IMAQ™

NI Vision Builder for Automated Inspection Tutorial

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Contents

Chapter 4
Inspecting for Multiple Correct Instances of an Object

Chapter 5
Inspecting an Object that Spans Two Image Frames

Appendix A
Technical Support and Professional Services

Glossary

About This Manual

This manual is for manufacturing test engineers who need to acquire images of parts, process and analyze the images, make measurements, and make pass/fail decisions about the parts. This manual is well suited for people who have little experience with machine vision. The manual contains many techniques for using NI Vision Builder for Automated Inspection (Vision Builder AI) to solve visual inspection tasks including inspection, gauging, part presence, guidance, and counting.

Follow the instructions in this manual to familiarize yourself with the Vision Builder AI Configuration interface and solve common inspection tasks.

Conventions

The following conventions appear in this manual:

<> — Angle brackets that contain numbers separated by an ellipsis represent a range of values associated with a bit or signal name—for example, DIO<3..0>.

» — 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 documents contain information that you might find helpful as you read this manual:

- *NI Vision Builder for Automated Inspection: Configuration Help*, available by selecting **Help»Online Help** from the Vision Builder AI Configuration interface
- *NI Vision Builder for Automated Inspection: Inspection Help*, available by selecting **Help»Online Help** from the Vision Builder AI Inspection interface
- *NI Vision Builder for Automated Inspection Release Notes*, available from **Start»Programs»National Instruments»Vision Builder AI» Documentation**

1

Getting Started in Vision Builder AI

This chapter introduces the Vision Builder AI environment, teaches you how to create a short *inspection*, and shows you how to run an inspection.

Figures 1-1 and 1-2 show the general instructions for creating a Vision Builder AI inspection. Figure 1-1 describes the general steps for designing a Vision Builder AI inspection. The *Add Inspection Steps* module of Figure 1-1 is expanded in Figure 1-2.

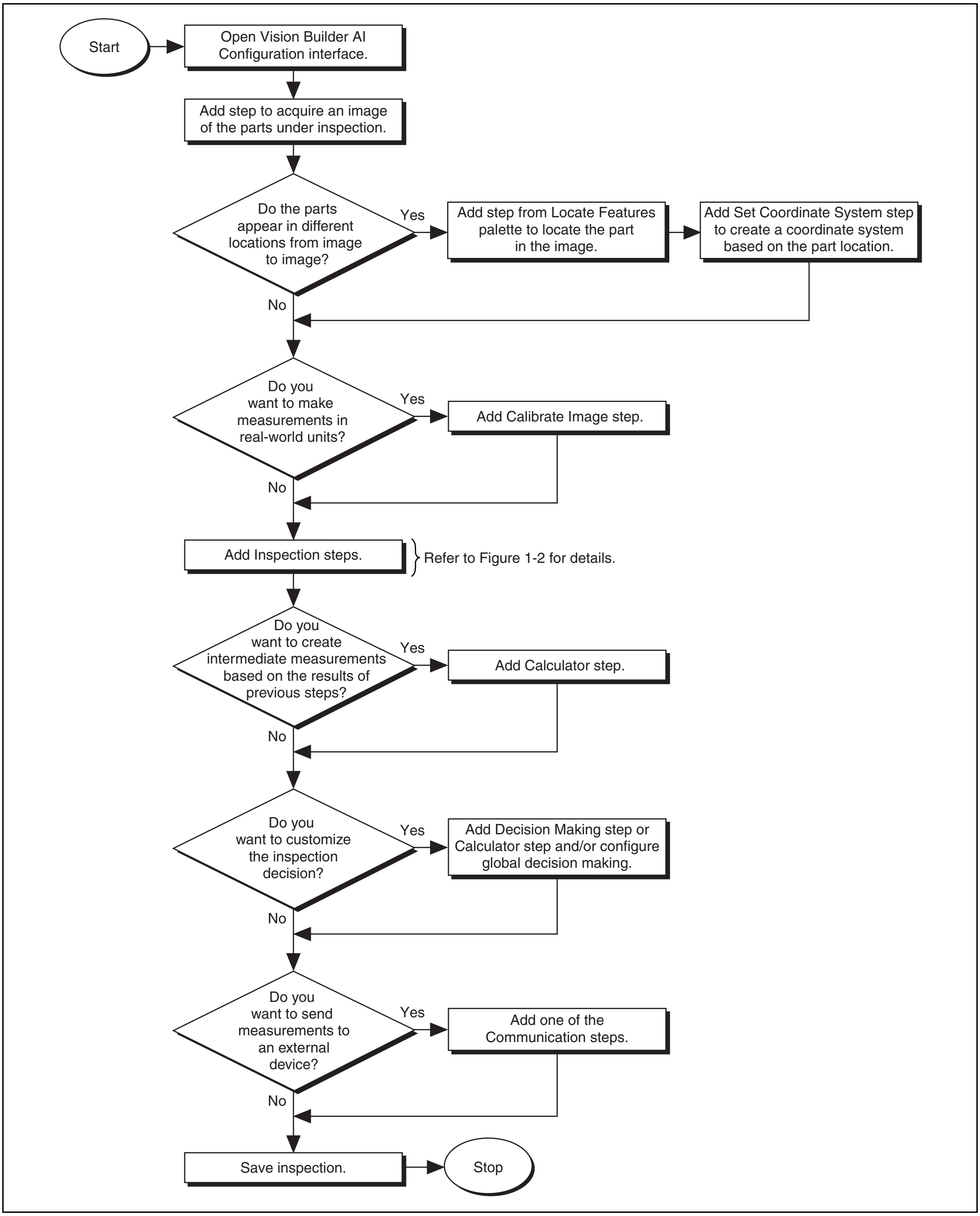


Figure 1-1. General Instructions for Creating a Vision Builder AI Inspection

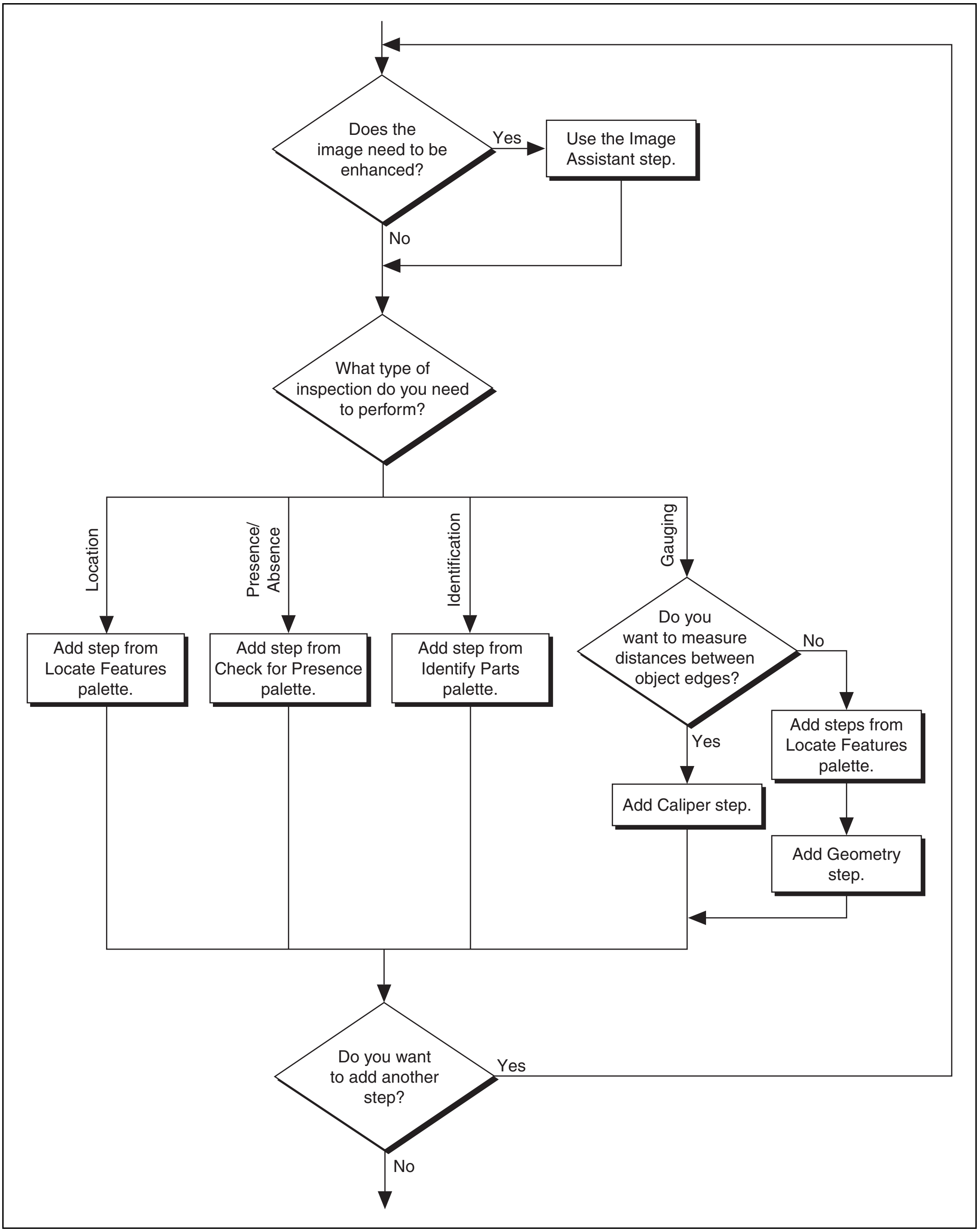


Figure 1-2. Adding Inspection Steps to a Vision Builder AI Inspection

Follow the instructions in this chapter to open Vision Builder AI and configure, test, save, and run an inspection.

Opening the Vision Builder AI Configuration Interface

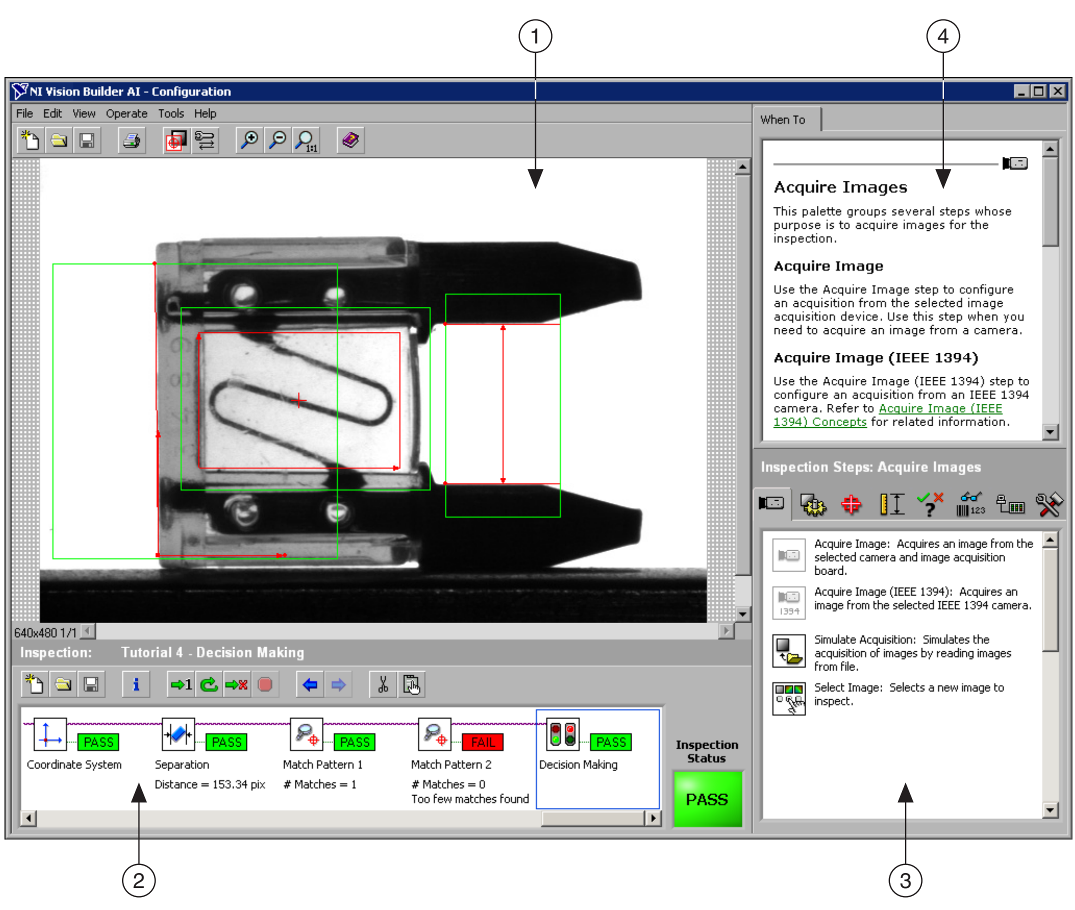
Vision Builder AI has two modes of operation: configuration and inspection. Use the Configuration interface to configure and test your inspection. Use the Inspection interface to deploy the software and perform online or offline visual inspection.

Follow these instructions to open the Vision Builder AI Configuration interface.

1. Go to the **Start** menu and select **Programs»National Instruments Vision Builder AI**. The **Welcome** screen opens.
2. Click **Configure Inspection**.

Elements of the Configuration Interface

Figure 1-3 shows the Vision Builder AI Configuration interface. The Configuration interface contains four areas: **Main** window, **Inspection Diagram** window, **Inspection Steps** palette, and **Embedded Help** window.



1	Main Window	3	Inspection Steps Palette
2	Inspection Diagram Window	4	Embedded Help Window

Figure 1-3. Vision Builder AI Configuration Interface

- **Main window**—Displays the image being processed, the **DataSocket I/O** property page, the **Modbus Slave** property page, the **Decision Making** property page, the **Serial I/O** property page, and the **Configure Inputs/Outputs** property page.
- **Inspection Diagram window**—Displays the sequence of Vision Builder AI *steps* that comprise the inspection.
- **Inspection Steps palette**—Lists and describes the steps you can use to create your inspection. Each tab in the palette represents a common machine vision task, such as acquiring an image or locating features in

an image. When you click most steps, the palette transforms into the property page for the step.

- **Embedded Help window**—Contains context-sensitive help about when to use a step, how to configure a step, the function of the user-interface controls, and frequently asked questions.

Configuring an Inspection

On startup, Vision Builder AI loads a blank inspection in the **Inspection Diagram** window. To build an inspection, you need to add and configure steps to the inspection.

This section teaches you how to create a simple inspection that checks for the presence of a label on a National Instruments FieldPoint device.

Acquiring an Image

In the **Inspection Steps** palette, the **Acquire Images** tab contains acquisition steps—**Acquire Image** and **Acquire Image (IEEE 1394)**—and a **Simulate Acquisition** step, which simulates image acquisition by loading images from file. The tab also contains a **Select Image** step, which enables you to switch to a previously acquired image that you need to process later in the inspection.

Note For simplicity, the exercises in this tutorial instruct you to use the **Simulate Acquisition** step. However, in your real-world inspection, use one of the image acquisition steps to acquire images of the object under inspection.

Follow these instructions to configure a **Simulate Acquisition** step that simulates acquiring images of FieldPoint devices.

1. In the **Inspection Steps** palette, select the **Acquire Images** tab.
2. Click the **Simulate Acquisition** step. The property page for the step opens.
3. In the **Step Name** control, enter Acquire Image.
4. Click the **Browse** button. The **Select an Image File** dialog box opens.
5. Navigate to <Vision Builder AI>\DemoImg\Tutorial 1.

Note If you installed Vision Builder AI in the default directory, you can find <Vision Builder AI> in the C:\Program Files\National Instruments directory.

6. Select the first image, `Image 01.jpg`, and click **Open**.
7. Make sure the **Cycle Through Folder Images** control is enabled. When this control is enabled, Vision Builder AI loads a different simulation image from the folder each time the step is run, which simulates a live acquisition of multiple parts.
8. Click **OK**. Vision Builder AI adds the **Simulate Acquisition** step to the inspection.

Checking for the Presence of a Feature Using Match Pattern

Follow these instructions to configure a **Match Pattern** step to check for the presence of the FieldPoint device label.

1. In the **Inspection Steps** palette, select the **Check for Presence** tab.

Note If a Vision Builder AI step can perform more than one machine vision task, the step appears under each applicable **Inspection Steps** tab. For example, the **Match Pattern** step appears in the **Locate Features** tab as well as the **Check for Presence** tab. A step that appears in multiple tabs functions identically in each tab it is located.

2. Click the **Match Pattern** step. The **Select a template in the image** dialog box opens.
3. Draw a region of interest (*ROI*) around the area of the image containing the label, as shown in Figure 1-4. This region becomes the *pattern matching template*.

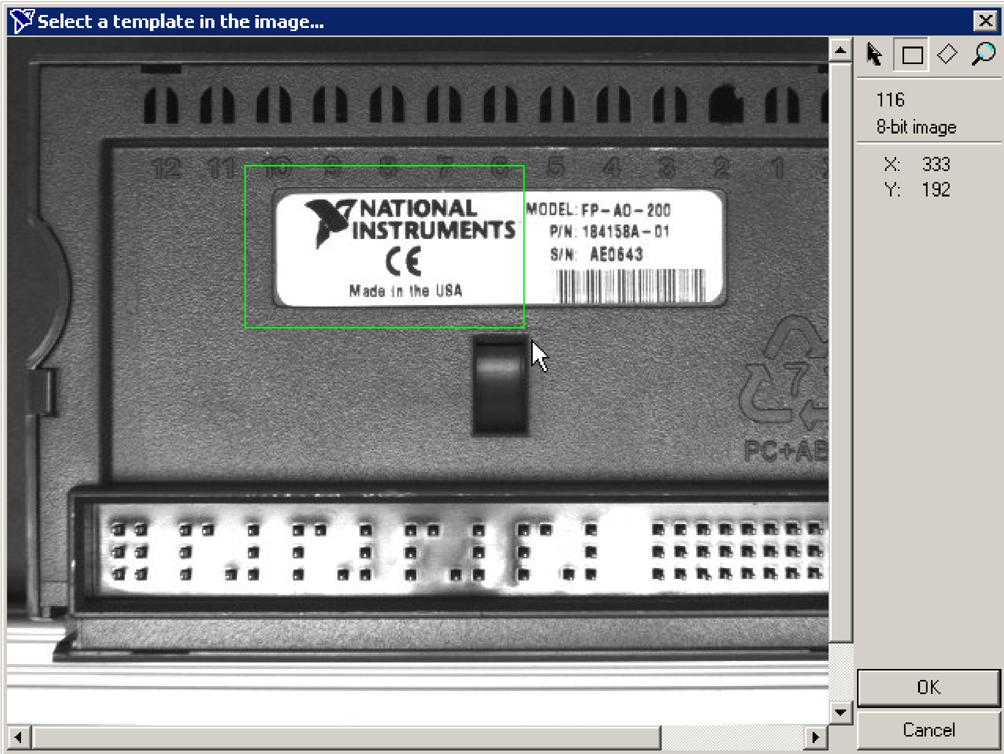


Figure 1-4. Creating a Template Pattern

4. Click **OK** to accept the template.

   Notice that Vision Builder AI locates the specified template in the green ROI. The location of the match is overlaid on the inspection image with a red rectangle.

5. In the **Main** tab, enter `Locate Label` in the **Step Name** control.

6. Redraw or decrease the default green ROI so that it surrounds only the portion of the device that contains the learned template, as shown in Figure 1-5.

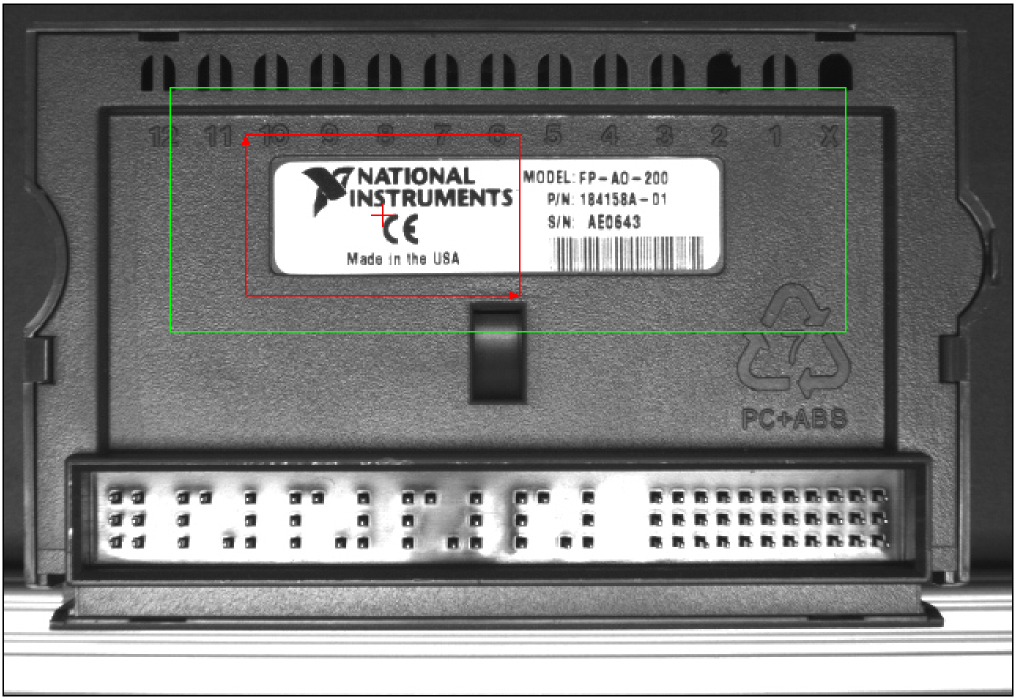


Figure 1-5. Limiting the Search Region

This ROI represents the area of the image in which Vision Builder AI searches for instances of the template.

7. In the **Settings** tab, set **Number of Matches to Find** to **1**.

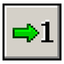
   Notice the **Minimum Score** control. By default, all instances of the template must have a *match score* of 800 or higher to be considered a valid match. **Minimum Score** can vary between 0 and 1,000. A match score of 1,000 indicates a perfect match.

8. In the **Limits** tab, enable the **Minimum Number of Matches** control, and set the value to **1**.

   Notice the **Matches** table contains two matches—a match that meets the requirements you set and the next best possible match. This feature helps you choose a minimum score high enough to discriminate correct parts from defective ones but not so high that the visual inspection cannot tolerate normal process variations.

Testing an Inspection Step

You can test a step before or after adding it to the inspection. Follow these instructions to test the **Locate Label** step to make sure the current step configuration returns the results you expect.



1. Click the **Run Once** button located in the **Inspection Diagram** window.

   Vision Builder AI loads the next image, `Image 02.jpg`, from the `Tutorial 1` folder and performs the **Locate Label** step on the image.

Note The name of the active image is displayed in the **Simulate Acquisition** module of the inspection diagram.

   Notice that the value of **Step Status** is **PASS**.

2. Test the other images in the `Tutorial 1` folder. Table 1-1 lists the test images, the step status to expect for each image, and an explanation of the status.

Table 1-1. Expected Results for the FieldPoint Label Inspection

Image Name	Inspection Status	Explanation
`Image 03.jpg`	PASS	The label is present.
`Image 04.jpg`	PASS	The label is present.
`Image 05.jpg`	FAIL	The label is missing.
`Image 06.jpg`	FAIL	The label is upside down.

Note If `Image 02.jpg`, `Image 03.jpg`, or `Image 04.jpg` do not pass inspection, slightly reduce the value of the **Minimum Score** control located in the **Settings** tab.

3. Click **OK** to add the step to the inspection.

Saving an Inspection

Follow these instructions to save the example inspection.

1. Select **File»Save**. An **Inspection Properties** dialog box opens.
2. In the **Inspection Name** control, enter `Lesson 1`.

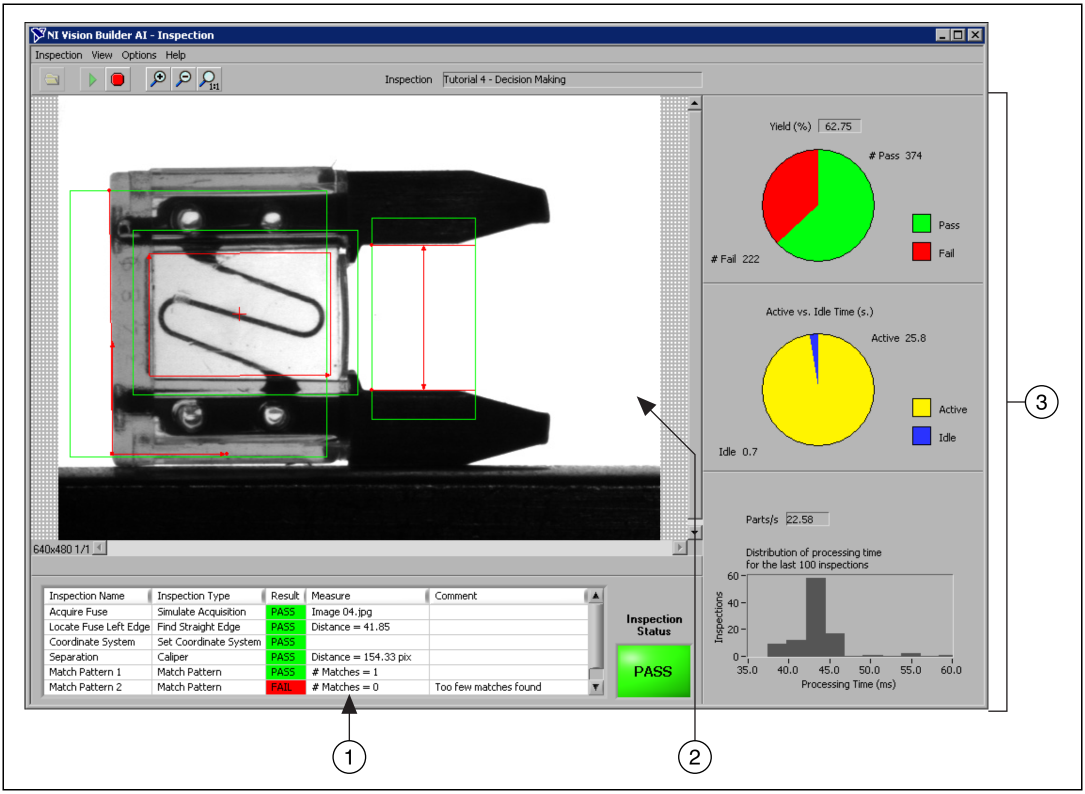
3. In the **Description** field, enter the following:

   ```
   This inspection checks for the proper application
   of a label on a FieldPoint module using pattern
   matching.
   ```

4. Click **Save** to save the inspection and its description.

Running an Inspection in the Inspection Interface

As mentioned in the *Opening the Vision Builder AI Configuration Interface* section, you deploy and run an inspection from the Vision Builder AI Inspection interface. Figure 1-6 shows the Inspection interface, which has three main areas: the **Results** panel, the **Inspection Statistics** panel, and the **Display** window.



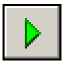
1	Results Panel	2	Display Window	3	Inspection Statistics Panel

Figure 1-6. Vision Builder AI Inspection Interface

- **Results panel**—Lists the steps in the inspection by name. For each inspection step, Vision Builder displays the step type, result (PASS or FAIL), measurement made, and a comment explaining the reason of a FAIL. **Inspection Status** shows the result of the complete inspection.
- **Display window**—Displays the part under inspection.
- **Inspection Statistics panel**—Contains three indicators that display the yield (ratio between PASS and FAIL), active versus idle time, and processing time of the inspection.

Follow these instructions to run the inspection from the Inspection interface.

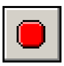
1. Select **File»Switch to Inspection Interface** to launch the Inspection interface. The steps of **Lesson 1** are listed in the **Results** panel.



2. Click the **Start Inspection** button. Vision Builder AI begins running the inspection on the simulation images and updating the three areas of the Inspection interface with the most recent inspection data.

   By default, Vision Builder AI displays all the inspection images in the **Display** window. You can change the display settings in the **View** menu to view only images that fail or to have no display. You also can change the magnification of the displayed images in the **Options** menu.

   Notice the performance data displayed in the **Inspection Statistics** panel. This data can help you determine how efficiently your inspection is running. Based on this data, you can make adjustments to improve the inspection speed.



3. Click the **Stop Inspection** button to stop the inspection.
4. Select **File»Switch to Configuration Interface** to return to the Configuration interface.

2 Checking for the Presence of a Part

This chapter introduces the **Measure Intensity** and **Set Coordinate System** steps. Follow the instructions in this chapter to create an inspection that checks for the presence of a spray bottle cap regardless of the bottle position in the inspection images.

Note Launch Vision Builder AI if it is not open. Refer to the *Opening the Vision Builder AI Configuration Interface* section of Chapter 1, *Getting Started in Vision Builder AI*, for more information.

Creating a New Inspection

Select **File»New**. Vision Builder AI loads a new, blank inspection into the **Inspection Diagram** window.

Simulating Image Acquisition

Follow these instructions to configure a **Simulate Acquisition** step that simulates acquiring images of spray bottles.

1. In the **Inspection Steps** palette, select the **Acquire Images** tab.
2. Click the **Simulate Acquisition** step. The property page for the step opens.
3. In the **Step Name** control, enter `Acquire Spray Bottle`.
4. Click the **Browse** button. The **Select an Image File** dialog box opens.
5. Navigate to `<Vision Builder AI>\DemoImg\Tutorial 2`.
6. Select the first image, `Image 01.jpg`, and click **Open**.
7. Make sure the **Cycle Through Folder Images** control is enabled so that Vision Builder AI loads a different simulation image from the folder each time the step is run.
8. Click **OK** to add this step to the inspection.

Defining a Feature on Which to Base a Coordinate System

In a machine vision inspection, you typically limit your inspection and processing to a region of interest (ROI) rather than the entire image for the following reasons:

- To improve your inspection results by avoiding extraneous objects
- To increase inspection speed

To limit the inspection area, the parts of the object you are interested in must always be inside the ROI you define.

If the object under inspection is fixtured and always appears at the same location and orientation in the images you need to process, defining an ROI is straightforward. However, if the object under inspection appears shifted or rotated within the images, the regions of interest need to shift and rotate with the object under inspection.

For the regions of interest to move in relation to the object, you need to set a *coordinate system* relative to a significant and original feature of the object under inspection. Choose a feature that is always in the *field of view* of the camera despite the different locations that the objects may appear in from image to image. Also, make sure the feature is not affected by major defects that could drastically modify the visual appearance of the feature.

Follow these instructions to configure a **Match Pattern** step that locates a bottle feature on which you can base a coordinate system.

1. In the **Inspection Steps** palette, select the **Locate Features** tab.
2. Click the **Match Pattern** step. The **Select a template in the image** dialog box opens.
3. Draw an ROI around the base of the sprayer, as shown in Figure 2-1. This region becomes the pattern matching template.

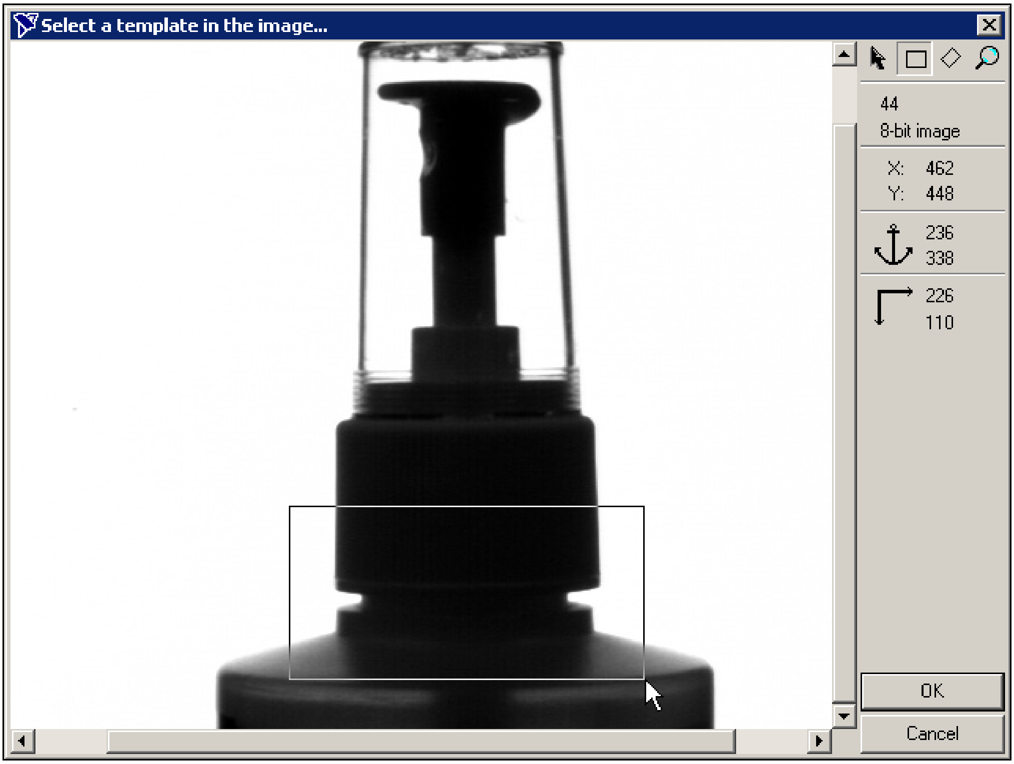


Figure 2-1. Creating a Template Pattern

4. Click **OK** to accept the template.
5. In the **Main** tab, enter `Locate Sprayer Base` in the **Step Name** control.

The green ROI specifies the area of the image in which Vision Builder AI tries to locate the template. Assuming that the bottles are fixtured in such a way that they can move only horizontally within the field of view, you can limit the ROI so that it surrounds only the area of the image that may contain a template match during inspection.

6. Redraw or decrease the default green ROI so that it surrounds only the lower portion of the image, as shown in Figure 2-2.

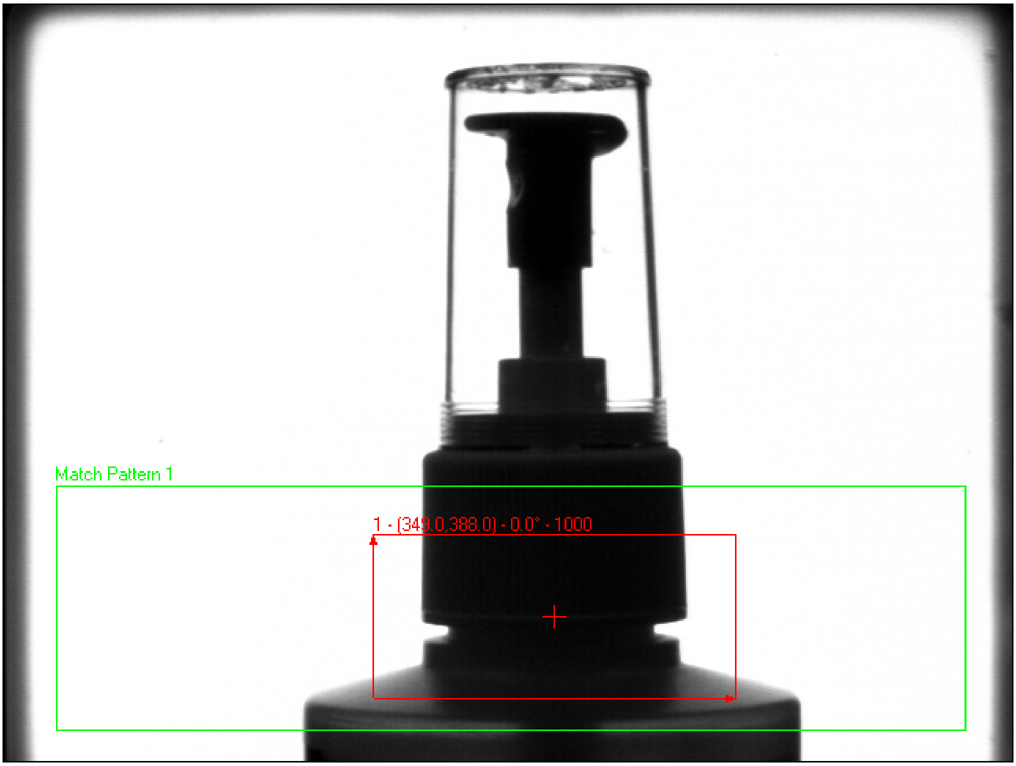
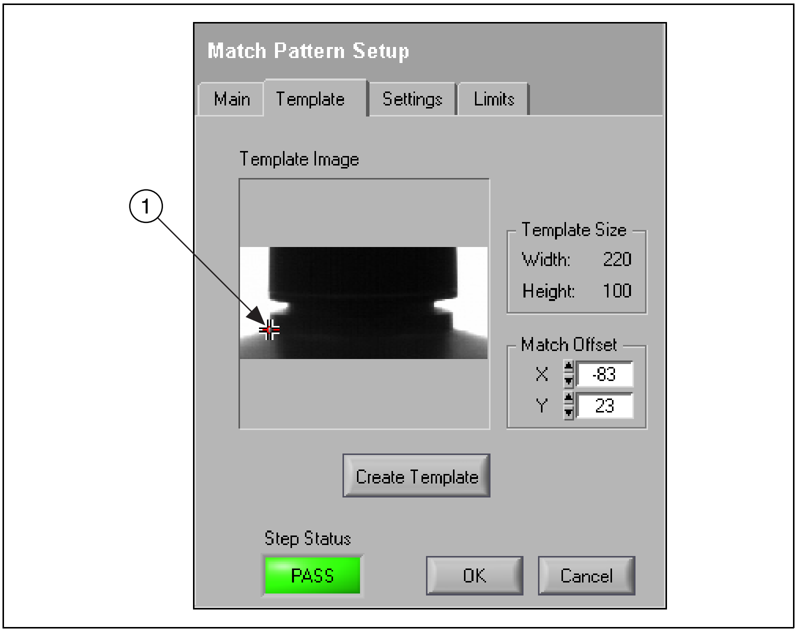


Figure 2-2. Limiting the Search Region

7. In the **Template** tab, drag the red crosshair mark in the template image to the left edge of the sprayer base, as shown in Figure 2-3. This changes the *focal point* of the template.

   The focal point indicates the part of the template that you want to return as the match location. By default, the focal point is the center of the template. You can modify the focal point by moving the red crosshair or by specifying a Match Offset. Later in this inspection, you use the match location as the origin of a coordinate system.



1 Focal Point

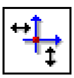
Figure 2-3. Adjusting the Focal Point of the Template

8. In the **Settings** tab, set **Number of Matches to Find** to **1**.
9. In the **Limits** tab, enable the **Minimum Number of Matches** control, and set the value to **1**.
10. Click **OK** to add the step to the inspection.

Setting a Coordinate System

Follow these instructions to configure a **Set Coordinate System** step based on the **Match Pattern** step you configured.

1. In the **Inspection Steps** palette, select the **Locate Features** tab.
2. Click the **Set Coordinate System** step.
3. In the **Main** tab, enter `Coordinate System` in the **Step Name** control.



4. In the **Settings** tab, select **Horizontal and Vertical Motion** from the **Mode** control because the bottles appear shifted but not rotated from one image to another.

Notice the **Origin** list. **Match 1**, the match location of the previous **Locate Sprayer Base** step, is the default origin of the coordinate system because it is the only location point created by previous steps in the inspection.

5. Click **OK** to add this step to the inspection.

Checking for the Cap Using Measure Intensity

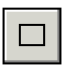
You can check for the presence of the cap by measuring the *pixel intensities* in the regions you expect the cap to be located. Follow these instructions to configure a **Measure Intensity** step that checks for the presence of a spray bottle cap.

1. In the **Inspection Steps** palette, select the **Check for Presence** tab.
2. Click the **Measure Intensity** step. The property page for the step opens.
3. In the **Main** tab, enter `Check Cap Presence` in the **Step Name** control.
4. Enable the **Reposition Region of Interest** control.

   Enabling this control allows you to link the regions of interest specified in this step to a previously defined coordinate system so that Vision Builder AI can adjust the location and orientation of the ROI from image to image relative to the specified coordinate system.

   The **Reference Coordinate System** list shows all the previously defined coordinate systems. **Coordinate System** is the default reference coordinate system because it is the only **Set Coordinate System** step in the current inspection.

Notice that the **Measure Intensity** step supports a variety of different tools that enable you to draw different shaped regions of interest, such as a point, line, broken line, freehand line, rectangle, ellipse, annulus, polygon, and freehand region. These tools are available in the main menu bar.



5. Using the default **Rectangle Tool**, hold down <Ctrl> to enable drawing multiple regions of interest, and draw three regions of interest that enclose edges of the cap, as shown in Figure 2-4.

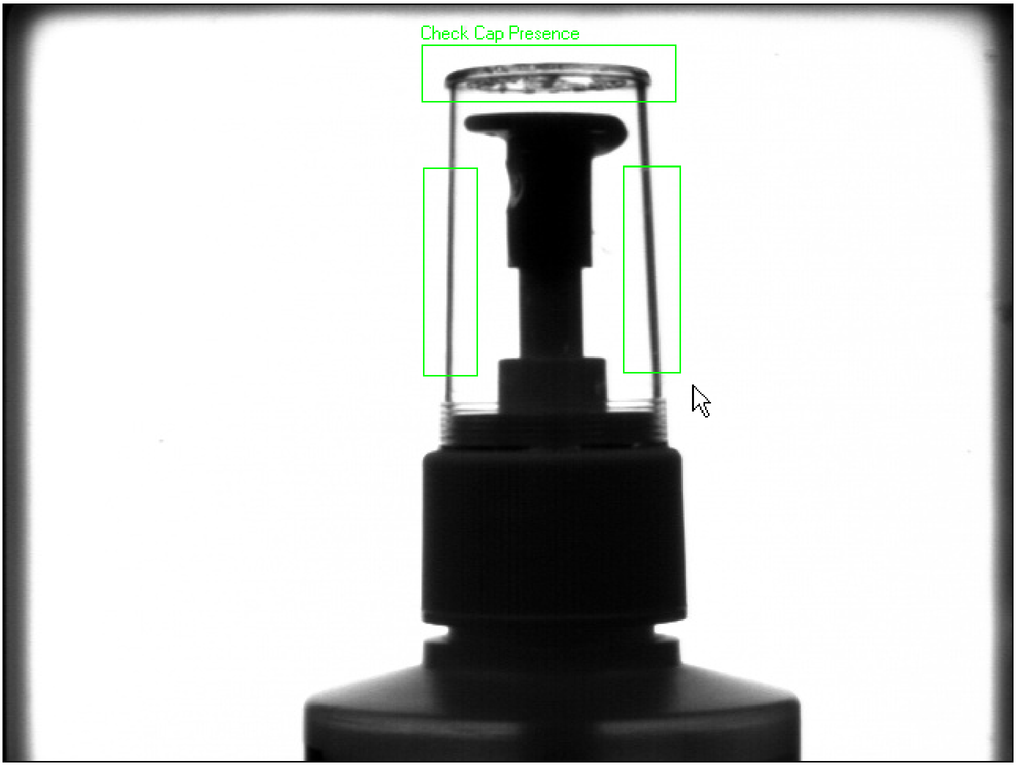


Figure 2-4. Defining Regions in Which to Measure Intensity

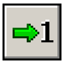
6. Select the **Limits** tab.

   At the bottom of the tabbed page, Vision Builder AI returns the intensity statistics of the pixels inside the regions of interest. Pixel intensities can range from 0–255, where 0 equals black and 255 equals white.

   The **Minimum Intensity** value at the bottom of the page returns the lowest pixel value inside the regions of interest. The backlit edges of the plastic cap appear in silhouette as dark pixels (which have low pixel intensities) on a bright background (which has high pixel intensities).

   Therefore, when the cap is present, the minimum intensity for the regions is low. When the cap is not present, the minimum intensity for the regions is high because the regions contain only bright background pixels.

7. Enable the **Minimum Intensity** control. Set the **Maximum** value to `50.00`.



8. Click the **Run Once** button located in the **Inspection Diagram** window.

   Vision Builder AI loads the next image, `Image 02.jpg`, from the `Spray Bottle` folder.

   Notice that the bottle appears closer to the left edge of the image. Vision Builder AI repositions the regions of interest based on the new location of the bottle. The **Step Status** for the image is PASS because the presence of the cap inside the regions of interest causes the **Minimum Intensity** value to fall within the limits you set.

9. Test the other images in the `Tutorial 2` folder. The following table lists the test images, inspection status to expect for each image, and an explanation of the status.

Table 2-1. Expected Results for the FieldPoint Label Inspection

Image Name	Inspection Status	Explanation
`Image 03.jpg`	PASS	The cap is present.
`Image 04.jpg`	PASS	The cap is present.
`Image 05.jpg`	FAIL	The cap is missing.

10. Click **OK** to add the step to the inspection.

Defining a Custom Overlay

By default, Vision Builder AI displays the last analyzed image at the end of each inspection. However, you can display an image including custom overlay elements at any point of the inspection using the **Display Image** step.

Follow these instructions to configure a **Display Image** step that specifies a custom overlay.

1. In the **Inspection Steps** palette, select the **Use Additional Tools** tab.
2. Click the **Display Image** step. The property page for the step opens.
3. Enter `Display Image` in the **Step Name** control.
4. Click **Edit Custom Overlay**. The Setup Custom Overlay property page opens.
5. Click **Add Text**.

6. In the **Text** control, type `Minimum Cap Intensity =`.
7. Click **Insert Data**.
8. In the **Inspection Data** tree, expand **Steps Data»Check Cap Presence**.
9. Select **Minimum Intensity**, and click **OK**.
10. Click **OK** in the **Overlay Text** dialog box to validate the text to display.
11. Click **Add Boolean**. The **Overlay Boolean Indicator** dialog box opens.
12. In the **Inspection Data** tree, expand **Inspection Information** and select **Inspection Status**.
13. Type `PASS` in the **True Case String** control.
14. Type `FAIL` in the **False Case String** control.
15. Set the **Indicator Position Y** control to **45**.
16. Click **OK** to validate the overlay of the Boolean indicator.
17. Click **OK** in the **Setup Custom Overlay** dialog box to validate the overlay.
18. Click **OK** to add the **Display Image** step to the inspection.

Saving the Inspection

Save the example inspection with the following name and description.

- **Inspection Name**—`Lesson 2`
- **Description**—`This inspection checks for the presence of a cap on a spray bottle using an intensity measurement and a coordinate system that is based on pattern matching.`

Refer to the *Saving an Inspection* section of Chapter 1, *Getting Started in Vision Builder AI*, for more information.

3

Inspecting Objects for Correct Measurements

This chapter introduces the **Calibrate Image**, **Detect Objects**, and **Geometry** steps. Follow the instructions in this chapter to create an inspection that measures the distance between holes in a gasket to verify that the gasket conforms to manufacturing specifications.

Note Launch Vision Builder AI if it is not open. Refer to the *Opening the Vision Builder AI Configuration Interface* section of Chapter 1, *Getting Started in Vision Builder AI*, for more information.

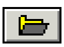
Creating a New Inspection

Select **File»New**. Vision Builder AI loads a new, blank inspection into the **Inspection Diagram** window.

Simulating Image Acquisition

Follow these instructions to configure a **Simulate Acquisition** step that simulates acquiring images of gaskets.

1. In the **Inspection Steps** palette, select the **Acquire Images** tab.
2. Click the **Simulate Acquisition** step. The property page for the step opens.
3. In the **Step Name** control, enter Acquire Gasket.



4. Click the **Browse** button. The **Select an Image File** dialog box opens.
5. Navigate to <Vision Builder AI>\DemoImg\Tutorial 3.
6. Select the first image, Image 01.jpg, and click **Open**.
7. Make sure the **Cycle Through Folder Images** control is enabled so that Vision Builder AI loads a different simulation image from the folder each time the step is run.
8. Click **OK** to add the step to the inspection.

Calibrating Images

By default, Vision Builder AI returns measurements in pixel units. If you want the inspection to return measurements in real-world units, you need to map pixel units to real-world units through a process called *spatial calibration*.

Follow these instructions to configure a **Calibrate Image** step that defines the type of calibration, the calibration parameters, and the real-world unit in which you want to express measurements.

1. In the **Inspection Steps** palette, select the **Enhance Images** tab.
2. Click the **Calibrate Image** step.
3. In the **Step Name** control, enter `Calibrate Gasket`.
4. Click **New Calibration** to launch the calibration wizard.

For this example, assume that the camera that acquired the inspection images is perpendicular to the image plane and lens distortion is negligible. Based on these assumptions, you can use **Simple Calibration** to calibrate your images. **Simple Calibration** transforms a pixel coordinate to a real-world coordinate through scaling in the x (horizontal) and y (vertical) directions.

5. Double-click **Simple Calibration** to open the **Simple Calibration Setup** dialog box.
6. In **Step 1 of 3**, make sure **Pixel Type** is set to **Square** because the camera that acquired the images for this exercise has square pixels.
7. Click **Next**.
8. In **Step 2 of 3**, carefully click the 0 mm and 50 mm markings on the ruler in the image, as shown in Figure 3-1.

Tip You may need to scroll down to see the ruler at the bottom of the image.

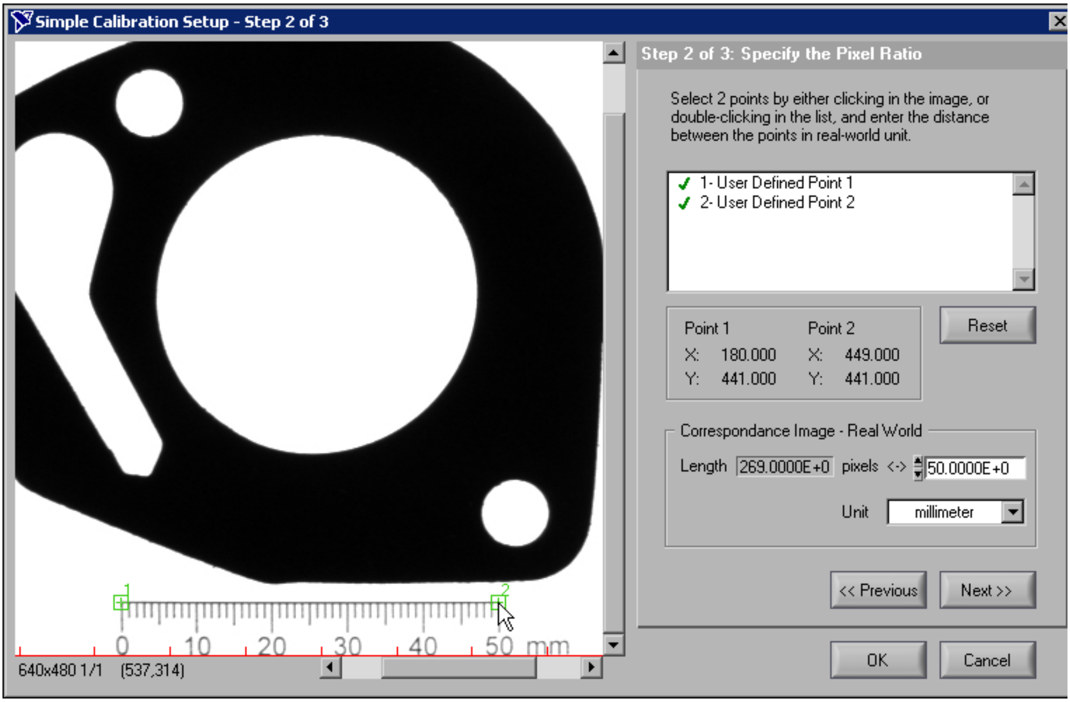


Figure 3-1. Specifying the Pixel Ratio

9. In the **Correspondence Image - Real World** control, enter `50` for the value, and select **millimeter** for the **Unit**.
10. Click **Next**.

In **Step 3 of 3**, you can define the origin and angle of the calibration axis anywhere in the image. By default, the bottom, left pixel in the image is the calibration axis origin, and the horizontal axis of the image is the calibration axis angle. Use the default calibration axis settings for this exercise.

Tip In some applications, you may want to measure between a fixed reference feature on the part and other features in the image. Setting the origin of the calibration axis to the location of the reference feature simplifies making measurements because the starting point for the measurements becomes 0.

11. Click **OK** to learn the calibration information and exit the calibration wizard.

    The **Calibration** and **Axis** tabs display information about the learned calibration.

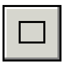
12. Click **OK** to add the step to the inspection.

Tip You can save the calibration information you set up in the wizard so that you can use the information later to calibrate images in another inspection. To save the calibration information, enable the **Save Calibrated Image to File** control, and specify a file path to which you want to save the calibrated image. When you click **OK** to add the step to the inspection, Vision Builder AI saves the calibrated file.

Locating Features to Measure

Follow these instructions to configure a **Detect Objects** step that finds small holes in the gasket.

1. In the **Inspection Steps** palette, select the **Check for Presence** tab.
2. Click the **Detect Objects** step. The property page for the step opens.
3. In the **Step Name** control, enter `Detect Small Holes`.



4. Using the default **Rectangle Tool**, draw a region of interest (ROI) around the entire gasket, as shown in Figure 3-2.

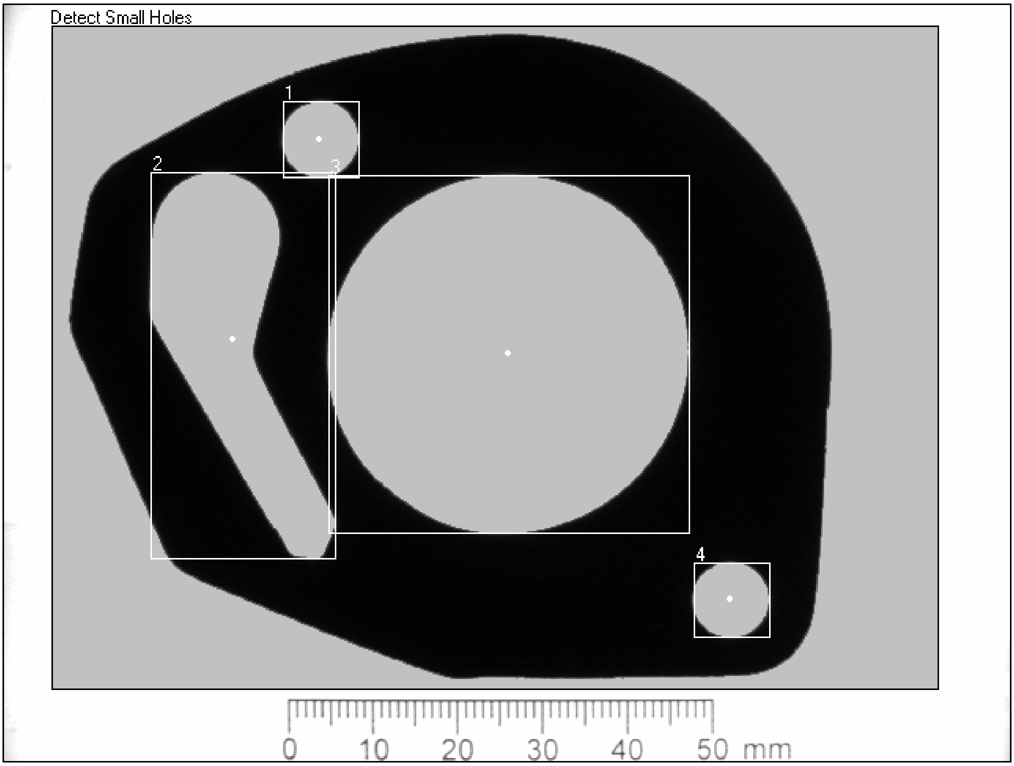


Figure 3-2. Defining the ROI

5. In the **Threshold** tab, select the **Bright Objects** control.

   Notice that the blue shading highlights all bright pixels—pixels with high intensity values that fall within the **Threshold Range**—in the ROI. Vision Builder AI groups contiguous highlighted pixels into *objects*, which are depicted by red bounding rectangles.

6. Click the **Settings** tab.

   The step locates four objects, which are listed in Table 3-1.

Table 3-1. Sizes of Gasket Holes

Object Number	Size (pix^2)	Size (mm^2)
1	1,807	62.43
2	13,351	461.26
3	40,816	1,410.15
4	1,780	61.50

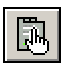
Object 1 and **Object 4** are the small holes of interest in this step. Use the **Minimum Object Size** and **Maximum Object Size** controls of the **Detect Objects** step to eliminate objects of no interest based on their size.

7. Enable the **Minimum Object Size** and **Maximum Object Size** controls.

   Based on the information in Table 3-1, the small holes have sizes of 62.43 mm^2 and 61.50 mm^2.
8. Set **Minimum Object Size** to `50` and **Maximum Object Size** to `70`.
9. In the **Limits** tab, enable the **Minimum Number of Objects** and **Maximum Number of Objects** controls. Set their values to `2`.
10. Click **OK** to add this step to the inspection.

Follow these instructions to find the large hole in the gasket.

1. Right-click the **Detect Small Holes** step in the **Inspection Diagram** window. A shortcut menu opens.
2. Select **Copy**.
3. Right-click the **Detect Small Holes** step again.
4. Select **Paste**. A copy of the **Detect Small Holes** step is placed after the original step.



5. Double-click the **Detect Small Holes** copy or click the **Edit Step** button to launch the property page of the step for editing.
6. In the **Step Name** control, enter `Detect Large Hole`.
7. Select the **Settings** tab.

   Based on the information in Table 3-1, the large hole has a size of 1410 mm^2.
8. Set **Minimum Object Size** to `1300` and **Maximum Object Size** to `1450`.

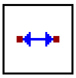
9. In the **Limits** tab, enable the **Minimum Number of Objects** and **Maximum Number of Objects** controls. Set their values to `1`.
10. Click **OK** to update the inspection.

Note Vision Builder AI returns the centers of mass for the holes as their locations.

Measuring Parts of the Gasket

Follow these instructions to measure the distance from the top small hole to the large hole to inspect whether the distance meets specifications.

1. In the **Inspection Steps** palette, select the **Measure Features** tab.
2. Click the **Geometry** step. The property page for the step opens.
3. In the **Step Name** control, enter `Top Distance`.



4. In the **Geometric Feature** control, select the **Distance** measurement.
5. Select points **1** and **3** by clicking the points in the image or selecting the points from the **Available Points** list.
6. In the **Limits** tab, enable the **Minimum Distance** control and set it to `32`. Enable the **Maximum Distance** control and set it to `35`.
7. Click **OK** to add the step to the inspection.

Follow these instructions to measure the distance from the large hole to the bottom small hole to inspect whether the distance meets specifications.

1. In the **Inspection Steps** palette, select the **Measure Features** tab.
2. Click the **Geometry** step. The property page for the step opens.
3. In the **Step Name** control, enter `Bottom Distance`.
4. In the **Geometric Feature** control, select the **Distance** measurement.
5. From the **Available Points** list, select **2** and **3**, which correspond to the bottom small hole and large hole, respectively.
6. In the **Limits** tab, enable the **Minimum Distance** control and set it to `38`. Enable the **Maximum Distance** control and set it to `40`.
7. Click **OK** to add the step to the inspection.

Testing the Inspection

Test the inspection to make sure it returns the results you expect. The following table lists the test images, the inspection status to expect for each image, and an explanation of the status.

Table 3-2. Expected Results for the Gasket Inspection

Image Name	Inspection Status	Explanation
`Image 01.jpg`	PASS	All steps passed.
`Image 02.jpg`	PASS	All steps passed.
`Image 03.jpg`	PASS	All steps passed.
`Image 04.jpg`	FAIL	The **Top Distance** step failed because the distance between the holes is too small.
`Image 05.jpg`	FAIL	The **Detect Small Holes** step failed because the bottom hole is missing. The missing hole also caused the **Bottom Distance** step to fail.

Refer to the *Testing an Inspection Step* in Chapter 1, *Getting Started in Vision Builder AI*, for more information.

Saving the Inspection

Save the example inspection with the following name and description:

- **Inspection Name**—`Lesson 3`
- **Description**—`This inspection locates holes in a gasket and measures the distance between the holes.`

Refer to the *Saving an Inspection* section of Chapter 1, *Getting Started in Vision Builder AI*, for more information.

4

Inspecting for Multiple Correct Instances of an Object

This chapter introduces the **Find Straight Edge**, **Caliper**, and **Decision Making** steps. Follow the instructions in this chapter to create an inspection that measures the distance between the blade connectors of a fuse and checks the integrity of the fuse conductor regardless of the fuse position or whether the fuse is inverted.

Note Launch Vision Builder AI if it is not open. Refer to the *Opening the Vision Builder AI Configuration Interface* section of Chapter 1, *Getting Started in Vision Builder AI*, for more information.

Creating a New Inspection

Select **File»New**. Vision Builder AI loads a new, blank inspection into the **Inspection Diagram** window.

Simulating Image Acquisition

Follow these instructions to configure a **Simulate Acquisition** step that simulates acquiring images of fuses.

1. In the **Inspection Steps** palette, select the **Acquire Images** tab.
2. Click the **Simulate Acquisition** step. The property page for the step opens.
3. In the **Step Name** control, enter `Acquire Fuse`.

4. Click the **Browse** button. The **Select an Image File** dialog box opens.
5. Navigate to `<Vision Builder AI>\DemoImg\Tutorial 4`.
6. Select the first image, `Image 01.jpg`, and click **Open**.
7. Make sure the **Cycle Through Folder Images** control is enabled so that Vision Builder AI loads a different simulation image from the folder each time the step is run.
8. Click **OK** to add the step to the inspection.

Defining a Feature on Which to Base a Coordinate System

The fuses can appear shifted horizontally and slightly rotated from one inspection image to another. Follow these instructions to configure a **Find Straight Edge** step that finds the left edge of the fuse so that regions of interest in subsequent steps can shift with the fuse.

1. In the **Inspection Steps** palette, select the **Locate Features** tab.
2. Click the **Find Straight Edge** step. The property page for the step opens.
3. In the **Step Name** control, enter `Locate Fuse Left Edge`.
4. Draw a region of interest (ROI) across the left edge of the fuse, as shown in Figure 4-1.

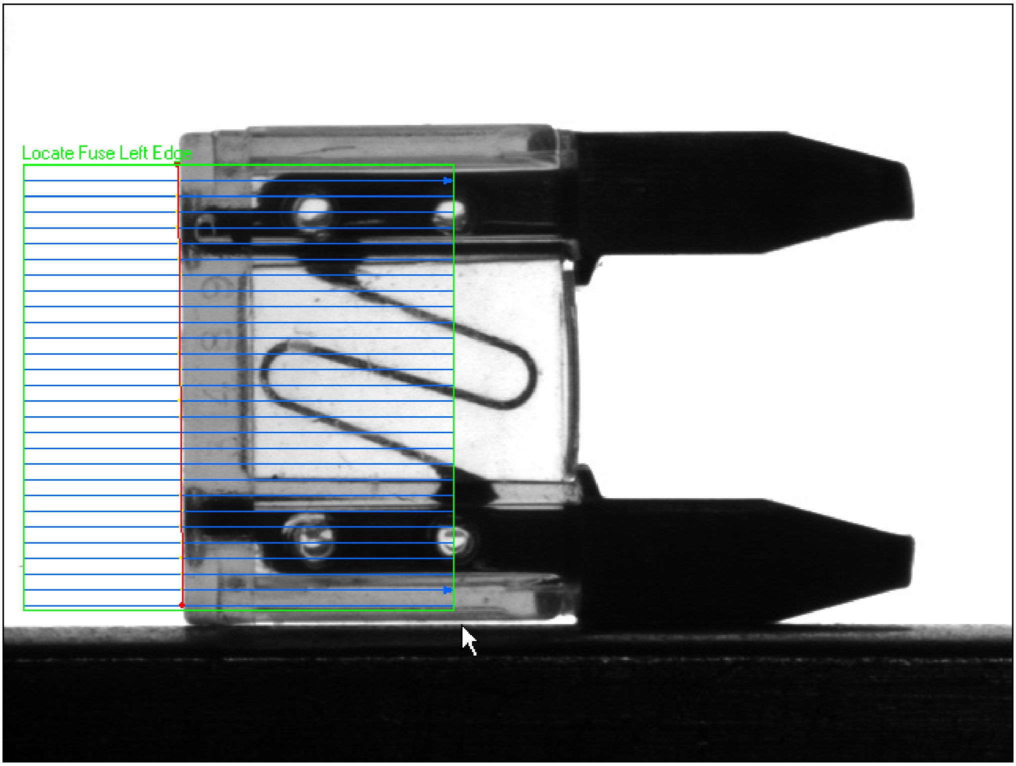


Figure 4-1. Finding a Straight Edge

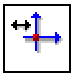
Notice that the ROI contains blue search lines. The step searches along the search lines for sharp transitions in pixel intensities, which usually represent object edges. The step fits a straight line through the individual detected edge points of each search line to determine the left edge of the fuse.

5. Click **OK** to add this step to the inspection.

Setting a Coordinate System

Follow these instructions to configure a **Set Coordinate System** step based on the **Find Straight Edge** step you configured.

1. In the **Inspection Steps** palette, select the **Locate Features** tab.
2. Click the **Set Coordinate System** step. The property page for the step opens.
3. In the **Main** tab, enter `Coordinate System` in the **Step Name** control.



4. In the **Settings** tab, select **Horizontal Motion** from the **Mode** control.

Notice the **Origin** list. **Point 1**, the first point of the straight line detected by the **Locate Fuse Left Edge** step, is the default origin of the coordinate system. In this exercise, the location of the origin does not affect the measurement you need to make. Therefore, use the default origin.

5. Click **OK** to add this step to the inspection.

Measuring the Separation between Connectors

Follow these instructions to configure a **Caliper** step that measures the distance between the blade connectors of the fuse.

1. In the **Inspection Steps** palette, select the **Measure Features** tab.
2. Select the **Caliper** step. The property page for the step opens.
3. In the **Main** tab, enter `Separation` in the **Step Name** control.
4. Enable the **Reposition Region of Interest** control.
5. Draw an ROI across the blade connectors, as shown in Figure 4-2.

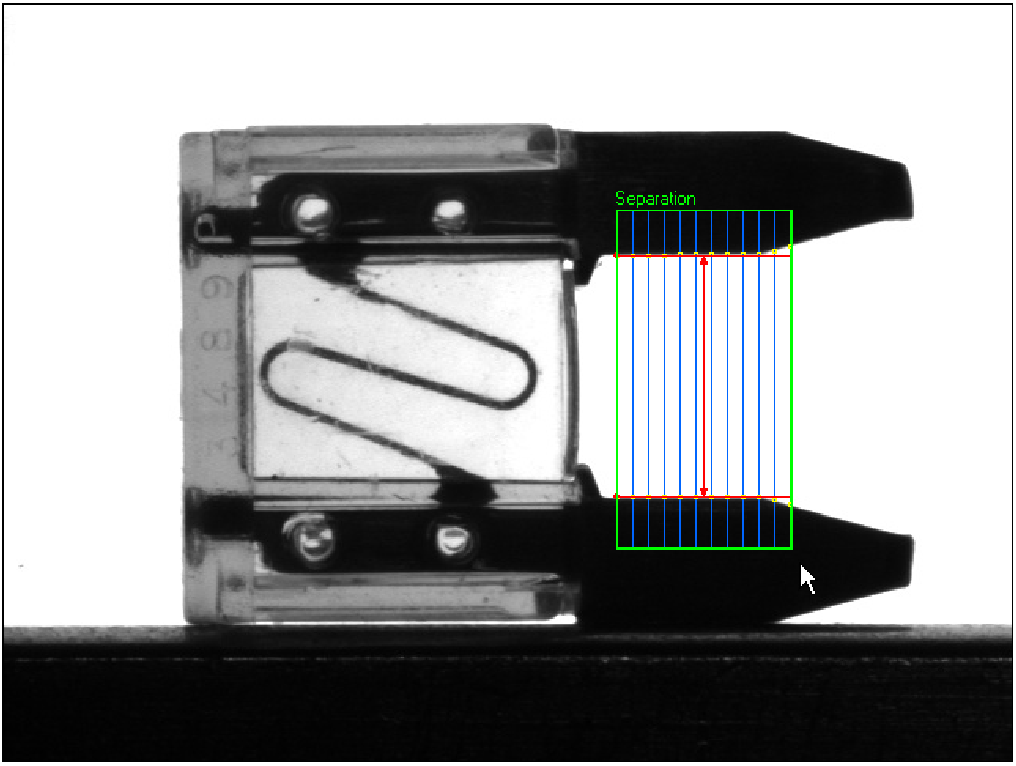
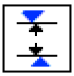


Figure 4-2. Measuring the Distance Between Two Edges



6. In the **Settings** tab, select the **Process** named **Vertical Min Caliper** to change the direction and orientation of the caliper search lines.
7. In the **Limits** tab, enable the **Minimum Distance (Pixels)** control and set the value to `150`. Enable the **Maximum Distance (Pixels)** control and set the value to `160`.
8. Click **OK** to add this step to the inspection.

Inspecting the Fuse Conductor

Follow these instructions to configure **Match Pattern** steps that inspect the integrity of the fuse conductor.

1. In the **Inspection Steps** palette, select the **Locate Features** tab.
2. Click the **Match Pattern** step. The **Select a template in the image** dialog box opens.

3. Draw an ROI around the conductor, as shown in Figure 4-3. This region becomes the pattern matching template.

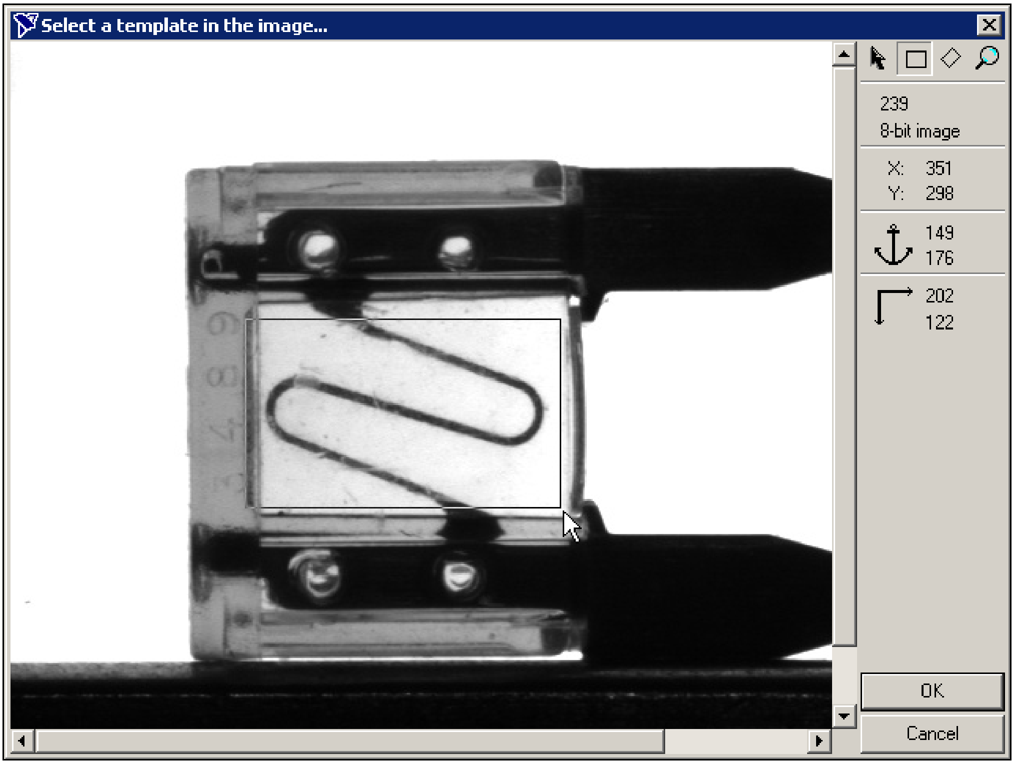


Figure 4-3. Creating a Template Pattern

4. Click **OK** to accept the template.
5. In the **Main** tab, enter `Match Conductor 1` in the **Step Name** control.
6. Make sure the **Reposition Region of Interest** control is enabled.
7. Redraw or decrease the default green ROI so that it surrounds an area slightly larger than the template, as shown in Figure 4-4.

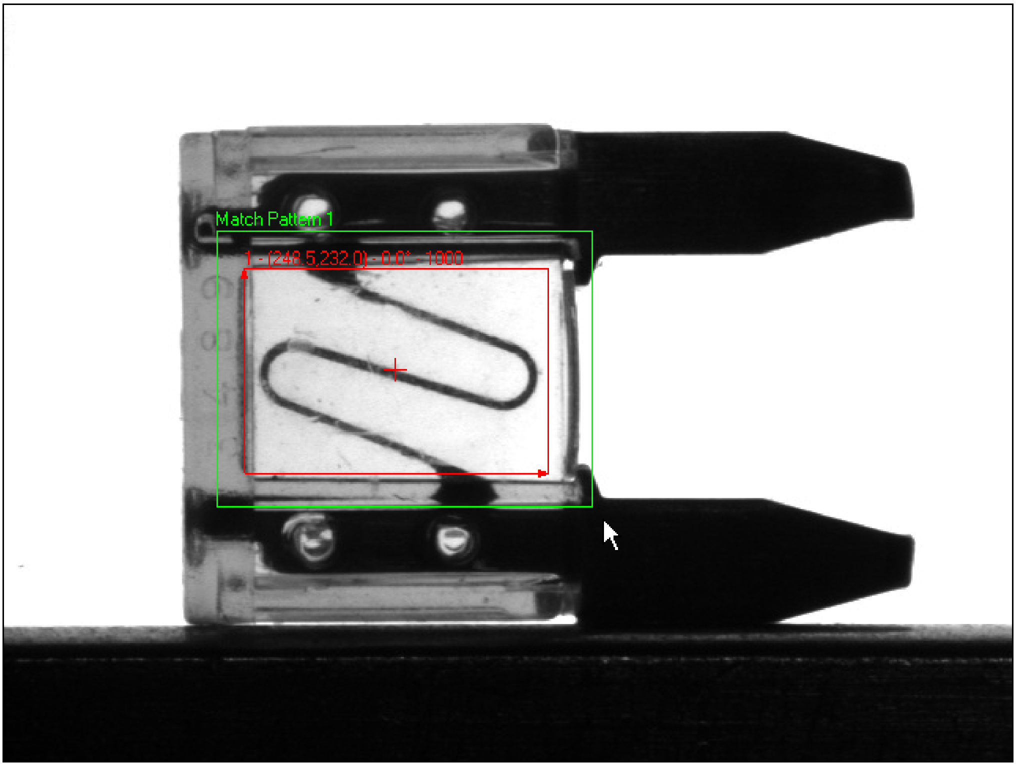
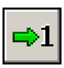


Figure 4-4. Limiting the Search Region

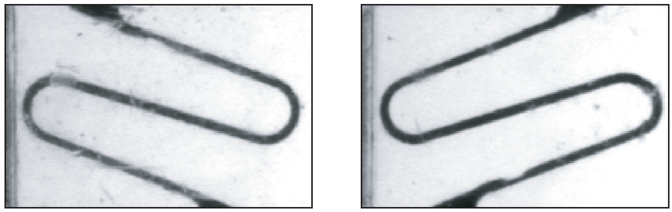
8. In the **Settings** tab, set **Number of Matches to Find** to **1**.
9. Enable the **Search for Rotated Patterns** control.
10. Set the **Angle Range +/– (degrees)** control to `10` to enable the step to locate the best match possible within ±10° of the learned template angle.
11. In the **Limits** tab, enable the **Minimum Number of Matches** control and set the value to **1**.
12. Click **OK** to add the step to the inspection.



13. Click the **Run Once** button *twice* so that `Image 03.jpg` becomes the active image.

Note The name of the active image is displayed in the **Simulate Acquisition** module of the inspection diagram.

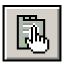
A fuse may be inverted when Vision Builder AI acquires an image of the fuse. This inversion causes the conductor to look different than the template, shown in Figure 4-5a. To prevent a good but inverted fuse from failing inspection, you need to learn a pattern matching template for the inverted instances of the conductor as well, shown in Figure 4-5b.



a. b.

Figure 4-5. Valid Templates for the Conductor

14. Copy and paste the **Match Conductor 1** step.



15. Double-click the copy or click the **Edit Step** button to launch the step property page for editing.
16. In the **Main** tab, enter `Match Conductor 2` in the **Step Name** control.
17. In the **Template** tab, click **Create Template**. A dialog box opens.
18. Draw an ROI around the conductor, similar to the region you drew in step 3.
19. Click **OK** to learn the inverted template.
20. Click **OK** to update the inspection.

Making Logical PASS/FAIL Decisions

Test the inspection using all of the images in the `Tutorial 4` folder. Notice that all of the images fail inspection. The images fail inspection because the **Match Conductor 1** and/or **Match Conductor 2** steps fail, or because the **Separation** step fails.

By default, the **Inspection Status** is the logical AND of the **Step Status** of all the steps in the inspection. Because the conductor under inspection can match only one of the patterns you specified, one of the **Match Pattern** steps always fails, causing the entire inspection to fail.

Using the **Decision Making** step, you can create a Boolean result that is based on the results of the previous inspection steps. Vision Builder AI takes this Boolean result into account when determining the **Inspection Status**.

Follow these instructions to configure a **Decision Making** step that causes the inspection to pass when the conductor matches either the template in **Match Conductor 1** or **Match Conductor 2**, and when the **Separation** step passes.

1. In the **Inspection Steps** palette, select the **Use Additional Tools** tab.
2. Click the **Decision Making** step. The property page opens in the **Main** window.
3. Enter `Decision Making` in the **Step Name** control.
4. In the **First Operand** frame, set **Step** to **Separation**. Set **Measure** to **Step Status**.

   Current Value displays the value of the measurement based on the current image.
5. Make sure **Second Operand** is set to **Constant**, and **Constant** is set to **True**.
6. Click **Add** to add this expression to the **Decision** table.
7. In the **First Operand** frame, set **Step** to **Match Conductor 1**. Set **Measure** to **Step Status**.
8. Make sure **Second Operand** is set to **Constant**, and **Constant** is set to **True**.
9. Click **Add** to add this expression to the **Decision** table.

   Notice the default binary operator **AND** in the last column of the **Decision** table.
10. In the **First Operand** frame, set **Step** to **Match Conductor 2**. Set **Measure** to **Step Status**.
11. Make sure **Second Operand** is set to **Constant** and **Constant** is set to **True**.
12. In the **Decision** table, click **Add** to add this expression to the **Decision** table.
13. Select the second expression, and click **AND/OR** to change the binary operator to **OR**.
14. Hold down <Shift>, and select the second and third expressions in the **Decision** table.
15. Click **()** to group the expressions.

The **Decision Making** property page should look like Figure 4-6.

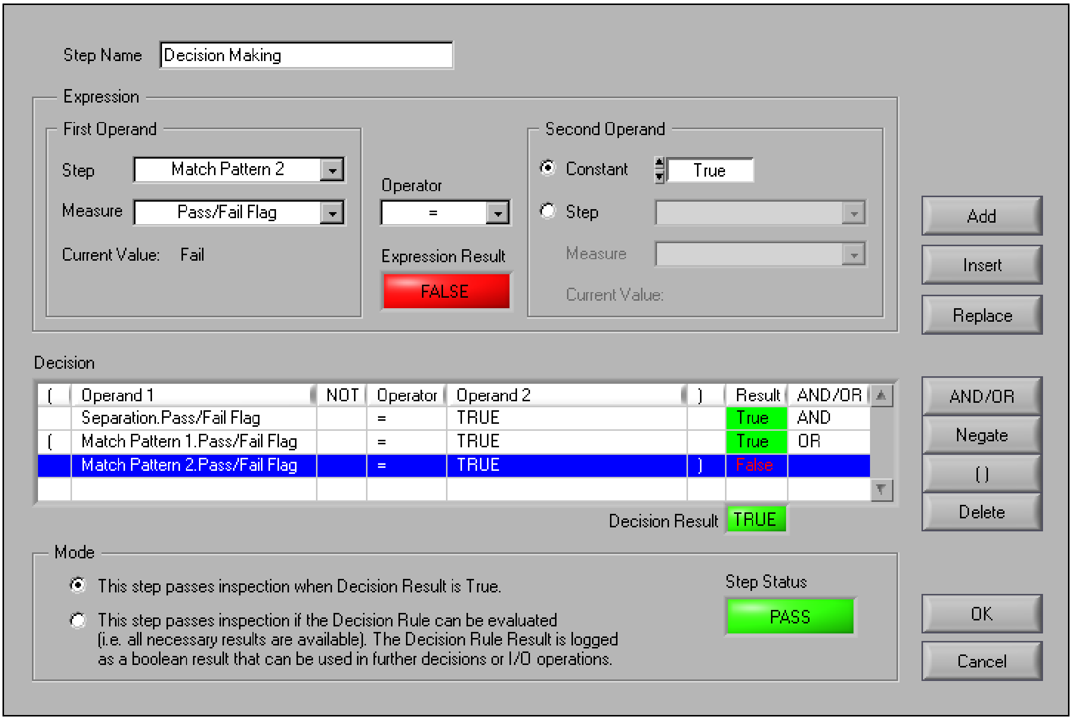


Figure 4-6. Decision Making Property Page

16. Click **OK** to add the step to the inspection.

Setting Global Decision Making Properties

Follow these instructions to configure Vision Builder AI to pass the inspection when the **Decision Making** step passes, regardless of the results of individual steps in the inspection.

1. Select **Tools»Configure Global Decision Making**. The **Global Decision Making Setup** dialog box opens.
2. Select **Inspection equals specified Decision Making Step result**. **Decision Making** is the only **Decision Making Step** in the inspection and, therefore, is the default **Decision Making Step**.
3. Click **OK**.

Testing the Inspection

Test the inspection to make sure it returns the results you expect. Table 4-1 lists the test images, the inspection status to expect for each image, and an explanation of the status.

Table 4-1. Expected Results for the Gasket Inspection

Image Name	Inspection Status	Explanation
`Image 01.jpg`	PASS	All steps pass but one **Match Pattern** step.
`Image 02.jpg`	PASS	All steps pass but one **Match Pattern** step.
`Image 03.jpg`	PASS	All steps pass but one **Match Pattern** step.
`Image 04.jpg`	PASS	All steps pass but one **Match Pattern** step.
`Image 05.jpg`	PASS	All steps pass but one **Match Pattern** step.
`Image 06.jpg`	FAIL	The **Separation** step fails because the blade connectors are too close together.
`Image 07.jpg`	FAIL	Both **Match Pattern** steps fail because the conductor is blown.
`Image 08.jpg`	FAIL	Both **Match Pattern** steps fail because the conductor is melted.

Saving the Inspection

Save the example inspection with the following name and description:

- **Inspection Name**—`Lesson 4`
- **Description**—`This inspection measures the distance separating the arms of a fuse and checks the integrity of the fuse filament.`

Refer to the *Saving an Inspection* section of Chapter 1, *Getting Started in Vision Builder AI*, for more information.

5

Inspecting an Object that Spans Two Image Frames

This chapter introduces the **Select Image** and **Calculator** steps.

Assume that you need to measure the width of a wide wooden plank with high accuracy. The only cameras available for the application have low pixel resolutions.

To measure the width of a plank, you need to locate its left and right edges. If you were to set up the imaging system so both edges of a plank fit within an available camera's field of view, the resulting image detail would be too low to yield accurate measurements. Because the required image detail exceeds the pixel resolution capability of a single camera, two cameras per plank are needed—one camera to acquire an image of the left edge and one camera to acquire an image of the right edge.

Follow the instructions in this chapter to create an inspection that measures the width of a wooden plank that spans two images.

Note Launch Vision Builder AI if it is not open. Refer to the *Opening the Vision Builder AI Configuration Interface* section of Chapter 1, *Getting Started in Vision Builder AI*, for more information.

Creating a New Inspection

Select **File»New**. Vision Builder AI loads a new, blank inspection into the **Inspection Diagram** window.

Simulating Image Acquisitions from Two Cameras

Follow these instructions to configure **Simulate Acquisition** steps that simulate acquiring images of the left and right sections of wooden plank.

1. In the **Inspection Steps** palette, select the **Acquire Images** tab.
2. Click the **Simulate Acquisition** step. The property page for the step opens.

3. In the **Step Name** control, enter `Acquire Part (Left)`.

4. Click the **Browse** button. The **Select an Image File** dialog box opens.
5. Navigate to `<Vision Builder AI>\DemoImg\Tutorial 5 Left`.
6. Select the first image, `Image 01.jpg`, and click **Open**.
7. Make sure the **Cycle Through Folder Images** control is enabled so that Vision Builder AI loads a different simulation image from the folder each time the step is run.
8. Click **OK** to add the step to the inspection.

Notice that `Image 01.jpg` contains a section of a ruler. Later in this lesson, you use the ruler to calculate the real-world width of the part across two images.

9. Click the **Simulate Acquisition** step again.
10. In the **Step Name** control, enter `Acquire Part (Right)`.
11. Click the **Browse** button. The **Select an Image File** dialog box opens.
12. Navigate to `<Vision Builder AI>\DemoImg\Tutorial 5 Right`.
13. Select the first image, `Image 01.jpg`, and click **Open**.
14. Make sure the **Cycle Through Folder Images** control is enabled so that Vision Builder AI loads a different simulation image from the folder each time the step is run.
15. Click **OK** to add the step to the inspection.

Calibrating the Image of the Right Edge

Follow these instructions to configure a **Calibrate Image** step that defines the type of calibration, the calibration parameters, and the real-world unit in which you want to express measurements.

1. In the **Inspection Steps** palette, select the **Enhance Images** tab.
2. Click the **Calibrate Image** step.
3. In the **Step Name** control, enter `Calibrate Part (Right)`.
4. Click **New Calibration** to launch the calibration wizard.

For this example, assume that the camera that acquired the inspection images is perpendicular to the image plane and lens distortion is negligible. Based on these assumptions, you can use **Simple Calibration** to calibrate your images. **Simple Calibration** transforms a pixel coordinate to a real-world coordinate through scaling in the x (horizontal) and y (vertical) directions.

5. Double-click **Simple Calibration** to open the **Simple Calibration Setup** dialog box.
6. In **Step 1 of 3**, make sure **Pixel Type** is set to **Square** because the camera that acquired the images for this exercise has square pixels.
7. Click **Next**.
8. In **Step 2 of 3**, carefully click the 38 cm and 42 cm markings on the ruler in the image, as shown in Figure 5-1.

Tip You may need to scroll down to see the ruler at the bottom of the image. You may also need to zoom in on the image in order to click more accurately on the markings.

9. In the **Correspondence Image - Real World** control, enter 4 for the value, and select **centimeter** for the **Unit**.

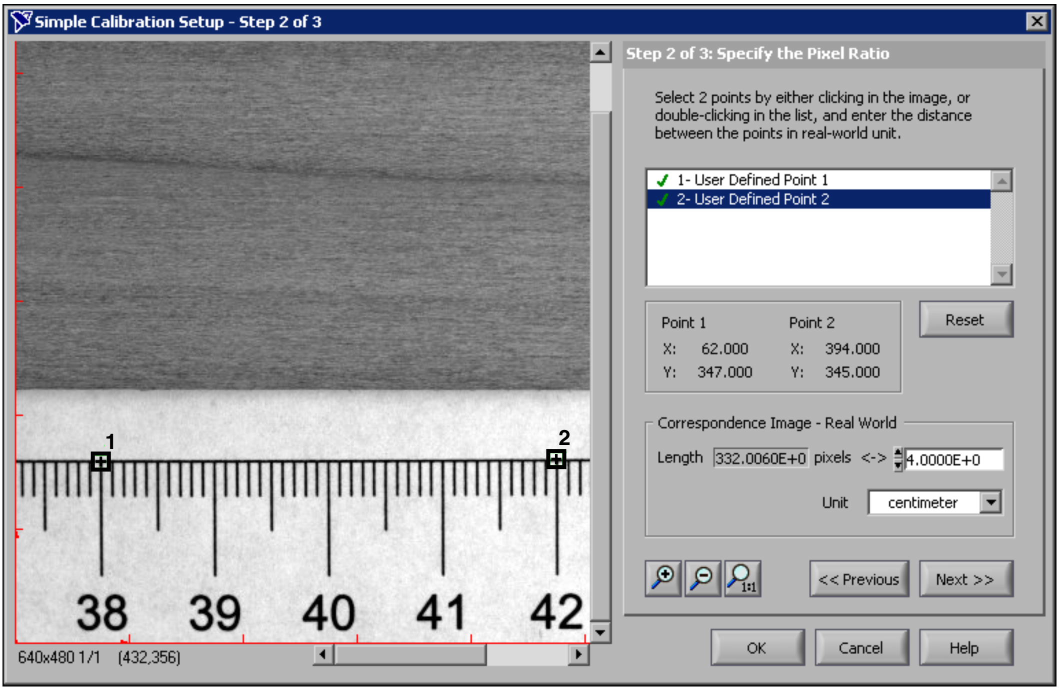


Figure 5-1. Defining the Pixel to Real-World Ratio

10. Click **Next**.

11. In **Step 3 of 3**, click the 38 cm marking to define it as the origin of the calibration axis. Draw a line horizontally and to the right along the edge of the ruler to define the angle of the calibration axis, as shown in Figure 5-2.

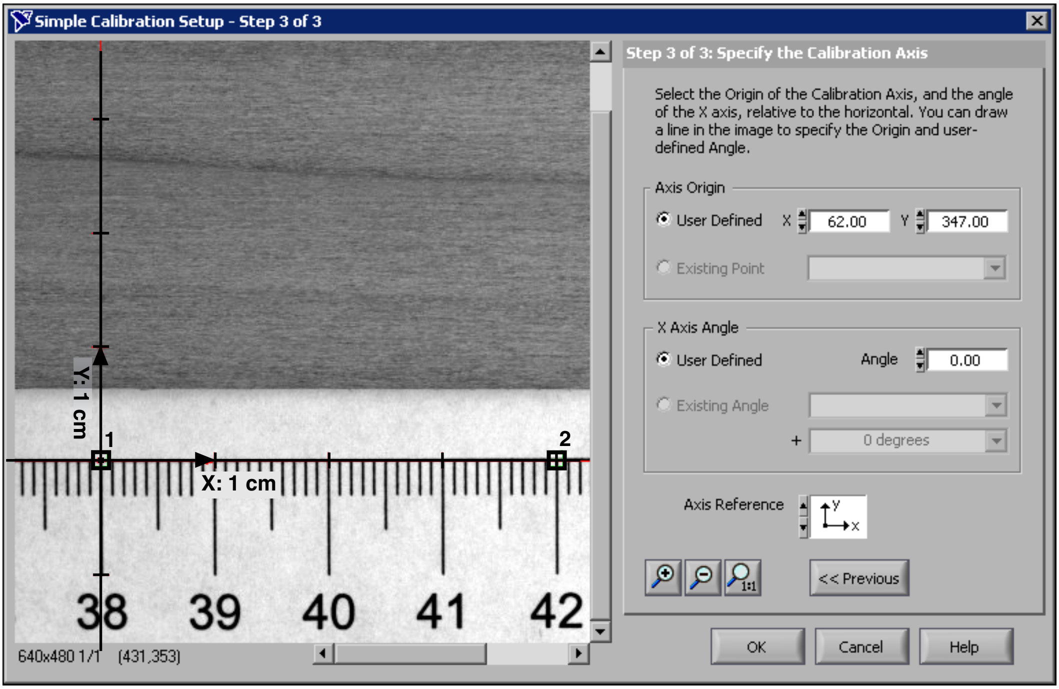


Figure 5-2. Defining the Origin and Angle of the Calibration Axis

12. Click **OK** to learn the calibration information and exit the calibration wizard. The **Calibration** and **Axis** tabs display information about the learned calibration.
13. Click **OK** to add the step to the inspection.

Locating the Right Edge of the Part

Follow these instructions to configure a **Find Edges** step that locates the right edge of the part.

1. In the **Inspection Steps** palette, select the **Locate Features** tab.
2. Click the **Find Edges** step. The property page for the step opens.
3. In the **Step Name** control, enter `Find Right Edge`.

4. Hold down <Shift> and draw a line across the right edge of the part going from right to left, as shown in Figure 5-3.
5. In the **Settings** tab, disable the **Auto Setup** control.
6. Select **First Edge Only** from the **Look for** list.
7. Select **Bright to Dark Only** from the **Edge Polarity** list.

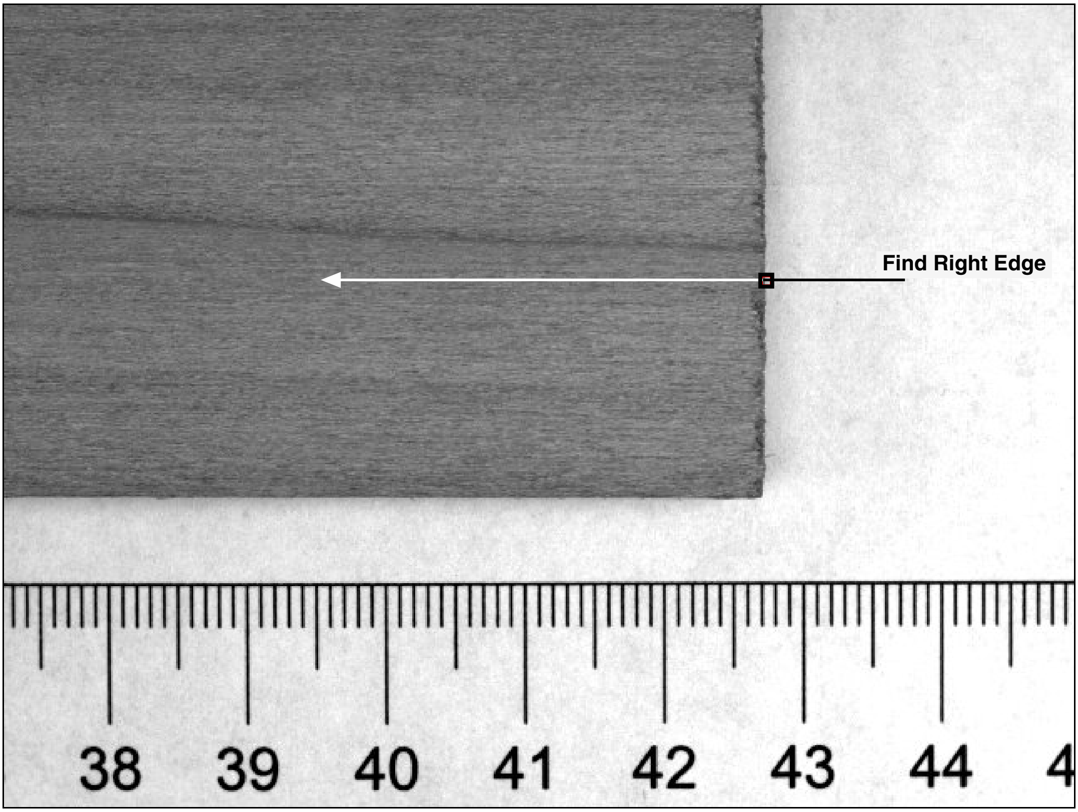


Figure 5-3. Finding the Right Edge of the Plank

Notice the red square on the search line. The step searches along the search line for a sharp transition in pixel intensities, which usually represent an object edge. The red square marks the location of the right edge of the part.

8. Click **OK** to add this step to the inspection.

Switching Images

Now that you have configured the inspection to locate the right edge of the wooden plank, you need to switch to the image of the left side of the plank. Follow these instructions to configure a **Select Image** step that makes the image of the left side of the plank active for processing.

1. In the **Inspection Steps** palette, select the **Acquire Images** tab.
2. Click the **Select Image** step. The property page for the step opens.
3. In the **Step Name** control, enter `Switch to Left Side`.
4. In the **Image Selection** list, select **Acquire Part (Left)**. The image of the left side of the part appears in the **Main** window.
5. Click **OK** to add this step to the inspection.

Calibrating the Image of the Left Edge

Follow these instructions to configure a **Calibrate Image** step that defines the type of calibration, the calibration parameters, and the real-world unit in which you want to express measurements.

1. In the **Inspection Steps** palette, select the **Enhance Images** tab.
2. Click the **Calibrate Image** step.
3. In the **Step Name** control, enter `Calibrate Part (Left).`
4. Click **New Calibration** to launch the calibration wizard.

Again, assume that the camera that acquired the inspection images is perpendicular to the image plane and lens distortion is negligible.

5. Double-click **Simple Calibration** to open the **Simple Calibration Setup** dialog box.
6. In **Step 1 of 3**, make sure **Pixel Type** is set to **Square**.
7. Click **Next**.
8. In **Step 2 of 3**, carefully click the 1 cm and 5 cm markings on the ruler in the image, as shown in Figure 5-4.

Tip You may need to scroll down to see the ruler at the bottom of the image. You may also need to zoom in on the image in order to click more accurately on the markings.

9. In the **Correspondence Image - Real World** control, enter `4` for the value, and select **centimeter** for the **Unit**.

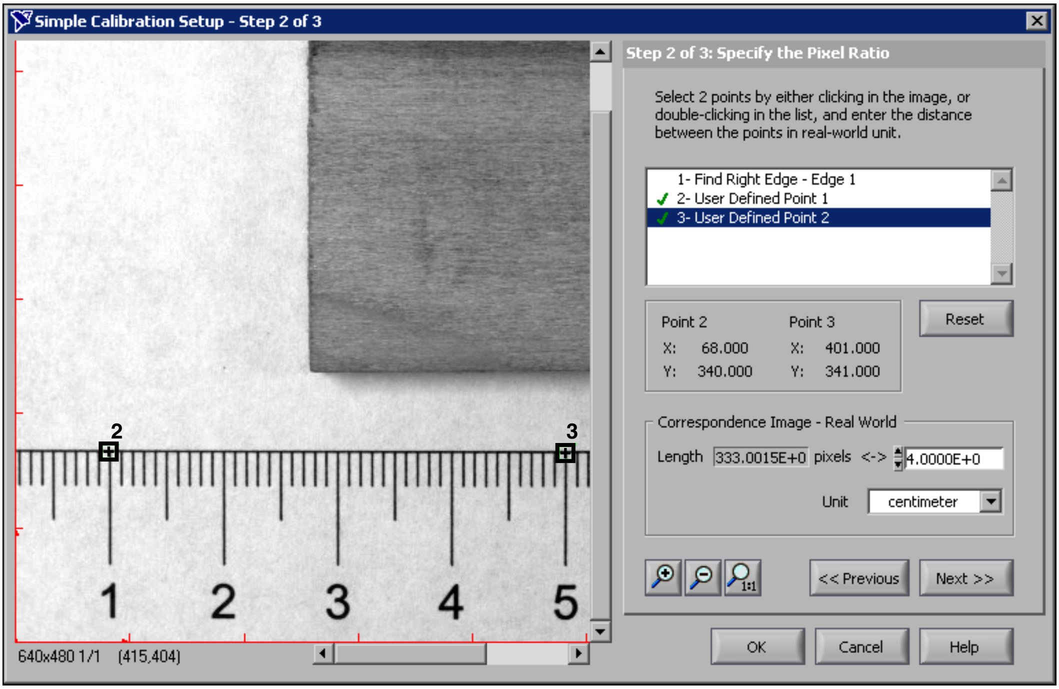


Figure 5-4. Defining Pixel to Real-World Ratio

10. Click **Next**.
11. In **Step 3 of 3**, click the 1 cm marking to define it as the origin of the calibration axis. Draw a line along the edge of the ruler to define the angle of the calibration axis, as shown in Figure 5-5.

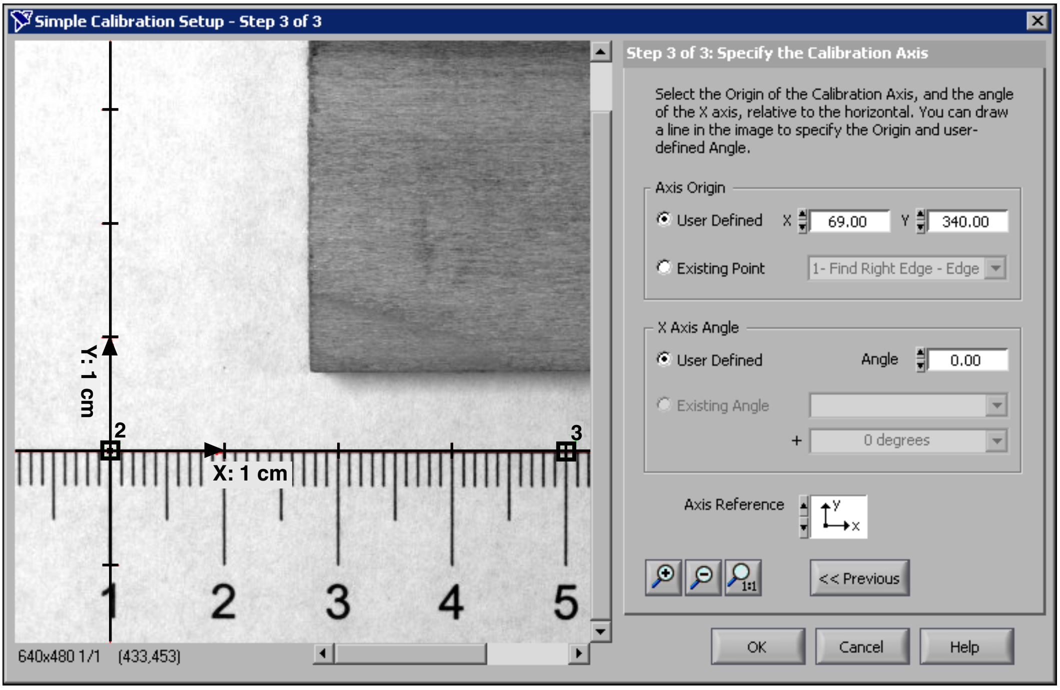


Figure 5-5. Defining the Origin and Angle of the Calibration Axis

12. Click **OK** to learn the calibration information and exit the calibration wizard. The **Calibration** and **Axis** tabs display information about the learned calibration.
13. Click **OK** to add the step to the inspection.

Locating the Left Edge of the Part

Follow these instructions to configure a **Find Edges** step that locates the left edge of the part.

1. In the **Inspection Steps** palette, select the **Locate Features** tab.
2. Click the **Find Edges** step. The property page for the step opens.
3. In the **Step Name** control, enter `Find Left Edge`.
4. Hold down <Shift> and draw a line across the left edge of the part going from left to right, as shown in Figure 5-6.
5. In the **Settings** tab, disable the **Auto Setup** control.
6. Select **First Edge Only** from the **Look for** list.

7. Select **Bright to Dark Only** from the **Edge Polarity** list.

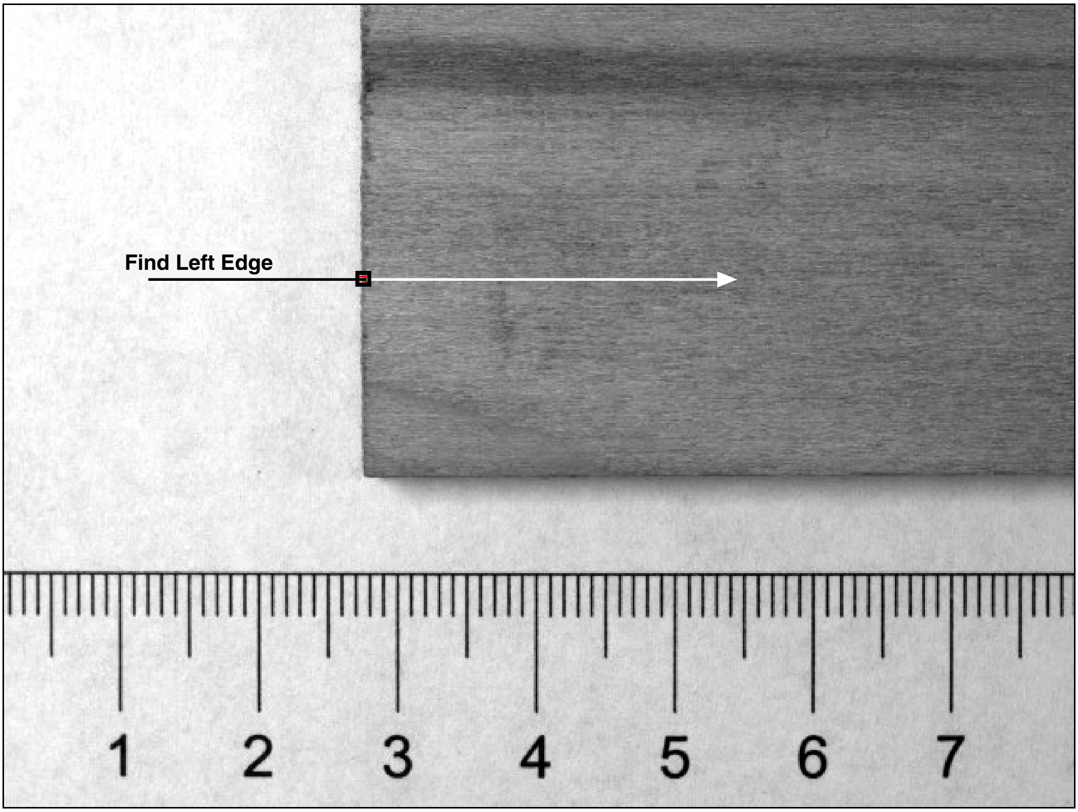


Figure 5-6. Finding the Left Edge of the Plank

The step searches along the search line and marks the location of the left edge with a blue square.

8. Click **OK** to add this step to the inspection.

Calculating the Width of the Part

Now that you have located the right edge of the part in one image and the left edge of the part in another image, you need to combine the measurements from those images to determine the width of the part.

Refer to the following equations as you configure the step.

$$Right\ (LC) = Right\ (RC) + (Origin\ R - Origin\ L) \tag{5-1}$$

$$Part\ Width = Right\ (LC) - Left\ (LC) \tag{5-2}$$

where *Right (LC)* = The x position of the right edge in the calibration axis of the left edge.

Right (RC) = The x position of the right edge in the calibration axis of the right edge.

Origin R = The x position of the origin in the calibration axis.

Origin L = The x position of the origin in the calibration axis.

Left (LC) = The x position of the left edge in the calibration axis of the left edge.

Setting Calculator Step Inputs and Outputs

Follow these instructions to select input measurements from the previous **Calibrate Image** and **Find Straight Edge** steps, and create output results for the calculated values.

1. In the **Inspection Steps** palette, select the **Use Additional Tools** tab.
2. Click the **Calculator** step. The Calculator Setup Wizard opens.
3. Click **Next** to proceed with the wizard.

Notice the **Input Measurements** list. The list contains all of the measurable data from each of the previous steps in the inspection.

4. Select the following measurements from the **Input Measurements** list:
   - **Find Right Edge»Edge 1.X Position (Calibrated)**
   - **Find Left Edge»Edge 1.X Position (Calibrated)**
5. Click **Next**.
6. Click **Add New Output Result**. A new output appears in the **Output Results** list.
7. In the **Name** control, enter `Part Width`. This output will contain the results of Equation 5-2.
8. Make sure **Type** is set to **Numeric**.
9. Click **Add New Output Result** again.

10. In the **Name** control, enter `Right (LC)`. This output will contain the results of Equation 5-1.
11. Make sure **Type** is set to **Numeric**.
12. Click **Finish** to close the Calculator Setup Wizard.

The **Main** window now displays a diagram with the measurement inputs and result outputs you specified in the Calculator Setup Wizard, as shown in Figure 5-7. The diagram also contains a default Boolean result named **Step Result**. You can connect the result of a computation to **Step Result**, which changes the status of the **Calculator** step to the result of the computation. Refer to the *Making Logical PASS/FAIL Decisions with the Calculator Step* section for more information about **Step Result**.

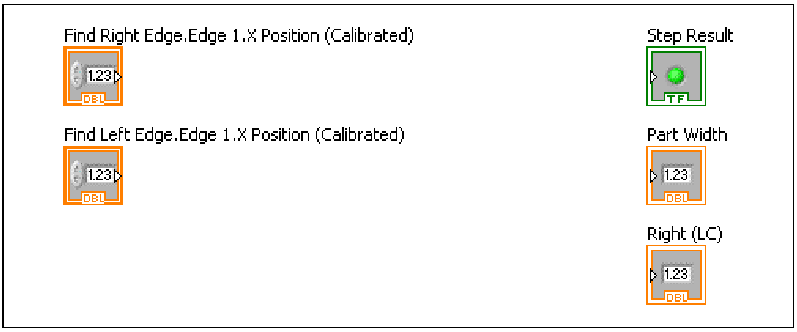


Figure 5-7. Calculator Diagram Elements

Notice that the inputs and outputs are framed with color and have codes at the bottom of their frames. These colors and codes visually group inputs and outputs into their respective *data types*—numerics, Booleans, or strings.

13. To simplify references to the input measurements, change the labels of the inputs to match their corresponding variables in Equations 5-1 and 5-2, as follows:
    - Triple-click the label of **Find Right Edge 1.XPosition (Calibrated)** to highlight the entire label, and type `Right (RC)`.
    - Triple-click the label of **Find Left Edge 1.XPosition (Calibrated)** to highlight the entire label, and type `Left (LC)`.
14. To simplify the process of connecting the diagram elements later in this chapter, arrange the elements into the configuration shown in Figure 5-8 by dragging them to their new positions.

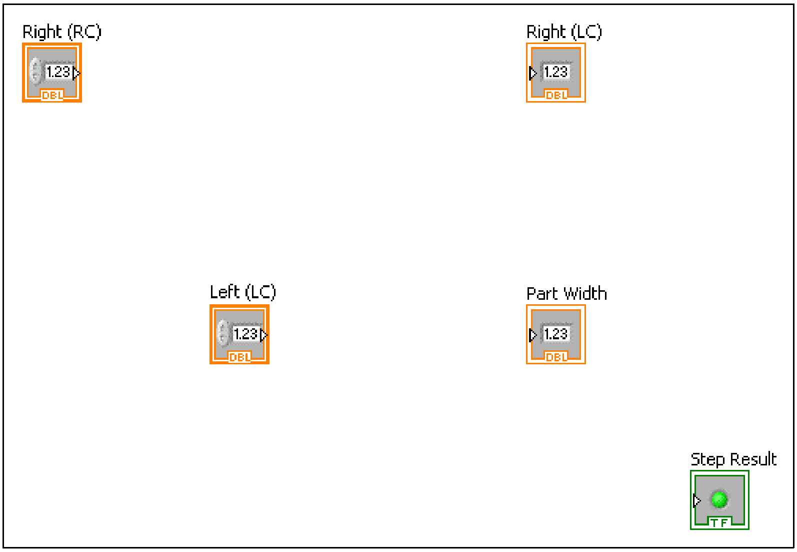


Figure 5-8. Arranging Diagram Elements

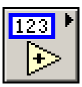
Adding Operators and Constants

Earlier in this chapter, you set calibration axis origins for the right and left sides of the part using **Calibrate Image** steps. These origins are the only elements of Equations 5-1 and 5-2 not yet represented in the Calculator diagram: (*Origin R* and *Origin L*).

In step 11 of *Calibrating the Image of the Right Edge*, you set the origin of the right side to the 38 cm marking of the imaged ruler. In step 11 of *Calibrating the Image of the Left Edge*, you set the origin of the left side to the 1 cm marking of the imaged ruler. Therefore,

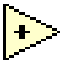
$$(Origin\ R - Origin\ L) = 38 - 1 = 37.$$

The distance between the calibration axis origins is a constant value. Add a constant with the value `37` to the Calculator diagram.



1. In the **Functions** palette, click **Numeric**.
2. Click the **Num Const** operator. Click inside the Calculator diagram below the **Right (RC)** input measurement to place the numeric constant on the Calculator diagram.

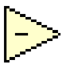
3. Double-click the numeric constant and type `37` to set the value of the constant.



4. Click the **Add** operator in the **Functions** palette. Click inside the Calculator diagram to the right of the **Right (RC)** input measurement.

Tip Place the **Add** operator close enough to the **Right (RC)** input so that the **Calculator** step automatically connects the two elements with a wire.

5. Enable the **Show Help Window** control on the **Main** tab of the **Calculator** step to launch the **Help** window, or click the **Help** button in the Calculator diagram toolbar. When you move your cursor over certain elements within the Calculator diagram, information about that item shows in the **Help** window.
6. Place your cursor over the **Add** operator. Notice in the **Help** window that the operator has an **x** input terminal, **y** input terminal, and **x+y** output terminal.



7. Click the **Subtract** operator in the **Functions** palette. Click inside the Calculator diagram to the right of the **Right (LC)** input measurement.

Your Calculator diagram should look similar to the one in Figure 5-9.

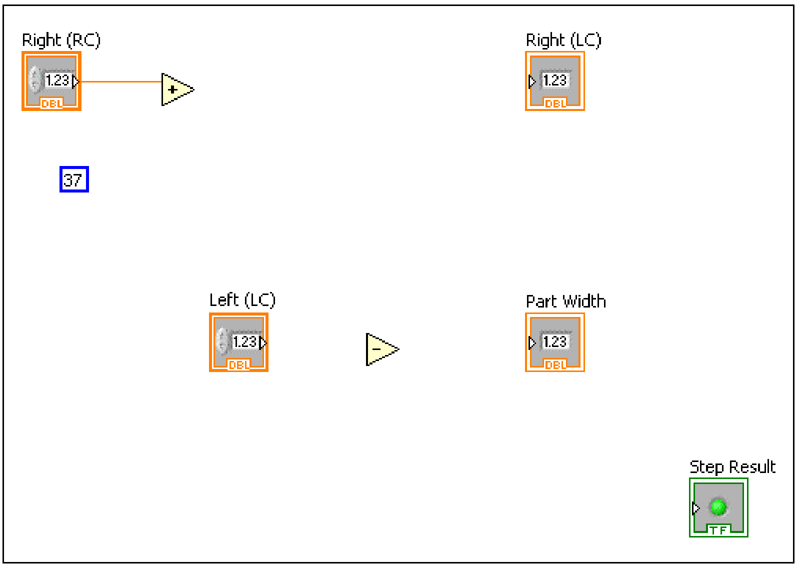


Figure 5-9. Unconnected Diagram Elements

Connecting the Equation Elements

Follow these instructions to wire the diagram elements together such that they form Equations 5-1: *Right (LC) = Right (RC)* + (37).

1. Place your cursor on the small, triangular terminal located on the right side of the numeric constant. The cursor changes into a Wiring tool.
2. Use the Wiring tool to click the terminal and release the mouse. As you move the cursor across the Calculator diagram, the **Calculator** step draws a wire between the terminal and the Wiring tool as though the wire were unwinding from a spool.
3. Without holding down the mouse button, move the cursor to the **y** input terminal of the **Add** operator. The **y** input terminal blinks. Use the Wiring tool to click the **y** input terminal and complete the connection.
4. Click the output terminal of the Add operator, and connect it to the input terminal of **Right (LC)**.

Tip If you do not terminate a wire correctly, the wire is broken and appears as a dashed black line with a red X in the middle. Click **Remove Broken Wires** in the **Main** tab to remove broken wires.

Follow these instructions to wire the diagram elements together such that they form Equations 5-2: *Part Width = Right (LC) – Left (LC)*.

1. Place the cursor on the wire that connects the **Add** operator to **Right (LC)**. The cursor changes into the Wiring tool.
2. Click the wire, and connect it to the **x** input terminal of the **Subtract** operator.
3. Click the **Left (LC)** output terminal, and connect it to the **y** input terminal of the **Subtract** operator.
4. Click the output terminal of the **Subtract** operator, and connect it to the input terminal of **Part Width**.

Your connected Calculator diagram should look similar to Figure 5-10.

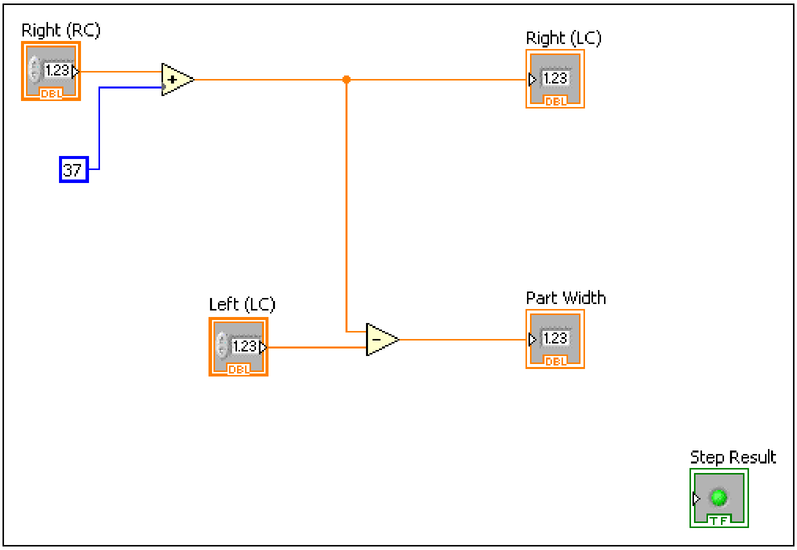


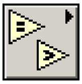
Figure 5-10. Connected Elements of Calculator Diagram

5. In the **Calculator** step property page, click the **Measurements** tab.
6. Click **Compute Results** to see the results of the calculation thus far.

Making Logical PASS/FAIL Decisions with the Calculator Step

Now that you have a created a diagram to measure the width of the part, you need a way to verify that the width meets manufacturing specifications. Follow these instructions to add diagram elements that compare the measured width to minimum and maximum width tolerances and decide whether the plank passes inspection.

1. Click the up arrow in the **Functions** palette to return to the main palette.



2. Select the **Comparison** palette.
3. Click the **Less?** operator in the **Comparison** palette. Click inside the Calculator diagram below **Part Width**.
4. Connect the wire between **Subtract** and **Part Width** to the **x** input of the **Less?** operator.
5. Click the up arrow in the **Functions** palette to return to the main palette.
6. Select the **Numeric** palette.
7. Click the **Num Const** operator in the **Numeric** palette.

8. Click close enough to the **y** input of **Less?** to automatically wire the numeric constant and **y** input together.
9. Type `40.5` to set the maximum width a plank can be to pass the inspection.
10. Click the up arrow in the **Functions** palette to return to the main palette.
11. Select the **Comparison** palette.
12. Click the **Greater?** operator. Click inside the Calculator diagram below the **Less?** operator.
13. Connect the wire between **Subtract** and **Part Width** to the **x** input of the **Greater?** operator.
14. Click the up arrow in the **Functions** palette to return to the main palette.
15. Select the **Numeric** palette.
16. Click the **Num Const** operator.
17. Click close enough to the **y** input of **Greater?** to automatically wire the numeric constant and **y** input together.
18. Type `39.5` to set the minimum width a plank can be to pass the inspection.
19. Click the up arrow in the **Functions** palette to return to the main palette.
20. Select the **Boolean** palette.
21. Click the **And** operator. Click close enough to the left side of **Step Result** to wire the two elements together.
22. Connect the **Less?** output to the **x** input of **And**.
23. Connect the **Greater?** output to the **y** input of **And**.

Your completed Calculator diagram should look similar to Figure 5-11.

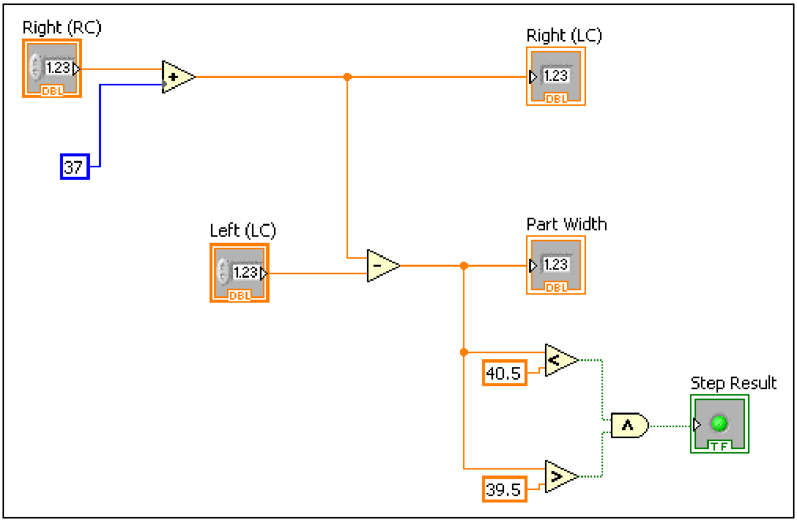


Figure 5-11. Calculator Diagram with Decision-Making Abilities

24. Enable the checkbox on the **Limits** tab to base the status of the entire inspection on the result of the **Step Result**.
25. Click **OK** to add the step to the inspection.

Testing the Inspection

Test the inspection to make sure it returns the results you expect. Table 5-1 lists the test images, the inspection status to expect for each image, and an explanation of the status.

Note Results may vary slightly based on the accuracy of the calibration and the edge detection location.

Table 5-1. Expected Results for the Plank Inspection

Image Name	Part Width	Inspection Status
`Image 01.jpg`	40.09 cm	Pass
`Image 02.jpg`	40.12 cm	Pass
`Image 03.jpg`	40.34 cm	Pass

Table 5-1. Expected Results for the Plank Inspection (Continued)

Image Name	Part Width	Inspection Status
`Image 04.jpg`	39.36 cm (too short)	Fail
`Image 05.jpg`	40.97 cm (too long)	Fail

Saving the Inspection

Save the example inspection with the following name and description:

- **Inspection Name**—`Lesson 5`
- **Description**—`This inspection measures in real-world units the width of a wooden plank. The right and left edges of the plank were acquired using different cameras because the plank is too wide to fit in one camera's field of view given the required measurement accuracy.`

Refer to the *Saving an Inspection* section of Chapter 1, *Getting Started in Vision Builder AI*, for more information.

A

Technical Support and Professional Services

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, go to `ni.com/services` or contact your local branch at `ni.com/contact`.
- **Training and Certification**—Visit `ni.com/training` for self-paced training, eLearning virtual classrooms, interactive CDs, and Certification program information. You also can register for instructor-led, hands-on courses at locations around the world.
- **System Integration**—If you have time constraints, limited in-house technical resources, or other project challenges, National Instruments Alliance Partner members can help. To learn more, call your local 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.

Glossary

Symbol	Prefix	Value
m	milli	10^{-3}

C

coordinate system — A reference location (origin) and angle in an image that ROIs can relate to when positional and angular adjustments of the ROI are necessary.
A coordinate system is depicted by two lines representing the orientation and direction of its two axes.

D

data type — A format for information. Acceptable data types for most functions are numeric, array, and string.

F

field of view — The area of inspection that the camera can acquire as an image.

FieldPoint — A modular distributed I/O system with industrial-grade performance.

focal point — The pixel location in a pattern matching template whose coordinates are returned as the location of a match in the inspection image.

I

inspection — A vision inspection application created in and ran from Vision Builder AI that can perform inline or offline visual inspections.

intensity — The gray-level value of a pixel in a grayscale image.

M

match score
: A number ranging from 0 to 1,000 that indicates how closely an area of an acquired image matches the template image. A match score of 1,000 indicates a perfect match. A match score of 0 indicates no match.

O

object
: A connected region or grouping of pixels in an image in which all pixels have intensity levels in the same range.

P

pattern matching
: The technique used to quickly locate a grayscale template within a grayscale image.

pixel
: picture element—The smallest division that makes up a digital image. For measurement tasks, optimum pixel dimensions are square (aspect ratio of 1:1, or the width equal to the height).

R

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

ROI
: region of interest—An area of the image that is graphically selected from a window displaying the image. This area can be used to focus further processing.

S

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

step
: A component of a Vision Builder AI inspection that performs a specific visual inspection task or supporting tasks, such as decision making and serial communication.

T

template — Pattern that you are trying to match in an image using the Match Pattern or Match Color Pattern steps. A template can be a region selected from an image or it can be an entire image.