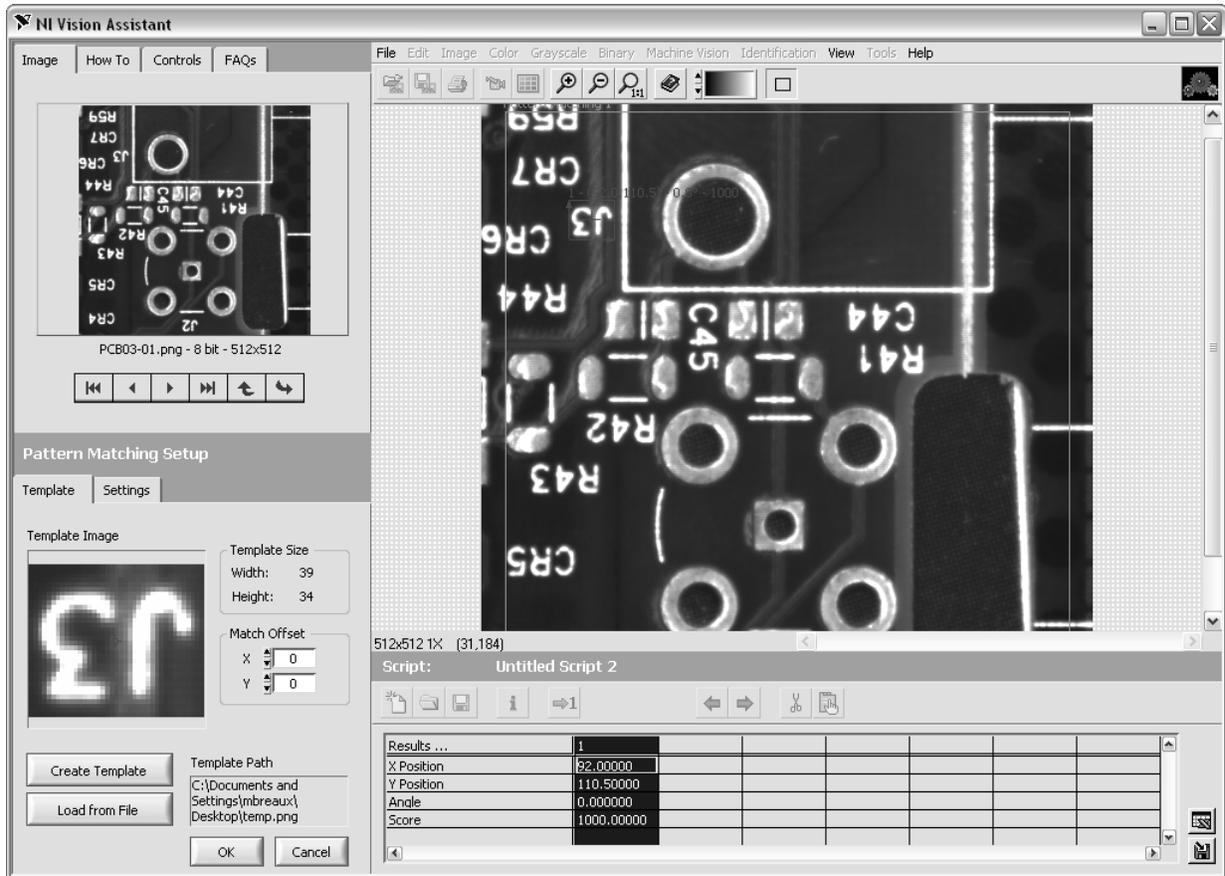


Figure 9. Selecting a Template in an Image

- Click **OK**. Vision Assistant prompts you to save the template file.
- Save the template to your desktop and name the file `template.png`.



Note A portable network graphic (PNG) file must be used for templates because the PNG format allows NI Vision to attach extra data to its header. The template vector map is saved in this header.



The selected template opens in the Pattern Matching Setup window. The table under the image window describes where each match was found, the score of the match (where a score of 1000 represents a perfect match), and the angle of rotation of the pattern. A red overlay highlights the patterns found in the image.

3. Change the settings and test your pattern matching on different images.
 - Click the **Settings** tab and enable the **Search for Rotated Patterns** checkbox.

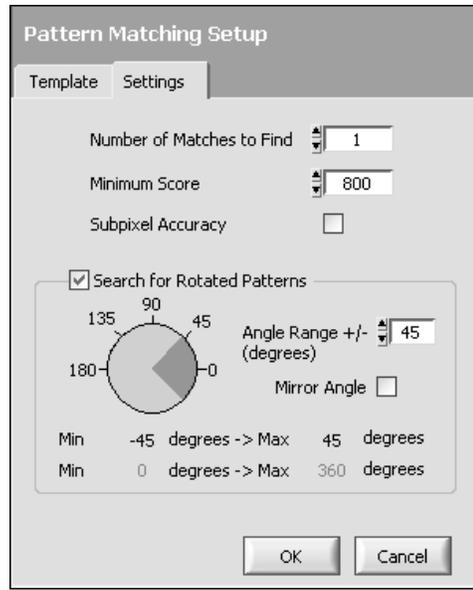


Figure 10. Pattern Matching Setup Window

- Click **OK**.
- Click the **Image** tab in the upper left corner of the Vision Assistant window.
- Click the **Next Image** button.
- Click the **Make Image Active** button to make the next image in the browser the active image.
- Click the **Run Once** button to run the script on the active image.
- Click **OK** when the script is complete and the pattern is found.
- Run the script on each image in the image browser by repeating Step 3.



Notice the score for each match and how the score is affected by changes in rotation. If you have an image in which the pattern is not found, try lowering the Minimum Score to 500. Change the Minimum Score in the Pattern Matching Setup window, on the Settings tab. As you lower the score, Vision Assistant reports matches that are less likely to be correct.

4. Create a LabVIEW VI from this Vision Assistant script.
 - Select **Tools»Create LabVIEW VI**.
 - Save your VI as C:\Exercises\LabVIEW Machine Vision\Pattern Matching\Pattern Matching.vi.
 - Click **Finish**.



On the block diagram, examine the file path constant wired to the IVA Match Pattern Algorithm VI. This control determines the path to the template pattern you are matching. Notice that the path is automatically populated with the location of the pattern you saved in Vision Assistant.



- Add the IMAQ Dispose VI (**Vision and Motion**»**Vision Utilities**»**Image Management**»**IMAQ Dispose**) as the final step.
- Wire the Error out cluster from the Palette Type property node to the Error in cluster of IMAQ Dispose to ensure proper execution order.
- Wire the image data type from the Image Out terminal of the IMAQ ReadFile VI to the Image In terminal on IMAQ Dispose.
- Save the VI. Your VI should look like the following figure.

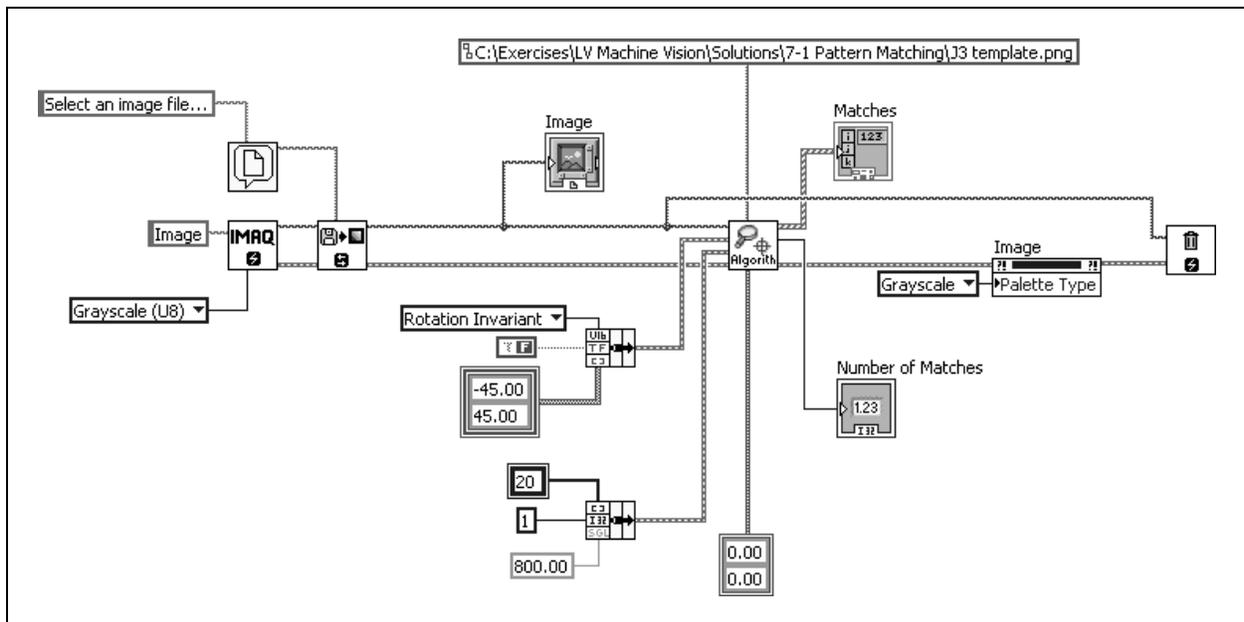


Figure 11. Block Diagram of Pattern Matching VI

5. Examine IVA Match Pattern Algorithm.vi.



- Double-click **IVA Match Pattern Algorithm.vi** to open it.
- Open the block diagram. Turn on the context help by pressing <Ctrl-H>.
- Display Frame 0 of the Sequence structure.



The parameters from the Setup Match Parameters cluster are unbundled and passed into the IMAQ Setup Match Pattern 2 VI. Refer to the context help for more information about this VI.

- Display Frame 1 of the Sequence structure.

Frame 1 performs the pattern matching that was configured in Frame 0. The Match Parameters cluster is unbundled and passed into the IMAQ Match Pattern 2 VI. The optional rectangle input is used to specify the location to search for the pattern.

Testing

6. Display the front panel and run the VI.
 - Select an image from C:\Program Files\National Instruments\LabVIEW 8.0\examples\Vision\Images\Pcb03.

The template you saved in Step 2 is automatically loaded and found in the image.

- Check the score from the Matches indicator to see how well the located pattern matched the template.

Challenge

7. Add code to interactively select a template when running this VI, rather than loading a saved template. Refer to the Exercise 2, *Concept: Region of Interest*, for ideas.
8. Save and close the VI. Keep LabVIEW and Vision Assistant open for the next exercise.

End of Exercise 3

Exercise 4 Locate Bracket Holes VI

Goal

Use morphological functions to analyze an object that could change position and shape.

Scenario

Although coordinate systems are useful for tracking objects that change position within an image, there are some situations in which using a coordinate system is inappropriate. In this example, the shape of a bracket must be verified before it is shipped.

You could assign a coordinate system to one of its distinct features, but this assumes that the other features of the bracket have the same relative location in every image. Instead, you can use morphological functions to find the features of the bracket regardless of their location. The features can be analyzed to determine the shape of the bracket.

Design

In this exercise you will create a VI that inspects an image of a bracket by thresholding the image. Then you will improve the binary image and measure the desired particles to determine the straightness of the bracket.

Flowchart

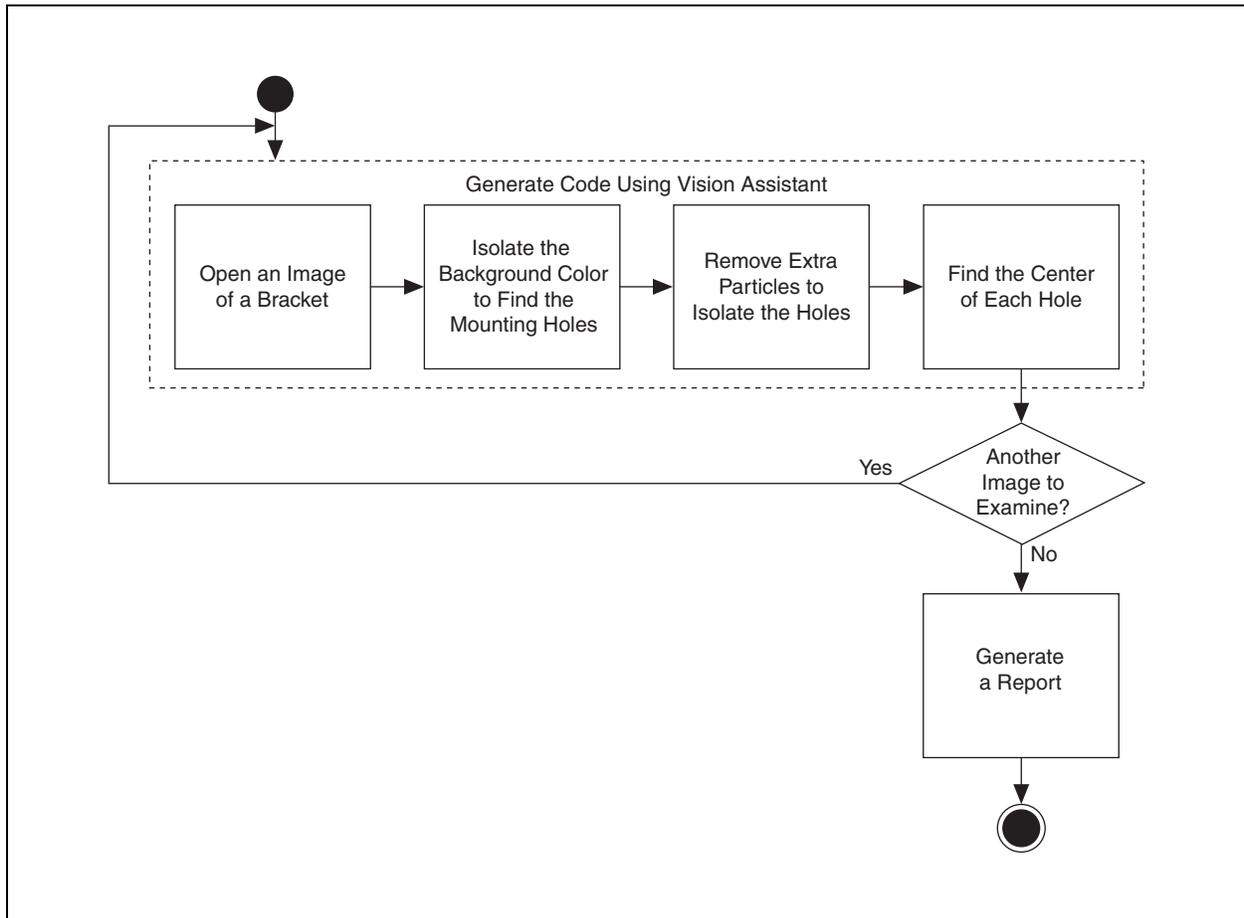


Figure 12. Flowchart of Locate Bracket Holes VI

Implementation

1. In Vision Assistant, click **File»Open Image**.
 - Browse to C:\Program Files\National Instruments\Vision Assistant 8.0\Examples\bracket. Select **Bracket1.jpg** and click **Open**.
2. Threshold the image to define the features of the bracket.
 - Select **Processing Functions: Grayscale»Threshold**.
 - Set the Look For drop-down listbox to **Dark Objects**.
 - Set the Maximum to 165.
 - Click **OK**.

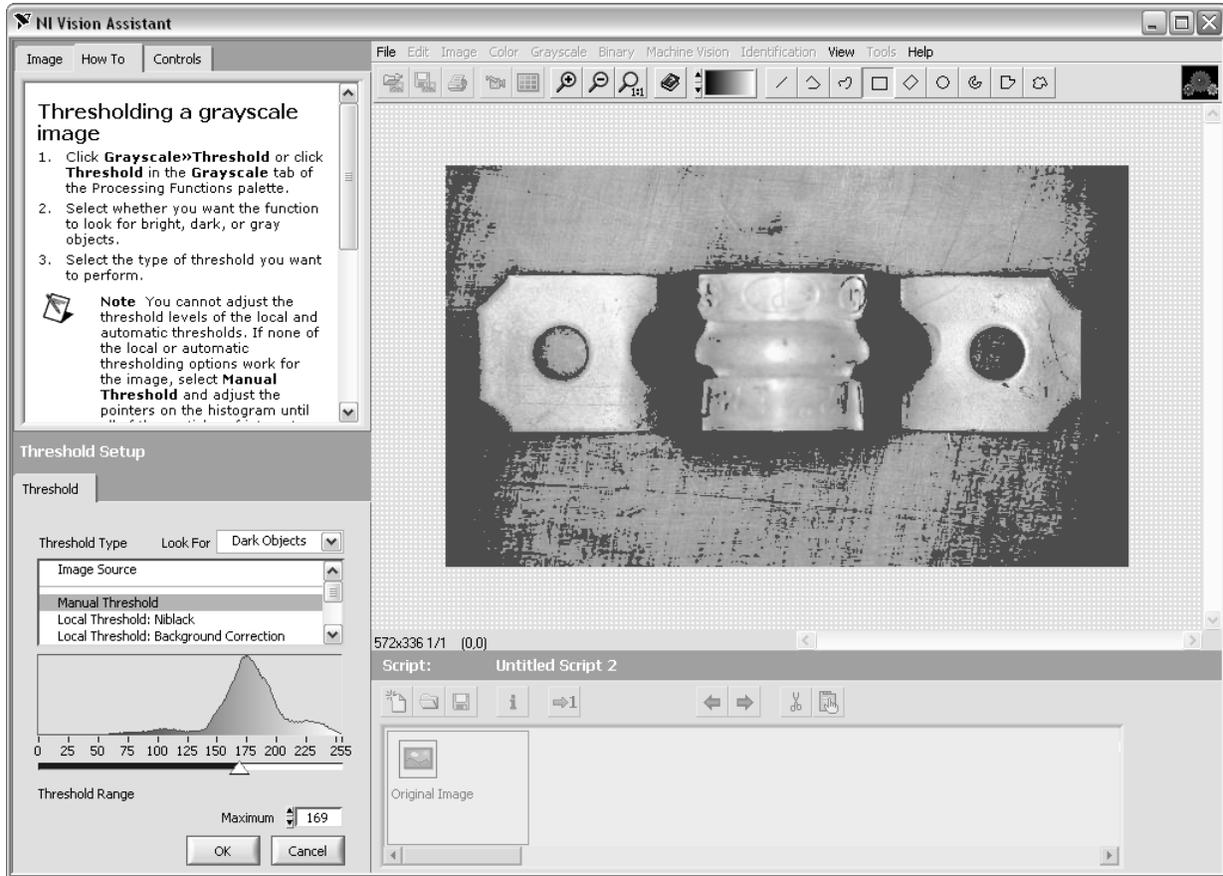


Figure 13. Thresholding the Bracket

3. Use binary morphological operations to isolate the bracket holes.
 - Select **Processing Functions: Binary»Adv. Morphology**.
 - Select **Remove border objects** from the list. This option eliminates particles that touch the edges of the image.
 - Click the **Connectivity** button. Notice the effect that pushing the button has on the process.
 - Click **OK** to save the step.
4. Fill in the holes of the bracket to create closed particles.
 - Select **Processing Functions: Binary»Adv. Morphology**.
 - Select **Fill holes** from the list.
 - Click **OK**.

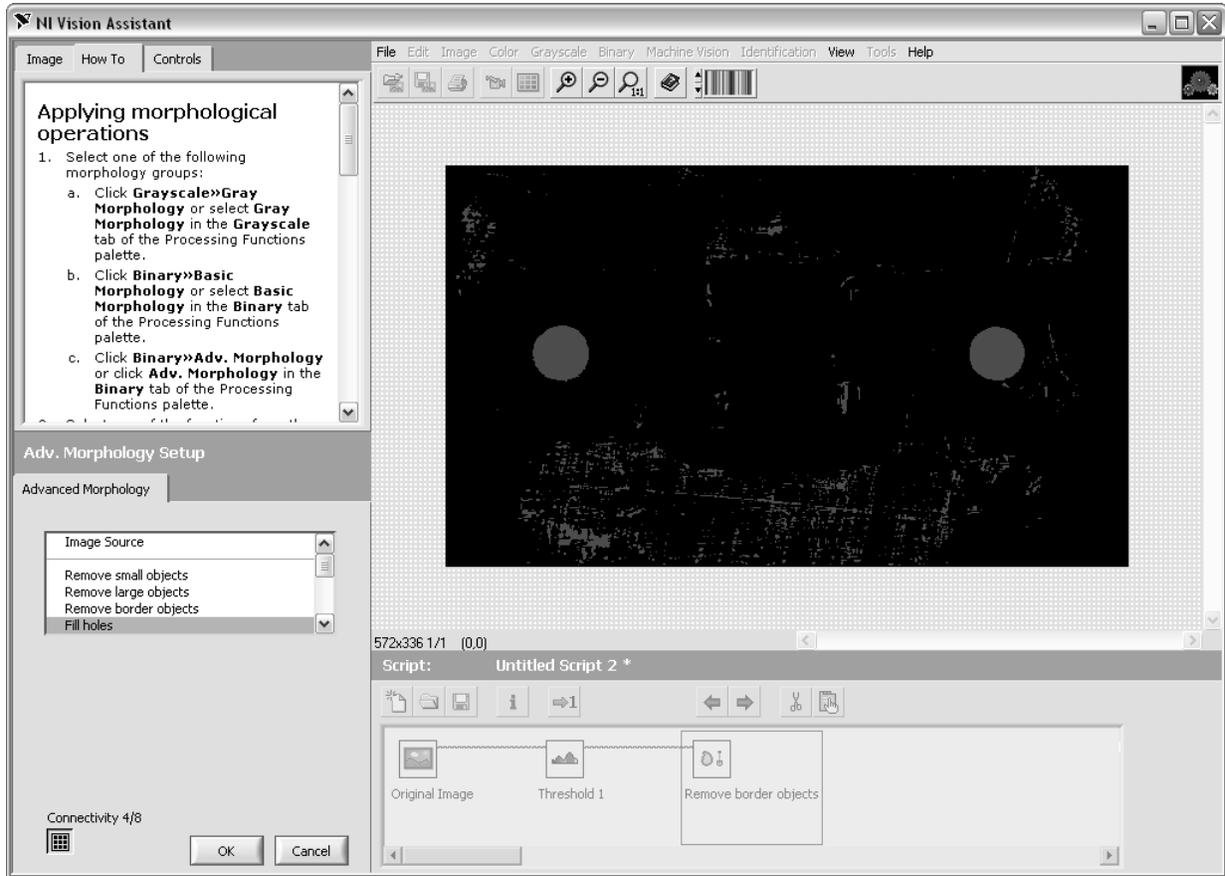


Figure 14. Filling the Holes of the Bracket

5. Use erosion and dilation to clean up noise in the image without affecting the size of the desired particles.
 - Select **Processing Functions: Binary»Basic Morphology**.
 - Select **Erode objects** from the drop-down listbox at the bottom of the screen.
 - Change the Size parameter to 7×7 to increase the size of the structuring element.
 - Click **OK**.

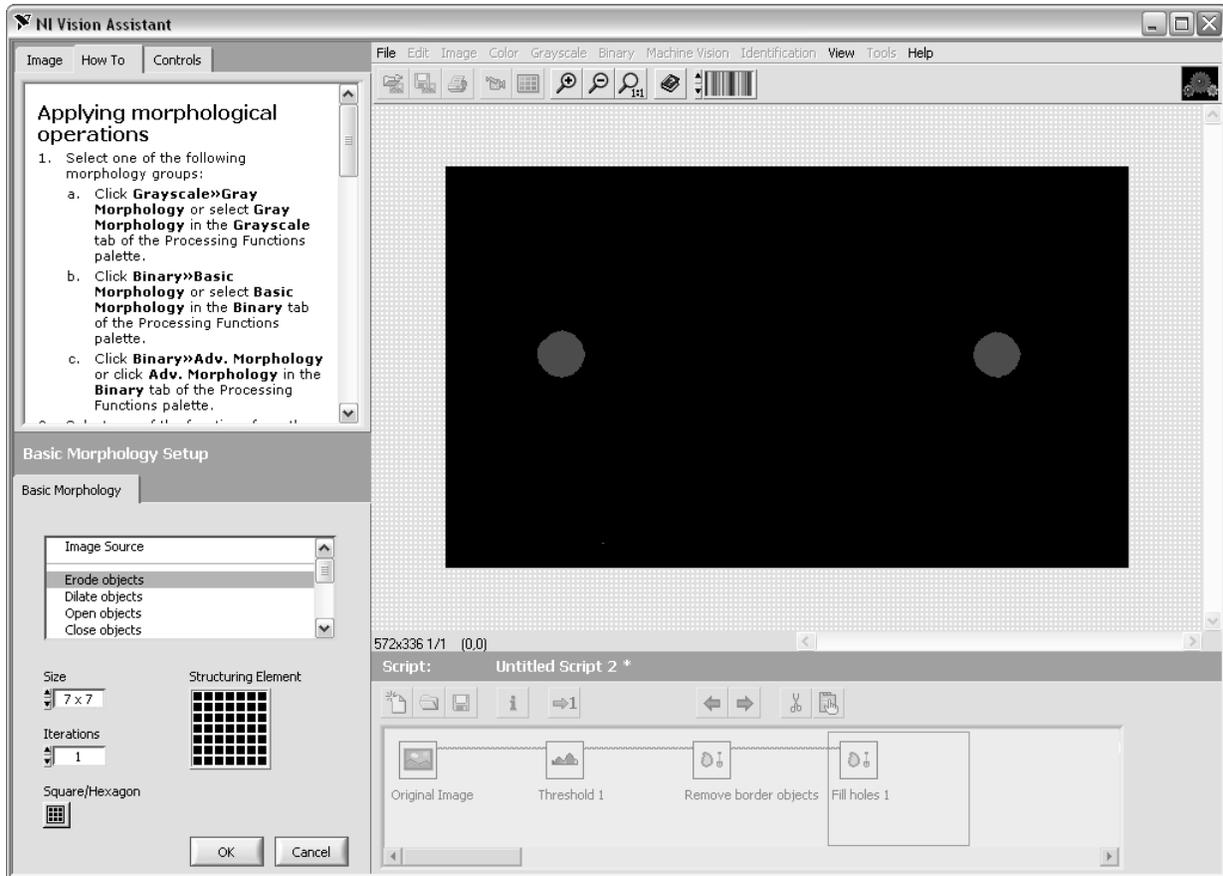


Figure 15. Using Erosion and Dilation

- Select **Processing Functions: Binary»Basic Morphology**.
- Select **Dilate objects** from the drop-down listbox at the bottom of the screen.
- Change the Size parameter to 7×7 to increase the size of the structuring element.
- Click **OK**.



Note Instead of using Erode objects and Dilate objects, you can try using the Particle Filter. Vision Assistant contains more than 50 different Particle Filter parameters that you can use to remove unwanted particles from your image. To use the Particle Filter in this exercise, select an Area filter and set the minimum value to 1000 and the maximum to 3000. You can evaluate the difference in processing time with the Performance Meter (select **Tools»Performance Meter**).

6. Now that the particles representing the holes of the bracket have been isolated, determine the size and location of the particles in the image.

Select **Processing Functions: Binary»Particle Analysis**.

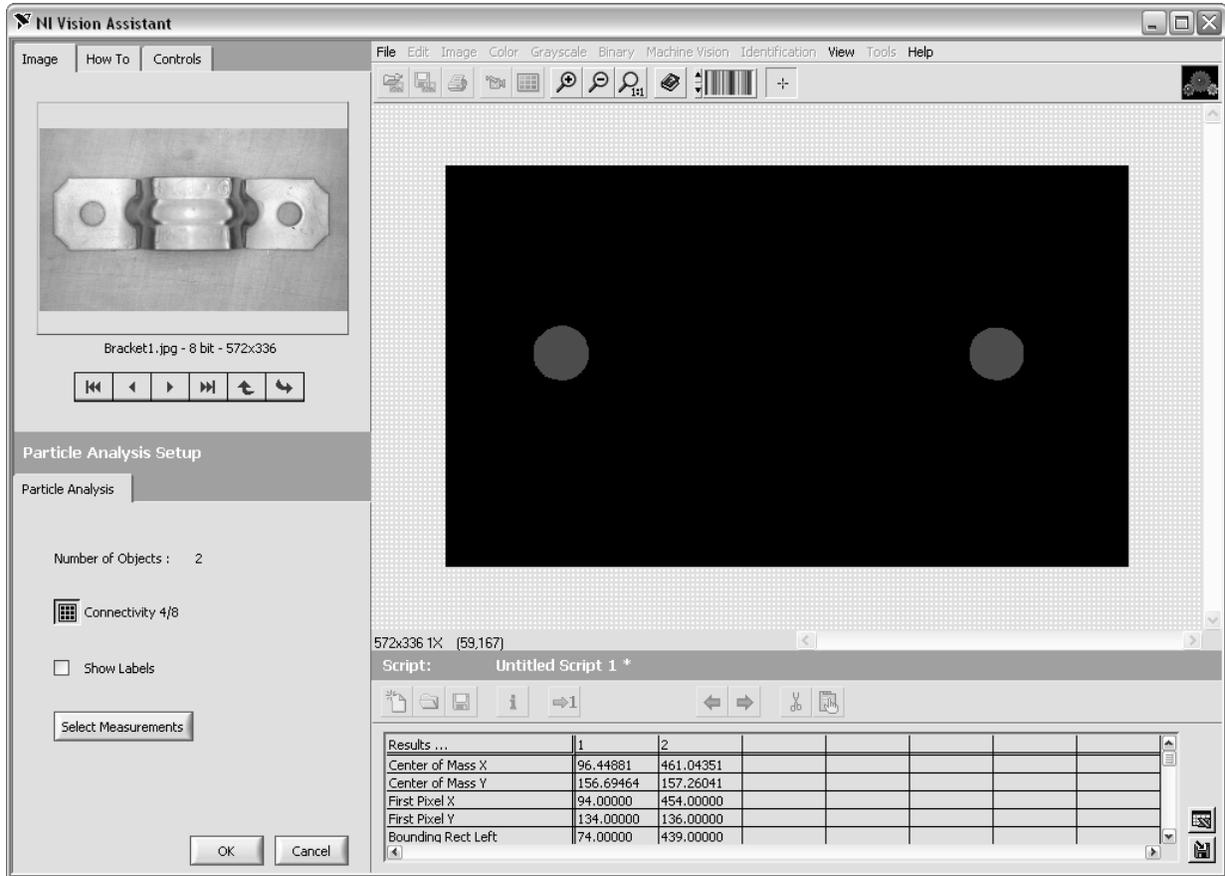


Figure 16. Using Particle Analysis on the Bracket

The table that opens shows an array of values that describe various features of the particles in the image. In this exercise, you only need to know the area and the location of the centers of the particles.

- Click the **Select Measurements** button to display a list of available measurements.



- Click the **Deselect All Pixel Measurements** button to disable the measurements.

- Check the **Center of Mass X, Center of Mass Y, and Area** measurements.

- Click **OK**.

- Click **OK** in the Particle Analysis Setup to save the step.

7. Save the script as `Locate Bracket Holes.scr` in the `C:\Exercises\LabVIEW Machine Vision\Locate Bracket Holes` directory.

8. Create a LabVIEW VI based on your Vision Assistant script.

- Select **Tools»Create LabVIEW VI**.
- When prompted, select LabVIEW 8.0 as the LabVIEW version desired and save the VI as `Locate Bracket Holes.vi` in the `C:\Exercises\LabVIEW Machine Vision` directory.
- Click **Finish**. LabVIEW launches and displays a block diagram.

9. Add memory management functions to the VI.

- On the front panel, right-click the Image Display control and select **Snapshot**.
- Display the block diagram and add the IMAQ Dispose VI to the end of code.
- Connect the image and error cluster wires to the IMAQ Dispose VI.
- Save the VI. Your VI should look like the following figure.

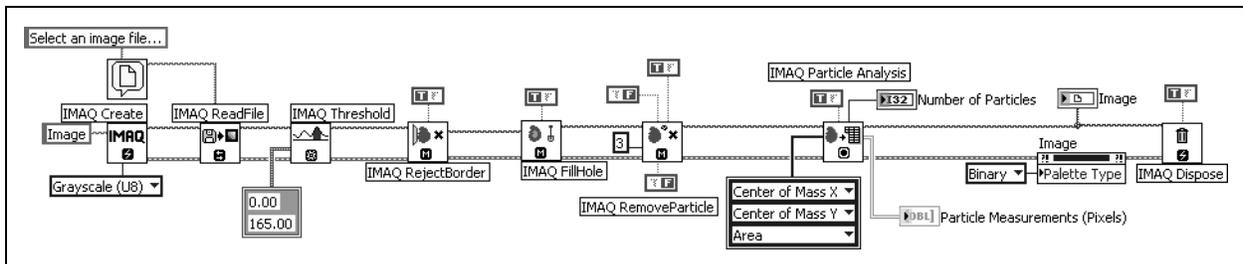


Figure 17. Block Diagram of Locate Bracket Holes VI

Testing

10. Display the front panel.
11. Run the VI.
12. When prompted, select one of the bracket images.

The analysis results are displayed in an array. You can expand the array to view all of the results. The rows represent individual particles. The columns represent the X-coordinate, Y-coordinate, and Area of the particle respectively.

End of Exercise 4

Using Color Tools

This appendix teaches you the basics of color image representation and how to use the color matching, color location, and color pattern matching tools in Vision Assistant.

Topics

- A. Introduction to Color
- B. Using Color Tools

A. Introduction to Color

Color is the wavelength of the light we receive in our eyes when we look at an object. In theory, the color spectrum is infinite. The human eye, however, can see only a small portion of this spectrum—the portion that starts at the red edge of infrared light (the longest wavelength) and ends at the blue edge of ultraviolet light (the shortest wavelength). This continuous spectrum is called the visible spectrum.

White light is a combination of all colors. The spectrum of white light is continuous and goes from ultraviolet to infrared in a smooth transition. You can represent a good approximation of white light by selecting a few reference colors and weighting them appropriately. The most common way to represent white light is to use three reference components, such as red, green, and blue (R, G, and B primaries). You can simulate most colors of the visible spectrum using these primaries. For example, video projectors use red, green, and blue light generators, and RGB cameras use red, green, and blue sensors.

The perception of a color depends on many factors, including the following:

- *Hue*, which is the perceived dominant color. Hue depends directly on the wavelength of a color.
- *Saturation*, which is dependent on the amount of white light present in a color. Pastels typically have a low saturation while very rich colors have a high saturation. For example, pink typically has a red hue but a low saturation.
- *Luminance*, which is the brightness information in the video picture. The luminance signal amplitude varies in proportion to the brightness of the video signal and corresponds exactly to the monochrome picture.
- *Intensity*, which is the brightness of a color and is usually expressed as light or dark. For example, orange and brown may have the same hue and saturation, whereas orange has a greater intensity than brown.

Image Representations

Color images can be represented in several different color spaces. These color spaces can contain all color information from the image or they can consist of just one aspect of the color information, such as hue or luminance. The most common image representation is 32-bit RGB format. In this representation, the three 8-bit color planes—red, green, and blue—are packed into an array of 32-bit integers. This representation is useful for displaying the image on your monitor. The 32-bit integer is organized as

0	RED	GREEN	BLUE
---	-----	-------	------

where the high-order byte is not used, and blue is the low-order byte.

HSL is a 32-bit color space based on hue, saturation, and luminance. This color space is used in image processing applications.

Each color plane can be returned individually. The red, green, or blue plane is extracted from the RGB image and represented as an array of 8-bit integers. The hue, saturation, luminance, and intensity planes also can be returned individually if you want to analyze the image.

B. Using Color Tools

Color Matching

Color matching can be used for applications such as color identification, color inspection, color object location and other applications that require the comparison of color information to make decisions.

How Color Matching Works

Color matching is performed in two steps. In the first step, the machine vision software learns a reference color distribution. In the second step, the software compares color information from other images to the reference image and returns a score as an indicator of similarity.

Color Identification

Color identification identifies an object by comparing the color information in the image of the object to a database of reference colors that correspond to predefined object types. The object is assigned a label corresponding to the object type with closest reference color in the database. Use color matching to first learn the color information of all the predefined object types. The color spectrums associated with each of the predefined object types become the reference colors. Your machine vision application then uses color matching to compare the color information in the image of the object to the reference color spectrums. The object receives the label of the color spectrum with the highest match score.

Several industries use color identification. One example is the automotive industry, where color identification helps verify the presence of the correct components during the assembly process.

Color Inspection

Color inspection detects simple flaws such as missing or misplaced color components and defects on the surfaces of color objects. You can use color matching for these applications if known regions of interest predefine the object or areas to be inspected in the image. You can define these regions or

they can be the output of some other machine vision tool, such as pattern matching used to locate the components to be inspected.

The layout of the fuses in junction boxes in automotive assemblies is easily defined by regions of interest. Color matching determines if all of the fuses are present and in the correct locations. Color matching compares the color of the fuse in each region to the color that is expected to be in that region.

Learning Color Distribution

The machine vision software learns a color distribution by generating a color spectrum. You provide the software with an image or regions in the image containing the color information that you want to use as a reference in your application. The machine vision software then generates a color spectrum based on the information you provide. The color spectrum becomes the basis of comparison during the matching phase.

Comparing Color Distributions

During the matching phase, the color spectrum obtained from the target image or region is compared to the reference color spectrum taken during the learning step. A match score is computed based on the similarity between these two color spectrums using the Manhattan distance between two vectors. The match score, ranging from 0 to 1,000, defines the similarity between the color spectrums. A score of zero represents no similarity between the color spectrums, while a score of 1,000 represents a perfect match.

Color Location

Use color location to quickly locate known color regions in an image. With color location, you create a model or template that represents the colors that you are searching. Your machine vision application then searches for the model in each acquired image, and calculates a score for each match. The score indicates how closely the color information in the model matches the color information in the found regions.

When to Use

Color can simplify a monochrome visual inspection problem by improving contrast or separating the object from the background. Color location algorithms provide a quick way to locate regions in an image with specific colors.

Use color location when your application has the following characteristics:

- Requires the location and the number of regions in an image with their specific color information

- Relies on the cumulative color information in the region, instead of how the colors are arranged in the region
- Does not require the orientation of the region
- Does not require the location with subpixel accuracy

The color location tools in NI Vision measure the similarity between an idealized representation of a feature, called a model, and a feature that may be present in an image. A feature for color location is defined as a region in an image with specific colors.

Color location is useful in many applications. Color location provides your application with information about the number of instances and locations of the template within an image. Use color location in the following general applications—inspection, identification, and sorting.

Inspection

Inspection detects flaws such as missing components, incorrect printing, and incorrect fibers on textiles. A common pharmaceutical inspection application is inspecting a blister pack for the correct pills. Blister pack inspection involves checking that all the pills are of the correct type, which is easily performed by checking that all the pills have the same color information. Because your task is to determine if there are a fixed number of the correct pills in the pack, color location is a very effective tool.

Identification

Identification assigns a label to an object based on its features. In many applications, the color-coded identification marks are placed on the objects. In these applications, color matching locates the color code and identifies the object. In a spring identification application, different types of springs are identified by a collection of color marks painted on the coil. If you know the different types of color patches that are used to mark the springs, color location can find which color marks appear in the image. You then can use this information to identify the type of spring.

Sorting

Sorting separates objects based on attributes such as color, size, and shape. In many applications, especially in the pharmaceutical and plastic industries, objects are sorted according to color, such as pills and plastic pellets. Using color templates of the different candies in the image, color location quickly locates the positions of the different candies.

What to Expect from a Color Location Tool

In automated machine vision applications, the visual appearance of inspected materials or components changes because of factors such as orientation of the part, scale changes, and lighting changes. The color

location tool maintains its ability to locate the reference patterns despite these changes. The color location tool provides accurate results during the following common situations: pattern orientation and multiple instances, ambient lighting conditions, and blur and noise conditions.

Pattern Orientation and Multiple Instances

A color location tool locates the reference pattern in an image even if the pattern in the image is rotated or scaled. When a pattern is rotated or slightly scaled in the image, the color location tool can detect the following:

- The pattern in the image
- The position of the pattern in the image
- Multiple instances of the pattern in the image (if applicable)

Because color location only works on the color information of a region and does not use any kind of shape information from the template, it does not find the angle of the rotation of the match. It only locates the position of a region in the image whose size matches a template containing similar color information.

Ambient Lighting Conditions

The color location tool finds the reference pattern in an image under conditions of uniform changes in the lighting across the image. Color location also finds patterns under conditions of non-uniform light changes, such as shadows.

Blur and Noise Conditions

Color location finds patterns that have undergone some transformation because of blurring or noise. Blurring usually occurs because of incorrect focus or depth of field changes.

Color Pattern Matching

Use color pattern matching to quickly locate known reference patterns or fiducials in a color image. With color pattern matching, you create a model or template that represents the object you are searching for. Your machine vision application then searches for the model in each acquired image, calculating a score for each match. The score indicates how closely the model matches the color pattern found. Use color pattern matching to locate reference patterns that are fully described by the color and spatial information in the pattern.

Using Color Pattern Matching

Grayscale, or monochrome, pattern matching is a well-established tool for alignment, gauging, and inspection applications. In all of these application areas, color simplifies a monochrome problem by improving contrast or

separation of the object from the background. Color pattern matching algorithms provide a quick way to locate objects when color is present.

Use color pattern matching in the following cases:

- The object you want to locate contains color information that is very different from the background, and you want to find the location of the object in the image very precisely. For these applications, color pattern matching provides a more accurate solution than color location—because color location does not use shape information during the search phase, finding the locations of the matches with pixel accuracy is very difficult.
- The object you want to locate has grayscale properties that are very difficult to characterize or that are very similar to other objects in the search image. In such cases, grayscale pattern matching may not give accurate results. If the object has some color information that differentiates it from the other objects in the scene, color provides the machine vision software with the additional information to locate the object.

The color pattern matching tools in NI Vision measure the similarity between an idealized representation of a feature, called a template, and the feature that may be present in an image. A feature is defined as a specific pattern of color pixels in an image.

Color pattern matching is the key to many applications. Color pattern matching provides your application with information about the number of instances and location of the template within an image. Use color pattern matching in the following three general applications: gauging, inspection, and alignment.

Gauging

Many *gauging* applications locate and then measure or gauge the distance between objects. Searching and finding a feature is the key processing task that determines the success of many gauging applications. If the components you want to gauge are uniquely identified by their color, then color pattern matching provides a fast way to locate the components.

Inspection

Inspection detects simple flaws, such as missing parts or unreadable printing. A common application is inspecting the labels on consumer product bottles for printing defects. Because most of the labels are in color, color pattern matching is used to locate the labels in the image before a detailed inspection of the label is performed.

Alignment

Alignment determines the position and orientation of a known object by locating fiducials. Use the fiducials as points of reference on the object. Grayscale pattern matching is sufficient for most applications, but some alignment applications require color pattern matching for quick location of specific color fiducials.

What to Expect from a Color Pattern Matching Tool

In automated machine vision applications, the visual appearance of materials or components under inspection can change due to factors such as orientation of the part, scale changes, and lighting changes. The color pattern matching tool maintains its ability to locate the reference patterns and gives accurate results despite these changes.

Pattern Orientation and Multiple Instances

A color pattern matching tool locates the reference pattern in an image even when the pattern in the image is shifted, rotated, or slightly scaled. The color pattern matching tool detects the following:

- The pattern in the image
- The position of the pattern in the image
- The orientation of the pattern
- Multiple instances of the pattern in the image (if applicable)

Ambient Lighting Conditions

The color pattern matching tool finds the reference pattern in an image under conditions of uniform changes in the lighting across the image. Color analysis is more robust when dealing with variations in lighting than grayscale processing. Color pattern matching performs better under conditions of non-uniform light changes, such as in the presence of shadows, than grayscale pattern matching.

Blur and Noise Conditions

Color pattern matching finds patterns that have undergone some transformation because of blurring or noise. Blurring usually occurs because of incorrect focus or depth of field changes.

Exercise A-1 Concept: Color Pattern Matching

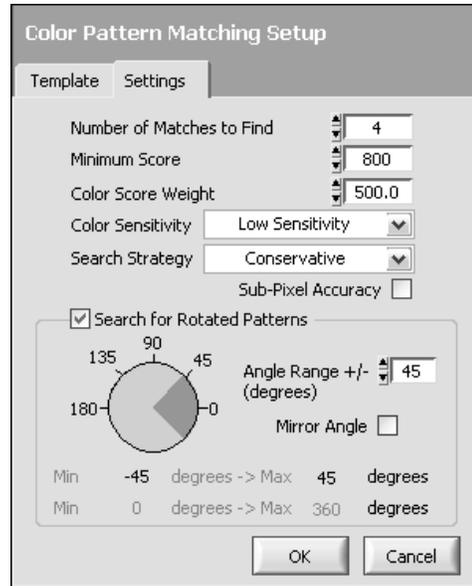
Goal

Use color pattern matching to search for a defined pattern in an image.

Scenario

Open a color image and learn how to configure a color pattern match in Vision Assistant. Learn how to use the color pattern match functionality with LabVIEW.

1. Launch Vision Assistant.
 - Select **Open Image**. Navigate to the `C:\Program Files\National Instruments\LabVIEW 8.0\examples\Vision\Images\PCBColor`.
 - Enable the **Select all Files** checkbox, and then click **OK**. The images now are loaded into the Vision Assistant browser.
 - Double-click the first image to make the image active.
2. Use Vision Assistant to perform color pattern matching.
 - Select **Processing Functions: Color»Color Pattern Matching**.
 - Click **Create Template**.
 - Draw an ROI around one of the yellow electrical components.
 - Click **OK**.
 - Save the template pattern to the desktop as `colortemplate.png`. Notice how the template is found in the image.
 - Click the **Settings** tab. Set the parameters so that they are the same as the parameters in the following illustration.



Notice that Vision Assistant found more instances of the template.

- Click **OK**. The Color Pattern Matching step is added to your script.
3. Examine the efficiency of the algorithm.
 - Select **Tools»Performance Meter**. This meter illustrates how fast the script operates under the present conditions.
 - Click **OK**.
 4. Test the color pattern matching script on all of the images in your browser.
 - Select **Tools»Batch Processing**. You can see your script with the first and only step highlighted. There are several options from this view. You can view the panel results and save the results to disk.

- Enable the **Open Results Panel** checkbox.

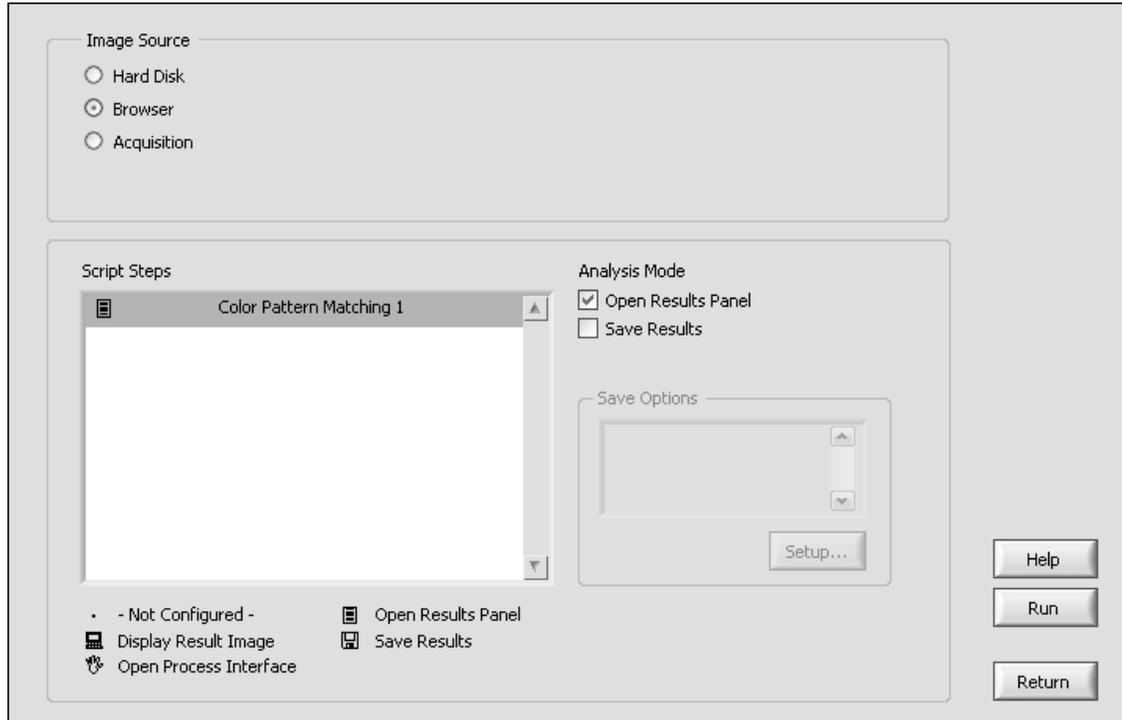


Figure A-1. Batch Processing Window

- Click **Run**.

Vision Assistant applies the script to all twelve images in the browser one at a time. If the pattern is found correctly, click **OK** to move on to the next image. If you have an image in which the pattern is not found, try lowering the value of **Minimum Score**. As you lower the score, Vision Assistant continues to find the pattern unless it is not fully within the image.

- When the batch processing is finished, click **OK**, and then click **Return**.

5. Generate a LabVIEW VI and examine the VI.

- Select **Tools»Create LabVIEW VI**. Follow the onscreen instructions to generate the VI.
- Save the VI as `Color Pattern Matching.vi` in the `C:\Exercises\LabVIEW Machine Vision` directory.
- Add a True constant to the All Images? (No) terminal of the IMAQ Dispose VI.



- On the front panel, right-click the Image Display control and select **Snapshot**.



- Examine the inputs to the IMAQ Setup Match Color Pattern VI and the IMAQ Match Color Pattern VI.

6. Run the VI.

- At the file prompt, select an image from the `C:\Program Files\National Instruments\LabVIEW 8.0\examples\Vision\Images\PCBColor\` directory.
- Modify the Color Pattern Match settings and see how the results change.
- Save and close the VI when you are finished.

Challenge

You may notice that the located component is not highlighted when the VI runs as it was in Vision Assistant. You must add the functionality yourself to the block diagram by adding `Overlay Matches Position Color.vi`, which is located in the following directory: `C:\National Instruments\Program Files\LabVIEW 8.0\examples\Vision\2. Functions\Color Pattern Matching\Color Pattern Matching Example.llb`.

End of Exercise A-1

Additional Information and Resources

This appendix contains additional information about National Instruments technical support options and NI Vision resources.

National Instruments Technical Support Options

Visit the following sections of the National Instruments Web site at ni.com for technical support and professional services.

- **Support**—Online technical support resources at ni.com/support include the following:
 - **Self-Help Resources**—For answers and solutions, visit the award-winning National Instruments Web site for software drivers and updates, a searchable KnowledgeBase, product manuals, step-by-step troubleshooting wizards, thousands of example programs, tutorials, application notes, instrument drivers, and so on.
 - **Free Technical Support**—All registered users receive free Basic Service, which includes access to hundreds of Application Engineers worldwide in the NI Developer Exchange at ni.com/exchange. National Instruments Application Engineers make sure every question receives an answer.

For information about other technical support options in your area, visit ni.com/services or contact your local office at ni.com/contact.

- **System Integration**—If you have time constraints, limited in-house technical resources, or other project challenges, National Instruments Alliance Partner members can help. The NI Alliance Partners joins system integrators, consultants, and hardware vendors to provide comprehensive service and expertise to customers. The program ensures qualified, specialized assistance for application and system development. To learn more, call your local NI office or visit ni.com/alliance.

If you searched ni.com and could not find the answers you need, contact your local office or NI corporate headquarters. Phone numbers for our worldwide offices are listed at the front of this manual. You also can visit the Worldwide Offices section of ni.com/niglobal to access the branch office Web sites, which provide up-to-date contact information, support phone numbers, email addresses, and current events.

Other National Instruments Training Courses

National Instruments offers several training courses for LabVIEW users. These courses continue the training you received here and expand it to other areas. Visit ni.com/training to purchase course materials or sign up for instructor-led, hands-on courses at locations around the world.

National Instruments Certification

Earning an NI certification acknowledges your expertise in working with NI products and technologies. The measurement and automation industry, your employer, clients, and peers recognize your NI certification credential as a symbol of the skills and knowledge you have gained through experience. areas. Visit ni.com/training for more information about the NI certification program.

NI Vision Resources

The following documents contain information that you may find helpful:

- *NI Vision Concepts Manual*—Describes the basic concepts of image analysis, image processing, and machine vision. This document also contains in-depth discussions about imaging functions for advanced users.
- *NI Vision for LabVIEW VI Reference Help*—Contains reference information about NI Vision for LabVIEW palettes and VIs.
- *NI Vision Assistant Tutorial*—Describes the NI Vision Assistant software interface and guides you through creating example image processing and machine vision applications.
- *NI Vision Assistant Help*—Contains descriptions of the NI Vision Assistant features and functions and provides instructions for using them.

These documents can be downloaded at ni.com/manuals.

The following Web sites contain information that you may find helpful:

- ni.com/vision
- ni.com/camera
- ni.com/labview
- ni.com/dataacquisition
- www.machinevisiononline.org
- www.edmundoptics.com
- www.graftek.com

Glossary

B

binary image An image in which the pixels have only one of two intensity values. Objects in the image usually have a pixel intensity of 1 (or 255), and the background has a pixel intensity of 0.

C

CCD Charge Coupled Device. A chip that converts light into electronic signals.

closing A dilation followed by an erosion. Closing fills small holes in objects and removes boundaries in objects.

color Wavelength of the light that is received by the human eye when looking at an object.

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 neighbors.

D

data line Parallel wires that carry digital signals corresponding to pixel values.

depth of field The maximum object depth that remains in focus.

dilation Increases the size of an object along its boundary and removes tiny holes in the object.

E

edge A sharp change or transition in the pixel intensities in an image.

enable lines Lines that indicate when data lines are carrying valid values.

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 location and orientation of the part in an image.
- field of view The area of inspection that the camera can acquire.

G

- grab Acquisition technique that loops continually on one buffer.

H

- histogram Indicates the quantitative distribution of pixels in an image based on their pixel intensities.
- histograph In LabVIEW, a histogram that can be wired directly into a graph.
- HSL Color encoding scheme using hue, saturation, and luminance information.
- hue Represents the dominant color of a pixel.

I

- image mask A binary image that isolates parts of a source image for further processing.
- interlaced video Acquisition method that splits a video into two images called fields. One field contains the odd-numbered lines, while the other contains the even-numbered lines. This acquisition method reduces visible flicker during screen updates.

L

- lens distortion Geometric aberration caused by optical errors in the camera lens.
- linear filter An algorithm that calculates the value of a pixel based on its own pixel value as well as 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.
- luminance The brightness information in a video picture.

M

morphological operations Operations that extract and alter the structure of objects in an image.

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.

O

open An erosion followed by a dilation. Opening removes small objects and smooths boundaries of objects in the image.

P

particle A connected region or grouping of pixels in an image in which all pixels have the same intensity level.

pattern matching A machine vision technique that locates regions of a grayscale image that match a predefined template.

perspective error Changes in the magnification of an object caused by errors in the imaging setup and determined by the distance between the object and the lens.

pixel clock Divides the incoming horizontal video line into pixels.

R

rake The rake algorithm computes the best line or circle, given the edge coordinates detected. Finds edges along parallel, concentric, or radial lines inside a region of interest.

region of interest An area of the image selected for further processing.

resolution The smallest feature size on your object that the imaging system can distinguish.

RGB Color encoding scheme using red, green, and blue color information.

ring Acquisition technique that continually acquires images using a circular buffer of images.

ROI *See* region of interest.

S

saturation The amount of white added to a pure color. Saturation relates to the richness of a color.

sensor resolution The number of columns and rows of CCD pixels in the camera sensor.

sensor size The size of a sensor's active area.

sequence Acquisition technique that acquires a sequence of images.

snap Acquisition technique that acquires a single frame or field to a buffer.

spatial calibration Assigning physical dimensions to the area of a pixel in an image.

subpixel analysis Finds the location of the edge coordinates in terms of fractions of a pixel.

T

tap A group of data lines that carry one pixel each. Also known as a channel.

template image A color, shape, or pattern selected for matching in an image. A template can be a region selected from a part of an image or an entire image.

threshold Separates objects from the background by assigning all pixels whose intensities fall within a specified range to the object and assigning the rest of the pixels to the background. In the resulting binary image, object pixels have a pixel intensity of 1 (or 255) and background pixels have a pixel intensity of 0.

W

working distance The distance from the front of the camera lens to the object under inspection.