IMAQ™

IMAQ™ Vision Builder Tutorial

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About This Manual

IMAQ Vision Builder is a tool that you can use to prototype and test image processing applications. The *IMAQ Vision Builder Tutorial* contains information you need to install and run IMAQ Vision Builder and begin building imaging applications.

This manual is designed to teach you the fundamental features of IMAQ Vision Builder through interactive discussion and examples. To get the most out of this manual, read it at your computer so you can test the concepts and perform the example tutorials in IMAQ Vision Builder.

Organization of This Manual

The *IMAQ Vision Builder Tutorial* is organized as follows:

- Chapter 1, *System Requirements and Installation*, lists system requirements and installation instructions and introduces the IMAQ Vision Builder environment.
- Chapter 2, *Introduction to Image Processing with IMAQ Vision Builder*, describes how you can use IMAQ Vision Builder to create and test your own image processing algorithms. It explains what types of images that IMAQ Vision Builder can load and process and how to get started in IMAQ Vision Builder.
- Chapter 3, *Analyzing the Structure of a Metal Using Blob Analysis*, describes blob analysis and provides step-by-step directions for completing a blob analysis tutorial in IMAQ Vision Builder.
- Chapter 4, *Using Gauging for Part Inspection*, describes gauging and provides step-by-step directions for completing a part inspection tutorial in IMAQ Vision Builder.
- Appendix A, *Customer Communication*, contains forms you can use to request help from National Instruments or to comment on our products and manuals.
- The *Glossary* contains an alphabetical list and description of terms used in this manual, including abbreviations, acronyms, metric prefixes, mnemonics, and symbols.
- The *Index* contains an alphabetical list of key terms and topics in this manual, including the page where you can find each one.

Conventions Used in This Manual

The following conventions are used in this manual:

<>	Angle brackets enclose the name of a key on the keyboard—for example, <Enter>.
»	The **»** symbol leads you through nested menu items and dialog box options to a final action. The sequence **Binary»Threshold** directs you to pull down the **Binary** menu and select the **Threshold** item.
☞	This icon to the left of bold italicized text denotes a note, which alerts you to important information.
bold	Bold text denotes tooltips and the names of menus, menu items, parameters, and dialog box buttons or options.
bold italic	Bold italic text denotes a note and tip.
italic	Italic text denotes emphasis, a cross reference, or an introduction to a key concept. This font also denotes text from which you supply the appropriate word or value, as in Windows 3.*x*.
`monospace`	Text in this font denotes text or characters that you should literally enter from the keyboard. This font is also used for the proper names of disk drives, paths, directories, programs, filenames and extensions.
paths	Paths in this manual are denoted using backslashes (\) to separate drive names, directories, folders, and files.

Related Documentation

The following documents contain information you might helpful as you read this manual and perform the tutorials:

- IMAQ Vision Builder online help, which you can access from the IMAQ Vision Builder **Help** menu.
- *Image Processing Manual* in PDF format, which you can access from the Windows **Start** menu (**Start»Programs»National Instruments IMAQ Vision Builder**). This manual contains conceptual information about imaging.

If you have purchased IMAQ Vision software from National Instruments, you have at least one of the following manuals, depending on which development environment you use. These manuals provide basic information about image processing and the IMAQ Vision functions.

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

Customer Communication

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

1

System Requirements and Installation

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

System Requirements

To run IMAQ Vision Builder, your computer must meet the following minimum requirements:

- Personal computer using at least a 133 MHz Pentium or higher microprocessor (233 MHz Pentium MMX or higher microprocessor recommended)
- Microsoft Windows 95/98 or Windows NT version 4.0
- 800 × 600 resolution (or higher) video adapter, 65536 colors (16 bit) or higher.
- National Instruments IMAQ hardware and NI-IMAQ 2.0 or later for Windows 95/98 or Windows NT (if you are acquiring images with National Instruments IMAQ hardware)
- Minimum of 32 MB RAM (64 MB recommended)
- Minimum of 30 MB of free hard disk space

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

Installing IMAQ Vision Builder

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

1. Insert the IMAQ Vision Builder CD into your computer.

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

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

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

Launching and Exiting IMAQ Vision Builder

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

To quit IMAQ Vision Builder, follow these steps:

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

IMAQ Vision Builder Environment

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

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

Features

IMAQ Vision Builder offers the following features:

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

- Reference window—Displays the original version of the image (image source) as you manipulate it in the processing window.
- Tools Palette—Displays a collection of tools for selecting regions of interest (ROI), zooming in and out, and changing the image palette.

Image Analysis Functions

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

- Histogram—Counts the total number of pixels in each grayscale value and graphs it.
- Line Profile—Returns the grayscale values of the pixels along a line that you draw with the line tool from the Tools palette and graphs it.
- Particle Analysis—Computes more than 40 measurements on objects in an image, including the perimeter and area of holes in an object of the image.
- 3D View—Displays an image using an isometric view. Each pixel from the image source is represented as a column of pixels in the 3D view. The pixel value corresponds to the altitude.

Image Processing Functions

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

- Filtering—Functions for smoothing, edge detection, and convolution.
- Morphology—Functions to modify the shape of objects in an image, including erosion, dilation, opening, and closing.
- Thresholding—Functions that enable you to select ranges of pixel values in grayscale and color images.
- Particle Filtering—Functions to filter objects based on shape measurements.

Machine Vision Functions

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

- Edge Detection—Finds edges along a line that you draw with the line tool from the Tools palette.
- Search-Correlate—Performs template matching on gray-scale images using correlation.

- Shape Matching—Searches for the presence of a template in the image and specifies the location of matching shapes.
- Circle Detection—Finds the center and radius of circular particles in an image.
- Caliper—Computes measurements such as distances, areas, and angles based on results returned from other machine vision and image processing functions.

Getting Help

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

IMAQ Vision Builder Online Help

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

- Access the IMAQ Vision Builder online help by selecting **Online Help** from the **Help** menu. There you can find information not available in this manual, such as function descriptions and directions for performing image processing functions.
- Tooltips appear when you move the mouse cursor over a button in the Processing toolbar, Tools palette, Script window, Reference window, Acquisition window, or Image Browser.
- Press the **Help** button in any function parameter window to get information about that function and its parameters.

IMAQ Vision Manuals

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

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

National Instruments Web Site

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

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

IMAQ Vision Builder Scripts

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

2

Introduction to Image Processing with IMAQ Vision Builder

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

Images

An image is light intensity as a function of spatial coordinates

$$f(x, y)$$

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

The spatial reference of the pixel with the coordinates (0, 0) is located at the upper-left corner of the image, as shown in Figure 2-1.

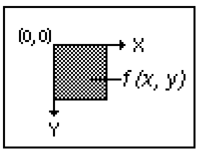


Figure 2-1. Spatial Reference of the (0,0) Pixel

Properties

Images have three properties: resolution, pixel depth, and number of planes.

- Resolution—The number of rows and columns of pixels. An image composed of m rows and n columns has a resolution of $m \times n$. This image has *n* pixels along its horizontal axis and *m* pixels along its vertical axis.

- Pixel Depth—The number of bits (*n*) used to code the intensity of a pixel. For a given *n*, a pixel can take 2^n different values. For example, if *n* equals 8-bits, a pixel can take 256 different values ranging from 0 to 255. If *n* equals 16 bits, a pixel can take 65,536 different values ranging from –32,768 to 32,767.

  The number of values a pixel can take on is called *definition*, which is the number of colors or shades that you can see in the image.

- Number of Planes—The number of arrays of pixels that compose the image. A gray-level or pseudo-color image is composed of one plane, while an RGB image is composed of three planes (one for the red component, one for the blue, and one for the green), as shown in Figure 2-2.

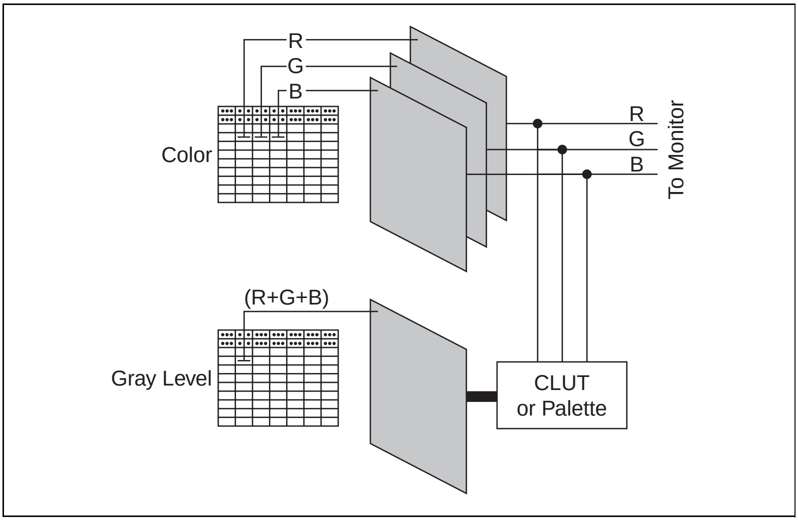


Figure 2-2. Number of Planes in an Image

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

Types

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

- Gray-Level Images—Gray-level images are composed of a single plane of pixels. Standard gray-level formats are BMP, TIFF, and AIPD. Standard 16-bit gray-level formats are TIFF and AIPD. AIPD is an internal file format that offers the advantage of storing the spatial calibration of an image. Gray-level images that use other formats and have a pixel depth of 8-bit, 16-bit, or 32-bit (floating point) can be imported into the IMAQ Vision libraries.
- Color Images—Color images are composed of three planes of pixels in which each pixel has a red, green, and blue intensity, each coded on 8-bit planes. Color images coded using the RGB-chunky standard contain an extra 8-bit plane, called the *alpha channel*. These images have a definition of 32-bit or 4 × 8-bit. Standard color formats are BMP, TIFF, and AIPD.
- Complex Images—Complex images are composed of complex data in which pixel values have a real part and an imaginary part. Such images are derived from the Fast Fourier Transform of gray-level images. Four representations of a complex image can be given: the real part, imaginary part, magnitude, and phase.

Getting Started in IMAQ Vision Builder

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

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

Follow these steps to get started in IMAQ Vision Builder.

1. Launch IMAQ Vision Builder from the **Start** menu (**Start»Programs»National Instruments IMAQ Vision Builder»IMAQ Vision Builder**).
2. To load images, select **File»Open Image**.

3. Navigate to `Program Files\National Instruments\IMAQ Vision Builder\Examples\Metal` and check the **Select All Files** option. Notice that IMAQ Vision Builder previews the images in the Preview Image window and displays information about the file type and image depth.
4. Click **OK**.

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

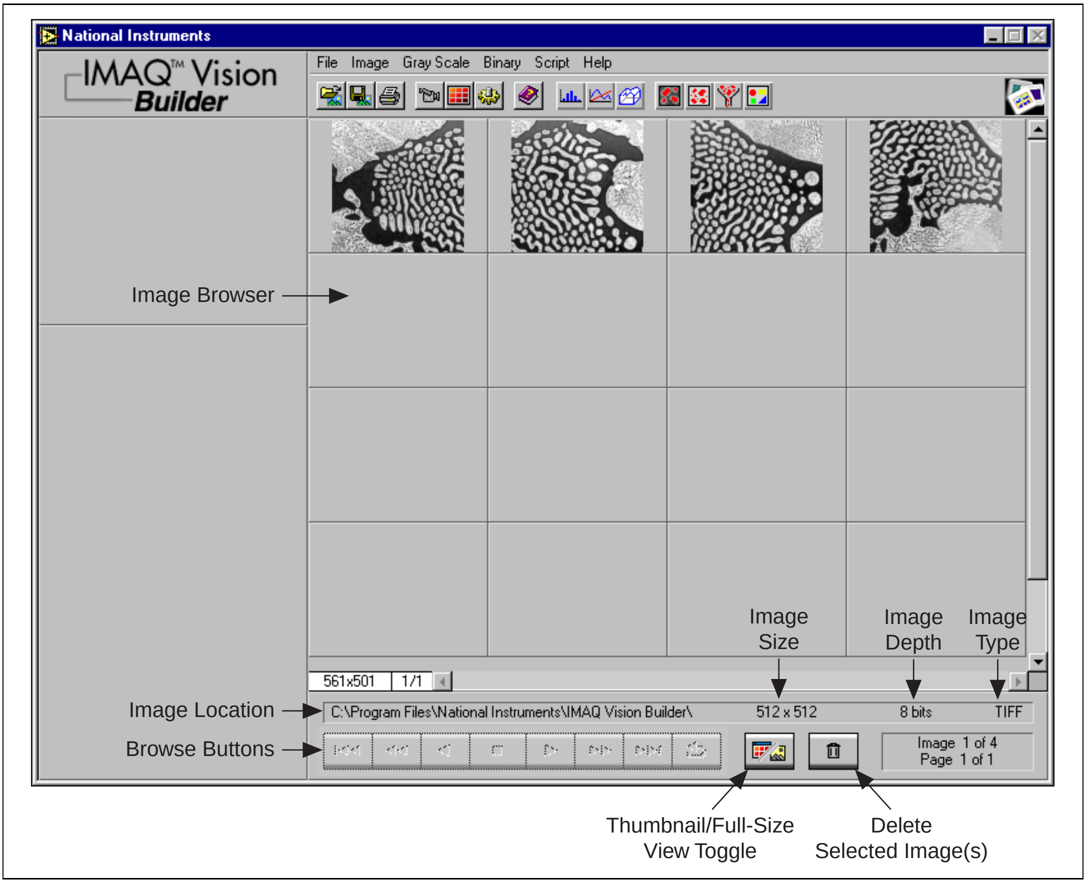


Figure 2-3. Image Browser

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

5. Click the **Thumbnail/Full-Size View toggle** to view the first image in full size.
6. Use the browse buttons to view `Metal4.tif`.
7. To enter processing mode, double click the image. IMAQ Vision Builder loads the image into the processing window, as shown in Figure 2-4.

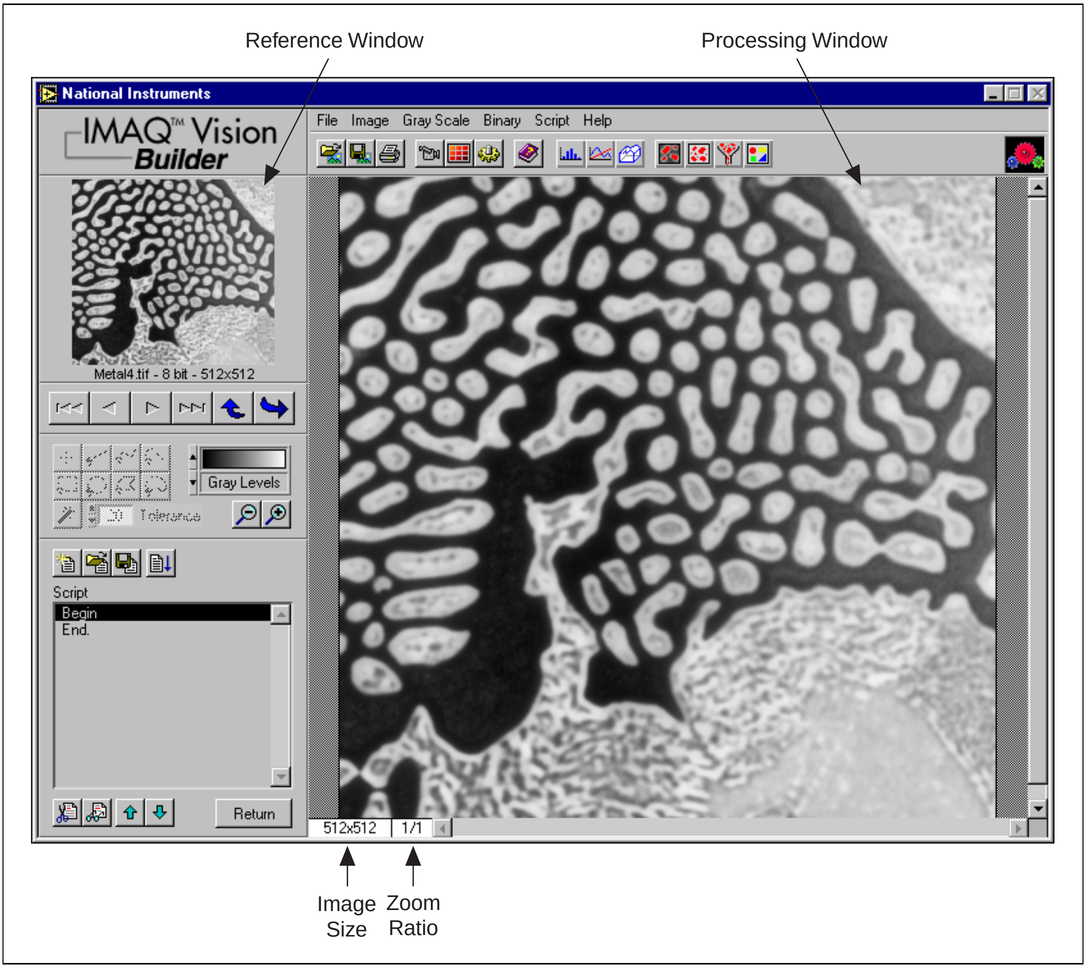


Figure 2-4. Processing an Image

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

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

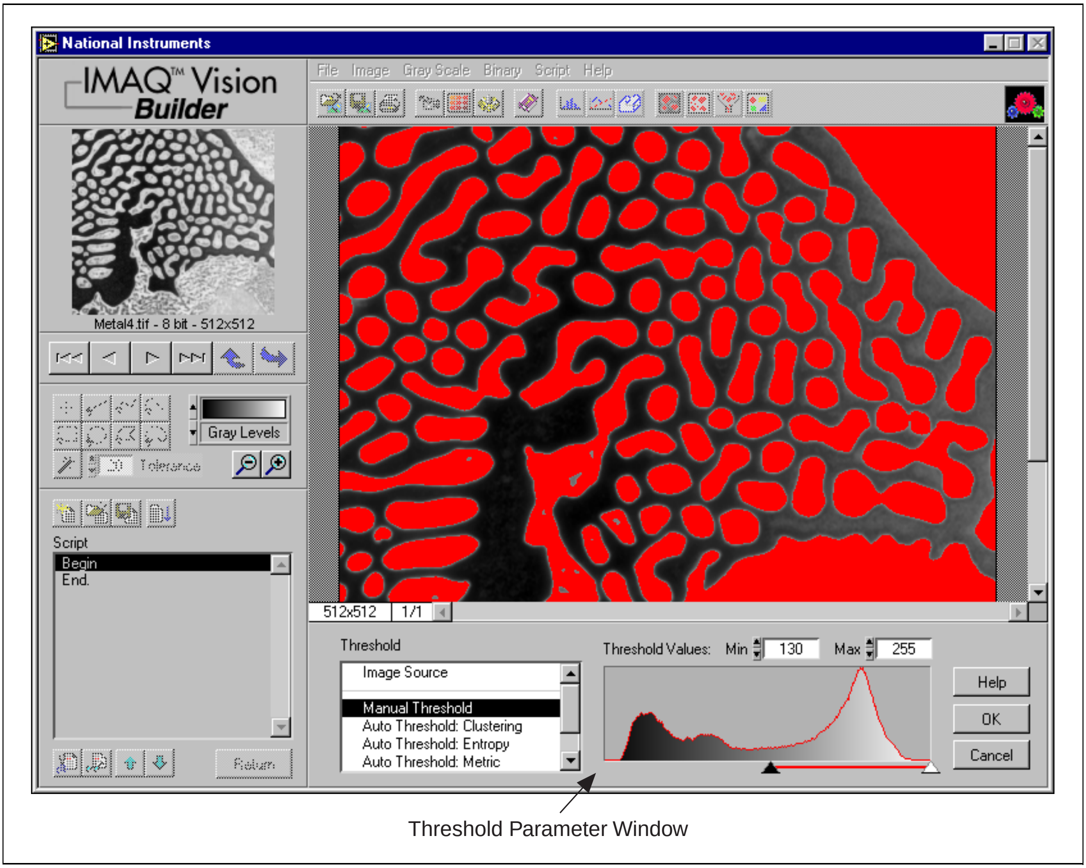


Figure 2-5. Thresholding an Image

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

9. From the Threshold parameter window, specify settings that work best for your application. For this threshold, set the **Min** and **Max** values to 130 and 255 to select all of the particles.

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

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

Refer to Figure 2-6, which displays the image after the threshold has been applied.

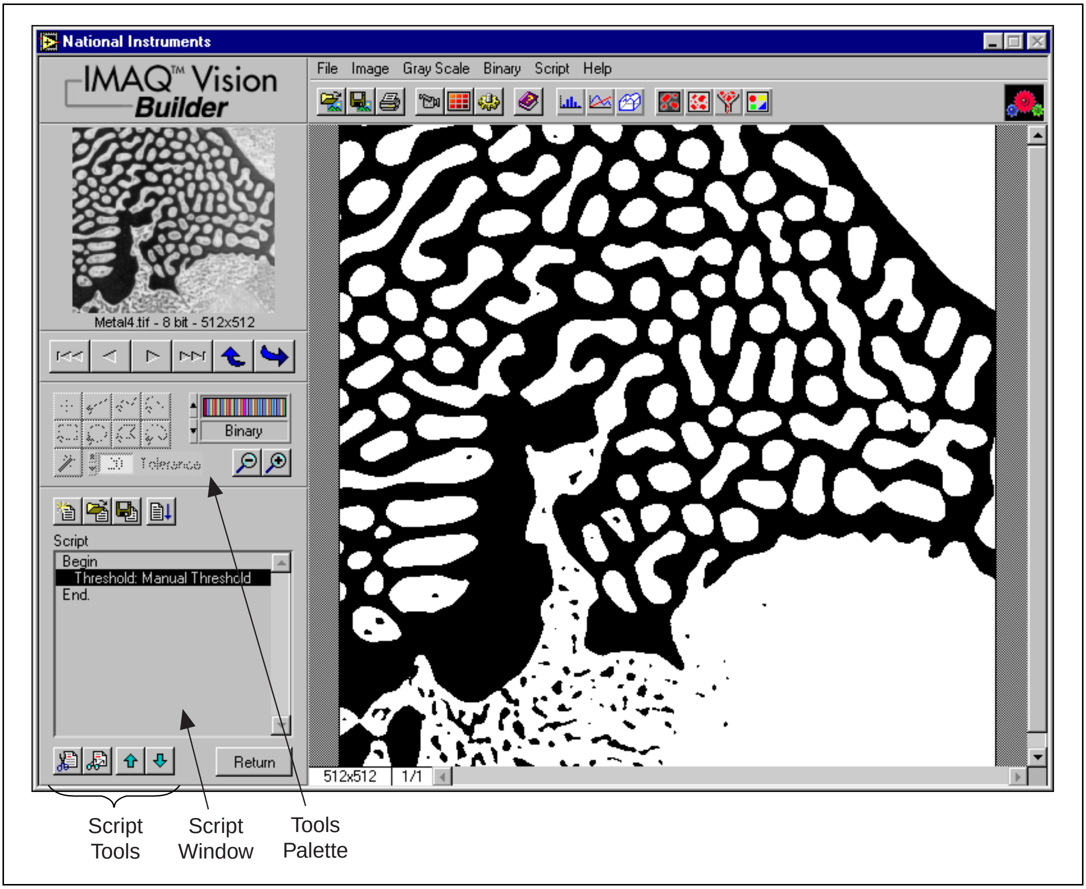


Figure 2-6. Thresholded Image

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

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

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

    a. Load the image.

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

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

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

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

Acquiring Images in IMAQ Vision Builder

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

Tip ***If you do not have IMAQ hardware and NI-IMAQ 2.0 or later, IMAQ Vision Builder simulates the acquisition process by displaying a sequence of images. You can stop the sequence at any frame, capture the image, and send the image to the Image Browser for processing.***

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

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

2. Press the **Acquire** button in the toolbar. IMAQ Vision Builder displays the Acquisition Interface window and acquisition property pages, as shown in Figure 2-7.

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

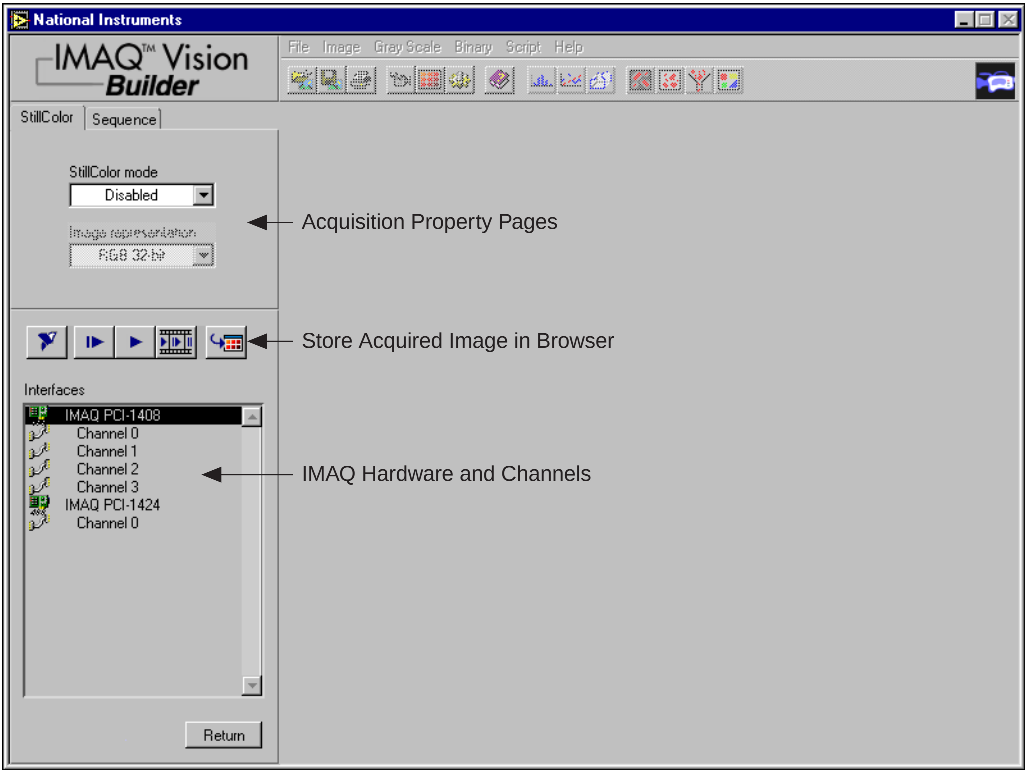


Figure 2-7. Acquiring Images in IMAQ Vision Builder

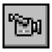
The property pages above the Interface window list properties available for the selected device. In Figure 2-7, the IMAQ PCI-1408 is selected. Because the 1408 can acquire StillColor if you have a color camera, you can set the following properties for StillColor acquisition.

- **StillColor Mode**—Selects the acquisition mode.
  - **Disabled** disables StillColor and enables monochrome mode. Disable StillColor if you have a monochrome camera.
  - **RGB** enables color mode with Tri-CCD cameras. This mode uses channels 1, 2, and 3, but you need to select a camera file only for channel 1.
  - **Composite** enables color mode for PAL or NTSC cameras.
- **Image Representation**—Selects the image representation.
  - RGB in 16-, 24-, 32-, 48-bit format.
  - Red, green or blue plane in 8-bit format.

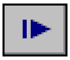
- Luminance, Hue, Saturation or Intensity in 8- or 16-bit format.
- HSL (Hue, Saturation, Luminance) in 32-bit format.
- HSI (Hue, Saturation, Intensity) in 32-bit format.

Note ***Your computer must have a National Instruments IMAQ board and NI-IMAQ 2.0 or later installed before you can acquire live images in IMAQ Vision Builder.***

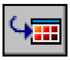
Snapping an Image (Single Acquisition)



1. Open the Acquisition window.



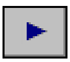
2. Click the **Acquire Single Image** button to acquire a single image with the IMAQ device and display it. This operation is also known as a *snap*.



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

Grabbing an Image (Continuous Acquisition)

1. Open the Acquisition window.

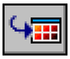


2. Click the **Live Acquisition** button to acquire and display images in continuous mode at the maximum rate. This operation is also known as a *grab*.

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

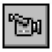
3. Click the **Live Acquisition** button again to stop the acquisition and display the last acquired image.

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

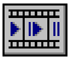


4. Press the **Store Acquired Image in Browser** button to send the image to the Image Browser.
5. Process the image as you would any other image in IMAQ Vision Builder. See Chapter 3, *Analyzing the Structure of a Metal Using Blob Analysis*, and Chapter 4, *Using Gauging for Part Inspection* for examples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

Acquiring a Sequence of Images



1. Open the Acquisition window.



2. Click the **Sequence Acquisition** button to acquire a sequence of live images.
3. Click the **Sequence** tab to view the Sequence property page.
4. Set the properties for the Sequence property page.
    - **Number of Frames**—Number of frames you want to acquire.
    - **Skip Count**—Number of frames you want to skip between acquisitions.
    - **Line**—Physical trigger line.
    - **Action**—Triggering action.
        - **Disabled** disables triggering.
        - **Trigger start of acquisition**
        - **Trigger each image**
    - **Timeout**—Time in ms within which the trigger must occur.

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

3

Analyzing the Structure of a Metal Using Blob Analysis

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

What Is Blob Analysis?

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

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

Tutorial

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

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

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

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

Loading Images into IMAQ Vision Builder

Perform the following steps to load an image:

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

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

4. Click **OK**.

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

Preparing an Image for Blob Analysis

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

Examining the Image

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

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

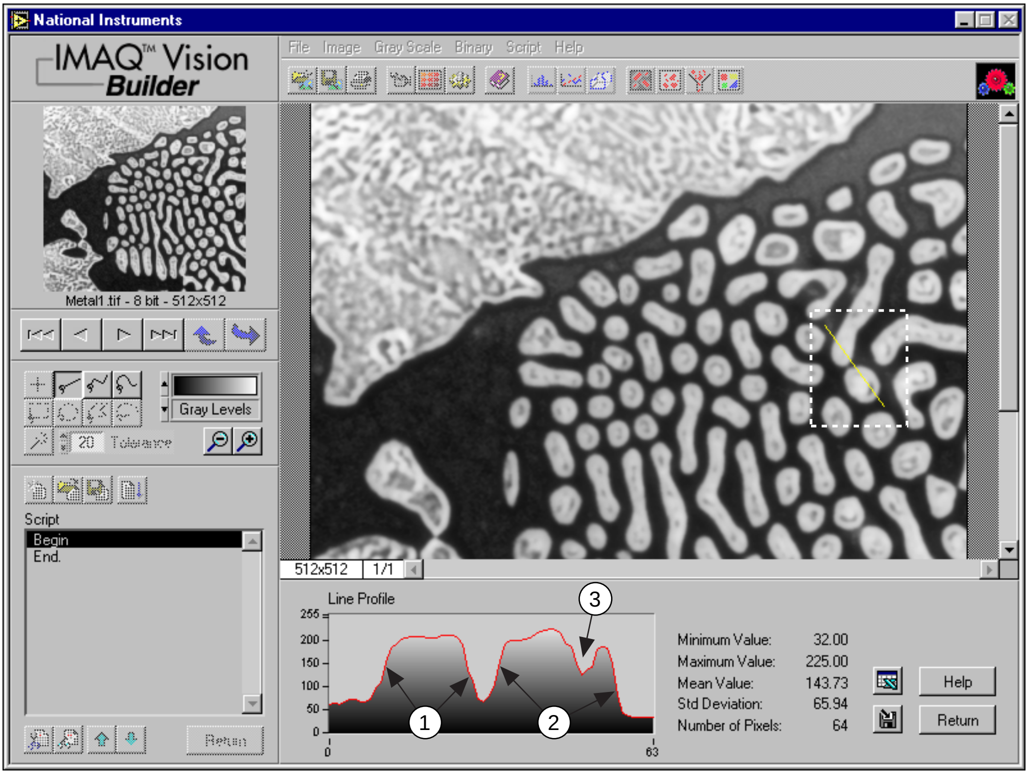


Figure 3-1. Using a Line Profile to Examine Edges

In Figure 3-1, the areas labeled 1 and 2 represent the edges of the particles. Notice that the edges of both particles have a slope. The greater the slope, the more variation you will have when you threshold the image. As you change the threshold level, you might change the shape or size of the particle. You can use the Highlight Details filter to define the edges of the particles and reduce the slope.

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

3. Click **Return**.

Filtering the Image

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

1. Select **Gray Scale»Filters**.
2. Select **Convolution–Highlight Details** from the Filters list. This function looks for sharp transitions and highlights edge pixels according to the kernel to make gaps more prominent.
3. Click **Apply** to add this step to the script.
4. Click **Close**.

Examining the Results of the Filtering

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

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

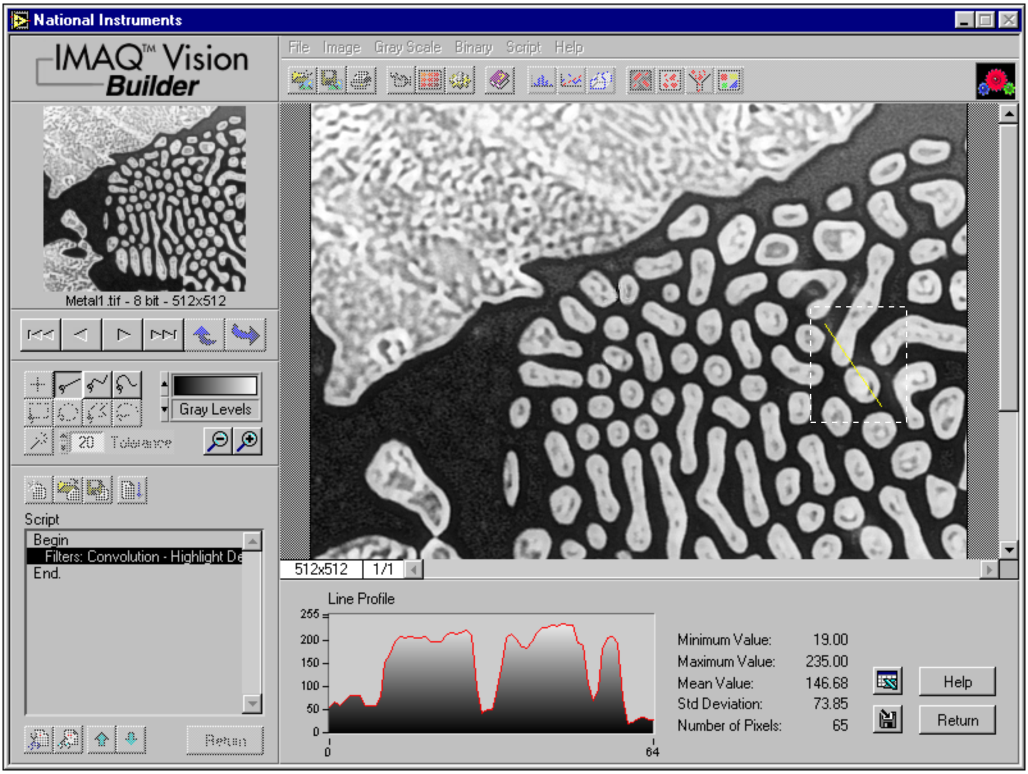


Figure 3-2. Using a Line Profile to Examine Particle Edges

3. Click **Return**.

Separating Particles from the Background with Thresholding

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

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

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

1. Select **Binary»Threshold**.
2. Select **Manual Threshold** from the Threshold list.
3. Select a range of **130** to **255**.

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

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

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

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

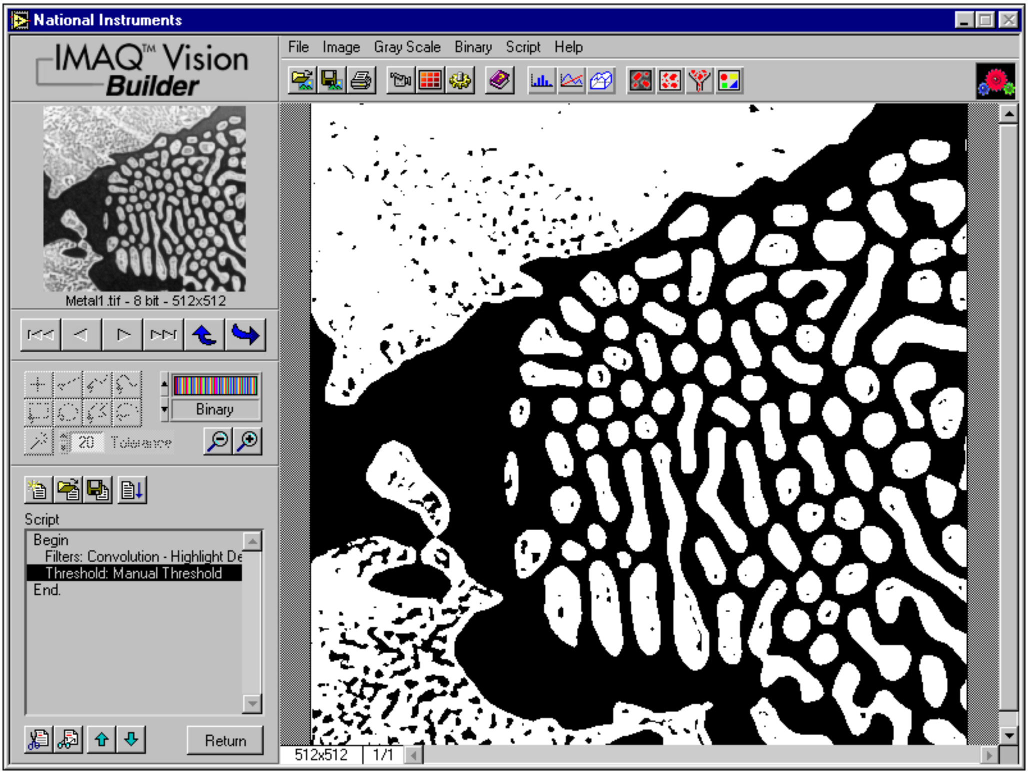


Figure 3-3. Separating Particles from the Background with Thresholding

Modifying Blobs with Morphological Functions

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

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

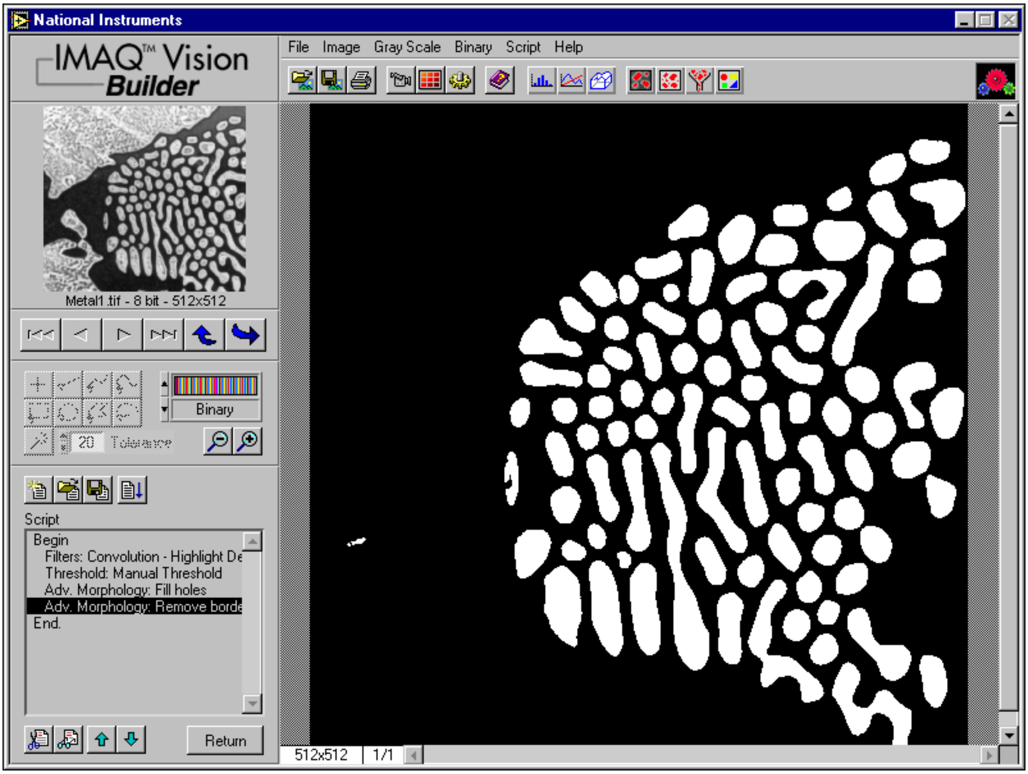


Figure 3-4. Modifying Blobs with Morphological Functions

5. Click **Apply** and **Close** to add this step to the script and close the Advanced Morphology window.

Isolating Circular Blobs

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

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

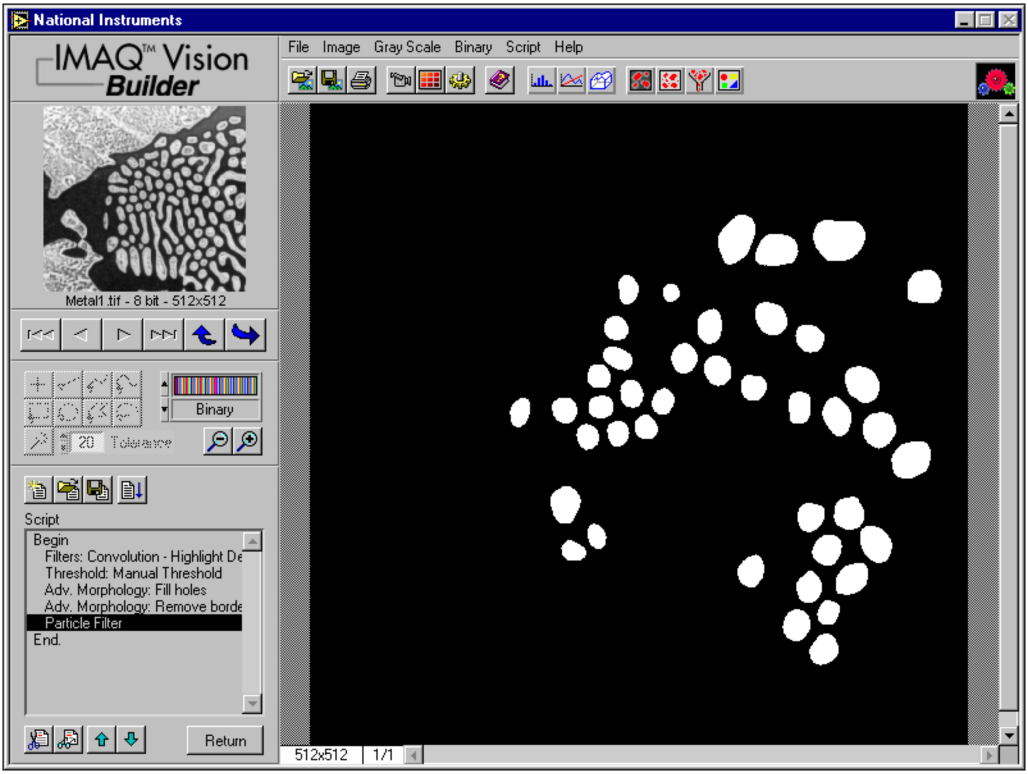


Figure 3-5. Isolating Circular Blobs

Analyzing Circular Blobs

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

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

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

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

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

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

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

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

Testing the Blob Analysis Script

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

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

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

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

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

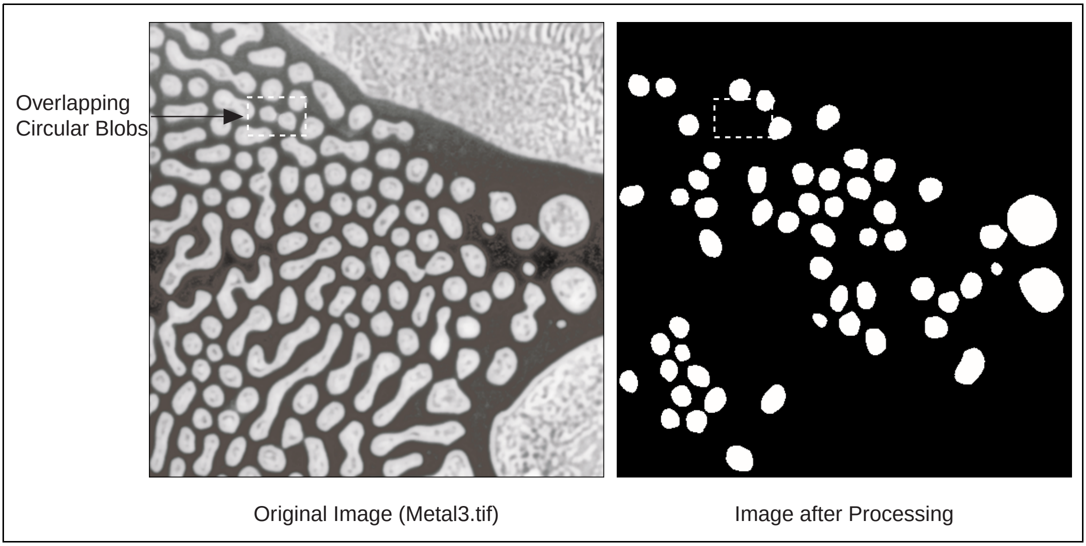


Figure 3-6. Comparing the Original Image to the Processed Image

4. Click **Cancel** in the Particle Analysis window to close the results table.

5. Double click the Threshold step in the script window to open the threshold parameters. Figure 3-7 shows `Metal3.tif` at the thresholding step of the script.

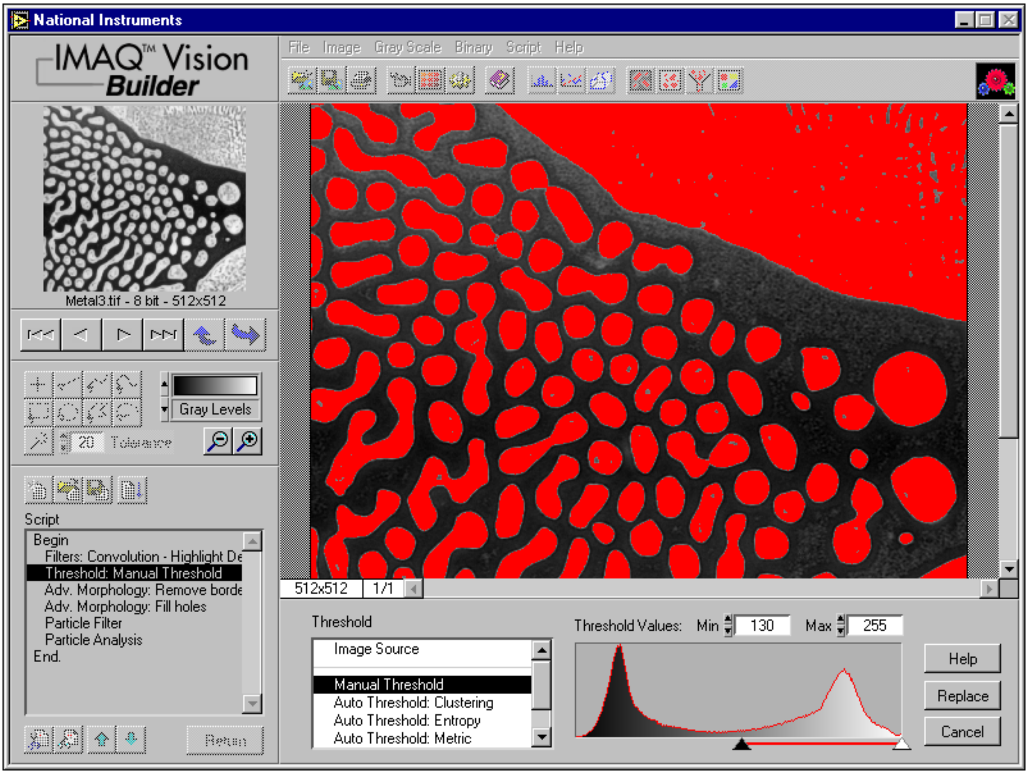


Figure 3-7. Testing the Blob Analysis Script

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

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

Saving the Blob Analysis Script

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

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

Implementing the Algorithm in LabVIEW

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

1. Select **Script»Builder File**. The Builder Information window lists all of the processing steps and the parameters for each.
2. Click the **Save** button.
3. Save the file as `blob analysis.txt`.
4. Use **File»Exit** to close IMAQ Vision Builder.
5. Open the file in a text editor or word processor and print the file.
6. Launch LabVIEW and use the step descriptions to build the blob analysis block diagram with IMAQ Vision VIs. The block diagram should look similar to Figure 3-8.

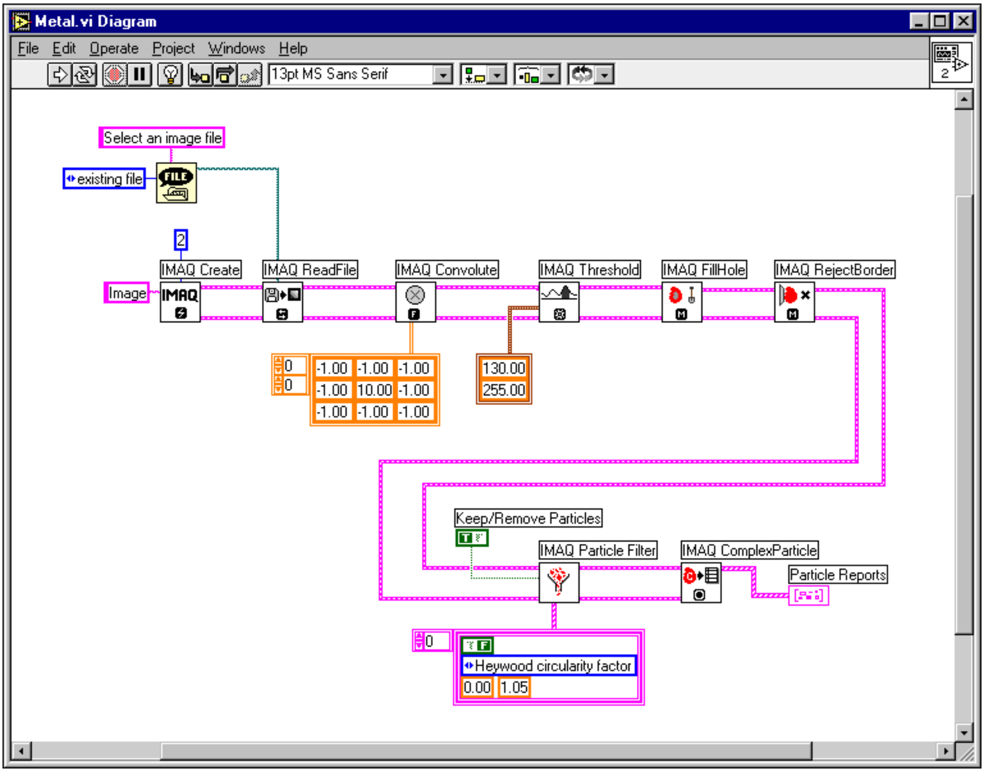


Figure 3-8. Blob Analysis Block Diagram

Tip ***The IMAQ Particle Filter VI is installed with IMAQ Vision Builder. You can find it in the*** `Program Files\National Instruments\IMAQ Vision Builder\VIs` ***folder.***

4

Using Gauging for Part Inspection

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

What Is Gauging?

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

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

Tutorial

In this tutorial, you analyze an image of a jumper to see if the jumper meets its physical specifications. A jumper is a plastic plug that fits over a pair of protruding pins to close an electrical circuit.

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

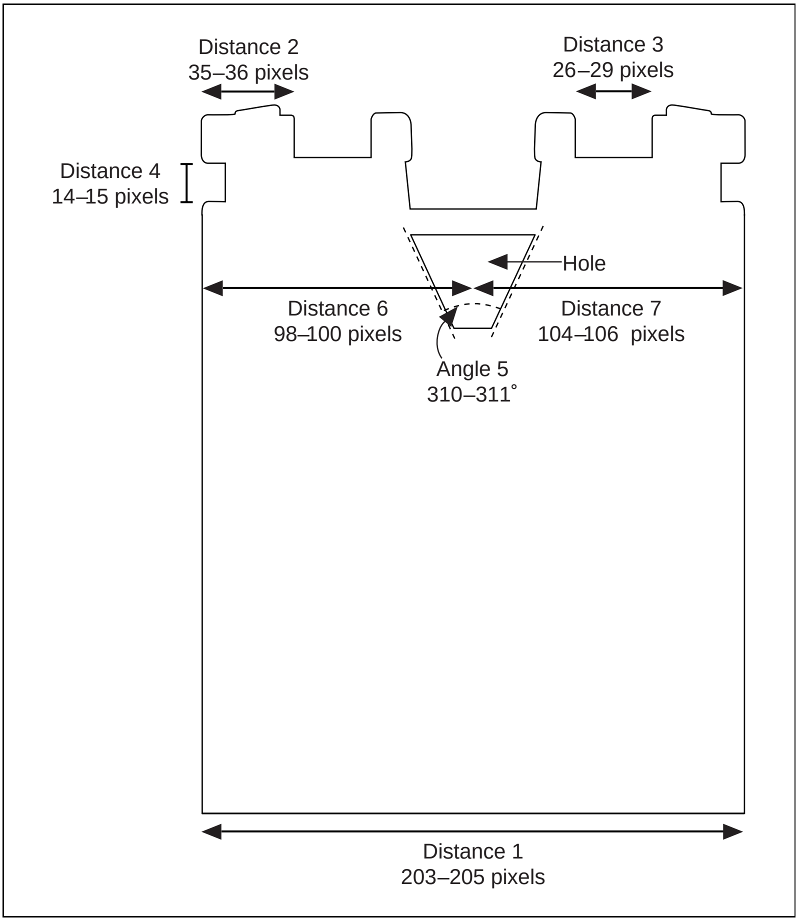


Figure 4-1. Jumper Specifications

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

Loading Images into IMAQ Vision Builder

Perform the following steps to load an image:

1. Launch IMAQ Vision Builder from the **Start** menu (**Start»Programs»National Instruments IMAQ Vision Builder»IMAQ Vision Builder**).
2. To load images, select **File»Open Image**.

3. Navigate to `Program Files\National Instruments\IMAQ Vision Builder\Examples\Jumper` and check the **Select All Files** option. Notice that IMAQ Vision Builder previews the images in the Preview Image window and displays information about the file format and size and pixel depth.

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

4. Click **OK** to load the image files into IMAQ Vision Builder. From this collection of images in the Image Browser, you can select the image that you want to process.
5. Double click the first image, `Jumper1.bmp`. The image is loaded into the processing window.

Finding Edges in the Image

Before you can compute the measurements, you need to detect edges on which you can base the measurements. The Edge Detector finds edges along a line that you draw with the line tool from the Tools palette.

1. Select **Gray Scale»Edge Detector**.
2. Select the **Simple Edge Tool**. The Simple Edge Tool is effective on images with sharp contrast between the background and objects.
3. Select **All Edges** so that IMAQ Vision Builder finds and labels every edge along the line you draw.
4. Select **Absolute Value**. Absolute Value indicates that you want to use pixel values to specify the threshold level. **Relative Value** indicates that you are specifying the threshold level as a percentage.
5. Set **Threshold Level** to 128. The threshold level specifies the difference in pixel values that you expect to constitute an edge in the image. Absolute detection considers a threshold level of 128 or greater as an edge.
6. Click and drag to draw a horizontal line across the middle of the jumper to find the edges that define Distance 1, as shown in Figure 4-2. IMAQ Vision Builder labels the edges 1 and 2.

Note ***You can obtain the same results by selecting* Relative Value *with a* Threshold Level *of* 50%.**

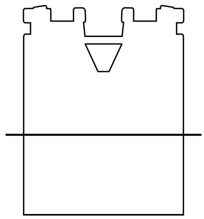


Figure 4-2. Finding the Edges for Distance 1

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

7. Click **Apply** to add this edge detection step to the script.
8. To find edges for the other measurements, click and drag to draw the lines as indicated in the Figures 4-3 to 4-6 and click **Apply** after each to add them to the script.

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

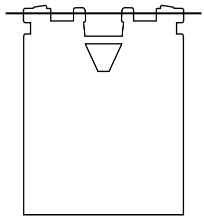


Figure 4-3. Finding the Edges for Distances 2 and 3

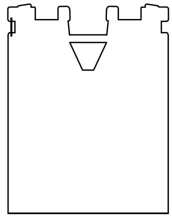


Figure 4-4. Finding the Edges for Distance 4

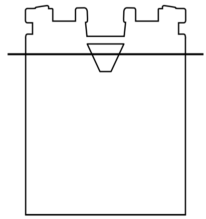


Figure 4-5. Finding the Edges for Angle 5 and Distances 6 and 7

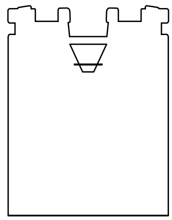


Figure 4-6. Finding the Edges for Angle 5

9. Click **Close** to close the Edge Detection window.

Storing the Original Image

To calculate Distances 6 and 7, you need to isolate the hole and find its center point. As you isolate the hole, you will alter the image. Because you need the original image to find the measurements, follow these steps to save a copy of the original image in an image buffer.

1. Select **Image»Image Buffer**.
2. Select **Push Image** to indicate that you want to copy the image to the image buffer.
3. Click **Apply** to add this step to the script. Notice that the image is copied to the buffer only after you click **Apply**.
4. Click **Close** to close the Image Buffer window.

Finding the Center Point in the Hole

To find the center point in the hole, you need to isolate the hole and then perform a circle detection.

Isolating the Hole

Follow these steps to isolate the hole:

1. Select **Binary»Threshold**. A threshold selects pixels based on their gray-level value and turns them white. All unselected pixels are turned black.
2. Select **Auto Threshold: Clustering**. Clustering applies an automatic thresholding algorithm. For this image, the thresholding range computed by the algorithm is between 135 and 255. This threshold range selects the objects and turns them white, converting them to blobs.
3. Click **OK** to add the threshold to the script and close the Threshold window.

The image now consists of two white blobs. Follow these steps to identify individual blobs with color:

4. Select **Binary»Adv. Morphology**.
5. Select **Label objects**. When you label objects, a different color is assigned to each blob. In this case, you see a green blob and a red blob.

Note ***You do not need to add the Label objects step to the script because it is not a necessary step in the processing algorithm. It was included here to show you how to color label objects in an image, which is especially useful for images containing many objects that are not clearly separated.***

To isolate the hole, which is the green blob, you need to remove the red blob. Because the red blob touches the border of the image and the green blob does not, you can use a function to remove all objects that touch the border.

6. Select **Remove border objects** from the Morphology list to remove the red blob.
7. Click **Apply** to add this step to the script.
8. Click **Close** to close the Morphology window.

Performing a Circle Detection

The circle detection function finds the center of circular particles in an image. If a particle is not circular, this function might not find the exact center. However, in this example, you do not need to find the exact center of the object. Instead, you are trying to find the center of a symmetrical object along the horizontal axis. Follow these steps to use circle detection to find the center of the hole:

1. Select **Binary»Circle Detection**. IMAQ Vision Builder finds the center of the hole and displays its coordinates in the results table, as shown in Figure 4-7.

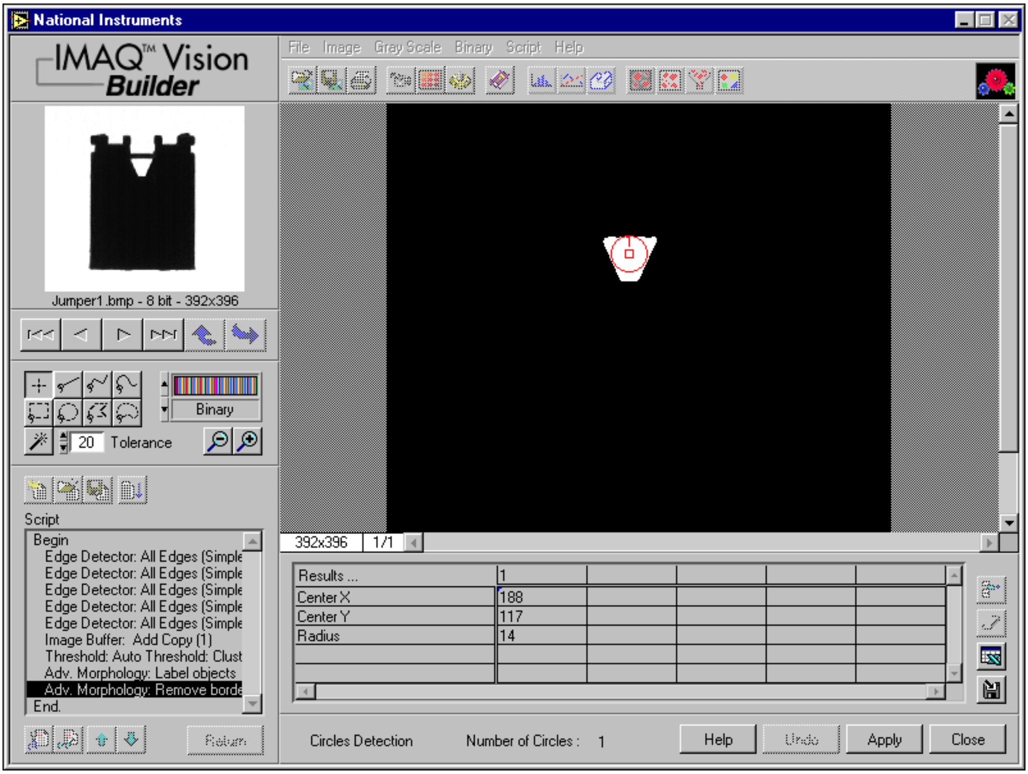


Figure 4-7. Finding the Center of an Object with Circle Detection

2. Click **Apply** to add this step to the script.
3. Click **Close** to close the Circle Detection window.

Restoring the Original Image

Perform the following steps to restore the original image so that you see the location of the edges on the original image:

1. Select **Image»Image Buffer**.
2. Select your image from the Image Buffer list.
3. Select **Pop Image**.
4. Click **Apply**. The original image is restored in the processing window.
5. Click **Close** to close the Image Buffer window.

Making the Measurements

Now that you have found all of the necessary edges and the center point in the hole, you can calculate the measurements with the Caliper function. The Caliper function is a tool that uses points on the image to calculate measurements, such as distances, angles, the center of a segment, or the area, depending on the number of points you have selected on the image. These points are results of earlier processing steps, such as edge detections.

Follow these steps to make the measurements:

1. Select **Gray Scale»Caliper**.
2. Click on points **1** and **2** to find the first measurement—Distance 1, which specifies the width of the entire image.

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

3. Click **Distance** as the type of measurement.
4. Click the **Measure** button to compute the distance and add the distance measurement to the results table, as shown in Figure 4-8.

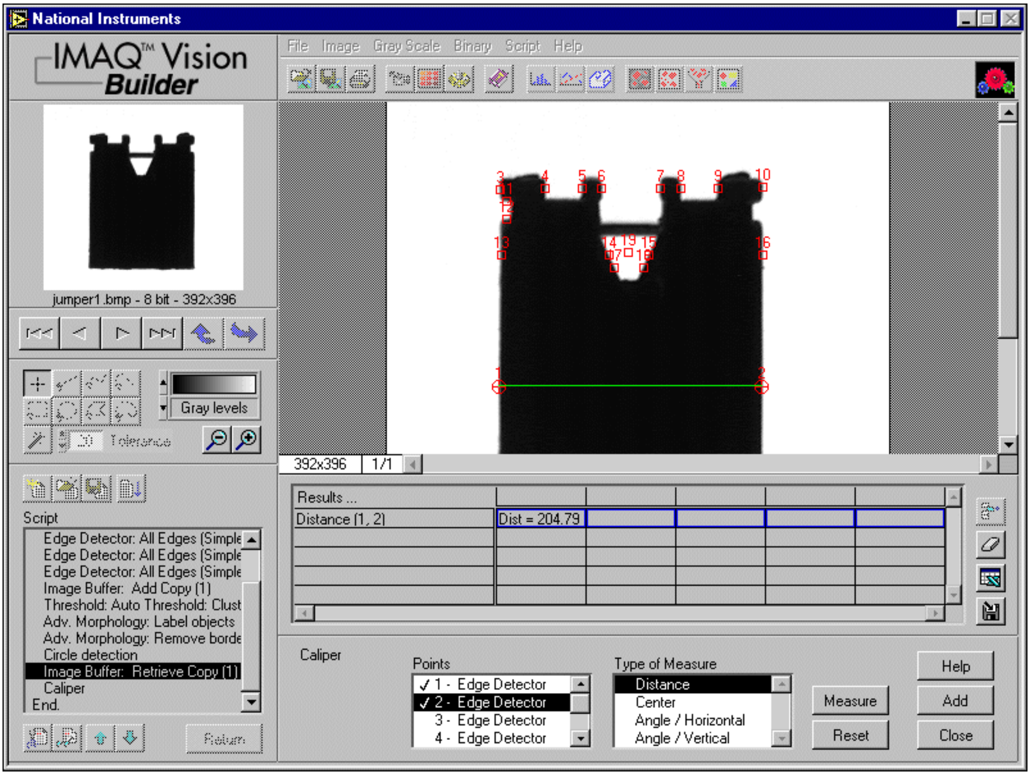


Figure 4-8. Using the Caliper Function to Find Distance 1

5. Using the data in the following table, repeat Steps 2–4 to find the remaining measurements:

Tip *Instead of clicking on the points in the image, you can double click on the points in the* **Points** *listbox to select them. When a point is selected, IMAQ Vision Builder places a checkmark next to it.*

To Make This Measurement	Select these Points	Type of Measurement
Distance 2	3,4	Distance
Distance 3	8,9	Distance
Distance 4	11,12	Distance
Angle 5	14,17,15,18	Angle

To Make This Measurement	Select these Points	Type of Measurement
Distance 6	13,19	Distance
Distance 7	19,16	Distance

Figure 4-9 shows a magnified view of the image with all of the caliper measurements selected on the image and displayed in the results table.

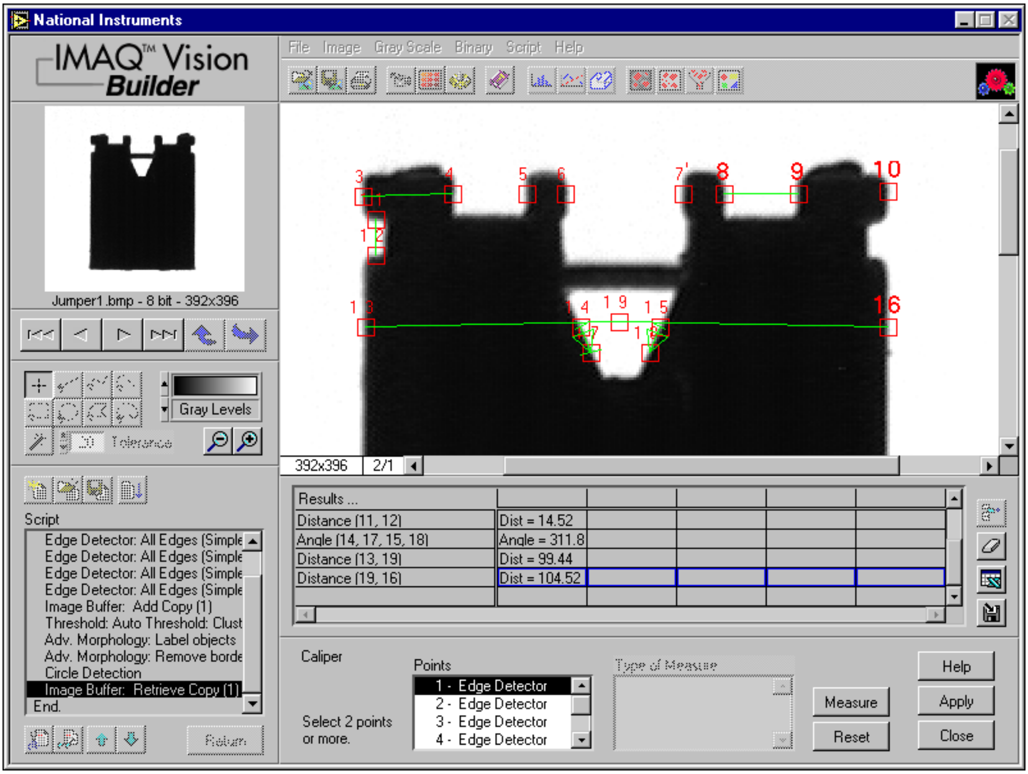


Figure 4-9. Using the Caliper Tool to Collect Measurements

6. Click **Add** to add these caliper measurements to the script and close the Caliper window.
7. Select **File»Save Script** and save the script as `jumpers.scr`.

Analyzing a Collection of Images with Batch Processing

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

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

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

3. Select Caliper in the list box.
4. Select **Save Results**.
5. Click the **Setup** button and set the following options:
   a. Select **One file for all results**.
   b. Press the **Browse** button, navigate to the directory where you want the file saved, and click **Select Cur Dir**.
   c. Name the file `jumpers.txt`.
6. Click **OK** to close the Setup options.
7. Click **Run** to start the batch process.

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

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

Analyzing the Results

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

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

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

The results are labeled and listed in the order in which they appear in the Image Browser. In this case, images are listed from `Jumper1.bmp` to `Jumper6.bmp`. The `Jumper1.bmp` results appear as follows.

Program Files\National Instruments\ IMAQ Vision Builder\Images\ Jumpers\Jumper1.bmp	10/23/98	3:17:16 PM
Distance (1, 2)	Dist =	204.79
Distance (3, 4)	Dist =	35.19
Distance (8, 9)	Dist =	28.81
Distance (11, 12)	Dist =	14.52
Angle (14, 17, 15, 18)	Angle =	311.8º
Distance (13, 19)	Dist =	99.44
Distance (19, 16)	Dist =	104.52

Table 4-1 lists the acceptable ranges for the jumper measurements and the actual values you might see for the jumper images. Notice that `Jumper1` is the only one that meets the specifications.

Note ***The bold values indicate which measurements caused the jumpers to fail.***

Table 4-1. Jumper Measurement Results

Measure	Ranges	Jumper1	Jumper2	Jumper3	Jumper4	Jumper5	Jumper6
1	203–205	204.79	204.79	204.79	204.79	**211.79**	203.79
2	35–36	35.19	35.19	**42.23**	35.19	35.19	35.19
3	26–29	28.81	26.81	28.81	28.81	28.81	**19.81**
4	14–15	14.52	**8.52**	14.52	14.52	14.52	14.52
5	310–313	311.8	311.8	311.8	**301.8**	311.8	311.8
6	98–100	99.44	99.44	99.44	98.44	99.44	**107.44**
7	104–106	104.52	104.52	104.52	104.52	**111.52**	**95.52**

A

Customer Communication

For your convenience, this appendix contains forms to help you gather the information necessary to help us solve your technical problems and a form you can use to comment on the product documentation. When you contact us, we need the information on the Technical Support Form and the configuration form, if your manual contains one, about your system configuration to answer your questions as quickly as possible.

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You can submit technical support questions to the applications engineering team through e-mail at the Internet address listed below. Remember to include your name, address, and phone number so we can contact you with solutions and suggestions.

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Brazil	011 288 3336	011 288 8528
Canada (Ontario)	905 785 0085	905 785 0086
Canada (Québec)	514 694 8521	514 694 4399
Denmark	45 76 26 00	45 76 26 02
Finland	09 725 725 11	09 725 725 55
France	01 48 14 24 24	01 48 14 24 14
Germany	089 741 31 30	089 714 60 35
Hong Kong	2645 3186	2686 8505
Israel	03 6120092	03 6120095
Italy	02 413091	02 41309215
Japan	03 5472 2970	03 5472 2977
Korea	02 596 7456	02 596 7455
Mexico	5 520 2635	5 520 3282
Netherlands	0348 433466	0348 430673
Norway	32 84 84 00	32 84 86 00
Singapore	2265886	2265887
Spain	91 640 0085	91 640 0533
Sweden	08 730 49 70	08 730 43 70
Switzerland	056 200 51 51	056 200 51 55
Taiwan	02 377 1200	02 737 4644
United Kingdom	01635 523545	01635 523154
United States	512 795 8248	512 794 5678

Technical Support Form

Photocopy this form and update it each time you make changes to your software or hardware, and use the completed copy of this form as a reference for your current configuration. Completing this form accurately before contacting National Instruments for technical support helps our applications engineers answer your questions more efficiently.

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Name ____

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Fax (___) ________________Phone (___) ____________________________

Computer brand____________ Model ___________________Processor_____________________

Operating system (include version number) ____________________________

Clock speed ______MHz RAM _____MB Display adapter __________________

Mouse ___yes ___no Other adapters installed____________________________

Hard disk capacity _____MB Brand___________________________________

Instruments used ____

____

National Instruments hardware product model_____________ Revision ______________

Configuration ____

National Instruments software product ___________________ Version ______________

Configuration ____

The problem is: ____

____

____

____

____

List any error messages: ____

____

____

The following steps reproduce the problem: _____________________________

____

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IMAQ Hardware and Software Configuration Form

Record the settings and revisions of your hardware and software on the line to the right of each item. Complete a new copy of this form each time you revise your software or hardware configuration, and use this form as a reference for your current configuration. Completing this form accurately before contacting National Instruments for technical support helps our applications engineers answer your questions more efficiently.

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Glossary

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

Numbers

1D — One-dimensional.

2D — Two-dimensional.

3D — Three-dimensional.

3D view — Displays the light intensity of an image in a three-dimensional coordinate system, where the spatial coordinates of the image form two dimensions and the light intensity forms the third dimension.

A

AIPD — National Instruments internal image format used for saving calibration information associated with an image and for saving complex images.

alpha channel — Channel used to code extra information, such as Gamma correction, about an image.

area threshold — Detects objects based on their size.

arithmetic operators — The image operations multiply, divide, add, subtract, and remainder.

auto-median function — A function that uses dual combinations of opening and closing operations to smooth the boundaries of objects.

B

binary image — An image containing objects usually represented with a pixel intensity of 1 (or 255) and the background of 0.

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

blob — Binary Large OBject. A connected region or grouping of pixels in an image in which all pixels have the same intensity level.

blob analysis — A series of processing operations and analysis functions that produce some information about the blobs in an image.

BMP — Image format commonly used for 8-bit images on PCs. Also called *bitmap*.

border function — Removes objects (or particles) in a binary image that touch the image border.

Builder file — IMAQ Vision Builder script file. Builder files are ASCII text files that list the processing functions and relevant parameters for an image processing algorithm that you created in IMAQ Vision Builder.

C

caliper — A function that calculates distances, angles, circular fits, and the center of mass based on positions given by edge detection, particle analysis, centroid, and search functions.

circle function — Detects circular objects in a binary image.

closing — A dilation followed by an erosion. A closing fills small holes in objects and smooths the boundaries of objects.

color images — Images containing color information, usually encoded in the RGB form.

color lookup table (CLUT) — Table for converting the value of a pixel in an image into a red, green, and blue (RGB) intensity.

complex images	Save information obtained from the FFT of an image. The complex numbers which compose the FFT plane are encoded in 64-bit floating-point values: 32 bits for the real part and 32 bits for the imaginary part.
connectivity	Defines which of the surrounding pixels of a given pixel constitute its neighborhood.
connectivity-4	Only pixels adjacent in the horizontal and vertical directions are considered neighbors.
connectivity-8	All adjacent pixels are considered as neighbors.
convex function	Computes the convex regions of objects in a binary image.
convolution	*See* linear filter.
convolution kernel	Simple 3 × 3, 5 × 5, or 7 × 7 matrices (or templates) used to represent the filter in the filtering process. The contents of these kernels are a discrete two-dimensional representation of the impulse response of the filter that they represent.

D

Danielsson function	Similar to the distance functions, but with more accurate results.
definition	The number of values a pixel can take on, which is the number of colors or shades that you can see in the image.
density function	For each gray level in a linear histogram, it gives the number of pixels in the image that have the same gray level.
device	Plug-in data acquisition board that can contain multiple channels and conversion devices.
differentiation filter	Extracts the contours (edge detection) in gray level.
dilation	Increases the size of an object along its boundary and removes tiny holes in the object.
distance calibration	Determination of the physical dimensions of a pixel by defining the physical dimensions of a line in the image.

distance function	Assigns to each pixel in an object a gray-level value equal to its shortest Euclidean distance from the border of the object.
driver	Software that controls a specific hardware device, such as a data acquisition board.

E

edge	Defined by a sharp change (transition) in the pixel intensities in an image or along an array of pixels.
edge contrast	The difference between the average pixel intensity before and the average pixel intensity after the edge.
edge hysteresis	The difference in threshold level between a rising and a falling edge.
edge steepness	The number of pixels that corresponds to the slope or transition area of an edge.
equalize function	*See* histogram equalization.
erosion	Reduces the size of an object along its boundary and eliminates isolated points in the image.
exponential and gamma corrections	Expand the high gray-level information in an image while suppressing low gray-level information.
exponential function	Decreases the brightness and increases the contrast in bright regions of an image, and decreases contrast in dark regions.

F

FFT	Fast Fourier Transform. A method used to compute the Fourier transform of an image.
Fourier spectrum	The magnitude information of the Fourier transform of an image.
Fourier transform	Transforms an image from the spatial domain to the frequency domain.
frequency filters	Counterparts of spatial filters in the frequency domain. For images, frequency information is in the form of spatial frequency.

G

Gaussian filter	A filter similar to the smoothing filter, but using a Gaussian kernel in the filter operation. The blurring in a Gaussian filter is more gentle than a smoothing filter.
grab	Acquisition technique that acquires and displays a continuous sequence of images using an IMAQ device. Use this acquisition technique when you need to focus your camera.
gradient convolution filter	*See* gradient filter.
gradient filter	Extracts the contours (edge detection) in gray-level values. Gradient filters include the Prewitt and Sobel filters.
gray level	The brightness of a point (pixel) in an image.
gray-level dilation	Increases the brightness of pixels in an image that are surrounded by other pixels with a higher intensity.
gray-level erosion	Reduces the brightness of pixels in an image that are surrounded by other pixels with a lower intensity.
gray-level images	Images with monochrome information.
gray-level morphology	Functions that perform morphological operations on a gray-level image.

H

highpass attenuation	Inverse of lowpass attenuation.
highpass FFT filter	Removes or attenuates low frequencies present in the FFT domain of an image.
highpass filter	Emphasizes the intensity variations in an image, detects edges (or object boundaries), and enhances fine details in an image.
highpass frequency filter	Attenuates or removes (truncates) low frequencies present in the frequency domain of the image. A highpass frequency filter suppresses information related to slow variations of light intensities in the spatial image.
highpass truncation	Inverse of lowpass truncations.

histogram	Indicates the quantitative distribution of the pixels of an image per gray-level value.
histogram equalization	Transforms the gray-level values of the pixels of an image to occupy the entire range (0 to 255 in an 8-bit image) of the histogram, increasing the contrast of the image.
hole filling function	Fills all holes in objects that are present in a binary image.
HSL	Color encoding scheme in Hue, Saturation, and Lightness.
HSV	Color encoding scheme in Hue, Saturation, and Value.

I

image	Light intensity as a function of the spatial coordinates $f(x, y)$ where x and y denote spatial coordinates and the value f at any point (x, y) is the light intensity at that point.
Image Browser	IMAQ Vision Builder feature that displays all of the images currently loaded. Through the Image Browser, you can select an image that you want to process by double clicking it.
image buffer	Memory location used to store images.
image file	A file containing image information and data.
image palette	The gradation of colors used to display an image on screen, usually defined by a color lookup table.
image processing	Encompasses various processes and analysis functions which you can apply to an image.
image source	Original input image.
image visualization	The presentation (display) of an image (image data) to the user.
inner gradient	Finds the inner boundary of objects.
inspection functions	Detects specific features in an image. The features detected include edges, peaks, and rotational shifts.
intensity range	Defines the range of gray-level values in an object of an image.

intensity threshold	Characterizes an object based on the range of gray-level values in the object. If the intensity range of the object falls within the user specified range, it is considered an object; otherwise it is considered part of the background.
interpolation	Is the technique used to find values in between known values when resampling an image or array of pixels.

K

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

L

labeling	The process by which each object in a binary image is assigned a unique value. This process is useful for identifying the number of objects in the image and giving each object a unique identity.
LabVIEW	Laboratory Virtual Instrument Engineering Workbench. Program development environment application based on the programming language G used commonly for test and measurement applications.
Laplacian filter	Extracts the contours of objects in the image by highlighting the variation of light intensity surrounding a pixel.
line profile	Represents the gray-level distribution along a line of pixels in an image.
linear filter	A special algorithm that calculates the value of a pixel based on its own pixel value as well as the pixel values of its neighbors. The sum of this calculation is divided by the sum of the elements in the matrix to obtain a new pixel value.
logarithmic and inverse gamma corrections	Expand low gray-level information in an image while compressing information from the high gray-level ranges.
logarithmic function	Increases the brightness and contrast in dark regions of an image, and decreases the contrast in bright regions of the image.
logic operators	The image operations AND, NAND, OR, XOR, NOR, difference, mask, mean, max, and min.

lookup table	Table containing values used to transform the gray-level values of an image. For each gray-level value in the image, the corresponding new value is obtained from the lookup table.
lowpass attenuation	Applies a linear attenuation to the frequencies in an image, with no attenuation at the lowest frequency and full attenuation at the highest frequency.
lowpass FFT filter	Removes or attenuates high frequencies present in the FFT domain of an image.
lowpass filter	Attenuates intensity variations in an image. You can use these filters to smooth an image by eliminating fine details and blurring edges.
lowpass frequency filter	Attenuates high frequencies present in the frequency domain of the image. A lowpass frequency filter suppresses information related to fast variations of light intensities in the spatial image.
lowpass truncation	Removes all frequency information above a certain frequency.
L-skeleton function	Uses an L-shaped structuring element in the Skeleton function.

M

mask	Isolates parts of an image for further processing.
mask image	An image containing a value of 1 and values of 0. Pixels in the source image with a corresponding mask image value of 1 are processed, while the others are left unchanged.
median filter	A low pass filter that assigns to each pixel the median value of its neighbors. This filter effectively removes isolated pixels without blurring the contours of objects.
morphological transformations	Extract and alter the structure of objects in an image. You can use these transformations for expanding (dilating) or reducing (eroding) objects, filling holes, closing inclusions, or smoothing borders. They mainly are used to delineate objects and prepare them for quantitative inspection analysis.
M-skeleton	Uses an M-shaped structuring element in the skeleton function.

N

neighborhood operations	Operations on a point in an image that take into consideration the values of the pixels neighboring that point.
nonlinear filter	Replaces each pixel value with a nonlinear function of its surrounding pixels.
nonlinear gradient filter	A highpass edge-extraction filter that favors vertical edges.
nonlinear Prewitt filter	A highpass edge-extraction filter that favors horizontal and vertical edges in an image.
nonlinear Sobel filter	A highpass edge-extraction filter that favors horizontal and vertical edges in an image.
Nth order filter	Filters an image using a nonlinear filter. This filter orders (or classifies) the pixel values surrounding the pixel being processed. The pixel being processed is set to the *N*th pixel value, where *N* is the order of the filter.
number of planes (in an image)	The number of arrays of pixels that compose the image. A gray-level or pseudo-color image is composed of one plane, while an RGB image is composed of three planes (one for the red component, one for the blue, and one for the green).

O

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

P

palette	The gradation of colors used to display an image on screen, usually defined by a color lookup table.
Parameter window	Displays parameters that you can set for an image processing function. Each IMAQ Vision function available through the menus has a parameter window where you set the parameters for that function.
picture element	An element of a digital image. Also called *pixel*.
pixel	Picture element.
pixel calibration	Directly calibrating the physical dimensions of a pixel in an image.
pixel depth	The number of bits (n) used to code the intensity of a pixel. For a given n, a pixel can take 2^n different values. For example, if n equals 8-bits, a pixel can take 256 different values ranging from 0 to 255. If n equals 16 bits, a pixel can take 65,536 different values ranging from 0 to 65,535 or –32,768 to 32,767.
Power 1/Y function	Similar to a logarithmic function but with a weaker effect.
Power Y function	*See* exponential function.
Prewitt filter	Extracts the contours (edge detection) in gray-level values using a 3 × 3 filter kernel.
probability function	Defines the probability that a pixel in an image has a certain gray-level value.
Processing window	IMAQ Vision Builder feature that updates the image as you change parameters. The Processing window is located on the right side of the IMAQ Vision Builder window.
proper-closing	A finite combination of successive closing and opening operations that you can use to fill small holes and smooth the boundaries of objects.
proper-opening	A finite combination of successive opening and closing operations that you can use to remove small particles and smooth the boundaries of objects.

Q

quantitative analysis	Obtaining various measurements of objects in an image.

R

Reference window	IMAQ Vision Builder feature that displays the original version of the image (image source) as you manipulate it in the processing window. The Reference window appears in the upper left corner of the IMAQ Vision Builder window.
region of interest	An area of the image that is graphically selected from a window displaying the image. This area can be used focus further processing. Also called *ROI*.
resolution	The number of rows and columns of pixels. An image composed of m rows and n columns has a resolution of $m \times n$. This image has n pixels along its horizontal axis and m pixels along its vertical axis.
Reverse function	Inverts the pixel values in an image, producing a photometric negative of the image.
RGB	Color image encoding using red, green, and blue colors.
RGB chunky	Color encoding scheme using red, green, and blue (RGB) color information where each pixel in the color image is encoded using 32 bits: 8 bits for red, 8 bits for green, 8 bits for blue, and 8 bits for the alpha value (unused).
Roberts filter	Extracts the contours (edge detection) in gray level, favoring diagonal edges.
ROI	Region of interest.
ROI tools	Collection of tools from the Tools palette that enable you to select a region of interest from an image. These tools let you select a point or line; polygon, rectangle, and oval regions; and freehand lines and areas.

S

script	List of image processing and analysis functions and the parameters for each of those functions. IMAQ Vision Builder records each function and relevant parameters as you prototype your image processing application.
Script window	The window in which IMAQ Vision Builder displays a script. From the scripting window, you can edit, remove, or add steps and run scripts. The Script window appears in the lower left corner of the IMAQ Vision Builder window.

segmentation function	Fully partitions a labeled binary image into non-overlapping segments, with each segment containing a unique object.
separation function	Separates objects that touch each other by narrow isthmuses.
sequence	Acquisition technique that acquires images according to settings that you specify in the acquisition property pages.
shape matching	Finds objects in an image whose shape matches the shape of the object specified by a template. The matching process is invariant to rotation and can be set to be invariant to the scale of the objects.
Sigma filter	A highpass filter that outlines edges.
skeleton function	Applies a succession of thinning operations to an object until its width becomes one pixel.
skiz function	Obtains lines in an image that separate each object from the others and are equidistant from the objects that they separate.
smoothing filter	Blurs an image by attenuating variations of light intensity in the neighborhood of a pixel.
snap	Acquisition techniques that acquires and displays a single image.
Sobel filter	Extracts the contours (edge detection) in gray-level values using a 3×3 filter kernel.
spatial calibration	Assigning physical dimensions to the area of a pixel in an image.
spatial filters	Alter the intensity of a pixel with respect to variations in intensities of its neighboring pixels. You can use these filters for edge detection, image enhancement, noise reduction, smoothing, and so forth.
spatial resolution	The number of pixels in an image, in terms of the number of rows and columns in the image.
Square function	*See* exponential function.
Square Root function	*See* logarithmic function.

structuring element	A binary mask used in most morphological operations. A structuring element is used to determine which neighboring pixels contribute in the operation.
sub-pixel analysis	Used to find the location of the edge coordinates in terms of fractions of a pixel.

T

template	Pattern or shape that you are trying to match in an image using the search-shape matching function or the search-correlate function. A template can be a region selected from an image or it can be an entire image.
thickening	Alters the shape of objects by adding parts to the object that match the pattern specified in the structuring element.
thinning	Alters the shape of objects by eliminating parts of the object that match the pattern specified in the structuring element.
threshold	Separates objects from the background by assigning all pixels with intensities within a specified range to the object and the rest of the pixels to the background. In the resulting binary image, objects are represented with a pixel intensity of 255 and the background is set to 0.
threshold interval	Two parameters, the lower threshold gray-level value and the upper threshold gray-level value.
TIFF	Image format commonly used for encoding 8-bit and 16-bit images and color images on both Macintosh and PC platforms.
Tools palette	Collection of tools that enable you to select regions of interest, zoom in and out, and change the image palette.

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