ViewFlex

v.2.8

User Manual

100299 Rev. D (January 2002)

intelitek

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The printed ViewFlex User Manual that is supplied with the ViewFlex system contains an abridged version of the Matrox Inspector software manual.

The complete Matrox Inspector User Guide can be viewed and printed from the PDF file named **InsptrUG** included on the ViewFlex software CD.

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ViewFlex Installation

Unpacking the Equipment

Before installing the equipment, check for signs of shipping damage. If any damage is evident, contact your freight carrier, and begin appropriate claims procedures. Make sure you have received all the items listed on the packing list. If anything is missing, contact your supplier.

Installing the ViewFlex System

Install the ViewFlex system in the following order:

- Assemble the camera stand and attach the camera to it.
- Connect software protection key.
- Install the ViewFlex software. The ViewFlex installation is supplied on one CD ROM.

Do not plug the camera into the USB port of the computer until after the software installation.

Assembling the Camera Stand

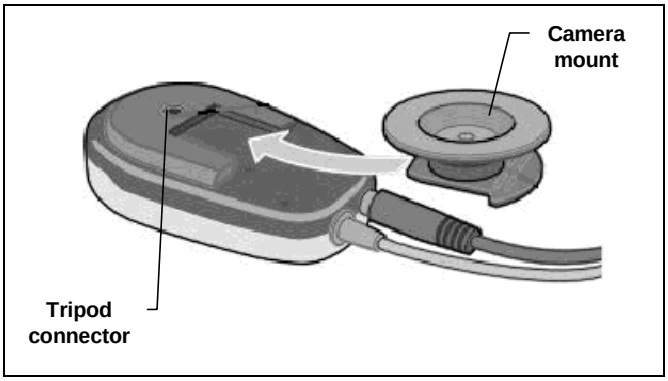
To assemble the camera stand, do the following:

1. Put one of the upright posts (hollow aluminum pole) into the base. Make sure it goes all the way in.
2. Lock the post into place by tightening the knob on the base. Make sure the post does not move.

   Option: if you want to place the base on the floor connect the two upright posts together.

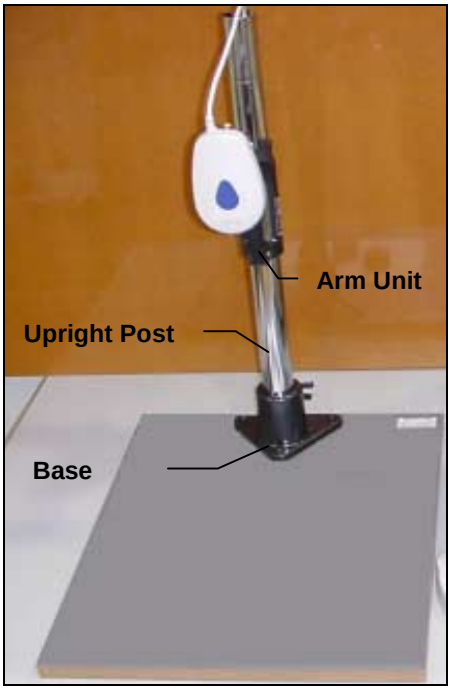
   - Insert the posts together.
   - Twist and lock the posts.
   - Insert the post assembly into the base.
   - Lock the assembly into place as described above.
3. Open the knob on the arm unit.
4. Slide the arm unit onto the post.

5. Tighten the knob.
6. Attach the camera rod to the arm unit.
7. Tighten the knob.
8. Slide the camera mount out of the Intel camera.
9. Attach the camera to the camera rod with the tripod connector on the bottom of the camera.



Camera connections

10. Place the completed assembly in a safe convenient location near the computer.



Camera attached to stand

Do not plug the camera into the USB port of the computer until after the software installation.

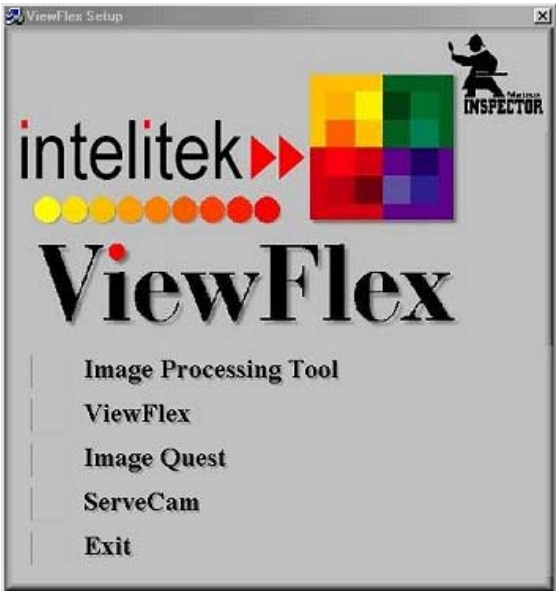
Software Protection Key

1. Without the software protection key, the software is programmed to run on a 30-day trial basis.
2. Plug the software protection key into the printer port of your computer.
3. If you also want to connect a printer to your computer, plug the printer cable into the connector on the software key.

Software protection key

Installing the ViewFlex Software

1. Place the ViewFlex CD-ROM in the drive.
2. The installation procedure should begin to run automatically. If it does not, select Start|Run, and select **Install.exe** from the CD-ROM.



ViewFlex Setup dialog box

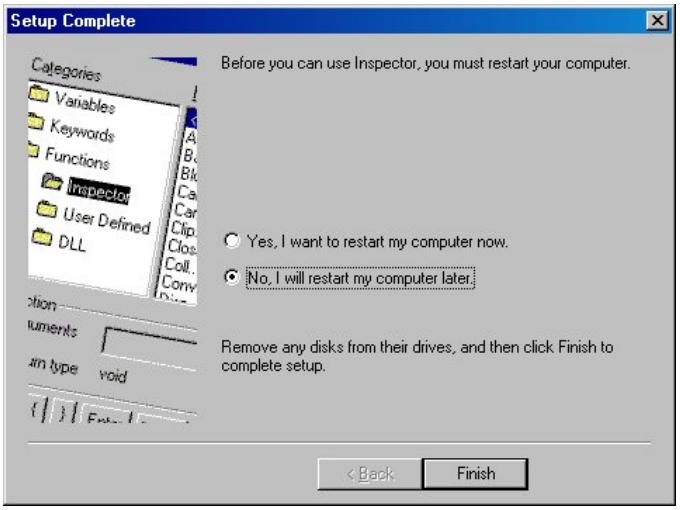
You must first install the **Image Processing Tool** module. Only then can you install the ViewFlex software.

3. Click on **Image Processing Tool**.

   The Matrox Inspector setup will begin to run.

4. Follow the directions on your screen.

5. Select **No, I will restart my computer later**, when prompted at the end of the installation process.

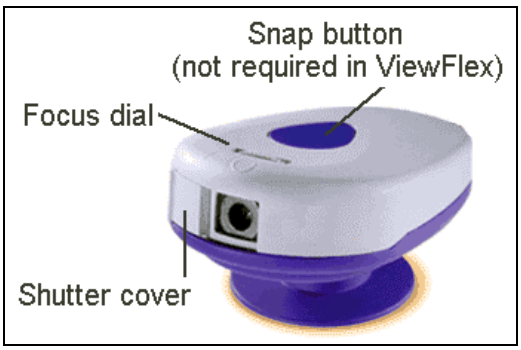


Setup complete

You only need to restart the computer after you have completed all three installations.

6. Click **Finish**.
7. From the ViewFlex setup click ViewFlex. A dialog box will appear prompting you to select one of three options:
   - **ViewFlex** (ER-5, ER-9, ER-14, SV3 and Open CIM)
   - **ViewFlex for SCORBASE** for ER-4pc
   - **ViewFlex for SCORBASE** for ER-4u
8. Follow the directions on the screen.
9. Select **No, I will restart my computer later**, when prompted at the end of the installation process.
10. Click **Finish**.
11. From the ViewFlex setup dialog box, select **Image Quest**.

    The Image Quest installation will begin.
12. Follow the directions on the screen.
13. Restart the computer after you have completed the Image Quest installation.
14. Make sure the camera's shutter is open.



Digital PC camera

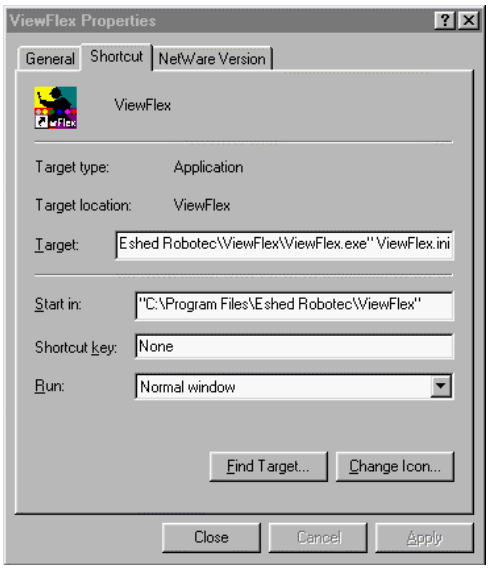
15. Connect the camera to a USB port if you are installing ViewFlex on the PC.

    Note: If you are installing ViewFlex for SCORBASE you will need to install the ViewFlex ServeCam on another computer with USB connection that is also connected to a network.

16. A driver message will appear. Click OK.

Software Initialization

The ViewFlex.ini file initializes the ViewFlex software.



ViewFlex Properties

The ViewFlex.ini file includes the following:

The directory in which the script files are located (only for the ViewFlex Device Driver).

[Device Driver Definitions]

ScriptPath= \Vision Script

You can choose the controller type – A, B, PC, USB.

[Controller Setting]

Controller=A

(Note: You can choose: ER4, ER4u, ER5, ER9, ER14, SV)

RobotType=ER14

Activating ViewFlex

To start the ViewFlex software, double-click the ViewFlex icon on the desktop.

OR

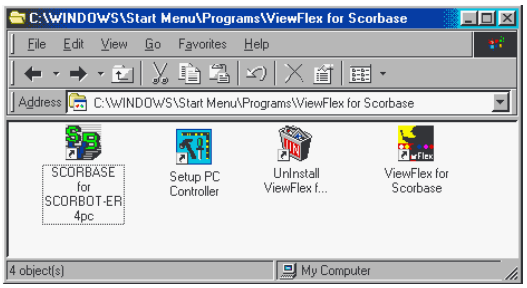
From the Start menu, select **Programs | ViewFlex | ViewFlex**.

Activating ViewFlex for SCORBASE for ER-4pc

To start ViewFlex for SCORBASE, do the following:

1. Activate ServeCam.
2. Double-click the SCORBASE icon.

   Or, double-click the ViewFlex for SCORBASE icon.



ViewFlex for SCORBASE Program Group

2

Software Operation

ViewFlex Toolbar

The ViewFlex Toolbar contains icons that are shortcuts for selecting certain commands and functions:

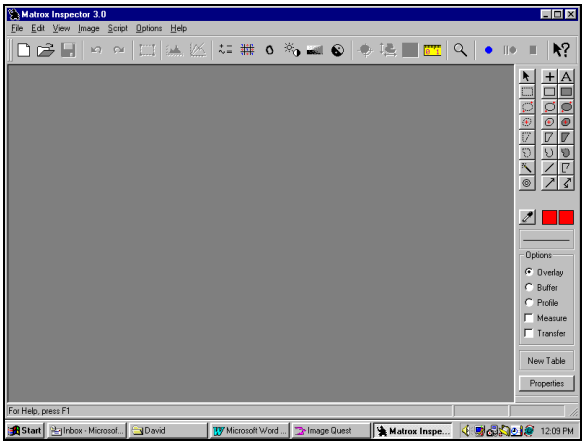
ViewFlex Toolbar

- Image Processing Tool
- Camera 1
- Camera 2
- ACL Terminal (for ViewFlex)
- Abort All
- Go Position
- Calibration
- OpenCIM Device Driver
- About
- Exit

Image Processing Tool

Open the image processing tool (*Matrox Inspector*).

(*Refer to the Matrox Inspector Instruction Manual for more information.*)



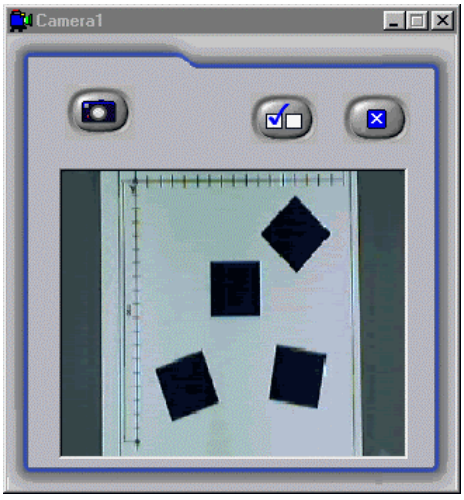
Matrox Inspector

Camera (Camera 1 / Camera 2 / ServeCam)

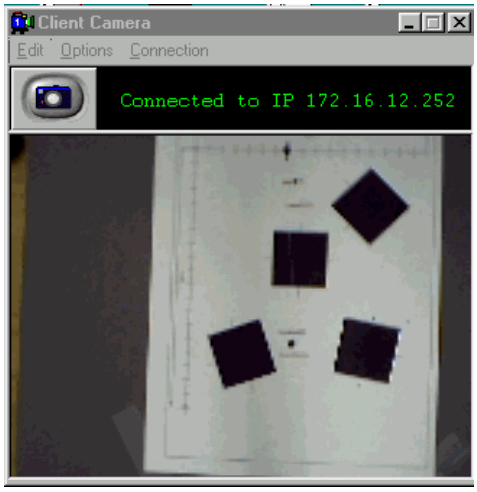
When two cameras are used, a **Select Video Device** dialog box will prompt you. The camera icon opens the **Camera** (capture) window or the **Client Camera** window.

Client (remote) camera operation is available only in ViewFlex for SCORBASE for ER 4pc.

As soon as Client Camera is activated, it connects to the server, and displays the computer IP address where the ServeCam is located as soon as it detects it.



Camera window



Client Camera window

Snap

Grabs (captures) a picture and displays it in a frame.

OR

Inserts an updated picture from the ServeCam.

Options

Opens a dialog box use for video settings and configuration.

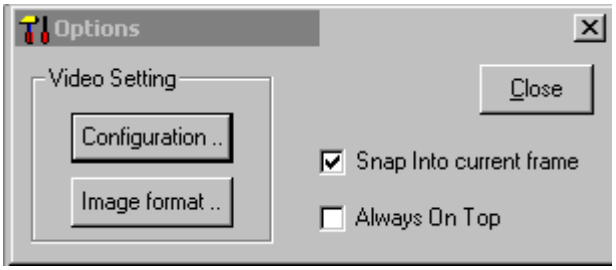
Connection (available only in Client Camera)

Enables connection of remote cameras on a network.

Exit

Closes the Camera window.

Camera Options



Camera Options

Always On Top:

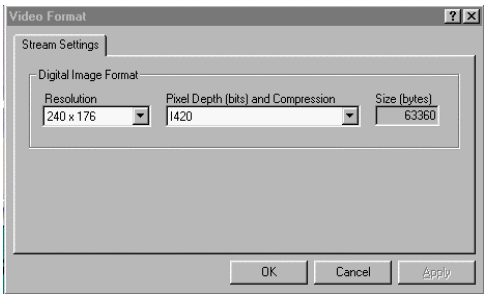
Checking this box prevents the Camera window from being hidden by other windows.

Snap Into Current Frame

The captured image will be put into the current frame in the Image Processing Tool. The part of the image that will be inserted into the frame depends on the current frame size. If left unchecked, a new frame will be created each time an image is captured (every Snap).

Image Format

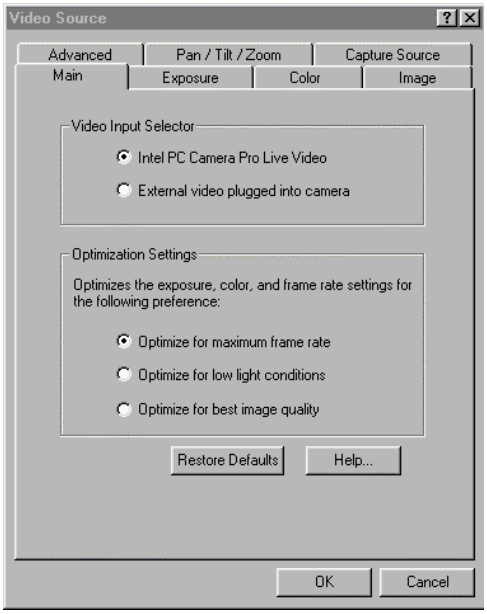
Opens the Video Format dialog box.



Video Format dialog box

Configuration

Opens the Video Source dialog box.



Video Source dialog box

Video Source – Camera Configuration

Main

Video Input

Choose the video source for the applications that use video. Your options for video source include the Intel PC Camera Pro or you can attach an external video device like a VCR or camcorder.

When you select an external video source, some options are not available.

Optimize for maximum frame rate

Ensures that the frame rate never drops below 15 frames per second (in dim light the video may appear dark).

Optimize for low light conditions

Ensures that the video is properly exposed in low light conditions like when indoors, but may appear washed out in bright light conditions. The frame rate for this option is between 8 and 15 frames per second. This option is not available when the video source is an external video device.

Optimize for best image quality

Ensures that each frame of the video is high quality, but it does reduce the frame rate so that the frame rate never exceeds 15 frames per second.

Exposure

Choose **Automatic Exposure** control to have the camera automatically adjust the image according to the brightness slider setting.

- Use the **Light Sensitivity** slider to control how long the image must be too dark or too light before the camera adjusts. Move the slider all the way to the left for the camera to adjust immediately. Move the slider all the way to the right for the camera to adjust after 10 continuous seconds of poor exposure.
- Use the **Brightness** slider to set how bright the automatic exposure should make the scene.

Choose **Manual Exposure** control to adjust the exposure settings yourself.

- Use the **Gain** slider to make the scene dimmer or brighter.
- Use the **Exposure Time** slider to set the length of time light will hit the sensor for each image.

Click **Restore Defaults** to set the sliders to the factory settings for this tab.

Color

This tab lets you control the colors in the video. Using the sliders, you can instantly see the effect each is having on the video picture as you move the slider. Adjust the sliders until you are satisfied with the picture.

Saturation

Drag the slider to the right to increase the intensity of the colors, drag the slider to the left to decrease the intensity. Moving the slider all the way to the left changes the colors to black and white.

Hue

Drag the slider to the left to increase the blue in the video, drag the slider to the right to increase the green.

Red, Green, Blue

Drag the red, green and blue sliders left and right to decrease and increase the tones of the colors in the video. This option is not available when the video source is an external video device.

Click **Restore Defaults** to set the sliders to the factory settings for this tab.

Image

White Balance

White balance is not available when the video source is an external video device.

Automatic White Balance.

Automatically makes the whitest color in the video whiter and adjusts the other colors proportionately. Move the slider to the left to make the video appear cooler (adds blue), move the slider to the right to make the video appear warmer (adds red).

Any changes made take a few seconds to happen.

Manual White Balance

When switching from automatic to manual, the settings from the automatic white balance control are initially matched until you change them. Move the slider to the left to make the video appear cooler (adds blue), move the slider to the right to make the video appear warmer (adds red).

Manually adjusting the white balance may be useful when using a laptop computer in differing lighting conditions, for instance going from room lighting to sunlight, or when automatic adjusting is unsatisfactory.

Image Effects

Click **Mirror Image** to reverse the image in the video window.

Click **Flip Image** to have the image flip from top to bottom. This could be used when the camera is upside down, for instance when mounted underneath a cabinet.

Image Sharpness

Drag the slider left to soften the image, drag the slider right to sharpen the image.

Advanced

USB Bandwidth

When you have multiple USB devices in use at the same time, and the camera is using too much of the USB bus, use this control to specify how much of the bus to allocate for the camera.

Drag the slider to the left to decrease the amount of the bus used by the camera, drag the slider to the right to increase the amount of the bus used by the camera.

Changes made here won't take effect until video is stopped and restarted.

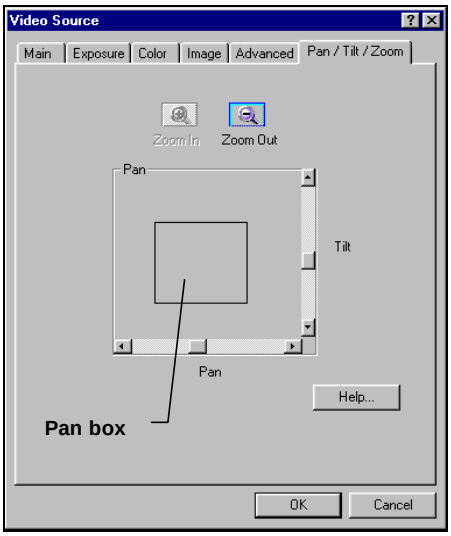
CPU Usage

When using the camera on a computer with a processor running at 233MHz or less, the minimize CPU Usage checkbox is enabled by default. On computers with faster processors, only use this control when the computer becomes sluggish while using the camera.

Click **Restore Defaults for All Camera Settings** to restore all of the tab settings to their factory settings.

Pan/Tilt/Zoom

Controls the location of the image in the field of view.



Pan/Tilt/Zoom tab

Pan

Moves across the image horizontally. This option does not work when the camera is zoomed all the way out or when the capture size is 640 x 480.

Tilt

Moves across the image vertically. This option does not work when the camera is zoomed all the way out or when the capture size is 640 x 480.

Zoom In

Zooms in on the portion of the image currently visible in the video window. The size of the rectangle shows the amount that the camera is zoomed.

Zoom Out

Zooms out on the portion of the image currently visible in the video window. The size of the rectangle shows the amount that the camera is zoomed.

Shortcuts

Right-clicking the mouse inside the pan area opens a menu with the following:

- MaxZoom In: the camera zooms all the way in
- MaxZoom Out: the camera zooms all the way out
- Center View: places the image in the center of the field of view.
- Always on top: prevents the Camera window from being hidden by other windows.

Camera Connection (Client Camera only)

Connect to

If there is more than one ServeCam on the network, then you can make a connection to the specific ServeCam that you want by entering the IP address of that ServeCam's computer.

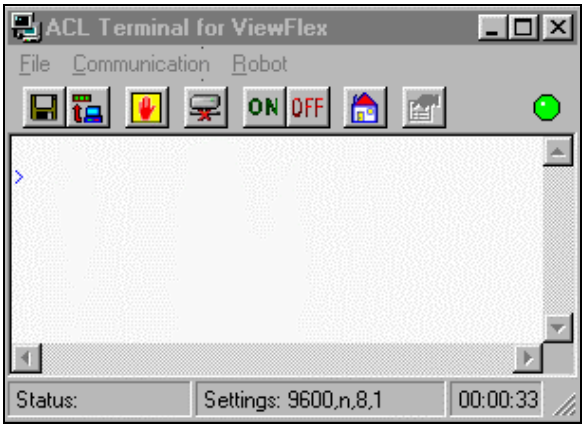
The default IP address is the one that initially appears in the box, which was automatically detected.

Clicking OK will connect to the ServeCam at the IP address shown.

ACL Terminal for ViewFlex

ACL, Advanced Control Language, is an advanced, multi-tasking robotic programming language.

The ACL Terminal for ViewFlex is the software interface that provides access to the controller from a PC, and provides functions needed to configure, program and operate the robot system.



ACL Terminal for ViewFlex

Save

Saves a listing of all user programs, variables and positions in one file. The files are in ACL format (.acl).

Download

Downloads data from a user-backup file in the host computer to the controller. (Does not erase or modify existing programs.)

Abort All

Immediately aborts all running programs and stops movement of axes.

On-Line/Off-Line

Opens/closes the communications port.

ON-CON

Enables servo control for all axes, a specified group of axes, or a single axis.

OFF-COFF

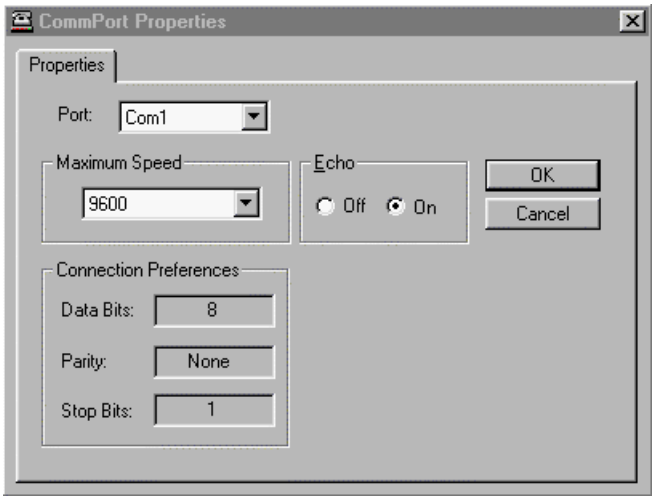
Disables servo control for all axes, a specified group of axes, or a single axis.

Home

Drives all robot axes to their home position.

Port Properties

Opens a dialog box that allows you to configure the RS232 serial communication port in the PC that communicates with the robot controller:



ACL Terminal CommPort Properties

ACL ViewFlex String Commands

The ViewFlex String Commands are written as:

Print / Println "%ViewFlex string commands %"

ViewFlex helps you make applications that combine vision and robot guiding that will use the ACL language for controlling and executing robot tasks.

ViewFlex Variable

Vision functions are written in Visual Basic (VB) script. The vision script will operate the vision task. To synchronize the vision and robot tasks, there is the Global Variable (VF). After executing the Vision Function or subroutine, the VF value will be 1 (VF=1).

SNAP

Format: %SNAP%

Description: Will capture an image from the camera and put it into the Image Processing Tool.

RUN

Format: %RUN prog%

Description: Where: **prog** is the name of a function or subroutine in the script. The function returns the ACL command back to the controller.

Examples: PRINTLN %RUN prog%

This executes the function or subroutine in the open VB script file. If you execute the function, the results will be sent to the controller.

The script must be loaded before it can be executed from the ACL.

SETPOS

Format: %SETPOS Position, Table index, Table name, Z(mm)%

Description: Where:

Position is a defined robot position.

Table index is a position of the object in a measurement table that was found in the image after searching. The reserve word ALL means that if a Position is the name of a vector all the positions in the table will be set.

Table name is the name of the measurement table. If omitted, it means Current table.

Z is the value of the Cartesian coordinate Z in millimeters.

Examples: PRINTLN "%SETPOS *pos,1, , 60*%"

Position *pos* receives the coordinate value of position *1* in the Current measurement Table, while the coordinate value of Z is *60* mm.

PRINTLN **"**%SETPOS *pv[4],3,table1 , 80*%"

Position *pv[4]* receives the coordinate value of position *3* in the measurement table named *table1*, while the coordinate value of Z is *80* mm.

PRINTLN "%SETPOS *pv,ALL,table2 , 80*%"

Vector *pv* receives the coordinate values of *ALL* positions in the measurement table named *table2*, while the coordinate value of Z is *80* mm.

Project: The following example project shows how the ACL program is used with the Vision System, in order to automate the robot and the Vision System. The example is made from two programs:

- **ACL:** for the robot task
- **Visual Basic Script**: for the vision task.

GOPOS.ACL

(Note: N should be a Global Variable.)

- The code initiates the global variable VF before sending comments to the Vision System, so that it can cause the ACL program to wait until the vision command is finished. This happens when VF is 1.
- The program tells the Vision System to Snap, then executes the GetPos function in the script. The results of the GetPos function is a string that is an ACL command. **If the search results are 3, for example, then set N to 3 ("set n=3")**.
- SETPOS takes the position of the object from the measurement table that was found after the search, and converts it to positions that can be sent.
- ALL takes every position from the Measurement Table and sets them into positions in the vector.
- At the end of GoPos, the program moves the robot to the position in the vector.

```
PROGRAM GOPOS
**********************
SET VF = 0
PRINTLN "%SNAP%"
WAIT VF = 1
SET VF = 0
PRINTLN "%RUN GETPOS%"
WAIT VF = 1
SET VF = 0
PRINTLN "%SETPOS POS,ALL,,60%"
WAIT VF = 1
FOR I = 1 TO N
  MOVED POS[I]
ENDFOR
END
```

GETPOS.BAS

- In order for the Run command to work, the script must be loaded.
- The model for the object whose script will be searched should also be loaded.
- When the script will be executed, a measurement table with the positions will be created. The script will also send a command that initiates a sign of the number of objects that were found.

```
Function GETPOS()As String
 I_IMAGE1$ = Insptr.ImgGetCur
 Insptr.ImgSetCurrent I_IMAGE1$, R_Def$,
ALL_BANDS
 Insptr.ImgConvertType(TO_8U)
 Insptr.MeasNew()
 M_X_MOD$=Insptr.PatGetCur
 Insptr.PatSetCur M_X_MOD$
 x=Insptr.PatFind
 Insptr.ImgClose
 Num=Insptr.MeasGetLastID
 GETPOS="SET N=" + CStr(num)
 End Function
```

Abort All

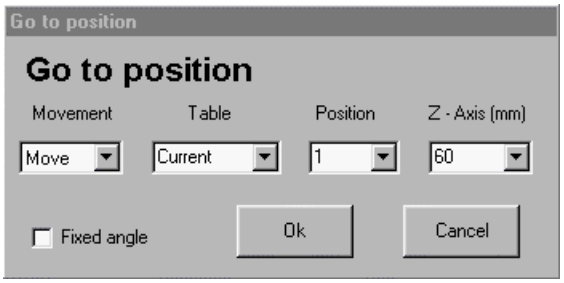
Format: [Ctrl] + A

Description: Immediately aborts all running programs and stops movement of axes.

[Ctrl] + A is the fastest software method for stopping program execution and halting movement of all axes. It can be used at any moment, even while entering another command, in order to instantly halt programs and axes.

This command is entered from keyboard, but does not require [Enter] for execution.

Go To Position



Go to Position dialog box

Movement

Move/MoveL (Move Linear).

Table

Can be the Current table, or any other named measurement table.

Position

The index of a position in the measurement table.

Z-axis (mm)

The Cartesian coordinates in millimeters.

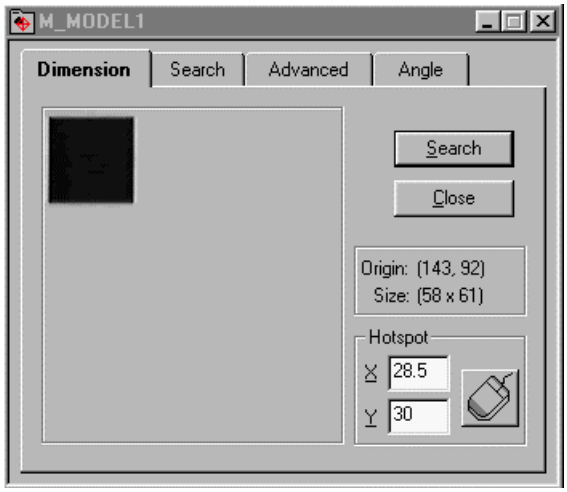
Fixed Angle

Enabling this option causes only the X and Y axes to be. This option can be used with circular objects when the gripper rotation is not important.

Example of Using Go To Position

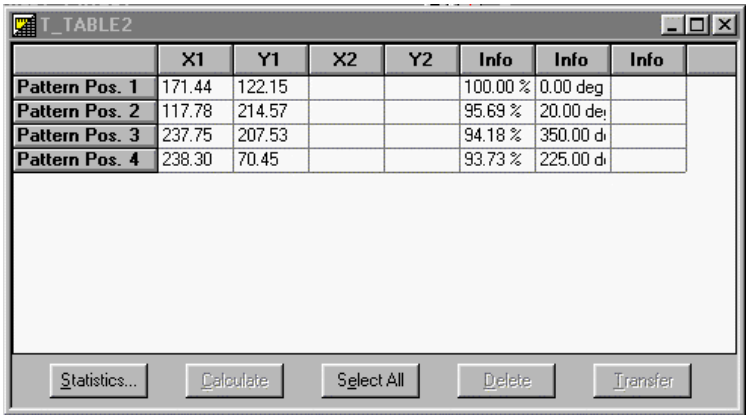
1. System must be calibrated, so that real-world measurements correspond with the Vision System's world of pixels.
2. Open Camera 1.
3. Click the Image Processing Tool icon.
4. In this example, put a cube down within the camera's field of vision, so that its edge is parallel to the edge of Camera 1 dialog box's border.

   In order for both the robot gripper and the cube to be set to zero degrees, the cube must be defined as parallel to the X-axis of the camera's world. Subsequently, the robot arm's rotation will now be relative to this point.
5. In Camera 1, click Snap.
6. Click the ROI (Region of Interest) icon, and outline the perimeter of the cube that was set.
7. Click the Pattern Matching icon.

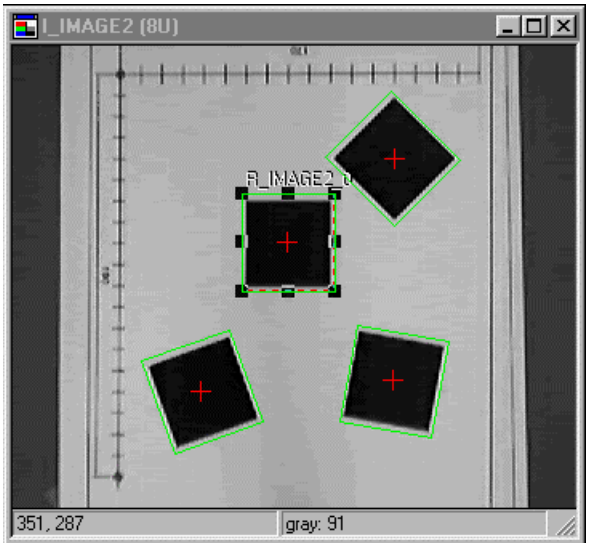


Pattern Matching Model dialog box

- From the Dimension tab, you will see the cube that was outlined using the ROI icon.
- From the Search tab, click All.
- From the Angle tab, check Enable Search With Rotate. Then enter 180 for Delta Negative, and 180 for Delta Positive (this enables a full 360-degree search).
- Click Search. This will build a Measurement Table containing all the positions of the object relative to Pos 1.



Measurement Table



Searched Images

8. In this example, choose the Current table (which will be the opened table), and Position 1 (Pos 1). Click OK.

   The robot will move according to the Go To Position and find the cube.

Calibration

Synchronizing the Vision System and the Robot

To calibrate real-world measurements with the Vision System's world of pixels, it is necessary to perform the following steps:

1. Make sure that there is communication between the controller and the robot.

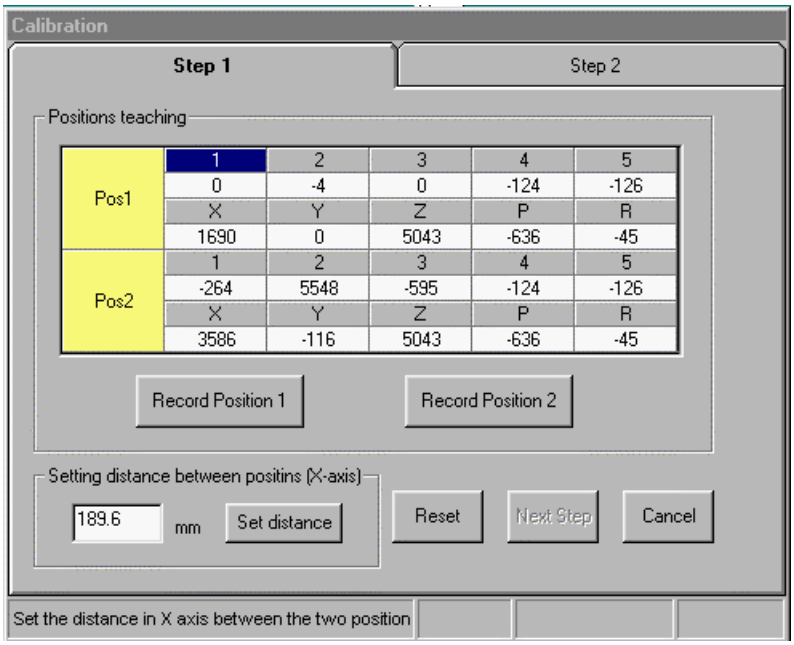
   Click the ACL Terminal icon. Click the On-Line/Off-Line icon if necessary.

2. Execute the HOME routine.
3. Open Camera 1.

   Check camera to make sure that the picture is adjusted, clear, and free of distortions.

4. Click the Calibration icon. This automatically establishes a connection between controller and robot.
5. Move robot arm into desired position within the camera's field of vision.
6. Using a pen or marker, mark a position on a piece of paper (or on the coordinate grid) close to the robot and strong enough to be seen in the

camera picture. This position should be aligned with the TCP (tool center position – the exact center of the robot gripper). This first position is called Pos 1.



Calibration Step 1 dialog box

Click Record Position 1. (*If using Controller-B, be sure it is in Auto Mode*.)

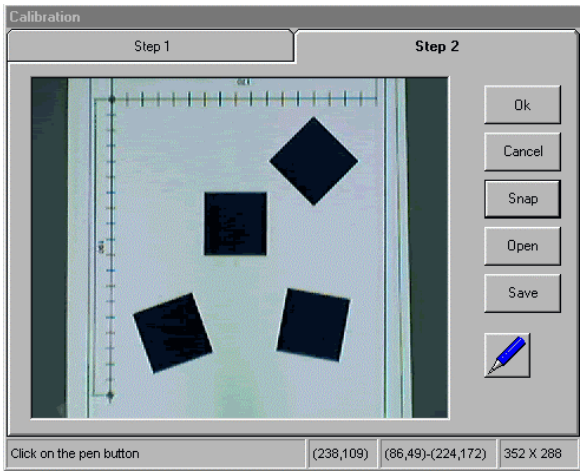
If trying to record a position produces a beep sound the reason may be that the Teach Pendant has not been changed from Teach Mode to Auto Mode. (In the ACL Terminal, type Auto, then click Enter.)

7. Only along the X-axis, move the robot to a position on the X-axis that would be greater (+X) than Pos 1. Take a writing instrument and mark the position. This second position is called Pos 2.

   Click Record Position 2. (*If using Controller-B, be sure it is in Auto Mode*.)

8. Now you will see in the Combo box the distance between the two positions (Setting Distance) on the X-axis. To achieve the most accurate measurement, take a ruler and measure the distance between Pos 1 and Pos 2 by hand.

   - Change the distance if necessary according to the hand measurement.
   - Click Set Distance.
   - Click Next Step. This will take you to the Step 2 dialog box.



Calibration Step 2 dialog box

9. If necessary, move robot arm out of the camera's view.
10. Click Snap in the Step 2 dialog box.
11. You will be able to recognize Pos 1 and Pos 2 in the image.
    - Click the Pen icon. The Pen icon will start flashing after being engaged. Your mouse arrow will become a cross.
    - Click on Pos 1, then make a dragging motion, using your mouse, toward Pos 2. This movement represents an increase in the X-axis. (shows the direction of increase of the X-axis).
12. Click the Pen icon again. Now the X and Y-axes are set and the distances are in real-world millimeters.

    When you move your mouse along the image, Pos 1 becomes coordinate 0,0 (center-point), and the directions of X and Y are now the same as the robot. The movement of the mouse along the axes shows changes in X and Y.
13. Click OK. Now the Vision System is calibrated and synchronized with the robot, and all new images will become calibrated.

Opening and Saving Calibration Files

The Configuration Step 2 dialog box enables file management operations.

Save

The Save icon saves the calibration. The extension of the files is .CAL.

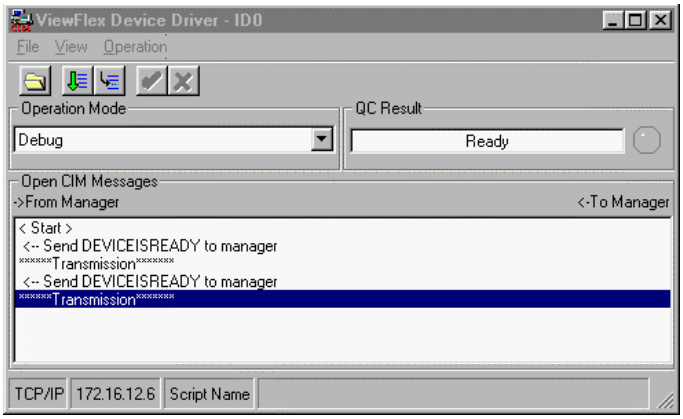
Open

The Open icon will allow you to load backup calibration files. When the OK icon is clicked, the system is calibrated.

You can configure immediately in the Step 2 dialog box and open the calibrated file.

OpenCIM Device Driver

The ViewFlex Device Driver interfaces between the OpenCIM network and the Vision Machine System as a quality control device.



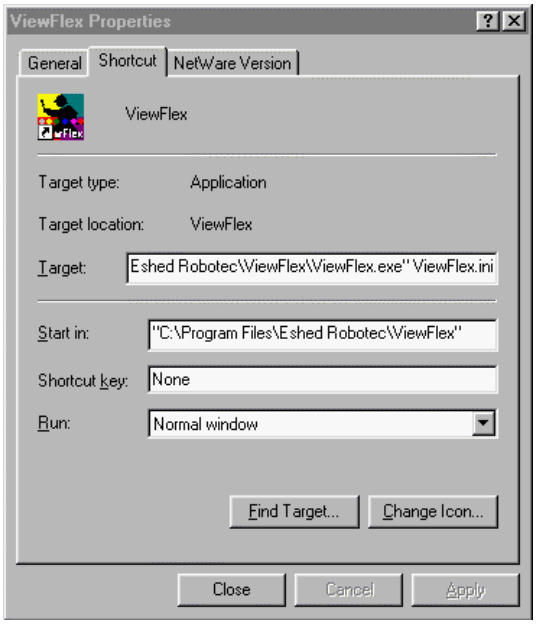
ViewFlex Device Driver

Each quality control test is defined as a separate process in the Machine Definition module. The quality control test consists of three parts:

- **File**: The File is the Script File (.bas) that contains the Program (Function) to be executed.
- **Program**: The Program is the Function from the File that returns the results of the quality control process to the OpenCIM Manager as Pass/Fail or Error.
- **Fail %**: Simulates test results (only in Simulation Mode) by determining the Pass/Fail according to the percentage of failure that was input.

The ViewFlex Device Driver performs the following functions:

- Activates a test on the Vision Machine System.
- Receives status messages from the Vision Machine System and from the OpenCIM Manager. (OpenCIM Messages dialog title in the ViewFlex.)
- Allows you to test and debug the Vision Machine process.
- Emulates the Vision Machine System in Simulation mode.



ViewFlex Properties

ViewFlex.exe

After the ViewFlex is installed, copy ViewFlex.exe to the OpenCIM\Bin folder.

ViewFlex.ini

Be sure to update the script-path to the folder where the scripts files are. An example of where the directory that the script files are located in:

[Device Driver Definitions]

ScriptPath= C:\opencim32\lib\ViewFlex

Operation Modes

The Operation Mode lets you to define the control mode ViewFlex Device Driver is running in:

On-Line

On-Line mode the ViewFlex Device Driver waits for the commands from the OpenCIM Manager, and then Snap, Load Script, Execute Program Script, and Send Results.

Manual

Manual Mode allows you to test the OpenCIM Manager and manually simulate conditions of Fail and Pass.

The following are activated only in Manual Mode, after a request from the OpenCIM Manager:

Send Pass

Sends pass to the Manager.

Send Fail

Sends fail to the Manager.

Simulation

Simulation Mode allows you to simulate test results by determining the Pass/Fail according to the percentage of failure that was input to the OpenCIM Manager.

Debug

The Debug Mode allows you to debug every step of the script. This is made for testing the script before it will be run online.

The following are activated only in Debug mode:

Open File lets you load the script.

Run Script icon executes the script that has been chosen.

Step-By-Step icon lets you to execute each command line of the script individually.

Example of Script for Pass/Fail Test

The following script is an example for testing Pass/Fail Models. A Model refers to the pattern for which you are searching, and the image for which it is extracted.

The following program will try to find the “x” object by using the x-model (x.mod). If found, Fail is sent (QCR=“Fail”). If not found, then it will try to find the “v” object. If found, Pass is sent (QCR=“Pass”). If neither is found, Error is sent (QCR=“Error”).

For more information on the commands, refer to Inspector’s online help.

```
Function QCR() As String
 Dim x As Integer
I_IMAGE1$ = Insptr.ImgGetCur
 Insptr.ImgSetCurrent I_IMAGE1$, R_Def$, ALL_BANDS
 ' X.mod is a Model Search of object for Fail sign
 M_X_MOD$ = Insptr.PatLoad("C:\OpenCIM32\MICROUSA\WS3\X.mod")
 Insptr.PatSetCur M_X_MOD$
 Insptr.ImgConvertType(TO_8U)
 Insptr.MeasNew()
 x=Insptr.PatFind

 If x=1 Then
 QCR="Fail"
```

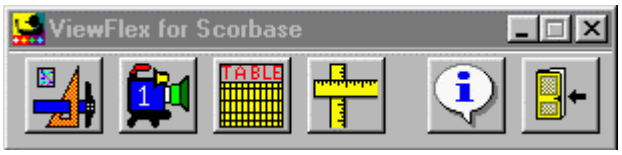
```
Else
' V.mod is a Model Search of object for Pass sign
M_Y_MOD$ = Insptr.PatLoad("C:\OpenCIM32\MICROUSA\WS3\V.mod")
Insptr.PatSetCur M_Y_MOD$
x=Insptr.PatFind
If x=1 Then
QCR="Pass"
Else
QCR="Error"
End If
End If
Insptr.PatClose
Insptr.ImgClose
Insptr.MeasClose
Insptr.CloseAll
End Function
```

3

ViewFlex for SCORBASE

ViewFlex for SCORBASE Toolbar

The ViewFlex Toolbar contains icons that are shortcuts for selecting certain commands and functions:

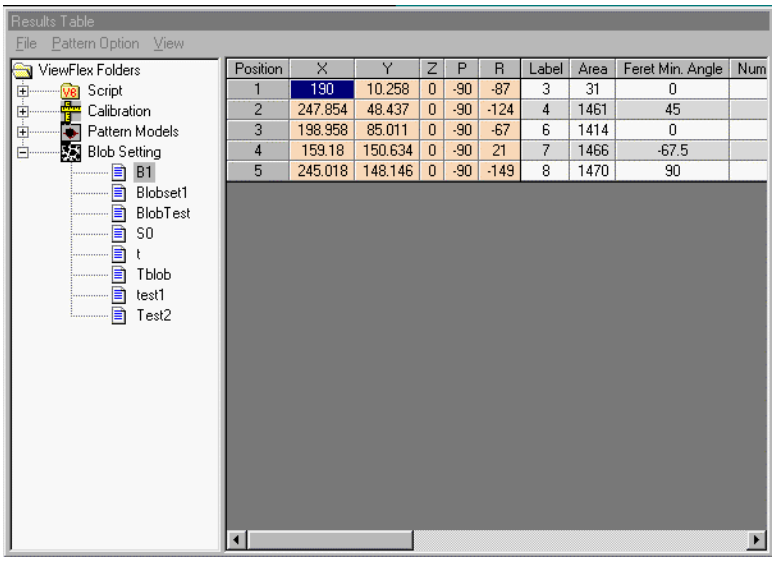


ViewFlex Toolbar

- **Image Processing Tool**; see details in Chapter 2
- **Camera** (Client Camera: for ER-4pc only); see details in Chapter 2
- Results Table
- Calibration
- About
- Exit

Results Table

The Results Table window is divided into two sections: one section is a tree representing the ViewFlex folders, and the second section is a table with the coordinates of the object in the robot world – including blob features.



Results Table

Every time a new file is saved in one of the ViewFlex for SCORBASE folders, the tree is updated.

- Selecting one of the **Pattern Models** executes Find Object with the model on the current image.
- Selecting one of the **Blob Settings** executes Find Blobs with the Blobset on the current image
- Selecting one of the **Scripts** executes the first function/ subroutine in the Script.

File

Save Results to file so that they can be opened with Excel.

Load results from file into the Results Table.

Pattern Option

Foreground: Defines whether black pixels or white pixels are to act as the foreground (or blob) pixels.

With Blob Features: Adds the blob feature to the robot coordinate in the table. This applies only to Find Object.

View

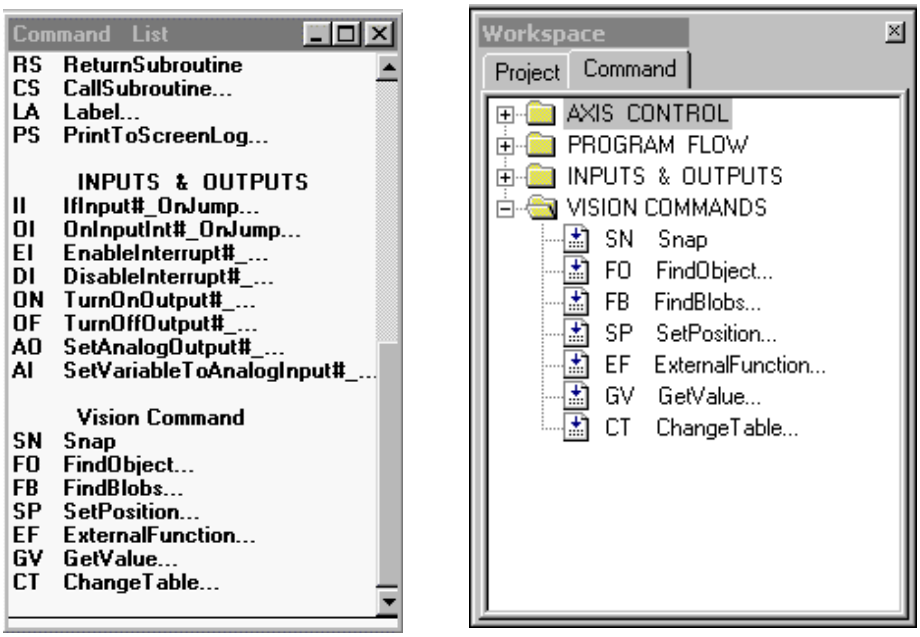
Always on top: Checking this box prevents this window from being hidden by other windows.

Vision Commands in SCORBASE

All SCORBASE programming commands are available from the Command List and are easily compiled into a robot program.

The list shows the two-letter hot-key combinations that allow you to enter commands from the keyboard.

Many commands open dialog boxes for completing the command line parameters.



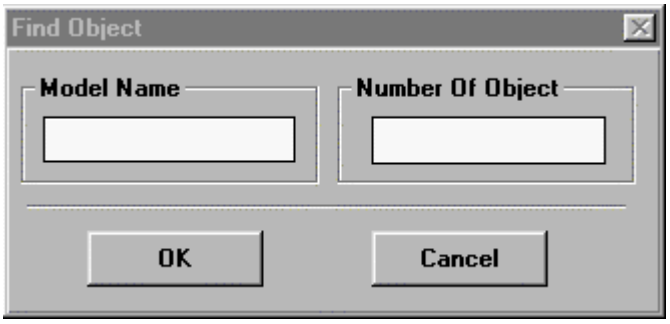
Left: Command list with the Vision Command (ER 4pc).
Right: Vision Command Group (ER 4u).

SN Snap

Captures an image.

FO Find Object

Finds object according to the Pattern Model Name that has been saved in the Pattern folder. Returns **Number of Object**.



Enter the name of the model in the **Model Name** field.

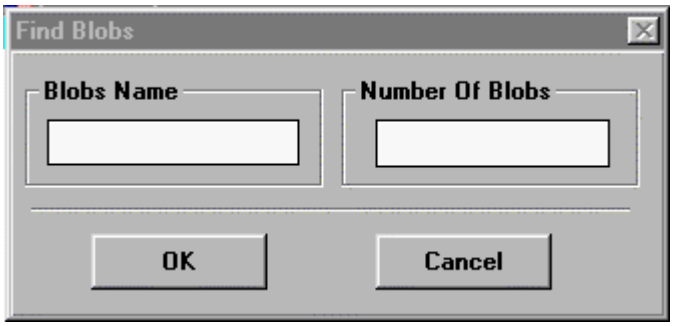
(Note: The name must be the same as it is in the Result Table.)

The SCORBASE variable must be entered into the Number of Object field. The results (Number of Object) will be assigned to the variable.

All of the robot's coordinates and blob features will be put into the Results Table

FB Find Blobs

Finds blobs according to the blob analysis name that has been save in the Blobs folder. Returns **Number of Blobs**.



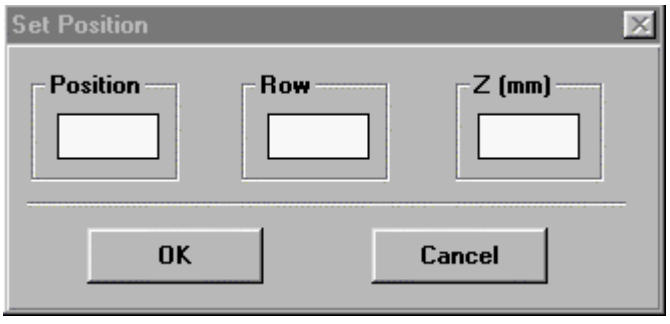
Enter the name of the model in the **Blobs Name** field. (*The name must be the same as it is in the Result Table.*)

The SCORBASE variable must be entered into the Number of Blobs field. The results (Number of Blobs) will be assigned to the variable.

All of the robot's coordinates and blob features that were defined by the user will be put into the Results Table.

SP Set Position

Sets coordinate value from the Results Table into the SCORBASE Position Number.



In the **Position** field, insert SCORBASE Position Number.

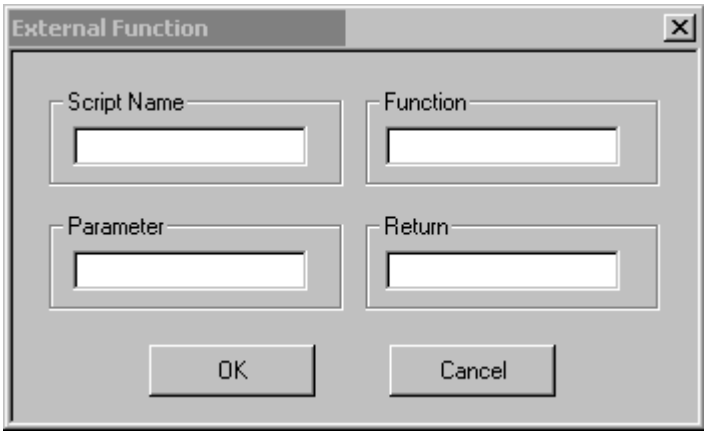
In the **Row** field insert the Position Number (Row) in the Results Table.

In the **Z (mm)** field insert the Z-coordinate, by default the value in the Z-coordinate will be the same as the value of the calibrated position.

Z can be a variable or constant.

EF External Function

Executes the function or subroutine that the user writes in the Matrox script.



The results of the function will be assigned to the variable.

In the **Script Name** field, insert the name of the script in the script folder.

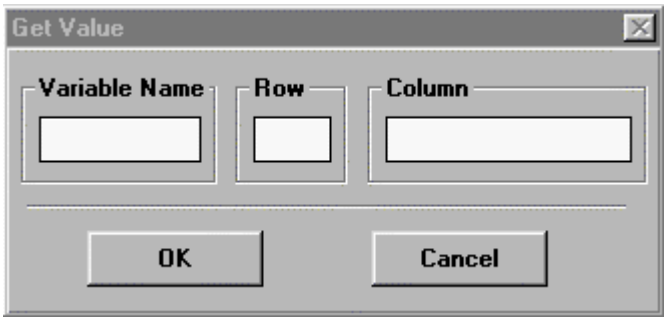
In the **Function** field insert the function or subroutine name that is in the script.

In the **Parameter** field insert the parameter that can be the SCORBASE variable or constant. (*Note: Available for ViewFlex for SCORBASE for ER-4u only*.)

In the **Return** field, insert SCORBASE variable that will get the function return.

GV Get Value

Receive a value from any cell in the Results Table.



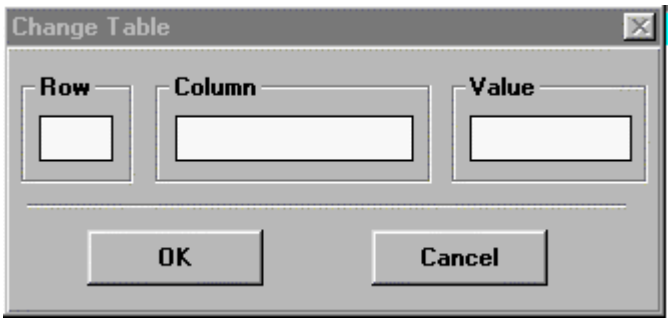
In the **Variable Name** field, insert the SCORBASE Variable. The cell value will be assigned in the variable.

In the **Row** field insert the cell row in the Results Table.

In the **Column** field insert the column name in the Results Table. The **Column** can be a number or the exact column name.

CT Change Table

Change value in any cell of the Results Table.



In the **Row** field insert the cell row in the Results Table.

In the **Column** field insert the column name in the Results Table. The **Column** can be a number or the exact column name.

In the **Value** field insert the SCORBASE variable, or constant that you want the cell to have.

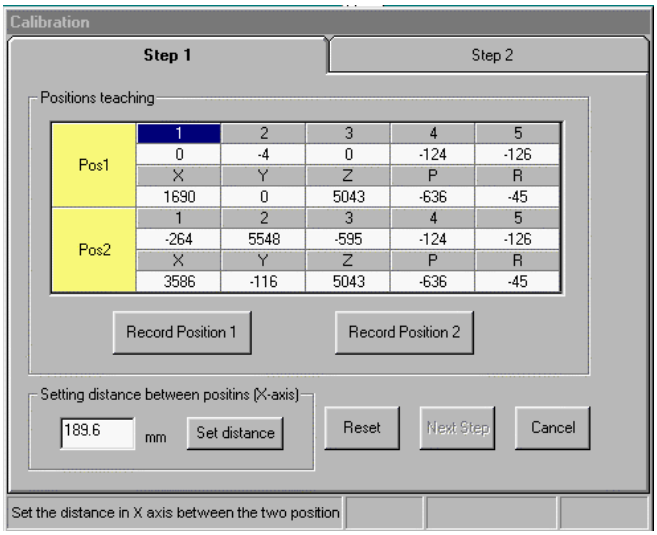
Calibration

Synchronizing the Vision System and the Robot

To calibrate real-world measurements with the vision system's system of pixels, it is necessary to perform the following steps:

1. Execute the HOME routine.
2. Open Client Camera.

   Check camera to make sure that the picture is adjusted, clear and free of distortions.
3. Click the Calibration icon.
4. Move robot arm into desired position within the camera's field of vision.
5. Using a pen or marker, mark a position on a piece of paper (or on the coordinate grid) close to the robot and strong enough to be seen in the camera picture. This position should be aligned with the TCP (tool center position – the exact center of the robot gripper). This first position is called Pos 1.
6. Click Record Position 1.



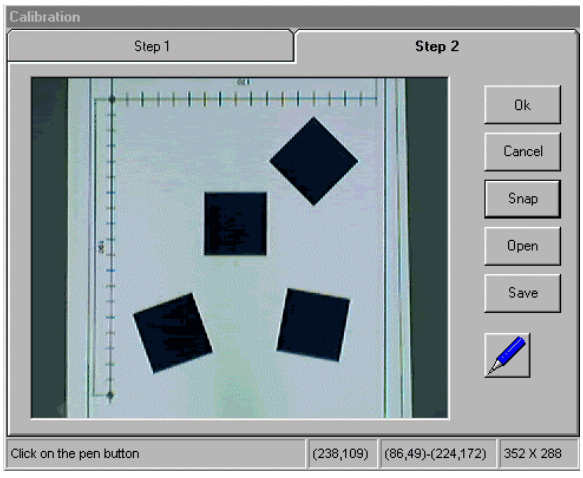
Calibration Step 1 dialog box

7. Only along the X-axis, move the robot to a position on the X-axis that would be greater (+X) than Pos 1. Take a writing instrument and mark the position. This second position is called Pos 2.

   Click Record Position 2.

8. Now you will see in the Combo box the distance between the two positions (Setting Distance) on the X-axis. To achieve the most accurate measurement, take a ruler and measure the distance between Pos 1 and Pos 2 by hand.

   - Change the distance if necessary according to the hand measurement.
   - Click Set Distance.
   - Click Next Step. This opens the Step 2 dialog box.



Calibration Step 2 dialog box

9. If necessary, move robot arm out of the camera's view.
10. Click Snap in the Step 2 dialog box.

11. You will be able to recognize Pos 1 and Pos 2 in the image.
    - Click the Pen icon. The Pen icon will start flashing after being engaged. Your mouse arrow will become a cross.
    - Click on Pos 1, then make a dragging motion, using your mouse, toward Pos 2. This movement represents an increase in the X-axis. (shows the direction of increase of the X-axis).
12. Click the Pen icon again. Now the X and Y-axes are set and the distances are in real-world millimeters.

    When you move your mouse along the image, Pos 1 becomes coordinate 0,0 (center-point), and the directions of X and Y are now the same as the robot. The movement of the mouse along the axes shows changes in X and Y.
13. Click OK. Now the Vision System is calibrated and synchronized with the robot, and all new images will become calibrated.

Opening and Saving Calibration Files

The Configuration Step 2 dialog box enables file management operations.

Save

Saves the calibration. The file name extension is CAL.

Open

Allows you to load backup calibration files. When the OK icon is clicked, the system is calibrated.

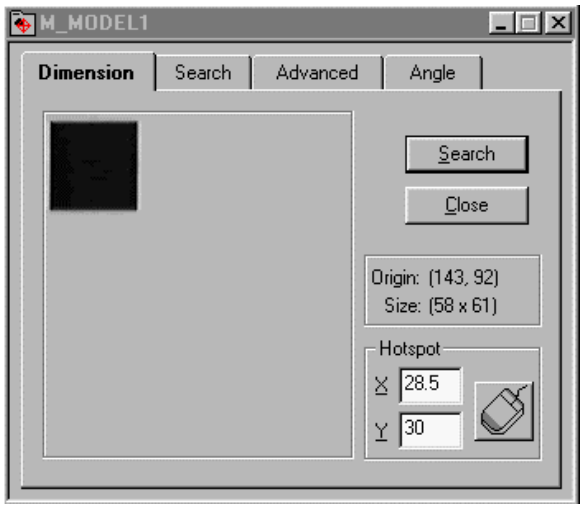
You can configure immediately in the Step 2 tab and open the calibrated file.

Example of Creating a Pattern Model

1. System must be calibrated, so that real-world measurements correspond with the vision system's set of pixels.
2. Open Client Camera.
3. Click the Image Processing Tool icon to open Matrox Inspector.
4. For this example, set a cube down within the camera's field of vision, so that its edge is parallel to the edge of the Client Camera window.

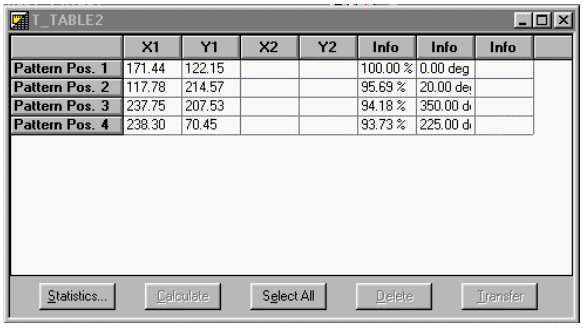
   In order for both the robot gripper and the cube to be set to zero degrees, the cube must be defined as parallel to the X-axis of the camera's world. Subsequently, the robot arm's rotation will be relative to this point.
5. In Client Camera, click Snap.
6. Click the ROI (Region of Interest) icon, and outline the perimeter of the cube that was set.

7. Click the Pattern Matching icon.

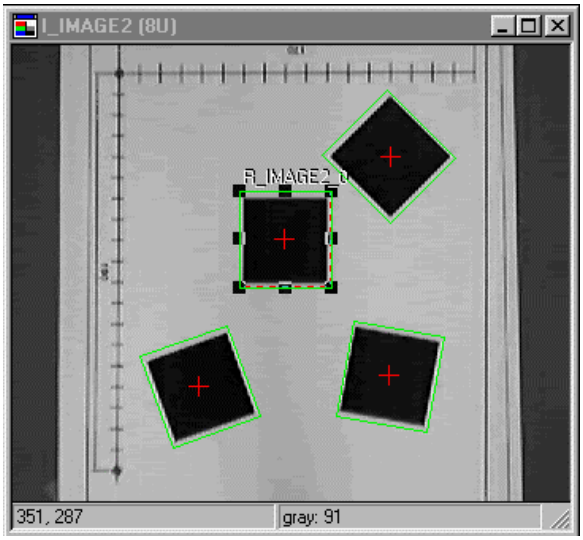


Pattern Matching Model dialog box

- From the Dimension tab, you will see the cube that was outlined using the ROI icon.
- From the Search tab, click All.
- From the Angle tab, check Enable Search With Rotate. Then enter 180 for Delta Negative, and 180 for Delta Positive (this enables a full 360-degree search).
- Click Search. This will build a Measurement Table containing all the positions of the object relative to Pos 1.



Measurement Table



Searched Images

8. Save the Pattern Matching Model in the Pattern Folder, located in the ViewFlex for SCORBASE root folder.
9. Open the Results Table and expand the Pattern Models in the folder tree. Check that the name you gave is listed in the tree.
10. Use this name when you Find Object.

Matrox Inspector

version 3.0

User Guide

Manual no. 10478-301-0300

August 13, 1999

PRINTED IN CANADA

Contents

Part I:

Inspector

...Processing your images

Chapter 1: Getting started

This chapter presents the features of the Matrox Inspector application. It also describes what you need to run Matrox Inspector, and the installation procedure.

Welcome to Inspector

Inspector is a hardware-independent application designed to let you work interactively with images for image capture, storage, and processing applications. Inspector is a 32-bit Windows-based package, giving you the full potential and ease of use of a graphical interface. It is capable of running on any system that runs Windows 95/98 or Windows NT 4.0.

Acquiring images

With Inspector, you can load grayscale and color images from disk in a variety of file formats, or grab them from a wide range of supported input devices. They can then be saved to a file, exported to other applications, printed, or copied to the clipboard.

With Inspector, you can also load or grab sequences, and then play them back. Sequences are a set of sequential frames that can be grabbed from a camera or loaded from AVI, TIFF, or DICOM files. You can process a frame of a sequence as you would any Inspector image.

In order to grab with Inspector, you must have an installed Matrox frame grabber. Images can be grabbed one at a time or grabbed continuously, using any camera supported by your frame grabber.

Image processing capabilities

Inspector includes a variety of point-to-point, statistical, spatial filtering, Fourier transform, and morphological operations. You can use these operations, for example, to smooth, accentuate, or qualify images.

Inspector supports geometric operations including interpolated resizing, rotation, and distortion correction, as well as polar-to-rectangular unwrapping.

Processing can be restricted to a rectangular or non-rectangular region of interest (ROI). Processing can also be restricted to a selected component of a color image.

Image calibration

Image calibration allows measurements and analysis to be carried out in real-world coordinates. Various calibration mappings can compensate for non-uniform aspect ratios, rotation, perspective foreshortening, and other more complex distortions.

Pattern matching capabilities

Inspector's pattern matching capabilities allow you to find a pattern (referred to as a model) in an image, with sub-pixel accuracy. Pattern matching can help solve machine vision problems, such as alignment and inspection of objects. You can create a model manually or have Inspector automatically select a unique one (called an automodel) from an image. In addition, you can have Inspector search for all occurrences of the model, or the specified number of occurrences.

In some cases, the orientation of the model and/or the target image can play a factor in the search operation. Inspector includes a number of options to deal with such cases, each optimized for different image and background conditions. For example, you can find the orientation of a target image or you can search for occurrences of a model at any angle, in the target image.

Blob analysis capabilities

Inspector's blob analysis capabilities allow you to identify and measure connected regions of pixels (commonly known as blobs or objects) within a grayscale image. You can calculate upto forty selected features of these blobs, such as their area, center of gravity, perimeter, and Feret diameter. You can also automatically discard blobs that are not of interest, and classify the remaining blobs according to the values of the features.

The classification capabilities let you automatically classify blobs based on simple criteria, such as ranges (bins) of one value, or based on more sophisticated criteria such as combination of features (filter) or selection from viewing (training set).

Measuring capabilities

Inspector's measuring capabilities allow you to quickly take position, distance, angle, and area measurements within an image. You can also have Inspector locate and measure image characteristics (markers), such as edges and stripes (pairs of edges), in an image, based on differences in pixel intensities.

Edges and stripes are located with sub-pixel accuracy. You can also take measurements between positional results obtained from different image analysis operations.

Annotation capabilities

With Inspector, you can annotate your images with text, lines, filled shapes, or outlined shapes, in any specified color. These can also be used as ROIs. Annotation can be added directly into your images, or into an overlay buffer.

Exporting results

Inspector-generated data can be exported directly to any application that suports OLE automation. Exporting to Microsoft Excel or Word requires no scripting. If you want to export to an application other than Excel or Word, you can create a custom export script module modeled on the ones provided in Inspector for Microsoft Excel or Word.

Scripting capabilities

You can automate your applications by recording actions in a script. You can easily modify the script with the help of Expression Builder. The resulting script can be executed as many times as required with Inspector's Script interpreter. For easy recall, scripts can be associated with shortcut keys or buttons on the script bar or added as menu items. In addition, if your script has logical problems, you can use Inspector's debugging capabilities to determine where the problems occur.

Inspector offers two scripting languages: Basic and C-Script. The version of Basic used by Inspector is compatible with Microsoft Visual Basic for Applications. C-Script is a scripting language similar to C.

Both languages allow you to extend the functionality of your application by making script calls from Inspector to functions in external DLLs.

Using Basic, you can also use Inspector either as a client or a server of another Windows' based application that supports OLE (object linking and embedding) Automation. Basic can also be used to develop semi-autonomous scripts that support user intervention.

Collection files

With Inspector, you can create collection files. Collections are visual directories that contain thumbnails of images. They are useful for visually tracking and managing your image and sequence files.

You can drag and drop images and sequences into a collection from **Explorer** or the **Find File** dialog box (under Windows 95/98 or Windows NT 4.0). You can also drag and drop an open Inspector image/sequence into a collection. From a collection, you can open one or more images into the Inspector workspace.

Manual overview

This manual is divided into two parts. Part I describes how to load, grab, process, and analyze images. Part II describes how to automate your application and how to use Inspector as an automation client or server. The appendices describe aspects of Inspector not covered in previous chapters.

❖ This manual assumes you are familiar with basic Windows operations; if necessary, review your Windows documentation.

Note that all procedures, except for the ones in *Chapter 2: A few Tutorials*, are only available in the on-line help included with Inspector.

On-line help

You can obtain context-sensitive help by pressing **F1** or by using the context-sensitive button on the Inspector toolbar.

Image Quest

Included with Inspector is Image Quest, a multimedia introduction to image processing that is divided into two parts: theory and problem solving. It includes text, images, video, as well as real-life applications implemented with Inspector.

What you need to run Inspector

In addition to your Inspector CD, you will require a hardware key (a two-sided, 25-pin connector) to run your Inspector software once the 30-day evaluation period has expired. To use Inspector, you require the following:

- An 80486 processor or higher.
- Windows 95/98 or Windows NT 4.0. We recommend that you have at least 32 Mbytes of memory if you are running Inspector with a VGA card; 64 Mbytes if you are using a digitizer board.
- A Windows display adapter and compatible monitor.
- A Windows-supported mouse or another pointing device.

In addition to the above, you need a Matrox frame grabber in order to grab images.

Installation

You install Inspector by running the Inspector Setup utility (see below). Note that Inspector has been developed using the Matrox Imaging Library (MIL) and requires some of its driver and DLL components. If you have already installed MIL-Lite or if you have installed the full MIL development package, Inspector's setup will only re-install those drivers and DLLs that are out-of-date.

❖ If you have an installed Matrox frame grabber, you are presented with the **System Allocation** list box when you first load Inspector. This list box allows you to choose the system you want to use to run Inspector. It is primarily useful if you have two or more frame grabbers. The **System Allocation** list box is discussed later in this chapter.

Installing Inspector

If you abort the Setup utility prematurely (**Cancel**), some files might not be copied or modified. In this case, you should re-run the Setup utility to ensure that everything is installed.

To install Inspector:

1. Attach the hardware key to the parallel port of your PC (if another device such as a printer is attached to the parallel port, disconnect it, attach the hardware key, and then attach the printer connector to the other end of the hardware key). If a MIL hardware key is attached, connect them together.

2. Insert the Inspector CD into a CD drive. The Setup utility should run automatically. If the Setup utility does not run automatically, click on the **Start** button, select **Run**, and then type at the prompt, using the appropriate drive letter:

```
d:\setup
```

If Inspector is run without the hardware key, a temporary license is assigned to your system, allowing use of Inspector for 30 days. Each time you run Inspector, a dialog box appears indicating the number of days until the temporary license expires. Once this time period has elapsed, Inspector will not run unless a hardware key is attached.

❖ Note that Inspector's 30-day evaluation license can only be installed once. Any attempt to tamper with the PC's calender, before the date of expiry, will disable Inspector. In that event, Inspector can only be re-used once a hardware key is obtained.

After installation

Once Inspector is installed, a group titled **Matrox Inspector 3.0**, containing the icons for the Inspector application, is created. Note that one of the icons is for the *readme.chm* file. This is an on-line help file containing important information about troubleshooting and features specific to imaging boards. Be sure to read it.

The following are also created after installation:

- An entry for Inspector in the Windows registry. This contains information used by Inspector during start-up.
- Directories containing image, sequence, C-Script, Basic script, utility, and sample automation project files.

Note that, if you add a frame grabber after installing Inspector, you should uninstall MIL from the Control Panel, otherwise the drivers will not be installed. Then, re-run the Inspector Setup utility. This will ensure that the necessary files are added.

Uninstall under Windows 95/98 or NT 4.0

You can uninstall Inspector as follows:

3. Select **Settings** from the **Start** menu.
4. Select **Control Panel** from the presented sub-menu.
5. Select **Add/Remove Programs** from the **Control Panel** menu. The **Add/Remove Programs Properties** dialog box appears, with the **Install/Uninstall** tab active.
6. Select **Matrox Inspector 3.0** from the presented list box.
7. Click on **Add/Remove**.

❖ To completely remove Inspector from your system, you should also uninstall **Matrox Imaging Library Products**, if present.

System Allocation

If you have an installed Matrox frame grabber, you are presented with the **System Allocation** list box when you run Inspector. This list box contains all the systems that Inspector detects on your computer. If your computer only has one board, you can check the **Don't ask me again** option, and the next time you open Inspector, it will open using that board. The system choice you make is saved in the registry.

If you are always going to use the same system to run Inspector, you can disable the **System Allocation** list box for future sessions, in which case the system specified in the registry is used to run Inspector. To disable the **System Allocation** list box, use the **Options Preferences** command (in the **General** tab).

Inspector documentation conventions

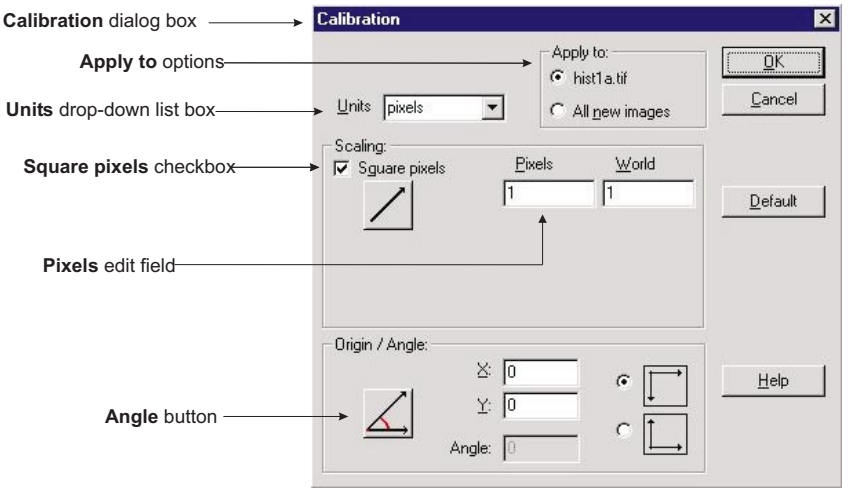
This section describes some conventions used in this manual.

Menu conventions

This manual refers to operations, accessible through the menus, as commands, and refers to them by their menu and sub-menu names. For example, selecting **Geometry** from the **Tools** menu and then selecting **Scale** from the presented sub-menu is referred to as the **Tools Geometry Scale** command.

Dialog box conventions

In general, when a command is called, a dialog box appears. Dialog boxes allow you to specify how you want the command performed. To use a dialog box, you might have to enter values in edit fields, select items from list boxes, specify options, or click on buttons and selectors.



An ordinary list box differs from a drop-down list box in that the list is immediately visible. To view the contents of a drop-down list box, click on the arrow next to the box.

Multiple tabs

Most of Inspector's dialog boxes are actually multiple dialog boxes, that is, different dialog boxes overlaid one on top of the other. The main dialog box is referred to as a dialog box, while its internal dialog boxes (or property pages) are referred to as tabs. The tab name appears at the top of the tab.

Chapter 2: A few tutorials

This chapter introduces you to image processing and provides a tutorial on Inspector's processing operations.

Image processing

Pictures, or images, are important sources of information for interpretation and analysis. These might be images of a building undergoing renovations, a planet's surface transmitted from a spacecraft, plant cells magnified with a microscope, or electronic circuitry. Human analysis of these images or objects has inherent difficulties: the visual inspection process is time-consuming and is subject to inconsistent interpretations and assessments. Computers, on the other hand, are ideal for performing some of these tasks.

For computers to process images, the images must be numerically represented. This process is known as *image digitization*. The digitization process divides an image into a two-dimensional grid of small units called *pixels* (picture elements). Each pixel has a value that corresponds to the intensity or color at that location in the image. Each pixel in the image is identified by its position in the grid and is referenced by its row and column number.

Once images are represented digitally, computers can reliably automate the extraction of useful information using digital image processing. Digital image processing performs various types of image enhancements, distortion corrections, and measurements.

Inspector and image processing

Inspector provides a comprehensive set of image processing operations. There are two main types of processing operations:

- Those that enhance or transform an image.
- Those that analyze an image (that is, generate a numeric or graphic report that relates specific image information).

Image enhancement and transformation

Inspector's image enhancement and transformation operations allow you to improve the quality of your image and/or transform your image. These include:

- **Point-to-point operations.** These operations include brightness and contrast adjustment, constant thresholding, arithmetic, and image mapping operations. Point-to-point operations compute each pixel result as a function of the pixel value at a corresponding location in either one or two images.
- **Spatial filtering operations.** These operations are also known as convolution. They include operations that can enhance and smooth images, accentuate image edges, and remove 'noise' from an image. Most of these operations compute results based on an underlying neighborhood process: the weighted sum of a pixel value and its neighbors' values. You can use one of Inspector's pre-defined filters or create your own filter(s).
- **Morphological operations.** These operations include erosion, dilation, opening, and closing of images. These operations compute new values according to geometric relationships and matches to known patterns (structuring elements) in the source image. If necessary, you can create your own structuring element for one of Inspector's morphological operations.
- **Geometric operations**: These operations include scaling, rotating, translating and flipping of images, as well as polar-to-rectangular and distortion correction.

Image analysis

Inspector's image analysis operations summarize a frame of pixels into a set of values which relate specific image information. These include:

- **Basic statistical operations.** These operations extract statistical information from a specified region of an image, such as its distribution of pixel values or its profile.
- **Pattern matching operations.** These operations allow you to determine how similar certain areas of the image are to a pattern.
- **Blob analysis operations.** These operations allow you to identify and measure aggregated regions of pixels within an image (commonly known as blobs).
- **Measurement operations.** These operations allow you to locate edges or pairs of edges (known as stripes) and measure their features. In addition, they allow you to take a variety of measurements between their positional results, and get quick on-the-spot measurements, such as length, area, and angle.

For most image analysis operations, you can maintain statistics in Inspector.

Typical application steps

Although there are many applications for which Inspector can be used, most involve the same basic steps:

1. Load an image from disk or grab one from an input device.
2. To optimize the image(s), use Inspector's enhancement and transformation operations. You might need to use some of Inspector's analysis operations to determine your optimization strategy.
3. To generate the required image information, use Inspector's analysis operations.
4. Save and/or export numeric results. Inspector can export results to most popular spreadsheet and database packages. Calculated data can then be compared with existing data or used in statistical computations.

A few examples

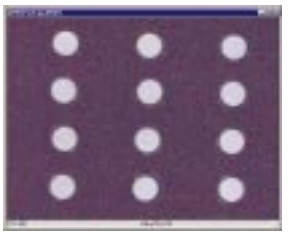
To get you started, the remainder of this chapter will serve as a tutorial. As such, we provide four examples that will familiarize both novices and advanced users with Inspector's operations. The four examples have been chosen to introduce you to processing operations, as well as reveal shortcuts, suggest hints and alternative methods for efficient use of Inspector's imaging software. Each example is presented as a sequence of operations, and lists the steps to complete the relevant task at hand.

The first and second examples serve as a warm up. They allow you to perform some general commands (for example, load an image file from disk), as well as enhance and analyze an image. Since blob (object) analysis and pattern matching (recognition) are the most common uses of Inspector's image processing capabilities, the first and second example focus on blob analysis and pattern matching, respectively. The second example has been chosen to introduce you to Inspector's calibration and edge (stripe) finding capabilities.

The third and fourth examples focus on dealing with many images and grabbing (digitizing) an image from an input device (camera), respectively. These examples build on techniques presented in the first two examples and allow you to take full advantage of useful commands and/or operations such as window leveling and locking targets.

Example 1: Analyzing a blister package

In the first example, you will analyze an image of a blister package that could be found along a pharmaceutical inspection line. For the initial assessment, you will perform a basic histogram operation, which gives you a intensity distribution graph of the entire image. Then, you will focus on a selected area in an image to determine an enhancement and analysis strategy suited to the image. You will perform "thick" horizontal and vertical line profiles, each of which provides a graph of the pixel values along a small horizontal and vertical line segment, respectively, to assess the lighting condition in the selected region. Then, you will perform a histogram of this same selected region since, like most images, this one contains some noise. Then, to enhance the image and remove some of the noise, you will perform a smoothing (spatial filtering) operation.



For image analysis, you will segment the pills from the background. Since the image has been smoothed, you will ensure that the edges of the pills are distinct enough for the segmentation. To do this, you will make use of both "thick" line profiles. Then, after segmentation, you will perform a pill (blob) count to confirm the presence of the specified number of pills. At the same time, you will extract some basic feature information that will allow you to determine which pill is missing if one is missing.

Loading an image file into Inspector's workspace

1. Load the *blispac4.jpg* image of the blister package filled with pills from the ***\IMAGES*** folder. Use the **File Open** command or drag the image from Windows Explorer into Inspector.

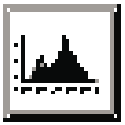
   In general, to open more than one image file at a time from the same folder using the **File Open** command or Windows Explorer, click on the first image file, then do one the following:

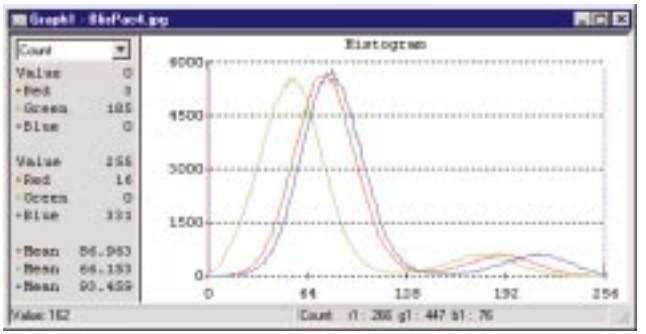
   - If the files are in consecutive order, hold down the **Shift** key and click on the last item of the group of files to be included.

- If the files are not in consecutive order, hold down the **Ctrl** key while clicking on each file to be included in the group.
  - Note that when an image file is of a type that does not correspond to one of those presented in the **Files of type** drop-down list box, use the **Open As** drop-down list box to specify the file's data type.

Performing a histogram on the whole image

Perform a histogram operation on this color image. To do so, click on the **Histogram** button; alternatively, use the **Image Statistics Histogram** command. The histogram graph displays the three color bands present in the image (default ROI).





  - Note, that the histogram for the entire image is basically smooth, despite the fact that there is some random noise in the image.

Converting a color image to grayscale

To simplify the statistical analysis of the image, we will convert the image to an 8-bit, unsigned grayscale image. After conversion, the statistical graphs generated will show only one band, instead of three.

Working with a grayscale image is useful since you will need one to perform blob analysis later on. Inspector can only perform blob analysis on 8-bit, one band images, however, if you do not perform this conversion operation manually, Inspector will perform it automatically (if necessary) for any blob analysis operation.

To convert the image from color to grayscale, use the **Image Convert** command. Alternatively, right-click on the image to generate the image's context menu, and then select **Convert**.

Then, choose **8-bit Unsigned** from the sub-menu.

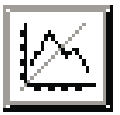
Image processing-initial approach

The best approach to analyze the noise that is present in the image is to analyze a small region that should have a uniform dark pixel intensity. You will use the statistical tools available in Inspector to do so.

Performing a line profile to check lighting conditions

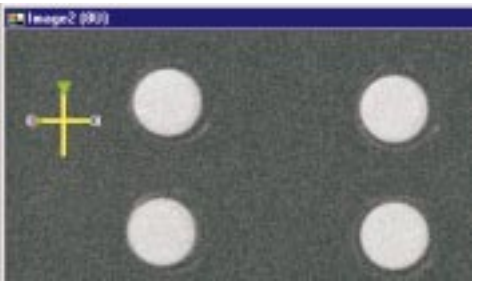
To determine whether or not the lighting condition is uniform in the small region, you will create a thick line profile in the horizontal and vertical direction, respectively. Performing a line profile across what should be a uniform area will determine if the lighting condition is uniform in that direction. A "thick" line profile will be generated, so that an average of the pixel values along the width of the line segment will be obtained.

1. To set the thickness of the line profile, click on the line above the Options section of the **Drawing Tools** toolbar. The **Drawing Tool Properties** dialog box appears.
2. Ensure the **Outline** tab is selected. Set the line's pixel width in the **Width** edit field to **4**. You can use the incremental push button arrows, or type in this value directly.

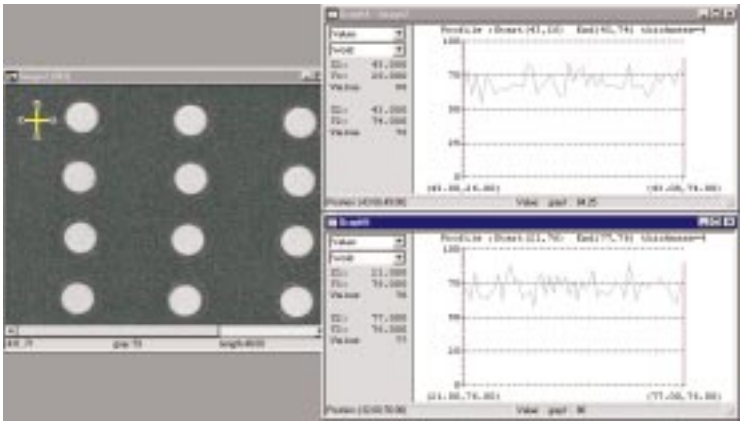


3. Now, click on the **Line Profile** tool, or use the **Image Statistics Line Profile** command. Alternatively, you can enable the **Profile** option and then use the line tool in the **Drawing Tools** toolbar.
4. Create a short horizontal line in a uniform dark region of the image by clicking at the start position and dragging across to the final position.

5. Create a short vertical line in a similar fashion. Draw the lines intersecting as illustrated.



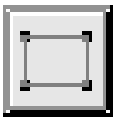
6. Position these two graphs generated in a tile fashion, so that they are both easily visible on screen. Ensure there is enough work space to view the two line profiles and the image.



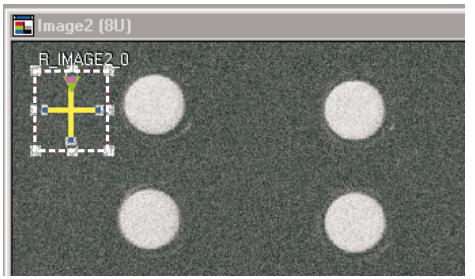
The line shows a relatively constant variation along its entire length (minimum and maximum pixel intensity show little variation, respectively, from the average value). Therefore, the background lighting is evenly distributed in the horizontal and vertical direction in this small region. Analyzing the noise in this small region will provide valid pixel intensity results (as opposed to values due to lighting artifacts).

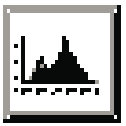
Performing a histogram to analyze noise

To analyze the noise in the region, you will take its histogram. A histogram on the background pixels will determine how the pixel values deviate from the expected value.

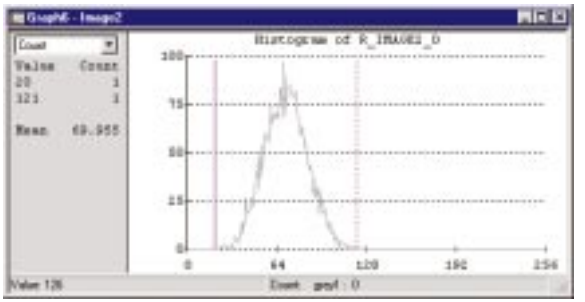


1. Draw a small ROI enclosing the lines used for the profiles. To do this, enable the ROI drawing tool. Click on the ROI drawing tool button in the tool button bar. Alternatively, choose the rectangular ROI tool from the **Drawing Tools** toolbar.





2. Click on the **Histogram** button; alternatively, use the **Image Statistics Histogram** command. The histogram graph displays the grayscale pixel values present in the defined ROI.

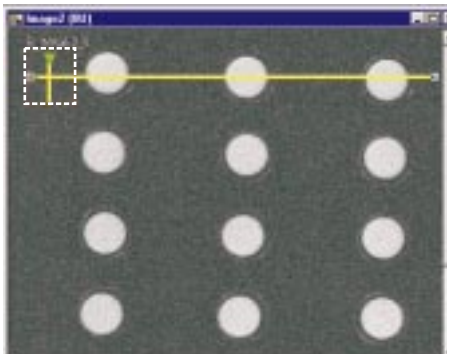


From the shape of the histogram of this small uniform area, it is apparent that there is random noise in the image.

Using a line profile to check for sharp edges

To remove the noise in the image, a smoothing operation (spatial filter) will be performed. However, applying a spatial filter might cause the edges between the background and the pill objects to lose their sharpness. An easy way to keep track of edge sharpness after a processing operation is to monitor changes in the edge width and edge angle of the line profiles taken across the pills in both directions. To take these profiles, you will deselect the small ROI, and reactivate the original lines. Then, extend these lines across the pills in the horizontal and vertical direction, respectively.

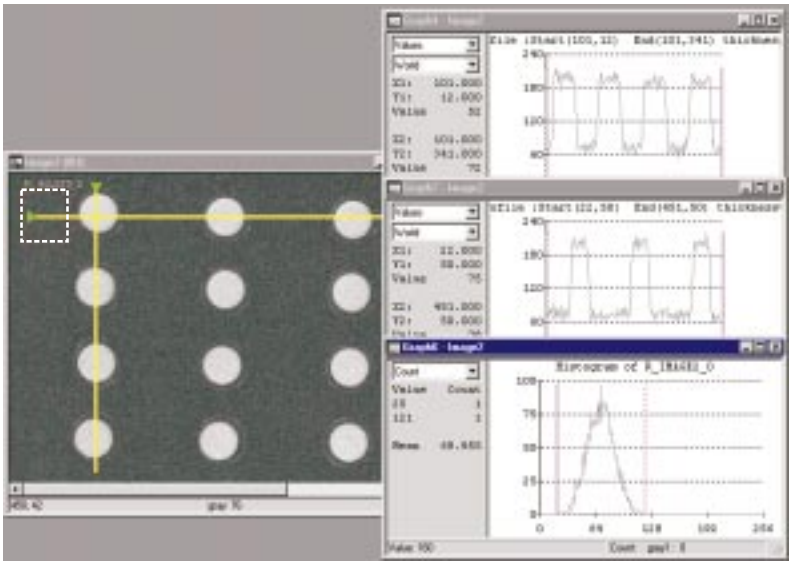
1. Click on the original horizontal line profile.
2. Create a horizontal line stretching across a row of pills in the image by dragging the line's handles across to the final position. Extend the line as illustrated.



3. Reposition the vertical line profile by enabling and then dragging the line. Then, resize it by moving the vertical line's handles so as to extend it across a column of pills.

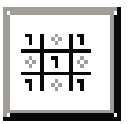
   Both line profile graphs are updated with new line profile data.

4. Position the graphs in Inspector's workspace in a tiled fashion, so that they are all easily visible on screen. Ensure that the image is also visible. You can change the height and width of the histogram window.



Removing random noise from an image using a filter

Although the noise in the image leads to variation in pixel intensity, the distribution is relatively random; therefore, the noise in the image can be removed using a smoothing filter. You will determine the number of times to apply the filter based on the histogram of the flat area, since a narrow histogram curve will indicate that there is a more uniform area.



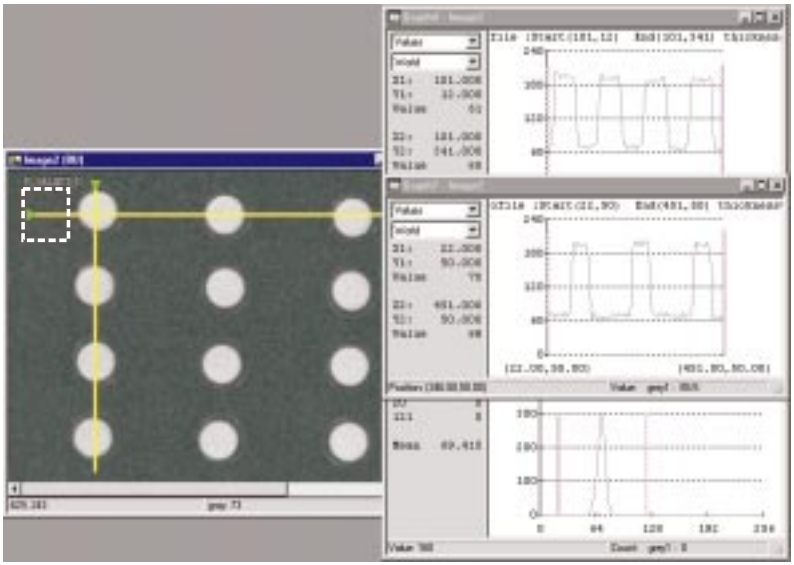
1. Click on the **Filters** tool button, or use the **Image Processing Filters** command. Alternatively, right-click on the image to obtain the image's context menu and select **Processing**. The **Processing Operations** dialog box is presented.

2. Ensure that the **Filters** tab is displayed. Select **Smooth5x5** from the list box.

3. Make sure the destination **(D) Selector** bar at the bottom of the **Processing Operations** dialog box is set to **R_BLISPAC4_JPG** (*not New 3-Band RGB*).

4. Click on **Apply** two times to perform the smoothing operation twice. Note how the graphs changes each time.

   - From the change in the histogram of the small region, you can see that the background noise is reduced and the region has a more uniform value.



Look at the pixel intensity values. The pill pixel values are quite distinct from the background pixel values. Moreover, the edge width and edge angle (between the foreground and background) is well-maintained. Therefore, the edges should be sharp enough so that a single threshold value can be chosen that will properly segment your foreground objects from the background.

Undoing a processing operation

After an enhancement or transformation operation has modified an ROI, such as the smoothing operation just performed, the operation can be undone by clicking on the **Undo** button or using Inspector's **Edit Undo** command.

- Note, you can specify the number of operations that can be undone in the **General** tab of the **Options Preferences** command. Note also that an operation that places results in a new window cannot be undone.

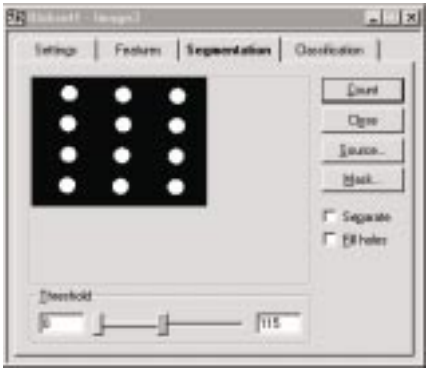
To reverse the undo, click on the **Redo** button or use the **Edit Redo** command

Blob analysis

Now, perform a blob analysis operation on the grayscale image, so that you can determine if there are the correct number of pills in the blister package. The first step will be segmentation, that is, providing a pixel intensity threshold value such that pill objects (blobs) are white (foreground object) and the background is black. Then, you will count these blobs, as well as obtain some statistical information about each blob.

1. Click the **Blob Analysis** button; use the **Analysis Blob New** command; or alternatively, select **New Blob** from the image's context menu. A blob settings (**Blobset**) dialog box appears.
2. Select the **Segmentation** tab to identify your objects. A segmentation mask is presented.
3. Use the **Threshold** slider to verify that the background lighting is evenly distributed throughout the entire segmentation mask image. To do this, drag the slider from **70** to **130**.

4. Threshold the segmentation mask using a value that is between the maximum background value and the minimum foreground value returned from the previous line profile. For this example, set the **Threshold** value to **115**. You can type the setting directly into the edit field or use the slider.



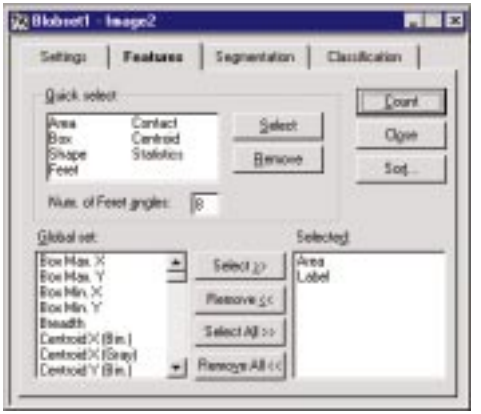
5. Magnify the previewed segmentation mask to view small artifacts. To do this, select the **Zoom** button and click on the center of the segmentation mask. To increase the magnification, continue to left click on the center of the segmentation mask. **Zoom** in 2 more times.

   - To zoom out by standard increments, right-click the mouse.

   Now, deselect the zoom tool (magnifying glass icon) by clicking on the **Zoom** button again.

6. Since there are small artifacts after segmentation, which will affect the pill count, have Inspector ignore these by choosing a minimum area for the blob analysis search. To do this, select the **Settings** tab and type the value 100 in the **Min. area** (minimum area) edit field, located in the **Remove Blobs** section. This will remove any small artifact from the blob count that has an area less than 100 pixels^2.

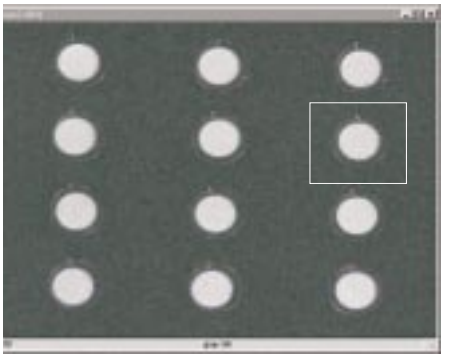
7. Select the **Features** tab of the **Blobset** dialog box.

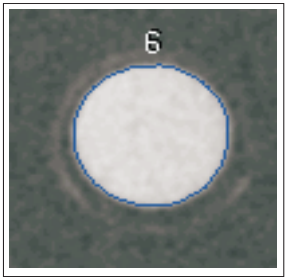


8. Choose the **Centroid** features from the **Quick Select** list box. Then, click on the **Select** button. Alternatively, double-click on this feature. All centroid features are added for calculation and are listed in the **Selected** list box.

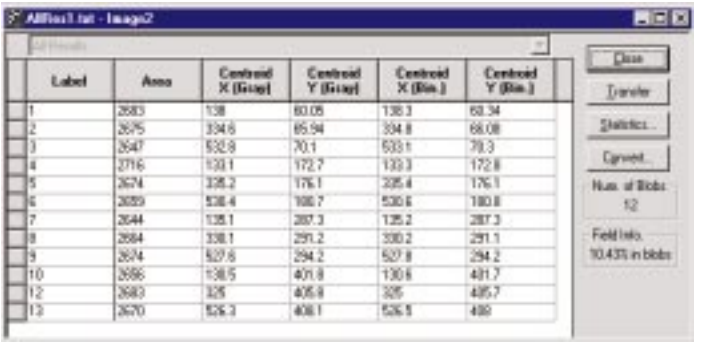
   ❖ Note that a label is always associated to each blob and an area is always calculated.

9. Select **Count** to count the blobs in the image and calculate the specified features (minimum area and features related to centroid). A blue line outlining each blob that has an area above the specified minimum is displayed along with the blob's label number.





In addition, an **AllResults** table is displayed which shows the blob count, and lists all blobs meeting specifications, including their calculated blob features.



Inspector should count the correct number of pills (blobs)- 12. However, if an artifact with an area greater than 100 pixels^2 is present in your image, take note of its area. Then, you can return to the **Settings** tab and increase the minimum area to a value above that for the remaining artifact(s). Then, click the **Count** button again. An updated blob count will appear in the **AllResults** table.

If pills are missing, you could use the coordinates of each pill's centroid to determine the pockets which are empty.

Demos...

To familiarize yourself with other blob analysis tools in Inspector, run the *MissingBlobDemo.bas* and *MoneyToClassify.scr* scripts included with your software package. To do so, use the **File Open** command or Windows Explorer to open the script files. The *MissingBlobDemo.bas* Basic script is in the ***\Basic Files*** folder, while the *MoneyToClassify.scr* C-Script script is in the ***\Files*** folder.

The *MissingBlobDemo.bas* script determines if a pill has been placed in each pocket. It uses an alternative approach to the one we just presented; it calculates and searches for the pill at each position. Then, the Inspector script returns a flag each time a blob is not present at the expected position.

The *MoneyToClassify.scr* is an Inspector script that sorts coins in an image, counts the different denominations, and then returns the values into a text file.

Example 2: Scaling-calibration and pattern matching

This second example focuses on processing an image of three pins on a computer chip. The image has a square pixel aspect ratio (each pixel represents the same real distance both in width and in height), but the chip in the image does not have the same size as in the real world since the camera positioning has resulted in a magnified image. You will calibrate your imaging setup in Inspector so that the image's pixels are scaled to real-world dimensions. With these scaled dimensions, measurement results will be returned in real-world units.

Subsequently, you will perform a pattern matching and measurement operation to determine if the correct number of pin-legs are present in the image, and if they are structurally intact. To determine if the correct number of pin-legs are present in the image, a pattern (model) is used as the basis for finding similar patterns in the image. Then, the location of the first model will be used as the relative origin for finding the pin-legs seen as stripes (pairs of edges) in the image. Inspector's measurement capabilities will determine the structural integrity of the pin-legs.

Although in this example you find stripes in the image manually, the approach taken is amenable to using Inspector's automating (scripting) capabilities.

1. Load the image, *threepins.tif*, from the ***\IMAGES*** folder. To do so, use the **File Open** command, or drag the file from Windows Explorer into Inspector.

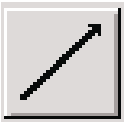
2. To magnify the region between the central and right-most pin, first, zoom in 2 times on the image using the **Zoom** tool button.

3. Then, once the appropriate magnification is obtained, deselect the **Zoom** tool.

Calibration: pixel-world scaling

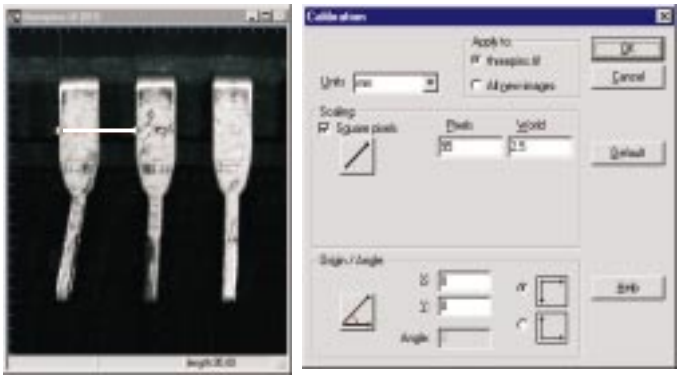
Now, calibrate the pixel-to-world scaling of your imaging setup using the *threepins.tif* image.

1. Select the **Options Calibration New** command. The **Calibration** dialog box is presented, which is used to create a calibration object.
2. Make sure the **Square Pixels** option is selected from this **Calibration** dialog box.
   - Note, for this example, the pixels are square, but in Inspector, you can also create a calibration object that corrects an image with a distorted aspect ratio.



3. Assign a specified number of pixels to a specified number of real world units. To do so, click on the calibration line which flashes blue when selected.
4. Using the mouse, draw a line extending from the first edge of the first pin to the first edge of the second pin in the image. The length of this line should be 95 pixels. The length will be displayed at the bottom of the image in the status bar. Adjust this line if necessary and click the calibration line button a second time when finished.
5. Inspector places the line's pixel length in the **Pixels** edit field.
6. The distance from the first edge of the first pin to the first edge of the second pin is 2.5 millimeters (mm). So, type 2.5 in the **World** edit field.
7. Select millimeters (mm) from the **Units** drop-down list box.

8. Apply the calibration object to the current image by ensuring that the **Apply to** option is set to the *threepins.tif* image. Then, click **OK**.

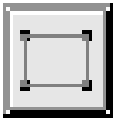


Note that although the image remains the same after calibration, you will now obtain measurements and positional results from the scale-calibrated image in real world units. To test this, move the cursor over the image and note the reported coordinated in the image's status bar.

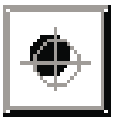
It is important to mention that most dialog boxes (for example, measurement and pattern matching) take positional and measurement data in uncalibrated (pixel) units, while all tables present results in calibrated units. Interactively, you can determine the uncalibrated equivalents by setting the status bar to show uncalibrated coordinates. Scripting functions which access results can access results in calibrated or uncalibrated units.

Pattern matching

Now, you will perform a pattern matching operation on the calibrated *threepins.tif* source image. You will first define a rectangular region to be used as the search model (search pattern). Then, you will search the whole image for occurrences of matches to your model to ensure that the three pins are present. In addition, the position of the first occurrence of the pattern will be used to set up the subsequent stripe finding operation.



1. Use the **ROI** tool button, or select the ROI rectangle tool from the **Drawing Tools** toolbar, to draw a region around the pin's waist. The ROI's origin should begin at coordinate location **(1.40,4.40)** and its width (w) and height (h) should be roughly **1.50** and **0.85**, respectively, as illustrated below.

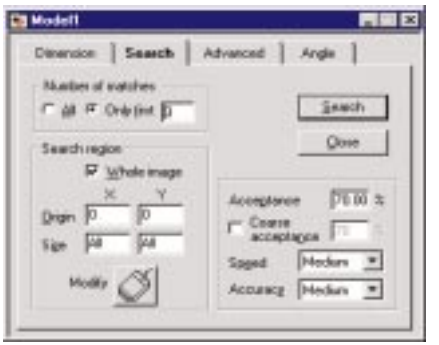


2. Click on the **Pattern Matching** button. Alternatively, use the **Analysis Pattern New Model** command.

3. The **Model** dialog box appears with the **Dimensions** tab selected, and the search model displayed in the upper-left corner.

- Note, for some images, it is advisable to mask the undesired areas using the colored eyedropper tool to minimize interference from background pixels and increase the accuracy of your search.

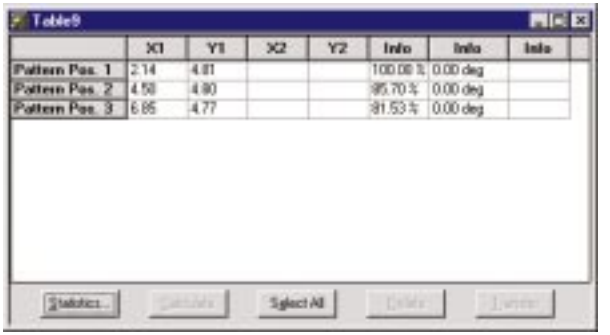
4. Now, select the **Search** tab from the **Model** dialog box. Since we are expecting a maximum of three pins in the image, type **3** in the **Only first** edit field.



5. To ensure that search results are drawn with a bounding box (graphic object) in the image's overlay, right-click on the **Model** dialog box. The **Model Properties** dialog box is presented. Select the **Draw graphic object in image** option under the **General** tab.

6. Click the **Search** button to search for the three occurrences of the model in the image.

7. A measurement table is displayed listing the calibrated positions of all models found in the image in the **X1** and **Y1** columns, and the match score (%) obtained for each occurrence, in the **Info** columns.



Do not close this table since this positional data will be used shortly.

- By default, you will also obtain an on-screen log for all pattern matching operations. To disable this option, right-click on the measurement table and choose **Properties** from the table's context menu. A **Measurement Table Properties** dialog box is presented. Choose the **Results** tab, and then disable the **Log results** option.

A few points to consider...

It is important to note that for this example, you perform a pattern matching operation in a source image with a square pixel aspect ratio (1:1). Accordingly, it is not necessary to physically correct the image when performing the pattern matching operation. However, as a general rule, you must physically correct an image if its distortions can significantly impact your particular processing operation.

For example, significant perspective distortion can affect the success of a processing operation like pattern matching.

Even if your imaging setup causes your images to have a non-unity aspect ratio, and you want to find a model that can appear within an angular range, you will have to correct your image before performing the search. In these cases, after calibrating your image, use the **Image Advanced Geometry Correct** command to correct your image using its associated calibration object. Note that after correction, results are still returned in real-world units.

Search using an occurrence of a pattern as the relative origin

Next, you will search for and measure three pin-legs in the image. In this case, you will use coordinates of the first pin waist (Pattern 1 match), determined from the pattern matching operation, as the relative origin for setting up a search area (search box).

When automating this application using scripting, it is important to note that Inspector's scripting functions take values only in uncalibrated units, although they can return results in either calibrated or uncalibrated units. It is important to remember most dialog boxes and tables do not take and return values in an identical fashion.

Changing status bar display settings from calibrated units to uncalibrated units

Interactively, get uncalibrated positional data in the status bar. To do so, right-click on the image and choose **Properties** from the image's context menu. The **Image Properties** dialog box appears. Select the **Display** tab, and then set the **Status Bar Format** option so that **Show Calibrated** is not selected.

Finding stripes and angles in an image

Now, we will use Inspector to check for the structural integrity of the three pin-legs on the chip in our image, because after much wear and tear, the pin-legs might be bent. Since the pins themselves constitute a pair of edges (a stripe), an easy way to determine if their legs are bent is to search for three edge-pairs (stripes) in the image, and then analyze the angle measurements calculated by Inspector.

1. To accomplish the stripe search, click the **Edge and Stripe** button; alternatively, use the **Analysis Measurement Edge and Stripe** command. The **Edge and Stripe** dialog box is presented.
2. Click on the **Stripe** option (*not Edges*).
3. Select the **Multiple** search option to search for multiple instances of the stripe.
4. Type **3** in the **Number** edit field, since there are three pins in the image.
   - A 0 in the number or spacing edit field means that Inspector will search for any number of stripes or stripes that are separated by any amount of space, respectively. These settings will result in slower processing since the search algorithm will need to determine these values automatically. The search algorithm is much more efficient and more robust if the expected number of stripes and their spacing (in pixels) are specified as opposed to being left as 0 (unspecified).
   - The default auto-polarity setting is suited for this example.

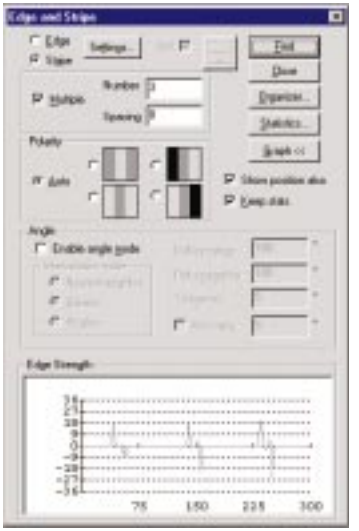
5. Set the initial search box orientation to **Vertical**, since the pin-legs will be in a vertical orientation.
6. Click on the **Draw the Search Box** button within the **Edge and Stripe** dialog box. This search box button flashes blue.

Defining a search area

7. Now, draw a rectangular search box that encloses the upper portion of the three pin-legs. The search box should be placed just below the pin's waist. To accomplish this, the box should have a negative horizontal offset of 50 pixels, and a negative vertical offset of 30 pixels from Pattern 1's X and Y coordinates, respectively. The height of the box should be 20 pixels. A suitable search box with dimensions 290 pixels (width) x 20 pixels (height) is illustrated below.

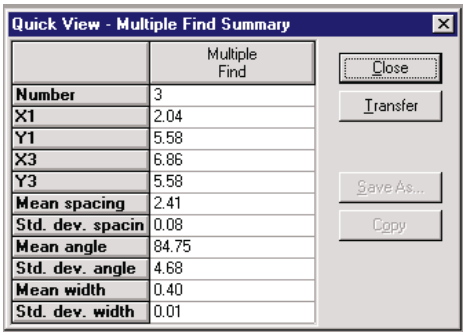
8. Adjust your search box area if necessary, and then click the flashing search box button a second time when finished.
9. Now, click on the **Graph>>** button to see the edge values for every edge profile value in the search box region.

On the graph, six peaks are presented. Each pair of adjacent peaks represents two distinct edges; one positive and one negative. An edge value greater than +/- 10 is necessary for accurate edge/stripe finding results.

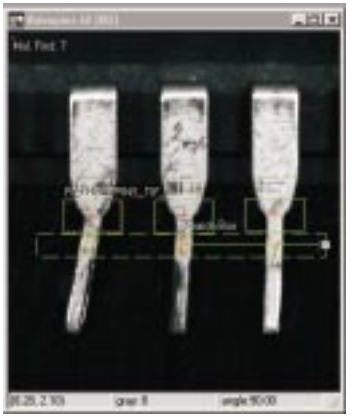


10. Click the **Find** button. The centers of the three stripes found by Inspector will appear as pink crosses.
11. A **Quick View-Multiple Find Summary** dialog box appears. A synopsis of the stripe search results including the number and mean angle of the 3 stripes found are displayed in this dialog box. Other data is also generated in calibrated units.

    Look at the mean angle and standard deviation generated from the stripe search. If the standard deviation is within the expected range, you can be reasonably assured that the stripes found are valid. Otherwise, choose **Close** and redefine the stripe find operation.

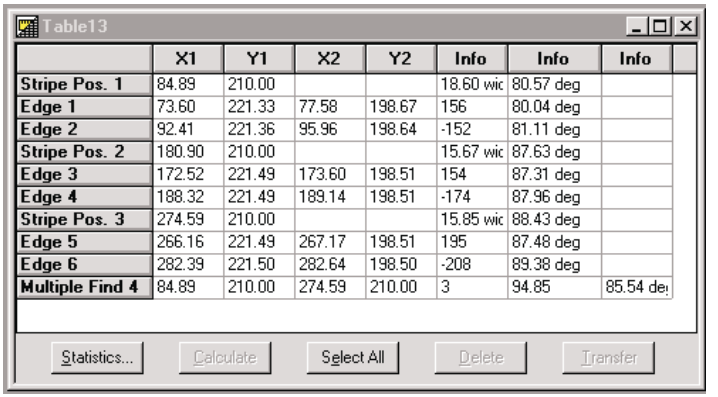


12. Select **Transfer** to transfer positional and angle results to a measurement table. In addition, edge and stripe centers are now shown in yellow.



13. To determine whether or not there are bent pins, look at the angle values determined for each stripe in the second **Info** column (column 6) of the measurement table. From the measurement data generated for the left-most pin, rows one (**Stripe Pos. 1**), this pin is clearly bent. That is, its stripe

angle (in addition to its two edge angles) is not close enough to 90 degrees as compared to the other two stripes **(Stripe Pos. 2** and **Stripe Pos. 3)**.



	X1	Y1	X2	Y2	Info	Info	Info
Stripe Pos. 1	84.89	210.00			18.60 wic	80.57 deg	
Edge 1	73.60	221.33	77.58	198.67	156	80.04 deg	
Edge 2	92.41	221.36	95.96	198.64	-152	81.11 deg	
Stripe Pos. 2	180.90	210.00			15.67 wic	87.63 deg	
Edge 3	172.52	221.49	173.60	198.51	154	87.31 deg	
Edge 4	188.32	221.49	189.14	198.51	-174	87.96 deg	
Stripe Pos. 3	274.59	210.00			15.85 wic	88.43 deg	
Edge 5	266.16	221.49	267.17	198.51	195	87.48 deg	
Edge 6	282.39	221.50	282.64	198.50	-208	89.38 deg	
Multiple Find 4	84.89	210.00	274.59	210.00	3	94.85	85.54 de

If you obtain lines that go off at undesired angles after the stripe finding operation, try one or both of the following:

- Narrow the search box region.
- Look at the stripe area that you have selected. Ensure that in this area the pin-legs have no artifacts or large dark areas. Otherwise, reposition the search box to avoid these areas.

Demos...

To see more examples of calibration operations in Inspector, run the Calibration and Image Correction demos. For an example of a stripe finding and pattern matching operation, respectively, run the Broken Gear and Track Object demo, respectively. To run any of these demo:

1. Use the **File Open** command or Explorer to open the demo launcher *BasicDemo.bas* that can be found in the ***\BasicFiles*** folder. Alternatively, use the **Options Utilities Basic Demo** command.
2. Choose the **Wait for user response** option to run the demo.
3. Select the demo, and then click the **OK** button.

The Calibration (*Calibration.bas*) demo is a Inspector script that has been written to physically correct a radially distorted image. It first determines the correction needed by calibrating the imaging setup using a grid image and then applying the correction to the destination image.

Similarly, the Image Correction demo (*CalibGrid.bas*) is an Inspector script that has been written to physically correct an image with a distorted perspective by first calibrating the imaging setup using a grid.

The Broken Gear demo (*BrokenGear.bas*) is an Inspector script that incorporates a multiple stripe find operation to detect the broken teeth of a gear.

The Track Object demo *(TrackingDemo.bas*) is a script that uses a pattern matching operation to track a moving object in a sequence file. This demo will also serve as a good introduction to the next example topic.

Example 3: Working with many images and non-standard image file types

In this example, you will open a collection of sample images, and work with a sequence of diagnostic medical images. This sequence is an angiogram which isolates a major blood vessel and its primary branches during the course of a few cardiac cycles.

You will play all the frames in this sequence of angiogram images, and then do a histogram to obtain a dynamic representation of the pixel values in a defined region in the sequence.

In addition, you will remap the pixel values in some of the sequence's grayscale images to confer greater distinction (contrast) between the blood vessels and the gray background. To do this, you will take advantage of Inspector's live preview and locked preview capabilities. These will help you choose the

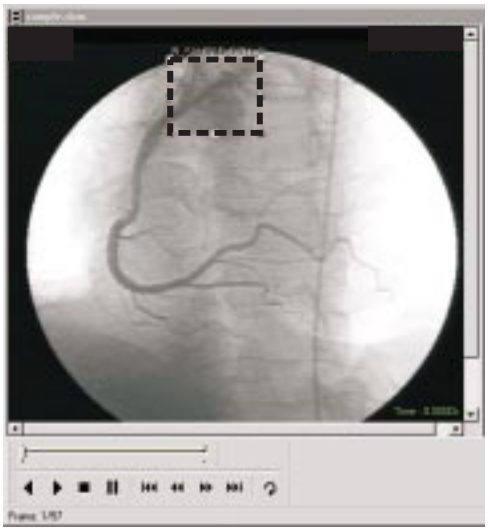
most appropriate remapping. After this, you will create your own short sequence with images that you will enhance, and then apply the selected remapping.

Finally, you will use the magic wand ROI tool to distinguish a specific region of the vasculature in order to show changes in vessel positioning during the circulatory cycle.

Loading a collection of images

1. Load the collection of image and sequence files, *Sample.col*, from the ***\IMAGES*** folder. To do this, use the **File Open** command or drag the collection file from the Windows Explorer folder into Inspector.
2. Double-click on the *sample.dcm* sequence file which appears as a single thumbnail image in the collection. The *sample.dcm* sequence is loaded; the 57 thumbnail frames which make up the sequence are also displayed.
3. Use the scroll bar to scroll through the 57 thumbnail frames which make up the sequence.

4. Now, click the **Play** button to view the sequential series of frames.
5. Using the **ROI** tool button or the rectangular ROI tool from the **Drawing Tools** toolbar, draw a small rectangle around the blood vessel in the first sequence frame as illustrated below. This is an area where the vessel is ruptured and dynamic changes in blood flow are easy to see.



6. Click the **Histogram** button to get a graphical representation of the pixel intensity distribution for this particular ROI.
7. Click the **Play** button to view the automatic and dynamic histogram update, for the region selected, as the blood flow through the ruptured vessel undergoes dynamic changes.

Window leveling

Now, you will determine the appropriate window leveling setting to use to remap the range of pixel intensities in the source region (or entire image) to a new range that yields greater contrast. Inspector automatically sets the input range using the minimum and maximum pixel values in the source ROI. Values below / above the values in the input range are mapped to the lowest / highest value, respectively, of the output range. By stretching the range of pixel values, window leveling allows you to make use of all available intensities.

1. To select the appropriate window leveling settings for the entire vascular bed (not just a small ROI), expand the small ROI so that it encompasses the entire vasculature for all frames in the sequence. To do this, select the ROI **(R_SAMPLE_DCM_0)** and drag one of its handles to make a rectangle of the required size.

2. Now click on the **Window Leveling** button to remap the range of pixel values in the larger ROI. Alternatively, use the **Image Processing Mapping Window Leveling** command.

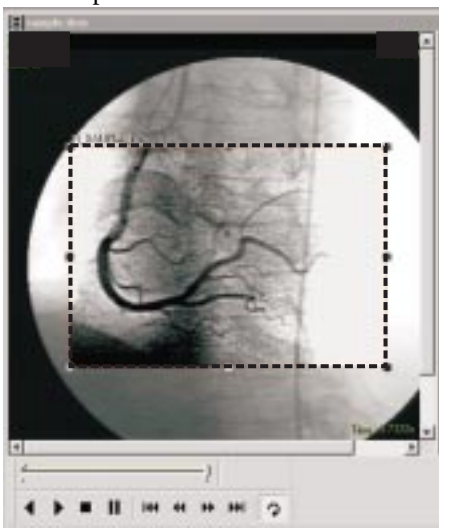
   As a third alternative, right-click on the active sequence and choose **Processing** from the context menu. The **Processing Operations** dialog box appears. Select the **Mapping** tab of the **Processing Operations** dialog box.

   The **(WL) Window Leveling** button will be selected by default.

Live preview and locking the live preview

Determining the output pixel value range that produces the best contrast in your image might be difficult. However, Inspector allows you to obtain a live preview of any mapping modifications and maintain this live preview over all the required frames in a sequence.

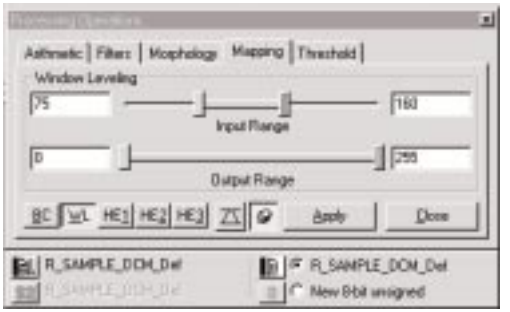
1. Ensure that the **Output Range** is set for the full pixel value range, from **0** to **255**.
2. Adjust the pixel intensity **Input Range** to between **50** and **175** using the slider or type these values directly into the edit fields. A live preview is obtained.




3. Now, click the **Lock Live Preview** button to lock the on-screen display in preview mode. Alternatively, use the **Options Lock Preview** command. The locked live preview allows you to preview the remapped pixel range in the source region during playback, without making permanent changes to the pixel range.
4. Close the dynamic histogram graph to allow for a faster playback rate.

5. Click on the **Repeat** button and **Play** the sequence again.

6. Now, adjust the **Input Range** to between **75** and **160** during the playback while the preview is maintained. This pixel range should provide an optimal contrast level.



7. Click on the **Stop** button after a few iterations.
8. Now, unlock the **Live Preview** by clicking on the lock button again. The unlocked icon reappears.

Adjusting the playback range in a sequence

By viewing a limited range of frames in the angiogram sequence, it is possible to determine that the point of maximal dynamic flow from the ruptured vessel occurs in frames 6-10, and an instance of maximal displacement for the main vessel occurs in frame 28.

1. Adjust the range of frames in the sequence for playback to **1** and **30** by right-clicking on the dual slider and dragging. A small, yellow rectangular text box is displayed showing the frame numbers to be included in the sequence.

   Alternatively, you can select the range of frames for viewing by right-clicking on the image and then choosing **Properties** from the sequence's context menu.

2. In the **Properties** dialog box, select the **Sequence Info** tab. In the **Playback Range** section, type **1** and **30** in the **In** and **Out** edit fields, respectively.
3. Click on **Repeat** and **Play** to play this limited sequence.

Creating a memory sequence

Now, you will create a sequence made up of this limited range of frames. Since you cannot modify the frames of a sequence that is saved to disk (known as a disk sequence), you must

create a memory sequence. A memory sequence can be changed because each frame is allocated its own memory. Then, you can apply the window leveling to this range of frames in the sequence, to obtain a better contrast between all blood vessels and the background.

1. Use the **File New** command.
2. Select **Sequence** from the **New Inspector Document** list box.
   - Note, do not select *SequenceAVI* or *SequenceTIF* because these create disk sequences, that is, each frame added to either of these sequences is saved immediately to disk. Therefore, the frames of these sequences cannot be modified, only rearranged.
3. Reactivate the *sample.dcm* file.
4. Click on the thumbnail of frame 1.
5. Hold down the **Shift** key, and then click on frame 30.
6. Using the mouse, drag and drop these frames into the new sequence that you recently created. Check for the small (+) sign on the mouse cursor when you drag to the new memory sequence window.
   - Note, because *sample.dcm* is a disk sequence, the frames are copied, not moved to the open memory sequence. In the case of a memory sequence, you must hold down the **Ctrl** key when dragging frames to another sequence; otherwise, frames will be moved instead of copying.
7. Now, click on the **Window Leveling** button or use the **Image Processing Mapping Window Leveling** command to return to the **Mapping** tab of the **Processing Operations** dialog box.

8. Again, ensure that the **Output Range** is set for a full pixel range, from **0** to **255** and adjust the **Input Range** to between **75** and **160.**
9. Now, click on the **Apply** button to set this new pixel range to frame 1. This pixel range will provide optimal contrast to distinguish the vessel from the background.

- It is worth noting that once a processing operation is applied, the preview becomes unlocked automatically.

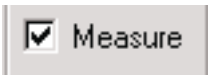
10. Click on the thumbnail of frame 12, and **Apply** the pixel re-mapping operation.
11. Apply this mapping operation to thumbnail frames 21 and 28 as well.

    - Note that you can apply the mapping to a specified range of frames in your sequence using scripting. To do this, you have to loop through each frame (*SeqSetCurrentFrame()*).

Using the magic wand tool to define and fill a region of interest

The positional changes of a vessel can be important during each cycle. To verify this for this example, you will define an ROI that traces the outline of a portion of the vessel in frame 1, and then you will fill this region with a distinguishing color. Next, you will playback the sequence, and note the frames wherein the vessel re-establishes its initial position, and where it shows maximal displacement from its initial position. Finally, you will use Inspector's measurement capabilities to determine the resultant displacement for this positional change.

1. To set the reference frame, click on the first thumbnail frame.
2. Enable Inspector's measurement capabilities, by clicking on the **Measure** option under the **Drawing Options** section of the **Drawing Tools** toolbar.



3. Generate an ROI outlining the main vessel using the **Magic Wand** ROI tool. This creates an ROI from connected regions with the same pixel value range. To do this, click on the **Magic Wand** button from the **Drawing Tools** toolbar.

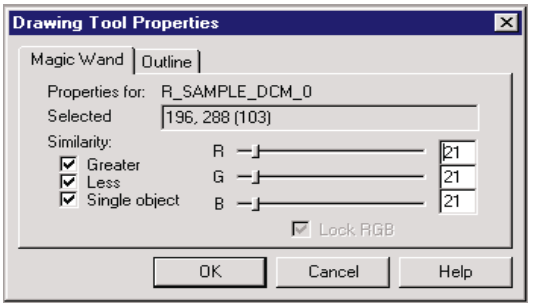
    - Note that the magic wand ROI tool also works on image previews, for example, of a watershed operation.

4. Click on the main vessel in the image (with the magic wand cursor).
5. Move the cursor over the red ROI outline which appears. A dashed-square box appears near the mouse cursor (arrow).

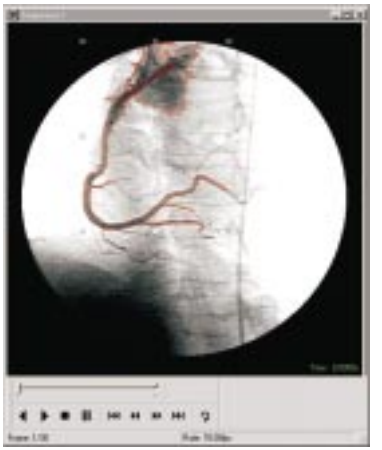
6. Right-click on the ROI outline, and then select **Magic Wand Properties** from the presented context menu.

   Alternatively, right-click on the **Magic Wand ROI** button in the **Drawing Tools** toolbar and select **Properties** from the list box presented to obtain the **Drawing Tools Properties** dialog box.

7. Adjust the wand properties to redefine which pixel values are included in the ROI. Set the value to **21** using the slider or type it directly into the edit field.

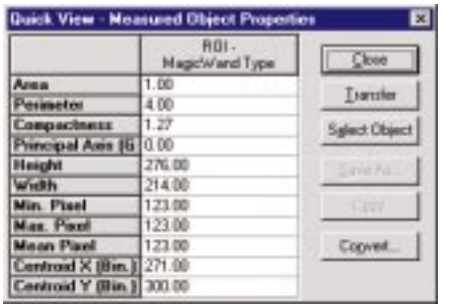


8. A modified red ROI outlining the vessel is generated.



- If you have not clicked directly on the vessel, the defined ROI will not isolate the vessel. In this case, delete the ROI selected using the **Edit Delete** command or use the **Delete** key on your keyboard.

9. In addition, a **Quick View-Measured Objects Properties** dialog box appears.



Take note of the centroid coordinates (X,Y) for the defined ROI.

10. To verify that the vessel re-establishes its initial position in frame 1, play back the sequence.

Adding a fill color to an ROI

Now, add a dark fill colour to distinguish this defined region of the vasculature.

1. To fill in the selected ROI, click the **Arithmetic** operation button. Alternatively, right-click on the image and select **Processing** from the image's context menu.

2. Select **Fill with value** from list box presented in the **Artithmetic** tab.

1. Type 1 in the **Color Picker** edit field, then click on **Apply** to fill the ROI with this color.

2. Playback all the frames, with this ROI overlayed on the sequence, to see the positional changes of the main vessel.

3. Click on the **Pause** button when the main vessel shows maximal displacement. In the sequence, this fame should correspond to frame 28.

4. Repeat the steps previously described to define an ROI that encompasses the curvature of the entire vessel in frame 28.

5. Take note of the centroid position (X,Y) for this defined ROI.
6. The resultant vector, between the initial vessel position and maximal displacement, can be determined by calculating the difference in the centroid coordinates of these two defined ROIs.

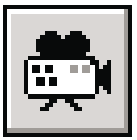
Collection demo...

To familiarize yourself with creating a collection in Inspector, run the *MakeCollection.bas* script provided in your software package. To do so, use the **File Open** command or Explorer to open the script file found in the ***\BasicFiles*** folder.

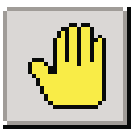
The *MakeCollection.bas* demonstration is a script which creates a sequence containing a variety of image files, of various file types, and displays each file as a single thumbnail image.

Example 4: Grabbing an image

In this example, you will grab two images using a camera and an installed frame grabber (digitizer). Then, you will perform a standard arithmetic operation to determine the pixel difference between these two grabbed images. As a final exercise, you will remap this small range of pixel values to the full pixel-value range for an 8-bit image (0 to 255) so that the difference in values is visible.

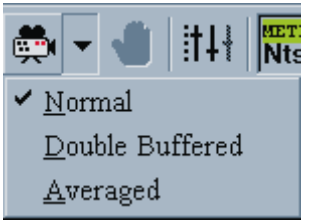


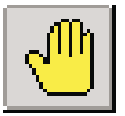
1. When a frame grabber is installed and a camera is attached, the **Continuous** (Grab) tool button will be available.
2. Click on the **Continuous** tool button to grab the required image. Alternatively, use the **File Grab Continuous** command. A live window is opened.



3. Use the **Digitizer Control** dialog box to make any necessary adjustments to your image. The changes are displayed immediately.

4. Make sure the **Continuous** drop-down list box is set to **Normal** as illustrated below.





5. Freeze the grab on the required frame by clicking on the **Halt Grab** tool button; alternatively, use the **File Grab Halt Grab** command.

6. Use the **File Save** command to save the first image, grabbed with the **Normal** setting, as *normal.jpg*.
7. Click on the **Continuous** tool button again to restore the live window.
8. Now, select the **Averaged** setting from the **Continuous** tool button's drop-down list box. This provides the average of 8 consecutive frames.
9. Again, freeze the grab by clicking the **Halt Grab** button or using the **File Grab Halt Grab** command.
10. Use **File Save** command to save this second image, grabbed with the **Averaged** setting, as *averaged.jpg*.

Performing arithmetic operations on images

In this part of the example, you will perform an arithmetic operation which provides the pixel difference between the normal and frame-averaged image.

1. Click the **Arithmetic** operation button. Alternatively, right-click on the image and select **Processing** from the image's context menu.
2. Select **Absolute of Difference** from the list box presented in the **Arithmetic** tab.

Locking and unlocking targets

Now, you will lock the images into their required roles (source and destination) by clicking on the required source or destination image, respectively.

1. Select the first grabbed image (*normal.jpg*) and lock it as Source 1. To do this, right-click on the normal grabbed image, and then select **Lock Source 1** from the image's context menu.

   - Note, by default, the target **Selector** bar at the bottom of the **Processing Operations** dialog box lists the last region activated as Source 1 **(S1)**.

2. Select your second grabbed image (*averaged.jpg*) and lock it as Source 2. To do this, select the file (*AVERGAED_JPG*) from the Source 2 **(S2)** drop-down list box of the **Selector** bar, which appears at the bottom of the **Processing Operations** dialog box. The list box presented lists all images that can be designated as S2.

   Alternatively, you can lock the grabbed frame-averaged image by right-clicking on the image, and then selecting **Lock Source 2** from the image's context menu.

3. Lock the destination image (**D**) as a new 8-bit, unsigned image. To do this, choose use the **Selector** bar at the bottom of the **Processing Operations** dialog box.

4. Now, click on the **Apply** button to implement this arithmetic operation.

   - Note, to remove the locks on all targets without performing the operation, that is, to return to the default source and destination images, select **Unlock All Targets** from the image's context menu.

5. Select the **Mapping** tab and click on the **Window Leveling** operation button to remap the pixel value range to a full range.

Chapter 3: Dealing with images

This chapter describes the types of images Inspector supports, dealing with grayscale (single-band) and color images, image conversion, image duplication, and band extraction. It also discusses how to use ROIs, special file types, how to use collection files, and special display effects, such as zooming, view as text, view 3D, and using palettes.

Images in general

Inspector supports the loading, saving, and creation of grayscale and color images, as well as the grabbing, displaying (directly or indirectly), and processing of these image types. Once you have loaded, grabbed, or created an image, it can be zoomed, converted into another data type, or associated with a display palette. You can perform operations on an entire image, individual color components of an image, or on a localized region of interest. Several images can be grouped into collections to facilitate maintaining images.

Inspector supports images with the following data types and pixel depths:

- 1-bit (packed binary) images.
- 8-bit, 16-bit, and 32-bit signed or unsigned images.
- 8-bit 3-band RGB and HSL images.
- 32-bit floating point images.

Inspector supports loading images from single-image files (for example TIFF, BMP, and JPEG), sequence files (for example, AVI and TIFF), and raw and DICOM images. For a list of supported file types, see Appendix B.

Note that 4-bit images can be loaded, but they are converted to 8-bit. In addition, HSL images can be loaded or saved but color space information is not retained. See *Color images*.

With Inspector, you can create a color or grayscale. (single-band) image and fill it with a specified value. See the on-line procedure, *To create a new grayscale or color image*.

Loading an image

An image can be loaded in one of several ways, most of which are standard Windows methods of opening files.

- The **File Open** command.
- The **Recent Files** and **Recent Scripts** list in the **File** menu.
- A collection file (discussed later in this chapter).
- **Explorer**. Select the required image(s), and then drag them into the Inspector workspace.

All methods, except for the Recent Files and Recent Scripts methods, allow you to open several images at once. You can change the maximum number of most-recently used files shown, as well as choose whether to display the complete path of each file or just the names, using the **Options Preferences** command (in the *General* tab).

You can view information about an image before loading it, using the **Info** button of the **File Open** command. In addition, you can obtain information about the image, such as file type and size, after it is loaded, by using the **View Properties** command.

Inspector will open files according to its extension, as long as the extension is listed in the **Files of type** drop down list. If your image has an unfamiliar extension, 7 you should specify how the image should be loaded by selecting the appropriate item in the **Open As** field of the **File Open** command. For example, you can specify to open an image as a raw image using this field.

If Inspector cannot determine the file type, the image will be opened as a raw image. See the section, *Raw format*.

Grayscale or single-band images

A **single-band** image is an image whose data has two dimensions, X and Y. These images are usually monochrome, or **grayscale**; grayscale images are essentially a subset of single-band images.

Single-band images, however, are not exclusively grayscale; they can contain color information. For example, unlike single-band images, color images have three dimensions: X, Y, and a color band dimension. Therefore a color image, which has three bands can be represented as three single-band images. See *Color images*, *Displaying single-band images with a palette*, and *Creating and using one-band color images*.

Grayscale or single-band images include packed binary images, 8-, 16-, and 32-bit signed and unsigned images, as well as 32-bit floating-point images.

The value ranges for the corresponding types of grayscale images are shown below.

- packed binary: 0 to 1
- 8-bit unsigned: 0 to 255
- 8-bit signed: -128 to 127
- 16-bit unsigned: 0 to 64 Kbyte-1
- 16-bit signed: -32 Kbyte to 32 Kbyte-1
- 32-bit unsigned: 0 to 4 Gbyte-1
- 32-bit signed: -2 Gbyte to 2 Gbyte-1
- 32-bit float: 1.17×10^{-38} to 3.40×10^{38}

Signed images

If you are performing operations that result in negative values, you should use a signed image type as a destination. Otherwise, negative values will wrap around to the higher end of the value range.

Processing a grayscale image

All processing and analysis operations can be performed on grayscale images. However, the pattern matching operations can only be performed on 8-bit unsigned grayscale images. Inspector will automatically convert the image to the appropriate type if required.

Non 8-bit images

Inspector uses deep buffers to store large image types, such as 16- and 32-bits (including 32-bit float). Such images are useful for storing intermediate processing results, since they can contain a wide range of values. You can also use 16-bit images to store data grabbed from 10- or 12-bit deep (camera) sources.

❖ Note that all non 8-bit single-band images can only be saved as *.mim* files.

If you want to view a histogram of a deep image that has only a small range of values, you can select the **View Zoom Interactive** command to draw the histogram with the small subset of the dynamic range of values in your image. See *Performing a histogram* of *Chapter 8: Histograms, profiles and measurements*.

Packed binary images

Inspector also supports packed binary images. Generally, processing operations are optimized for packed binary images, especially morphological operations. With all processing operations, you can specify if you want the results in a packed binary format.

❖ Packed binary images can only be saved in .mim format.

Displaying grayscale images

Regardless of your display resolution, image depths other than 8-bit unsigned or 3-band 8-bit color will require remapping to the display. Inspector displays these images by mapping them to a separate display buffer. When creating a new image with a type and depth other than 8-bit unsigned, you will be presented with a dialog box, where you can select a mapping method:

- **Autoscale**: The autoscale display method linearly maps the values in the image so that the minimum and maximum values in the display buffer are set to 0 and 255, respectively. Autoscale is the default remapping mode.

  Note that, if the image contains a single value (that is, if the image was created and filled with a single value), this value is mapped to 0, 127, or 255, depending in which third of the total data range (in the image) this single value falls.

- **Bitshift**: The bitshift display method bitshifts the image data so that the 8 most-significant valid bits of data are displayed. For this method, you should specify the number of bits that actually have significant data. For example, if you are grabbing into a 16-bit buffer with a 10-bit camera, use the bitshift display method, and set the significant bits to 10.

  This method should be used when you know how many bits of the image contain valid image data, for example, when storing a 10-bit image data in a 16-bit image. This ensures that as much of the available dynamic range of the 8-bit display buffer is used. This is particularly useful when most, but not all of your image values, lie within a small range.

  When selecting the bitshift method, you can also specify the number of bits that contain valid image data.

- **Logarithmic**: The logarithmic display method is a logarithmic remapping of values which emphasizes the lower values in the data range. This is particularly useful when your image is a 32-bit floating point image.

- **None**: When loading or creating an image, you can also select not to display the actual image data (the image window displays a "cross hatch" instead of image data). This method is useful if the image is to be used for processing only. Note that non-displayable images do not support graphic annotations, ROIs, and line profiles.

Note that even if a display buffer is used to display the image, the displayed image's status bar shows the *actual* value of the pixel under the cursor. If the image is associated with a palette, the mapped RGB component values (or gray values if using a grayscale palette) will also be displayed in the image's status bar.

You can change the display method at any time using the **View Properties** command.

Displaying single-band images with a palette

Inspector displays any single-band image with a display palette, in order to best represent the ideal colors of the image. Palettes map an image's pixel values to required display values; the image's data is not directly affected. Palettes can adjust the color and even improve the image for visualization purposes; this is sometimes called pseudo-coloring. By default, the palette associated with an image is linear gray.

You can view a 1-band image, a component of a color image, or a pane in 3D view in another color scheme by associating it with an Inspector palette. Although palettes are not available for color images viewed in composite mode, when a color image is viewed in component mode, each component can be associated with a different palette.

You can change an image's display palette using the **Palette Editor**, which is only available from the image's context menu.

The final quality of the colors displayed depends on the number of colors available in your Windows display resolution. If it has 256 colors, the settings of the **Options Preferences** command (in the *General* tab) will affect what is shown on the screen.

- Imaging boards with a display section which use digital keying, do not have a palette for displaying 8-bit unsigned images; therefore you cannot use the **Palette Editor** command or display a quantized image with its palette (see *Creating and using one-band color images*).
- The status bar will display both the pixel value and the RGB palette entry for that value whenever a non-default palette is chosen.

Creating user-defined palettes

Inspector has several predefined palettes, which can be used as-is, or can be used as a base upon which to create a user-defined palette. Any of a palette's 256 entries can be changed to create a user-defined palette. Single entries can be changed by selecting the entry and changing its values. If you want to change a range of colors, you can add nodes to the palette. A palette node is a point in the palette that interrupts the original color range. Adding one node simply changes the color of the entry, but when two or more nodes are added, the palette editor linearly interpolates the RGB values of entries between those that have been added as nodes, creating a user-defined palette. Adding nodes is a very efficient way of creating ramps and ranges of color.

To keep any user-defined palette, you must save it from the **Palette Editor** as a *.pal* file. The predefined palettes cannot be changed. Palettes can only be saved with the image in formats that support palettes, such as *.tif* or *.bmp*, but not *.mim*. Images opened from such files will use the palette from the file instead of the default grayscale palette.

See the on-line help: Description of Inspector palettes, and Creating a user-defined palette.

Creating and using one-band color images

You can convert a 3-band image into a 1-band image with a color palette by using the **Image Convert** command and selecting 8-bit Unsigned Quantized (this command is discussed later in this chapter). A 3-band 8-bit color image has 16.7 million possible colors. A quantized image has these 16.7 million possible colors reduced to 256 colors in a single band. When converting a 3-band image to a single-band color image, the Octree algorithm is used to reduce the number of color values. (Octree is one of three algorithms Inspector uses to optimize palettes in an 8-bit display resolution. See the section, *Using palettes with an 8-bit display resolution*.)

If you need to process a quantized image, you should first convert it to RGB to produce meaningful results. If your system cannot display quantized images, you can use the system bar and drag the image to the VGA system.

Color images

Color images include 8-bit 3-band images, such as RGB and HSL true color images.

Multiple views

Inspector provides a very flexible 3-band color image display. See the View menu. Color images can be displayed in:

- One window as a composite image, using the **View View Composite** command.
- Three separate windows, where each window displays one of the image's color components, using the **View View Components (MDI)** command.
- One window divided into three panes, where each pane displays one of the image's color components, using the **View View Components (3)** command.
- One window divided into four panes, where one pane displays the composite image and the remaining panes display each of the individual color components of the image, using the **View View Components (4)** command.

Even though the latter two view modes are part of the same window, each pane, once selected, can be resized and have its contents zoomed and scrolled independently. Select a pane by clicking on it; the active pane is identified in the image's title bar. Note that the palette of the active pane is favored when displaying the image with its own palette.

If a window or pane displays a single component, you can change its display palette, using the **Palette Editor**. This command is discussed later in this chapter.

Color spaces

The color space of a color image refers to the way color in that image is represented. Common color spaces are RGB and HSL.

RGB color space

In the RGB color space, color is represented as a combination of red, green, and blue components. This color space is generally used for display hardware, since it best matches the three colored phosphors of display monitors. It is also the color space of many cameras and input devices.

HSL color space

In the HSL color space, color is represented as a combination of hue, saturation, and luminance components. The hue component can be thought of as the actual color information. The 360 degrees of the ideal color wheel are mapped onto 256 values, starting with red at 0° and going through yellow, green, cyan, blue, and magenta. Saturation can be thought of as the measure of color purity or concentration. Luminance corresponds to the brightness of the colors, and is what a grayscale version of the image looks like.

The HSL color space is similar to the human way of describing colors. Each color has its own hue value (such as red, orange, or green). Once the hue value is chosen, changes to the saturation or the luminance alter only the color quality, not the basic color.

Representing color images

RGB and HSL true color images are represented using three 8-bit bands of data, where each band of data represents a color component of the image's color space.

RGB and HSL true color images

When you save true color (3-band) images, information about the color space (RGB or HSL) is not saved. Therefore, when Inspector loads any 3-band image, it assumes that it is an RGB color image. If you know that an image is an HSL color image, you should indicate this using the **View Properties** (in the **Image** tab) command.

Operating on regions of interest in your image

ROIs are defined regions of images. They are often rectangular, but they can have any shape. You might want to perform more localized processing on an ROI.

An image can contain several ROIs; when created, each is assigned a name beginning with R_. The default ROI is the entire image, and is named R_imagename_DEF. Unless you lock targets, only one ROI can be selected at any one time when performing operations. Even when the entire image is the ROI, make sure the required ROI is selected when performing operations; when selected, the ROI's name will appear in the selector bar.

Defining ROIs

To define ROIs based on areas of several different shapes, or on the gray or color values in an image. Use the ROI tools on the **Drawing Tools** toolbar. Certain types of ROIs can be resized and moved using the **Image ROI Properties** command. See *"Using ROIs and graphic annotations"* in *Chapter 12: Defining ROIs and annotating images, for more information about drawing tools*.

See the on-line help for the ROI tools commands.

You can use a user-defined ROI to process or analyze only a portion of an image (which reduces processing time), as well as to copy a specified portion of an image to the clipboard, or for export. A user-defined ROI can also be set as a destination for processing, and as a source or mask of blob analysis, and as a source for pattern matching model definition. Note the following processing restrictions of ROIs:

- Some operations, such as blob segmentation, use the bounding box of a non-rectangular ROI as the processing region. Pattern matching operations, for example, will also use the bounding box of a non-rectangular ROI for selecting the model pattern.

- General processing operations, except the **Geometry Rotation** command and **Image Convert** command. 8-bit Quantized operations, are performed on the active ROI instead of the entire image.
- Profiles access all pixels under the outline of the graphic object, regardless of whether it is in the ROI.

ROI properties

ROI properties are available by calling the **Image ROI Properties** command, or from the image's context menu. The properties window displays the ROI's width and height in pixels, and the pixel coordinates of the ROI's origin (the top left-hand corner of the bounding box). For rectangular or elliptical ROIs, you can change these fields directly from the properties window; for other ROIs you will have to move or resize their graphic objects manually.

Choosing a source and a destination

The ROI on which you apply an operation is called the *source region*. The default source region is the active ROI in the active window. The source region will hereafter be referred to as the source.

For operations that result in an image, results are placed into a *destination region*. The default destination region is set using the **Options Preferences** command (in the **Image** tab). The destination region can be either:

- The active ROI.
- A new image.

A new image destination inherits the same type as the source (if there are two sources of different types, the new image destination inherits the greater depth type of the two). A new image destination also inherits the display options of the source, if applicable. The size of the new destination region is determined by the operation. The destination region will hereafter be referred to as the destination.

Note that the names of an operation's source and destination regions appear on the **Selector** (at the bottom of the **Processing Operations** or **Geometry Operations** dialog box). To view the **Selector**, make sure that the **View Selector** command is enabled.

Selecting a different source and destination

For an operation, you can specify a source and/or destination other than the default one, by *locking* the required image/ROI into the required role. Locking is accomplished by using the **Targets Lock Source1**command. For operations that require two sources (such as some arithmetic operations), you must lock the second source by using the **Targets Lock Source2** command. A destination can also be set using the **Lock Destination** commands.

An alternative way to lock an image/ROI as a second source is to select it from the **S2** list box on the **Selector**.

Note that locked images appear in blue on the **Selector**. In addition, a blue icon appears in a locked image's context menu.

By default, locks are removed after the operation is performed. To keep images locked for more than one operation, use the **Targets Keep Targets** command. Targets remain locked until you call the command again or quit Inspector.

To remove locks without performing the operation, that is, to return to the default source and destinations, use the **Targets Unlock All Targets** command.

If you did not use the **Keep Targets** command for your operation and you want to use those targets again, use the **Targets Restore Targets** command. If there were no previously locked images, **Restore Targets** is disabled.

❖ Note that all these commands are also available from the image's/ROI's context menu.

Processing color images

Unless otherwise specified, processing operations are performed on all the color components of an image. In some instances, however, it is only necessary to process one of the image components. If you want to process the component in place without creating a new image, view the image in component mode, activate the required component, and then lock the component as a source using the **Targets Lock Source1** command. If you want a new image upon which to perform an operation, extract a band using the **Image Extract Band** command.

❖ When using the geometry operations, you cannot operate on a single component of an image. If you need to perform such an operation on a component of the image, you will first have to extract a band.

Duplicating images

Duplicating images is more powerful than simply copying images. The **Duplicate** command allows you to optionally duplicate the data objects associated with the image. The data objects that can be duplicated are:

- ROI objects
- Graphic objects
- Blob objects
- Measurement objects (note that once duplicated, measurement objects become "moveable" and are no longer associated with measurement table entries).

This command also copies the selection state of those data objects being duplicated. If the image or object is associated with a palette, or has been calibrated, the duplication command respects those associations.

Performing a color or data type conversion

With Inspector, you can convert an image between color and grayscale, convert a color image to a different color space, or convert a grayscale image to another grayscale type, by using the **Image Convert** command. The resulting image is always placed in a new image. Note that you can use an existing image as the destination by using a script function.

When processing images, you often need to perform such color conversions, because:

- All operations under the Analysis menu can only be performed on 8- or 16-bit unsigned grayscale images. (If your source is not 8- or 16-bit unsigned, an 8-bit unsigned image will be created automatically when using a command under the Analysis menu.)
- A specific color space might be better suited to a particular application, and converting to that color space minimizes the amount of processing. For example, you might want to determine how many basic colors are represented in an image

that contains several colored objects, some of which are in a shadow. If the image is an RGB color image, all three components must be examined before classifying a color. If, however, the same image is represented in HSL, only the hue component need be analyzed to determine a color. Portions of an object lying inside and outside of a shadow have the same hue, although their luminance and possibly their saturation values are different.

Note that if you perform an arithmetic copy operation using different types for the source and the destination, the data is simply copied, without being scaled or converted, to the destination.

❖ When converting to a smaller buffer depth, Inspector attempts to scale the data down as best as possible.

For a summary of how conversions are performed, see the on-line help, Grayscale source image, Source RGB image, Source 1 specified band of an RGB image, Source HSL image, Source 1 specified band of an HSL image, Source Binary image.

Other image and sequence file types

In addition to standard image and sequence formats, Inspector supports the reading of specialized image and sequence formats: raw and DICOM medical formats.

Raw format

The raw format is the most basic way of storing data; data is simply stored as an array of data values. Raw data can be either a single frame or a sequence. A raw image will typically consist of an optional frame header, the image data, and an optional frame footer. If the data is a sequence, there might be an optional file header for the entire sequence (as well as headers for each frame).

- 8-, 16-, and 32-bit grayscale, and 3-band 8-bit (24-bit) color data values are supported. Note that if raw data is color, the data is internally stored in a packed format. When determining the frame size for a 3-band color image, the number of bytes/pixel is 3.

When opening a raw image (as specified in the **Open as** field in the **File Open** command), or any image whose type Inspector cannot detect, the **Raw Image Information** dialog box opens. You can specify whether there are frame headers in the data, whether the data is unsigned or not, and if the image data has its bytes swapped by checking the appropriate check boxes.

You must specify the size of the image frame. Inspector guesses the image's dimensions based on the file's size (displayed at the bottom of the **Raw Image Information** window) and the pixel depth, which is selected from the radio buttons. The size of a given frame of raw data is defined in bytes, and the width times the height is the number of pixels in the image:

Frame size = # bytes/pixel * width * height

If the settings which appear for your image are inappropriate, start at the Pixel depth radio buttons, and the image's height and width are automatically recalculated. If you open the image with inappropriate settings, you will not be able to work with the image.

If the raw data is a sequence, the **Number of frames** field will show the number of frames in the sequence, which is calculated based on the specified size of the frames.

DICOM medical format

DICOM is an industry standard format for representing and transmitting medical images, and was developed as a method of communication between a medical instrument and the computer. Typical types of DICOM images are:

- **Ultrasound type images**. These are usually low resolution grayscale images, with 256 intensities. Typically, these images are in sequences, which render more information to the user.
- **Cardiac-based images**. These are usually of medium resolution, containing up to 10-bits deep. Typically these images are in sequences, which render more information to the user.
- **CT scans**, **magnetic resonance imaging** (**MRI**), and **X-ray-type images**. These are usually high resolution, containing up to 12-bits.

DICOM image and sequence files have no standard extension. Inspector recognizes files of type DCM. For other DICOMs, you must specify **Dicom medical** in the **Open as** field in the File Open command. There are several types of DICOM formats, and Inspector can read most types.

Many DICOM images have several types of information associated with them, such as Patient Relationship, Patient Identification, Image type, and Study Identification. If you require more information about your DICOM images, use the View Dicom Information command. In addition, you can choose whether or not to display this information in the image's overlay by using the View Dicom Overlay command.

See the on-line help for the explanations of these two dialog boxes.

Collection files

You can easily track and manage your images and sequences using collection files. Collection files are visual directories that contain image files, and there is no limit to the number of images in the collection, provided there is sufficient memory or disk space. Each collection keeps a thumbnail or file list representation of the images or sequences in the collection, as well as their file name and disk location (path). In addition, each collection keeps track of image types and sizes, allowing images of different types and sizes in one collection.

Using a collection, you can quickly identify the image/sequence file to work with from its thumbnail representation or from other information about that file, for example its type and size. You can also use a collection to group related images that have to be analyzed for a specific application. For example, a collection could contain images of parts on an assembly line, taken with a variety of lighting conditions. With these images, the collection could also contain images of the same parts showing expected defects. This collection could then be used to validate other images with an Inspector script.

Use the **File New** command to create new collections. Once you create the collection window, you insert image files into it using the **Collection Insert** command, or by dragging and dropping files from Explorer. Images that are open in the Inspector desktop can also be dragged and dropped into the collection. If you close your collection without saving, Inspector will prompt you.

Inspector will open files according to its extension, as long as the extension is listed in the **Files of type** drop down list. If Inspector does not recognize the file type, the image is inserted as an 8-bit grayscale raw image. See *Raw format* earlier in this chapter. See the on-line help for the procedure, To create a new collection.

Several collections can be opened (using the **File Open** command) and then maintained at the same time; however, the number of collections that can be opened at any one time depends on the amount of free memory in your system.

Image representations in a collection can be organized by dragging them from one position to another or by using the available sort commands. In addition, they can be dragged or copied between collections. See the on-line procedure, Organizing image representations.

From the collection window, you can also manage image files on disk. You can open images (by dragging them from the collection window onto the Inspector workspace), or delete images. Once an image is viewed in its full size, you can manipulate it as you would any other Inspector image. You can also change the current path of image files in your collection by using the **Collection Modify Paths** command. This is particularly useful when you are loading images from network drives.

The collection can be associated with a description, presumably the image theme of the collection. You can also associate a description with each image representation within a collection to distinguish the various images. When copying an image representation, its associated description, if any, is also copied. You can then change the description of the new image representation without affecting the description of the original image representation. See the on-line procedure, Identifying and maintaining collections.

Zooming

With Inspector, you can zoom in or out of an image up to 64 times. When working with a very small or very large image, if you perform a processing operation on the zoomed image, the zoom factor is maintained in the resulting image.

❖ Under Windows 95, any zoom factor that would make the vertical or horizontal dimension of the selected image greater than 32767K is not available. Under Windows 95 or Windows NT, any zoom factor that would make the selected image smaller than 1 pixel by 1 pixel is not available.

Use the **View Zoom In** and **View Zoom Out** commands to select the zoom factor directly. Zoom factors are presented as the proportion of the expected size to the original size (not to the current size). For example, a zoom factor of 8 zooms the original image by 8. Zooming occurs from the center of the image.

Use the **Zoom In/Out** button when you want to zoom on a specific section directly or are unsure of the required zoom factor. When the **Zoom In/Out** button is clicked, the cursor changes to a magnifying glass shape and you enter zoom mode. Once you are in zoom mode, you can zoom in or out on any area of the image by clicking on the area with the left or right mouse button, respectively. Each click zooms the image by an additional factor of 2 in both the horizontal and vertical directions, and the selected area is centered when possible. When you place your cursor over an image in zoom mode, the magnifying glass displays a plus sign (+) if the image is zoomed in or a minus sign (-) if the image is zoomed out.

If you want to view an image at its original size, hold the **Ctrl** key and click the left mouse button to "shrink" to the original size, or click the right mouse button to "grow" to the original size.

To return to normal viewing mode, press on **Esc** or click on the **Zoom** button again.

Frame size

When zooming in, the image's frame is normally expanded as the image is zoomed, up to a maximum size. If you do not want the image's frame to expand as you are zooming in on the image, select the **View Properties Display tab** and deselect the **Frame Expands** option from the tab.

Accessing context menus in zoom mode

Note that, in zoom mode, pressing the right mouse button will normally zoom the image out, if possible. To access the image's context menu in zoom mode, hold the **Shift** key and click the right mouse button.

Special scrolling mode

In addition to using the scroll bars to view different parts of an image, you can press the **Shift** key while dragging the cursor over the image. This mode allows you to move the entire image diagonally, rather than scrolling in one direction at a time.

View as text

With Inspector, you can display the pixel values of the current image as a series of hexidecimal numbers in an adjoining pane using the **View View as text** command. This feature is useful if you need to determine the numeric value for a given color at any point in the image; you can also precisely determine the position of a given pixel using the results of this command. For example, if you see a black strip along one of your image's borders, this might indicate that the selected .dcf's blanking width is not appropriate for your camera. Using the **View View as text** command, you can determine the number of pixels by which the blanking is off.

Note that when viewing a color image, the red component is represented by the most-significant bits.

The pixel coordinates are shown in the image's status bar when dragging the mouse over the text pane.

View 3D surfaces

You can display the image as a 3-dimensional surface, using the **View View 3D** command. This command maps the color intensities of the image to the "Z" or depth dimension in the 3D view. Therefore, the lightest colors in the image will be the highest in the 3D view, and the darkest colors will be the lowest. The surface can be drawn as a smooth shaded (Gouraud shaded) surface of triangular patches or four-sided polygons, or as a set of points or as a wire frame grid. You can control how the 3D image is drawn using the **View 3D settings** command. Display quality of 3D view in 256-color display resolution is poor due to the use of dithering; therefore, a true color display is recommended when using the **View View 3D** command.

The 3D image is drawn with triangular patches or 4-sided polygons, the size of which is determined by the sampling value. The sampling value is the number of pixels represented by a given triangle edge. A low sampling value will have lots of triangles, and follows the variations of the image more closely, but will be slower to draw and manipulate.

The 3D image can be zoomed or rotated about each of its 3 axes.

See the on-line help for the **View 3D** and **3D Settings** commands.

Using palettes with an 8-bit display resolution

When using a high or true color display resolution, color images are always displayed in true color. However, with an 8-bit display driver, there are only 256 colors (out of 16.7 M) available to the display at any given moment. When using an 8-bit display resolution, the Windows display palette determines the set of values currently loaded into your display hardware; the contents of the hardware palette can be seen using the **View Palette Viewer** command. The **Windows palette manager** determines how the 256 colors are shared among the Windows desktop and the open windows. The palette manager can share these colors by using one of the following methods found under the **Options Preferences - Display Tab** command.

❖ Note the Options Preferences Display tab is not available under a true color display resolution

- **Common palette** - In most applications, the current image asks to have its ideal palette loaded into the Windows display palette. The Windows palette manager responds by loading a certain number of the requested colors and approximating the others to colors it considers similar. This process is time consuming and must be done whenever a particular image is selected. To save processing time, Inspector maintains a **Common palette** which, when used, tells the palette manager to use the same palette (the **Common palette**) for all images. The palette manager tries to match the images' colors as closely as possible with those available in the palette. The **Common palette** contains several shades of red, green, blue, yellow for color images, and several shades of gray for single-band grayscale, and therefore provides adequate display colors for most images, and should suit most of your application needs. This option provides the fastest image repainting.

- **Own palette** - Sometimes the **Common palette** is unsuitable, for example when the image's ideal palette has few color in common with the common palette, or when grabbing directly into the VGA (for example, with Matrox Meteor-II). You can use the **Own palette** option in such a case, which tells the palette manager to use the currently selected image's palette for display purposes, and displays this image with the best quality possible. The palette manager then tries to provide the closest color match possible for the background images (images in windows other than the active window), if background repainting has not been disabled. However, with the Own palette option, the background images may not display properly, but their appearance can be improved by redrawing them using a matching scheme that finds the closest colors in the hardware palette for each of the image's requested colors. Since repainting of the background images takes time, you can choose not to repaint them if their display quality is not important.
- **Don't care about Background Quality** - When the **Own Palette** option is enabled, the palette manager ignores the palette requirement for the image's background. Essentially, this option, when selected, disables the background image remapping.

Palette optimization

The **Palette Optimization** command is only available in an 8-bit display resolution when the **Own palette** option has been selected from the Options Preferences command, and when the current image is a 3-band color image. This command remaps the pixel values to 256 discrete values. In effect, the **Palette Optimization** command improves the appearance of the image on the display. Note however, that the command requires a fair amount of computation, therefore it is not performed automatically whenever the content of a 3-band image is processed. The **Palette Optimization** command is most useful if your image has a large range of colors that do not exist in the common palette, or if you want a high-quality grayscale image.

Inspector uses three industry-standard algorithms to optimize the palette, **Median cut**, **Popularity**, and **Octree**. You can select one of these algorithms from the **Options Preferences** command. When you use the **Edit Palette Optimization** command, the palette will use the algorithm specified by the Options Preferences - Display tab command. For a more complete explanation on these algorithms, see *Computer Graphics Principles and Practice* second edition, Foley et al.

The **Options Preferences command** has an option, **At creation**, to optimize the palette upon creation or loading of an image. This option is only available when the **Own palette** option is selected; it is unchecked by default, and the common palette is used to display the image. Enabling this option essentially informs Inspector to find the best palette for the image when it is created or loaded by using the selected algorithm. Since palette optimization requires extensive computations, it is not always efficient to use the **At creation** option.

Chapter 4: Improving image quality

This chapter describes how to improve the quality of your images by increasing contrast, removing noise, and compensating for aspect ratio distortions.

Image quality

Prior to extracting information from an image, many applications require that you obtain the best possible digital representation of that image. Several factors affect the quality of an image. These include:

- **Poor contrast**. Often, the contrast (brightness attributes) in an image is poor. This usually means that the full dynamic range of pixel values (0 to 255) is not being used.
- **Random noise**. There are two main types of random noise:
  - Gaussian noise. When this type of noise is present, the exact value of any given pixel is different for each grabbed image; this type of noise adds to or subtracts from the actual pixel value.
  - Salt-and-pepper noise (also known as impulse or shot noise). This type of noise introduces pixels of arbitrary values that are generally noticeable because they are completely unrelated to the neighboring pixels.

  Random noise can be caused, for example, by the camera or digitizer because, in general, electronic devices tend to generate noise. If the images were broadcast, the distance between the sending and receiving devices also magnifies the random noise problem because of interference.
- **Systematic noise**. Unlike random noise, this type of noise can be predicted, appearing as a group of pixels that should not be part of the actual image. Systematic noise can be caused, for example, by the camera or digitizer, or by uneven lighting. If the image was magnified, microscopic dust particles, on either the object or a camera lens, can appear to be part of the image.
- **Distortions**. Distortions appear as geometric transforms of the actual image. These can be caused, for example, by the position of the camera relative to the object (if it is not perpendicular), the curvature in the optical lenses, or a non-unity aspect ratio of an acquisition device.

Techniques to improve images

If interference problems cannot be removed at the source, preprocessing might be required to improve the image as much as possible, without affecting the information that you are seeking. There are several techniques that you can use to improve your image:

- Adjust the intensity distribution of your image by performing a window leveling or a histogram equalization operation, or by changing the image contrast and brightness.
- Reduce Gaussian random noise and systematic noise with small scale variations by applying a low-pass spatial filter to your image. This technique replaces each pixel with a weighted sum of its neighborhood. Alternatively, to reduce Gaussian noise you can perform a frame averaging type grab.
- Remove salt-and-pepper noise by applying a median filter to your image. This technique replaces each pixel with the median pixel value of its neighborhood.
- Perform a morphological opening operation to remove small particles and break isthmuses between objects in your image.
- Perform a morphological closing operation to remove small holes in objects in your image.
- Remove systematic noise by determining the pattern(s) (frequencies) of the noise and filtering out these patterns. This can be done using an FFT transform.
- Reduce object shape distortions by making sure that the type of camera you allocate digitizes the image with *square* pixels (that is, a 1:1 aspect ratio). If this is not possible or does not correct the problem, you can resize or calibrate the image.

Adjusting the intensity distribution

From the histogram of an image, you obtain a concise representation of the pixel count versus the brightness in the image, commonly known as the intensity distribution. The width of the occupied portion shows the dynamic range. The distribution of the intensities within this range shows the image contrast.

Low contrast appears as a clump of pixels in one area of the image histogram; medium contrast appears as a good spread from black to white; high contrast appears as a bi-modal histogram in which peaks exist at the outer brightness regions. When an image has low contrast, there might be objects that are not easily distinguished because of their similarity in intensities.

Inspector supports three methods of adjusting or mapping the intensity distribution:

- Window leveling.
- Adjusting the brightness and contrast linearly.
- Histogram equalization mapping.

Window leveling

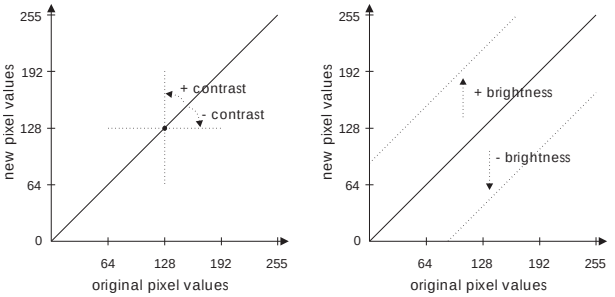
Window leveling takes a range of pixel values in the source image and maps these values to a different range in the destination image. In essence, the input range is linearly "stretched" or "contracted" to the output range.

By stretching the range of values actually present in an image to the full range available, window leveling allows you to use all available intensities in the image. Window leveling also allows you to examine a range of interest in more detail. For example, if your image produces a bi-modal histogram, you might want to stretch both ranges to examine them in detail.

To perform a window leveling operation, use the **Image Processing Mapping Brightness/Contrast/Window leveling/Histogram equalization** command.

Adjusting the brightness and contrast linearly

Using the **Image Processing Mapping Brightness/Contrast/Window leveling/Histogram equalization** command, you can adjust the brightness and contrast in your image. The brightness and contrast slide and stretch the intensity distribution, respectively, of an image relative to the center of the intensity range. The following diagram shows how changes to the brightness and contrast affect the image intensity mapping.



Note that a 100% increase in contrast moves all values above the middle intensity to the maximum intensity, and all those below the middle intensity to zero. A 100% decrease reduces an image to a single value (the middle value of the destination image's full dynamic range).

Histogram equalization mapping

Histogram equalization operations change the intensity distribution (histogram) of your image. With Inspector, you can perform a uniform histogram equalization, as well as an exponential and Rayleigh equalization. The uniform histogram equalization results in a more uniform distribution of your image's pixel values. The table below lists the density functions used for each equalization. Note, however, that you do not have to be familiar with these functions to perform a histogram equalization.

	Output probability density model	Transfer functions
Uniform	$P_g(g) = \frac{1}{g_{max} - g_{min}}$ $g_{min} \le g \le g_{max}$	$g = [g_{max} - g_{min}]P_f(f) + g_{min}$
Exponential	$P_g(g) = a\left(e^{[(-a)(g-g_{min})]}\right)$ $g \ge g_{min}$	$g = g_{min} - \frac{1}{\alpha}\ln[1 - P_f(f)]$
Rayleigh	$P_g(g) = \frac{g - g_{min}}{\alpha^2}\left[e^{\left[-\frac{(g-g_{min})^2}{2\alpha^2}\right]}\right]$ $g \ge g_{min}$	$g = g_{min} + \frac{1}{2}\left[2\alpha^2 \ln\left\{\frac{1}{1 - P_f(f)}\right\}\right]$

- The cumulative probability distribution, $P_f(f)$, of the input image is approximated by its cumulative histogram:

$$P_f(f) \approx \sum_{m=0}^{i} H_F(m)$$

- Refer to Digital Image Processing, William K. Pratt, United States, John Wiley & Sons, 1978, p.318.

For more information see the on-line procedure *To perform a histogram equalization operation*.

Applying low-pass spatial filters

Spatial filtering operations determine each pixel's value based on its neighborhood values. They allow images to be separated into high-frequency and low-frequency components. There are two main types of spatial filters which can remove high frequency components: low-pass filters and rank filters.

Low-pass spatial filters

Low-pass spatial filters are effective in reducing Gaussian random noise (and high frequency systematic noise) when the noise frequency is not too close to the spatial frequency of significant image data. These filters replace each pixel with a weighted sum of each pixel's neighborhood. Note that as these filters remove noise, they have the side-effect of selectively smoothing your image and reducing edge information.

Inspector provides several types of pre-defined, low-pass filter operations, among them: **Average**, **Smooth**, and **Smooth 5x5**. Use the **Image Processing Filters** command to select one of these filters.The average filter places the same importance on all pixels in the neighborhood, whereas the smooth filters place more importance on the pixels that are closer to the center of the neighborhood. All the predefined filters operate on a 3x3 neighborhood, except the **Smooth 5x5** filter, which operates on a 5x5 neighborhood.

Rank filters

Rank filter operations are more suitable for removing salt-and-pepper type noise since they replace each pixel with a value from its neighborhood rather than with a weighted sum of its neighborhood. A median filter is a type of rank filter that replaces each pixel with the median of its neighborhood. Inspector provides a pre-defined median filter, which operates on each pixel's 3x3 neighborhood.

❖ With Inspector, you can create your own filter. For more information, see the *Creating custom filters* section in Chapter 6.

Opening and closing

Another way of improving an image might be, for example, to remove small particles that were introduced by dust, or by filling holes in objects. These tasks can generally be accomplished with an opening or a closing operation, respectively. You can perform an opening or closing operation using the **Image Processing Morphology** command.

Opening and closing operations determine each pixel's value according to its geometric relationship with neighborhood pixels, and as such are part of a larger group of operations known as *morphological operations*.

Removing small particles

Besides removing small particles, opening operations also break isthmuses or connections between touching objects. Inspector provides the **Open** operation to perform a basic opening operation on 3x3 neighborhoods taking all neighborhood pixels into account.

Filling holes

Closing operations are very useful in filling holes in objects; however, in doing so, they also connect objects that are close to each other, as shown below. The **Close** operation performs a standard 3x3 closing operation taking all neighborhood pixels into account.

Note that opening is the result of eroding and then dilating an image, and closing is the result of dilating and then eroding an image. Erosion and dilation are discussed in *Operating on your images*.

Binary and no escape options

To speed up processing for opening, closing, erosion or dilation, operations you can select the Binary or No Escape options from the Image Processing Morphology tab. The No Escape option processes the operation faster by elimnating any user control over the operation (such as no preview or refresh). Note that when you select this option you cannot escape from the operation.

The Binary mode option forces processing in binary mode. If you select binary mode and your image is grayscale, all non-zero pixels are treated as foregound pixels and the result is white.

❖ With Inspector, you can customize an opening or closing operation. For more information, see the *Creating custom structuring elements* section in Chapter 6.

Basic geometrical transforms

Image distortion can affect application results. For example, in a medical application that analyzes blood cells, if the camera does not have a one-to-one aspect ratio and no correction is performed, the cells appear distorted and elongated, and incorrect interpretation might result. Dealing with distortion in such images can lead to incorrect results.To resolve distortion problems, you can either calibrate your imaging setup using Inspector, or you physically correct your image.

Calibrating offers a certain advantage over physically resizing in that the operation takes less time to perform. When you calibrate an image, however, you do not alter its size, so the image still appears distorted. If the physical appearance of an image is important, you might want to physically resize it.

Inspector provides some basic geometrical transform operations to improve your image, such as scaling, rotation, translation, and symmetry. In addition for more complex distortions, Inspector also allows you to transform your image based on its associated calibration. Calibration is discussed in *Chapter 15: Calibration*.

Scaling

Scaling allows you to correct for aspect ratio distortions in an image, or reduce or magnify the image to the appropriate size.

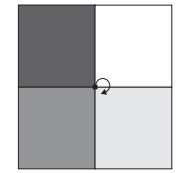
To scale your image, you can use the **Image Processing Geometry Scaling** command. You can resize the image along the horizontal and/or the vertical axis.

Rotating images

In some instances, the orientation of an image can lead to erroneous conclusions. When an image has been rotated from its original position, you can realign it using the **Image Geometry Rotation** command.

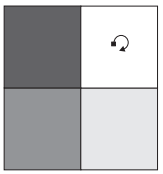
Center of rotation

When rotating an image, Inspector allows you to specify the center of the rotation. The center of rotation is the position, within the image, around which the rotation takes place. The default center of rotation is the center of the image. The diagrams below display the effect of rotating an image by 60°, around two different centers of rotation. In these cases, the rotated images have been "clipped" to the original image size.



Original image
Default center of rotation

Rotated 60°



Original image
Different center of rotation

Rotated 60°

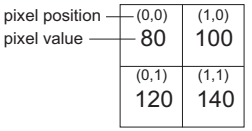
Translating and changing the symmetry

You can physically shift your image using the **Image Processing Geometry Translate** command. You can also flip the source image horizontally or vertically using the **Image Processing Geometry Symmetry** command.

Interpolation modes

When an image is resized or rotated, pixel positions in the destination image get associated with specific points in the source image. Then, the pixel value for each position in the destination image is determined from its associated point in the source image and from a specified interpolation mode.With Inspector, the following interpolation modes are available:

- Nearest neighbor. In this mode, Inspector determines the nearest value to a point, and copies that value into its associated position. In the image below, for example, "140" is the nearest value to point (0.5,0.5), so that value is copied into position (2,2) of the destination image.



Source image

(0,0) 80	(1,0) 80	(2,0) 100	(3,0) 100
(0,1) 80	(1,1) 80	(2,1) 100	(3,1) 100
(0,2) 120	(1,2) 120	(2,2) 140	(3,2) 140
(0,3) 120	(1,3) 120	(2,3) 140	(3,3) 140

Source image resized 200% in X & Y, using no interpolation

- Bilinear. In this mode, Inspector averages the values around a point, and copies that average into its associated position. Bilinear interpolation produces more accurate results than nearest neighbor interpolation, but can take three times as long to perform.
- Bicubic. This mode is like bilinear interpolation, except that Inspector uses more pixel values to determine the average. Bicubic interpolation produces the most accurate results, but can take 8-10 times longer to perform than nearest neighbor interpolation.

Chapter 5: Image transformations

This chapter describes basic transformation operations that can be performed on your images.

Operating on your images

Once you have improved your image using previously discussed techniques, you are ready to start operating on your image, to meet your specific needs.

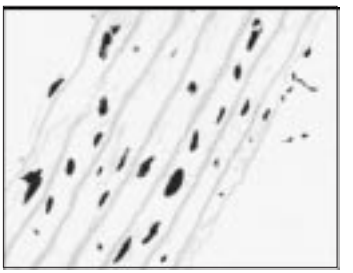
This chapter discusses image enhancements and transformations. The following chapter discusses advanced image analysis.

Thresholding images

Using the **Image Processing Threshold** command, you can threshold your image. Thresholding maps all pixels in a specified intensity range to a new constant value. Since a thresholded image contains fewer pixel values than the original image, some operations can be performed more efficiently. Note that images with full grayscale levels are useful for some tasks, but have redundant information for other tasks.

Binarizing

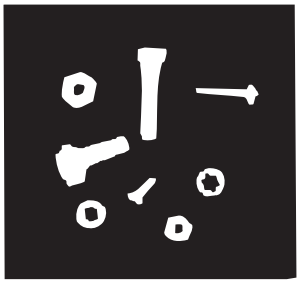
Thresholding can be used to binarize an image. Binarizing reduces an image to two grayscale values (for example, 0 and 255, as below). Note that binary images can be used as a mask to identify blobs in a blob analysis application.



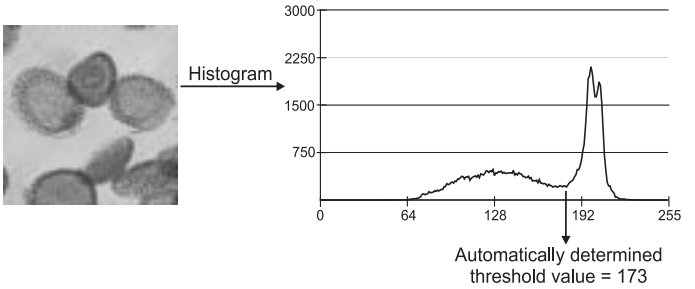
Band Pass or Two Level

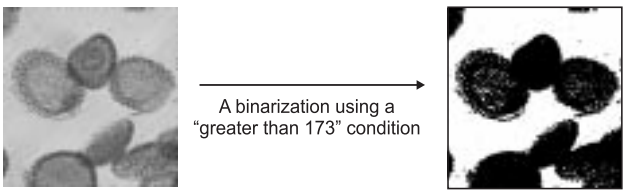
In the above image, the objects of interest (the nuclei) are darker than everything else in the image, so a simple binarization will separate the objects from the background. In other cases, the objects might be both darker and lighter than the background. To identify the objects in these cases, force values above and below object values to a suitable background

value and force object values to a suitable foreground value, as shown below. This can be done using a *band pass* (*two level)* threshold. Determining threshold value from histogram



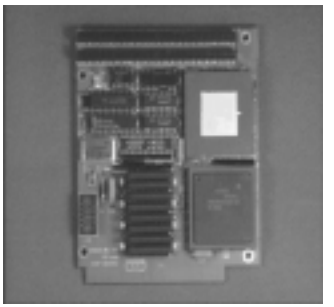
If you select the autothreshold check box of the **Image Processing Threshold** command, Inspector will automatically determine the threshold value from the source image's characteristics. Specifically, a histogram of the source image is internally generated; then the threshold value is set to the minimum value between the two most statistically important peaks in the histogram, on the assumption that these peaks represent the object and the background.





Accentuating edges

Many applications highlight locations of an image that are marked by a rapid change in pixel values. This is done, for example, to accentuate the edges surrounding the various objects and features in an image, or to highlight defects in a smooth object. In general, edges can be distinguished by a sharp change in intensity between adjacent pixels.



- Horizontal edges are created when vertically connected pixels have values that are different from those immediately above or below them.
- Vertical edges are created when horizontally connected pixels have values that are different from those immediately to the left or right of them.
- Oblique edges are created from a combination of horizontal and vertical components.

Edge operations

There are two main types of edge operations:

- One that engances edges to generate higher image contrast.
- One that extracts (detects) edges form the image.

Both these edge operations are types of convolutions (or spatial filtering operations) that replace each pixel with a weighted sum of its neighborhood. The weights applied to each pixel in a neighborhood determine the type of operation that is

performed. For example, certain weights produce a horizontal edge detection, whereas others produce a vertical edge detection.

Edge enhancers

Two edge enhancers are available:

- Sharpen1.
- Sharpen2.
- ReliefNW8U.

Using the **Image Processing Filters** command you can try both of these edge enhancers to see which is better suited to your application needs. Sharpen2 produces more enhanced or sharpened edges.

After an edge enhancement operation, the amplified edges accentuate all objects so that the eye sees an increase in detail. Note that this operation might not produce good results for further processing because when you enhance edges, you also enhance noise pixels.

Note, you obtain approximately the same result as the Sharpen1 filter by performing a Laplacian edge detection operation on the image and adding the found edges the original image.

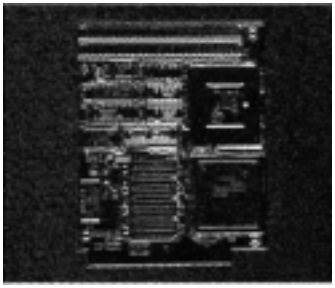
Edge detection

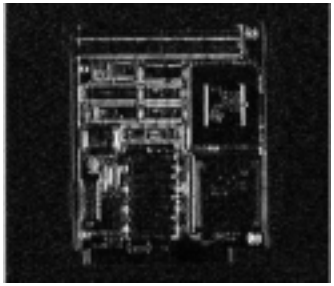
Inspector provides a number of edge detection operations, each offering different advantages depending on your application. Using the **Image Processing Filters** command you can select the following edge detection filters from the presented dialog box:

- Horizontal and vertical edge detection.
- Laplacian edge detection1 and Laplacian edge detection2.
- Sobel1, Sobel2 and Sobel angle.
- Prewitt.

Horizontal and vertical edge detection

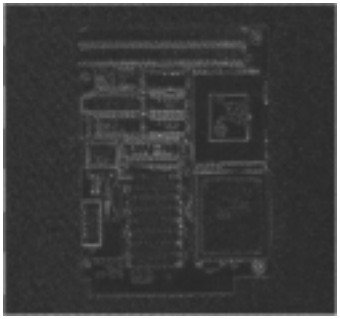
Finding the horizontal and vertical edges in an image can be useful to enhance edges in a certain direction and remove those in another.





Laplacian edge detection

The Laplacian operations emphasize the maximum values, or peaks, within an image.



Arithmetic with images

It is often very useful to perform arithmetic or logical operations on images. These operations apply the specified operator on individual pixel values in a source image or on pixels at corresponding locations in two source images. When the source images are color, the operation is applied on each component.

Point-to-point operations

Operations whose results do not depend on neighboring values are known as *point-to-point operations*. Arithmetic and logical operations fit into this category.

Arithmetic and logical operations

Using the **Image Processing Arithmetic** command you can perform the following arithmetic and logical operations:

- Add, subtract, multiply, divide, AND, NAND, OR, XOR, NOR, or XNOR two images, or an image and a constant. You can also add and subtract with saturation.
- Take the absolute difference between two images.
- NOT, negate, or take the absolute value of an image.
- Scale and offset an image.
- Perform a bit-shift left or bit-shift right operation.
- Fill an image with a specified value.
- Copy the contents of an image to another image. Note that, if the images are of different types, the data is not converted or scaled. To copy with conversion or scaling, use the **Image Convert** command. For more information, see *Performing a color or data type conversions* in Chapter 3.

Erosion and dilation

Erosion and dilation are neighborhood operations that determine each pixel's value according to its geometric relationship with neighborhood pixels, and as such are part of a group of operations known as *morphological operations*.

- An erosion peels layers from objects or particles, removing extraneous pixels and small particles from the image.
- A dilation adds layers to objects or particles, enlarging particles. Dilation can return eroded particles to their original size (but not necessarily to their exact original shape).

To perform an erosion or dilation operation use the **Image Processing Morphology** command.

Erosion and dilation can be used to find the perimeter of objects. If you XOR the eroded or dilated version of an image from the original image, you obtain the endoskeleton or exoskeleton of the object's perimeter.

Note that erosion and dilation are the basic operations used to perform the opening and closing operations discussed in the previous chapter. You can accelerate processing for erosion and dilation operations operations by selecting the **Binary mode** or **No Escape** options, which is discussed in the *Opening and closing* section of Chapter 4.

Erosion

When using grayscale mode, Inspector's predefined erosion operation replaces each pixel with the minimum value in its 3x3 neighborhood (if you are operating on bright objects) or with the maximum value (if you are operating on dark objects). When using binary mode, Inspector's predefined erosion operation uses an AND operation with the structuring element.

Dilation

When using grayscale mode, Inspector's predefined dilation operation replaces each pixel with the maximum value in its 3x3 neighborhood (if you are operating on bright objects) or with the minimum value (if you are operating on dark objects). When using binary mode, Inspector's predefined dilation operation uses an OR operation with the strucutring element.

If the predefined erosion and dilation operations do not suit your needs, you can create your own structuring element for either of these operations.

Other morphological operations

You can also perform distance, thick, or thin operations using the **Image Processing Morphology** command. Note that these morphological operations only operate on bright objects. If your objects are dark, you can invert your image (for example, through a thresholding operation) before performing one of these operations.

Distance

In a distance operation, each pixel's value is determined by the radial distance from that pixel to the background: the greater the distance, the brighter the value assigned to the pixel. Thresholding the result of a distance operation can be used to remove small particles.

Thick/Thin

A thick/thin operation adds/peels layers from an object. These operations are similar to the dilate/erode operations except, if continuously iterated, they will not convert all pixels into object pixels (as is the case of a dilation) or into background pixels (as is the case of an erosion). Instead, they will eventually reach a steady state (known as *idempotence*). In the case of a thin operation, this state is usually reached when objects are reduced to their skeleton.

Note that binary and grayscale thinning to idempotence produce different skeletons. For details on the binary and grayscale algorithms, see *Overview of morphological algorithms*.

- If the predefined thick and thin operations do not suit your needs, you can create your own structuring element for either of these operations; see *Creating custom structuring elements*.

Chapter 6: Advanced image processing

This chapter describes different advanced image processing techniques.

Advanced image processing

Inspector contains advanced image processing operations, which allow you to remove noise, separate objects from their background, and correct image distortions. They include neighborhood operations using custom structuring elements or kernels, and frequency transforms.

Creating custom filters

A spatial filtering operation (convolution) is a type of neighborhood operation that determines the new value for a pixel based on the weighted sum of the pixel and the pixel's neighboring values. The weights are often represented in a matrix (known as a *kernel*) and determine the effect of the filter. For example, applying the following kernel results in a sharpening of an image:

$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

If none of Inspector's predefined filters suit your needs, you can create your own filter or modify a predefined filter using the **Image Processing Filters** command and clicking on the **Edit** button. Note that it might be easier to simply modify a predefined filter, if the filter you need closely resembles a predefined filter.

A filter can contain up to nine kernels. A kernel can have up to seven rows and seven columns. The final pixel value produced by a kernel can be offset and divided by specified amounts; its absolute value can then be taken. After the results of each kernel are combined, a final offset and divide can be applied; the absolute value of this final result can then be taken. If saturation is enabled, final results that overflow or underflow the range of the destination image are set to the maximum or minimum value of the destination image, respectively. In summary, the order of operation is:

1. Inspector applies each kernel of the filter to the original image, using the offset, divide, and absolute value options defined for that kernel.
2. It then combines the results of each kernel. Inspector can either sum the results or take the maximum value of the results.
3. The final offset, divide, and absolute value options defined for the filter, are then applied.
4. If enabled results are saturated. If not enabled, overflows or underflows will wrap around.

For more information on how to filter your image see, the on-line procedure *To create a filter*.

Creating custom structuring elements

A morphological operation is a type of neighborhood operation that determines the new value for a pixel based on the relationship between its neighborhood and a given set of numbers. The numbers are often represented in a matrix (known as a *structuring element*). The type of morphological operation, and the structuring element, determine the effect of the operation.

With Inspector, you can create your own structuring element based on one of eight types of morphological operations (erode, dilate, thin, thick, hit-or-miss, match, open, and close) using the **Image Processing Morphology** command and clicking on the **Edit** button. The algorithms used by these operations are summarized in the *Overview of morphological algorithms* section.

A structuring element can contain up to sixteen kernels, that is, sixteen matrices (except for the open and close operations, which use only one kernel). In binary mode, a kernel can have up to sixteen rows and sixteen columns. In grayscale mode, a kernel can have up to seven rows and seven columns. Kernels can include "don't care" values, that is, values that you want the operation to ignore.

When creating the kernels of the structuring element, several predefined patterns are available. These include circle, cross, and prune, as well as patterns based on the Golay Alphabet. If the kernel is too large for the selected pattern, the pattern will only appear in the upper-left corner of the kernel. If the kernel is too small for the selected pattern, the pattern won't be fully represented.

You can create a structuring element that includes rotated versions of a kernel. In other words, you can create one kernel, then have Inspector automatically rotate it by 90°, 180°, and 270° into kernels 2, 3, and 4. You can also have Inspector rotate two kernels, in which case kernel 1 is rotated by 90°, 180°, and 270° into kernels 3, 5, and 7; kernel 2 is rotated by 90°, 180°, and 270° into kernels 4, 6, and 8. For more information see the on-line procedure *To create a structuring elemen*t.

Overview of morphological algorithms

The following summarizes the binary and grayscale algorithms used for Inspector's morphological operations. Note that the hit-or-miss and match operations use the same algorithm. Also note that morphological operations are not recursive, even if the source and destination images are the same. In these cases, an internal image is kept to perform the operation.

Operation	Binary	Grayscale
ERODE	If the kernel does not match the neighborhood exactly, set the center pixel to 0; otherwise, leave as is.	Subtract each kernel value from the corresponding pixel value in the neighborhood, then replace the center pixel of the neighborhood with the minimum value from the resulting neighborhood values.
DILATE	If any of the elements of the neighborhood match the corresponding kernel value, set the center pixel to 1; otherwise, leave as is.	Add each kernel value to the corresponding pixel value in the neighborhood, then replace the center pixel of the neighborhood with the maximum value from the resulting neighborhood value.

THIN	If a pixel's neighborhood matches the kernel exactly, set it to 0; otherwise, leave as is.	If MAX(0) < center pixel <= MIN(1), set center pixel to MAX(0) otherwise leave center pixel as is. MAX(0) is the maximum of all pixels in the neighborhood that correspond to 0 in the kernel, and MIN(1) is the minimum of all pixels in the neighborhood that correspond to 1 in the kernel.
THICK	If a pixel's neighborhood matches the kernel exactly, set it to 1; otherwise, leave as is.	If MAX(0) <= center pixel < MIN(1), set center pixel to MIN(1) otherwise leave center pixel as is. MAX(0) is the maximum of all pixels in the neighborhood that correspond to 0 in the kernel, and MIN(1) is the minimum of all pixels in the neighborhood that correspond to 1 in the kernel.
MATCH	Determine how many elements of the neighborhood match the corresponding value and set the center pixel to this number.	
OPEN	Binary erode, then binary dilate (using the same kernel).	Grayscale erode, then grayscale dilate (using the same kernel).
CLOSE	Binary dilate, then binary erode (using the same kernel)	Grayscale dilate, then grayscale erode (using the same kernel).
HIT-OR-MISS	If a pixel's neighborhood matches the kernel exactly, set it to 1; otherwise, set it to 0.	

Fast Fourier transformations

To identify consistent spatial patterns in an image (which can be caused, for example, by systematic noise), you can perform a fast Fourier transform using the **Image Fourier Transform** commands.

FFT defined

A fast Fourier transform of an image can be interpreted as the decomposition of the image into a set of basic 2-D patterns. The composition of these patterns make up the original image.

The forward Fourier transform is defined as:

$$F(u,v) = \sum_{x=0}^{N-1} \sum_{y=0}^{M-1} f(x,y) \exp\frac{(2\pi i x u)}{N} \exp\frac{(2\pi i y v)}{M}$$

where u and v are coordinates in the frequency domain and x and y are coordinates in the spatial domain. A forward FFT yields a real (R) and an imaginary (I) component of the image in a frequency domain (spectrum).

The inverse Fourier transform is defined as:

$$f(x,y) = \frac{1}{nm} \sum_{u=0}^{N-1} \sum_{v=0}^{M-1} F(u,v) \exp\frac{(-2\pi i x u)}{N} \exp\frac{(-2\pi i y v)}{M}$$

where x and y are the coordinates in the spatial domain and u and v are coordinates in the frequency domain.

Inspector and FFTs

The destination image of a forward FFT is of type FFT. It displays a logarithmic mapping of the magnitude of the image in the frequency domain. The magnitude provides a more visual understanding of the FFT results. It is calculated as $\sqrt{R^2 + I^2}$, where R and I are the real and imaginary components, respectively, of the image in the frequency domain. As such, the destination image is actually composed of two internally maintained floating point images: one for the real component and one for the imaginary component of the transform. In the status bar of the FFT image, you see the values of the real and imaginary components corresponding to a pixel. If necessary, the real and imaginary components can be accessed with a direct call to MIL using the *ImgGetRealMilID()* and *ImgGetImagMilID()* scripting functions, respectively.

Note that the destination image is displayed with the DC component in the center.

Note that if the height and width of the source image is not a power of 2, the destination image will be the next smallest power of 2.

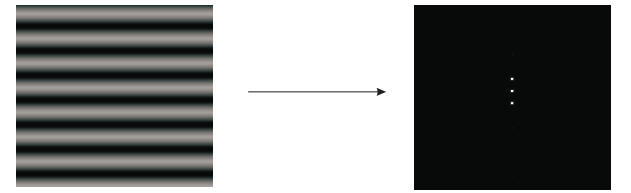
An example

The following figures show single-frequency images and their magnitude. Single-frequency images contain only one spatial frequency component (that is, these images can be represented with one basic 2-D pattern). Therefore, their corresponding frequency images contain a single point of brightness (spike) with its associated negative-frequency mirrors. Note that the spikes in the frequency domain appear in the direction of the pattern.

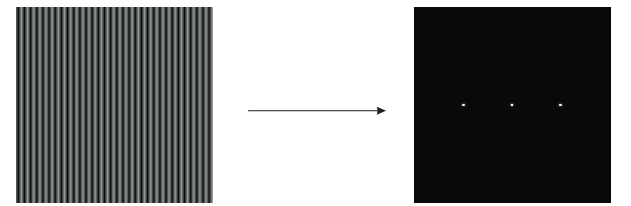
The distance between the spikes and the center (DC component) represents the frequency of the pattern (number of repetitions across the image). The higher the frequency, the further the spikes are from the DC component, and vice versa. The relationship between frequency and distance is evident in the following sets of images. The first image contains 7 cycles vertically, and the distance between the spikes and DC component is seven pixels away in the Y direction. The second

image contains 32 cycles horizontally, and in comparison to the first image, the distance between the DC component and the spikes is much greater, 32 pixels in the X direction. The third image exhibits a frequency of 8 cycles in both the X and Y direction.

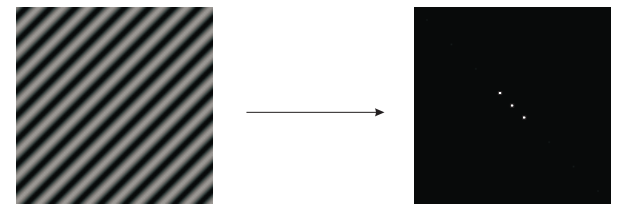
The fourth image is a combination of the other single frequency images and illustrates that the FFT of this complex image is a combination of the FFTs of the single frequency images. As such, it also illustrates that any image can be broken down and represented by its basic spatial patterns.



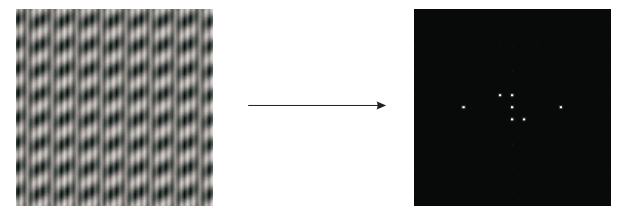
Vertical low frequency image. The image in frequency domain.



Horizontal high frequency image. The image in frequency domain.



Diagonal low frequency image. The image in frequency domain.



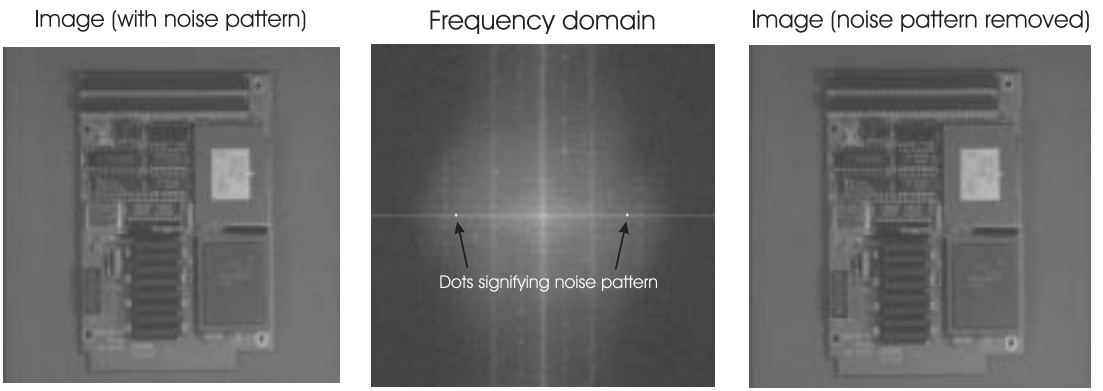
A combination of the three frequencies. The image in frequency domain.

Filtering in the frequency domain

After you have performed a fast Fourier transform and identified any consistent spatial pattern in your image which is noise, you can create a mask to remove the noise. Note that this section is written with the assumption that you are familiar with frequency domain mathematical relationships. The theory behind filtering in the frequency domain is not explained in this document.

To filter constant spatial patterns using FFTs, you must typically:

1. Perform a forward transform, which results in an FFT-type image.
2. Find the frequency components representing the noise and design a mask to remove these components.
3. Apply the mask to the FFT-type image. This directly affects the internally maintained real and imaginary components of the image.
4. Finally, perform an inverse transform to obtain a filtered image in the spatial domain.



Creating frequency filters

A convolution between an image and a filter (kernel) in the spatial domain corresponds to a point-to-point multiplication between the image and filter in the frequency domain. Mask locations with the value 1 let corresponding frequencies pass, and mask locations with the value 0 block or remove unwanted frequencies.

For a Fourier transform whose DC component is in the center, a low-pass frequency filter (smooth) is a circle filled with the value 1, centered on the image, and a radius that corresponds to the highest frequency you want to let pass. Similarly, a band-pass frequency filter is a torus (donut).

When you want to remove a particular frequency spike, it is important that you also remove the corresponding negative mirror spike, which is symmetric to the origin. If you do not remove the corresponding spike, the re-transformed image will contain ghost artifacts. The possibility of ghost artifacts and the difficulty in drawing very small ROI's accurately by hand, suggests that frequency filters should be created with a script rather than manually.

Inspector provides two utility scripts for creating frequency filter masks: *FFT_operation.bas*, written in Inspector Basic, and FFT.exe, which gives a slightly more sophisticated dialog for constructing filter masks. The masks that are constructed can be saved using the File Save command, and can be applied as filters in later sessions of Inspector.

FFT.exe which is located in the **Util** subdirectory of your Inspector installation, communicates with Inspector through OLE Automation. This utility uses the current image. If the current image is not an FFT-type image, *FFT.exe* will perform a forward transform on the image. It then creates a mask image, which is the same size as the transformed image, and allows you to add disks, spots, annuli, and annular sections to the mask.

When you execute *FFT.exe*, a dialog box is displayed with several options. You can select the filter type (for example, circle or donut), filter size, operations to perform on the FFT image, and the operations to perform on the mask such as **Add Black** and **Smooth**.

If you are filtering with a mask that has sharp transitions from background to foreground (0 to 1), it will produce some artifacts, sometimes called ringing. The **Smooth** option allows you to reduce ringing by blending the transition from 0 to 1.

Operations supported on FFT-type images

The following arithmetic operations are supported on FFT-type images: absolute value, absolute difference, add, add with saturate, copy, fill with value, maximum, minimum, subtract, subtract with saturate. These operations are applied to the real and imaginary parts.

Complex arithmetic, such as multiply and divide, is not supported. Also, morphological and logical operations on an FFT-type image are not supported.

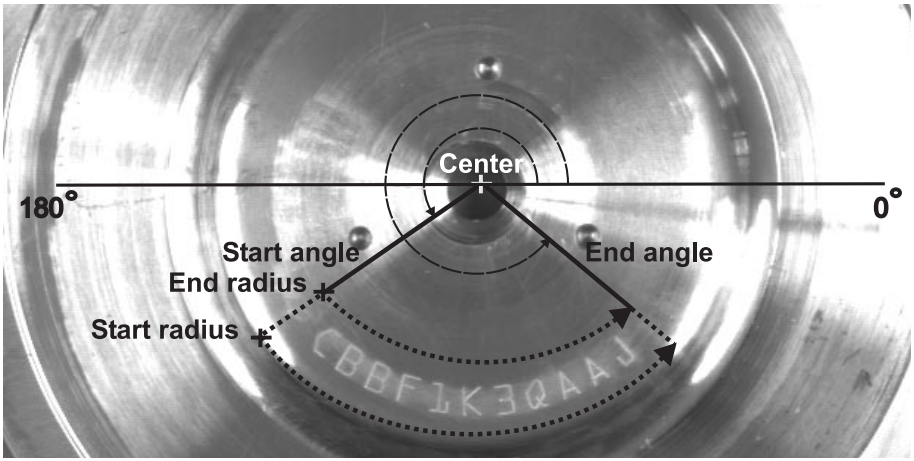
Inspector cannot apply mapping or threshold operations on an FFT-type image. However, it can display a live preview of these operations on the displayed image (logarithmic mapping of the magnitude). It is displayed to better visualize the transform.

If you want to display the phase of your FFT image, some direct calls to MIL are required. You can use the Inspector script functions *ImgGetRealMILID()* and *ImgGetImagMILID()* to access the real and imaginary MIL buffers that Inspector uses, respectively. The sample script *phase.bas* illustrates how to display the phase of your image. The techniques used in the *phase.bas* script can also be used to implement complex arithmetic operations.

Polar-to-rectangular and rectangular-to-polar transform

Polar-to-rectangular and rectangular-to-polar transforms allow conversion of polar coordinates to cartesian coordinates and vice versa. With Inspector, you can perform rectangular-to-polar or polar-to-rectangular transforms, using the **Image Advanced Geometry Polar** command.

The following is an example of a rectangular-to-polar transform. The dotted lines define the borders of the zone of interest:



The result will be mapped to the destination image as shown below:

For a rectangular-to-polar transform, the borders of the zone of interest are defined by specifying the center, the start and end radius, and the start and end angle in a source image. The function scans the specified zone from the start angle to the end angle. In our example, since the start angle is less than the end angle, the direction of the scan is counter clockwise.

The height of the destination image is equal to:

```
|Start radius - End radius|.
```

The width of the destination image is determined by the arc length. The arc length (in pixels) is equal to

```
outer radius * |Start angle - End angle|
```

where the angles are in radians.

The valid range of angle is from -360 to 360 degrees and the maximum span of the angle must not exceed 360 degrees. These values are then mapped to a destination image.

A polar-to-rectangular transform performs the reverse of the transform described above. It takes a source image and maps it to a destination image. The center, start angle, end angle, start radius, and end radius fields are used to specify the position of the contents of the source image in the destination image.

Watershed transformations

You can separate touching blobs by checking the **Separate** check box in the **Segmentation** tab of the **Blob New** command. Blobs are separated when a count operation is performed. The segmentation mask displays a preview of of a watershed transformation in an image. A watershed algorithm is used to separate touching blobs.

Inspector provides a *Watershed.exe* utility script to perform watershed transformations. It is located in the \Util directory.

Chapter 7: Analyzing images

This chapter describes how you can analyze your images using Inspector.

Analyzing images with Inspector

Once you have improved and transformed your image using previously discussed techniques, you can begin to analyze your image. In other words, you can begin to extract useful information from your image. This extracted information might be required to perform some subsequent operation in Inspector or in another software package. Alternatively, the extracted information might be required to summarize the effect of an operation.

The information to extract can be basic, such as the distribution of pixel values in an image (histograms), a line profile, X and Y profiles, the angle between specified markers, the convex perimeter of blobs, or the location of a model within an image. The information can also be of a more advanced nature, such as the population distribution of blobs based on specific features, the classification of blobs in pre-specified types (blob analysis), trends and statistics over time using several measurements, and finding and measuring edges.

Each of these operations is described in detail in subsequent chapters. Aspects common to these operations, such as the **Result Log** window, and the measurement table are discussed in this chapter.

To make summarizing your results easier, you can export them, save them to a file, print them, or copy them to the clipboard. As with most other operations, you can record analysis operations using Inspector's scripting tools. When you are scripting, results from blob analysis or measurement operations can be accessed using the *MeasGetCur()* and *BlobGetCur()* script functions, which are not recordable. Refer to Chapters 16 to 25 for more information on scripting, and to the on-line help for a listing and a description of these functions.

Result log window

Before performing one of the advanced analysis operations, you should confirm your result log window settings, using the **View Properties** command when the **Model**, **BLOBSET**, or measurement table is active or using their respective context menus. From the **Properties** tab you can select **Log results**, and **Verbose logged results** settings.

If the **Log results** option is enabled, the results of measurements or calculations appear in the **Result Log** window. If the **Verbose logged results** option is also enabled, more detailed results appear in the **Result Log** window, and all results are commented. Results and comments can be saved as ASCII text, copied to the clipboard, and printed.

Displaying results

You can specify how to display results of several operations, such as blob, measurement and pattern matching operations.

For pattern matching operations you can draw the result object in the corresponding image. To draw the result, select **Properties** from the **M_Model** dialog box's context menu and then select the **Draw graphic objects in image** option.

To set the display of counted blobs, select **Properties** from the **BLOBSET** dialog box and then select the **Display** tab. You can set the following display options:

- **Graphic object type**. Annotate blobs with the selected graphic object; outline, fill, or mark the centroid with a cross or marker. You can also choose not to draw any graphic objects.
- **Graphic object color**. Set the color for the graphic object type.
- **Blob label**. Select whether to display the blob label of the counted blobs.

- **Class label**. Select whether to display the class label of the counted blobs, if you have defined classes using the **Classification** tab (refer to the *Classifying blobs* section).

Note that the **Blob label** option must be enabled to display the class label.

To return to the **BLOBSET** dialog box, click on **OK**.

Set the display options for measurement operations by selecting the **Display tab** from the measurement table context menu.

- **Type**: Specify the type of annotation to use to identify measurement result objects. It can be set to one of the following:
- **None**: No graphic object.
- **Outline**: Outlined graphic object.
- **Color**: Specify the drawing color.
- **Show object's label**: Select whether to display the measurement result object's label (result identifier).
- **Show object's caption**: Select whether to display the measurement result object's caption.

The measurement table

The measurement table displays the results of measurement and pattern matching operations. It can also display the positional results of blob analysis, if these are transferred from the **All Results** or **One Result** table obtained after performing a blob analysis operation. Once results are in the measurement table, calculations can be made and further information extracted using the available measurement operations.

Note that the information that appears under the **Info** columns of the measurement table changes accordingly.

Working with the measurement table

You can save the measurement table using the **File Save** command, copy its contents to the clipboard using the **Edit Copy** command, export results using the **Edit Export** commands, and delete selected rows using the **Delete** button.

To select or deselect a row, click anywhere within the row. To select or deselect all rows, click on the **Select All** or **Unselect All** button, respectively. To modify a column's width, place your cursor over the column's border and drag it to the required width.

Calibration

Using Inspector, you can calibrate your imaging setup so that pixel coordinates map to world coordinates. Calibrating your imaging setup allows you to obtain analysis results in world units, view the current cursor position in world coordinates in status bar of the image, and if necessary, physically correct an image's distortions.

In general by getting results in world units, you automatically compensate for any distortion in an image. Therefore, you can get accurate results despite an image's distortions. In some cases, you have to physically correct a calibrated image using the **Image Advanced Geometry Correct** command. For more information, see *Calibration*.

Exporting results

Using the **Edit Export Settings** command, you can export results to packages that support OLE automation, such as Microsoft Excel and Microsoft Access. This allows you to compare calculated data with existing data and use these results to perform statistical computations.

Exporting results

Before you can export data, you must specify the application to which data will be exported and the format of this data. You need to specify the script that specifies this required information is set in the **Export** property sheet of the **Options Preferences** command. This script is called an export script module. Inspector provides two export modules *ExportToExcel.bas* and *ExportToWord.bas* to export to Excel and Word, respectively. If you want to export to an application other than Excel or Word, you can create a custom export module. However, after you specify a different export module, it will be used as the export module of the next export operation.

Creating custom scripts to export data is discussed in *Chapter 20: Communicating with other applications*.

Exporting graphics

To export graphic representations of analysis operations, copy them from an active window in Inspector to the clipboard and paste in the other application. Exporting graphical representations of data might be useful when documenting results.

Keeping analysis statistics

When performing blob analysis or measurement operations, Inspector maintains statistics on results. For example, if you are calculating the area of blobs in an image, Inspector maintains such statistics as the mean and minimum area.

❖ For blob operations, statistics are automatically maintained. For measurement operations, only those which you specify are maintained.

Each time results are calculated, statistics are updated. You can view and/or reset these statistics.

Statistics graph

You can view statistics in a trend or distribution graph. A trend graph displays the last *n* (feature or measurement) results that were kept. A distribution graph displays the number of results kept that fall into each range of result values. Note that a trend graph allows you to, for example, notice a failure before it becomes critical. A distribution graph allows you to determine classification ranges for different objects in an image.

Tolerances

You can compare results against specified tolerances. Specifically, you can compare results against:

- A minimum and maximum value.
- An expected value.

❖ Setting tolerances can be useful during automation, since results can be read and acted upon immediately.

If a minimum and maximum value are specified, results are compared against these values and graded a pass or fail. These pass/fail tests are summarized in the **Result Log** window. If the expected value is specified and the **Verbose logged results** option is enabled, the mean variation to the nominal is also returned in the **Result Log** window. Note that if a result does not pass, it is still included in the statistical results.

To determine appropriate tolerance values, you should analyze a few typical images and look at the resulting mean and standard deviation. The mean will give you an idea of what

expected value to use; the deviation from this mean will give you an idea of what minimum and maximum values to use. In general, the more sample images you have, the more appropriate your specified tolerances.

Note that tolerances can be set directly from the graph of the appropriate measurement statistic object or blob feature.

An example

Along a pharmaceutical inspection line, you might want to assess the quality of each package by calculating the diameter of each pill in the package. If a package has a pill with a diameter below a certain value, the package is not suitable for shipment. If you specify the acceptable range of values for the diameter, Inspector assesses each pill against these values and grades a pass or fail.

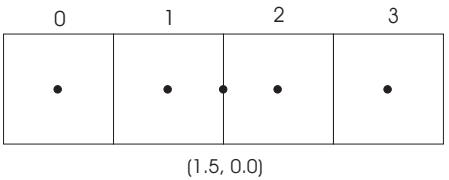
Pixel conventions

The center of a pixel is important for all Inspector functions which return positional results with subpixel accuracy. The reference position of a pixel is its center, and the resulting subpixel coordinates are with respect to the pixel's center.

With this in mind, the coordinates of the center of an image can always be found using the following formula:

$$\left(\frac{\text{Width} - 1}{2}, \frac{\text{Height} - 1}{2}\right)$$

For example, the following image contains 4 pixels. If the formula is applied, the center of the image is found at (1.5, 0).



Chapter 8: Histograms, profiles, and measurements

This chapter describes different basic techniques for examining pixel intensities in an image.

Performing a histogram

A histogram of an image is the pixel count of each color component intensity in the image. You can obtain the histogram of an image, using the **Image Statistics Histogram** command.

There are three main reasons to perform a histogram:

- To examine contrast in an image. This allows you to see if the full intensity range is being used (especially when operating on a grayscale image).
- To choose thresholding values to segment objects from the background. Note that if you only need one threshold value, you can choose to autothreshold, instead of performing a histogram and then the threshold operation.
- To determine the type and amount of noise present in what should be a flat (single color) region. Note that to use the histogram for this purpose, the region should not be a saturated area, otherwise you could make erroneous conclusions.

Histogram graph

Inspector plots histogram values on a two-dimensional graph: the horizontal axis represents the intensity level, while the vertical axis represents the pixel count for each intensity level.

Histogram window

The displayed information in your histogram graph window depends on what is selected from it's drop-down list box. The following is a list of options available in the histogram window:

- If **Count** is selected, the number of pixels at the position of the sliders is displayed.
- If **Area** is selected, the sum of values between these sliders is displayed as an actual number and as a percentage of the total sum.
- If **Accumulated** is selected, the sum of values to the left of these sliders is displayed as a percentage of the total sum.

Note that as you change the position of an ROI in an image, the histogram window is automatically updated.

Examining pixel values using profiles

With Inspector, you can take two types of profiles:

- The outline profile of a graphic object. This corresponds to the pixel values of the image beneath the outline of a graphic object.
- X and Y profile of a region. This corresponds to the summation of pixel values in each column or row, X or Y direction, respectively.

When you calculate a profile of an object or region, resulting values are plotted on a two-dimensional graph.

Profiles of line and other graphic objects

You can determine the outline profiles of the following graphic objects: line, angle, arrow, ellipse, rotated ellipse, or rectangle object. To obtain the profile of a graphic object, select **Profile** from the **Drawing Tools** toolbar, then draw a graphic object. The profile's graphic object is drawn in yellow

The line profile is most commonly used. You can select line profile not only from the **Drawing Tools** bar, but also using the **Image Statistics Line Profile** command or the Line Profile button.

Line profiles can be used to determine the following:

- Difference in intensities between foreground and background objects.
- If the background illumination is uniform.
- If an object at an expected location is absent or present.

Graphic object profile graphs

In a graphic object's profile graph, the horizontal axis represents the location along the object. The direction and first pixel that is plotted in the graph is indicated by the green arrow on the profile's graphic object. The vertical axis represents the color component intensity levels.

Outline thickness

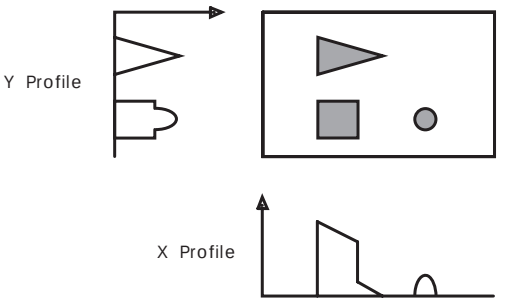
To obtain averaged profile values when your image contains noise, you can set the outline thickness of the graphic object. Values along the specified outline are averaged over its thickness. To set the outline thickness, click the **Line Style** button on the **Drawing Tools** toolbar.

You cannot specify the thickness of the outline of a filled graphic object. An outline of one pixel width will be used to calculate the profile of the filled graphic object.

If you want to obtain the pixel information for filled objects take an X and Y profile.

X and Y profiles of a region

The X and Y profiles (sometimes called projections) of a region are the sums of pixel values in each column or row of the source region, respectively.



In a grayscale image, it can be useful to calculate the X and Y profiles of a region rather than taking a graphic object's outline profile, because entire regions can be averaged, which minimizes the effect of noise.

To obtain an X and Y profile of an image, use the **Image Statistics X Profile** or **Image Statistics Y Profile**, respectively. Note that the source region need not be rectangular.

X and Y profile graphs

In X and Y profile graphs, the horizontal axis represents the columns or rows in the region, while the vertical axis represents the summation of pixel values in each column or row. If you are working with a color image, three lines are drawn on the graph, one for each color component.

Profile window

The displayed information in your profile window depends on what is selected from the drop-down list box. The following is a list of options available in the profile window:

- If **Values** is selected, the value of the graph at the position of these sliders is displayed.
- If **Distance** is selected, the distance between the values of the graph is displayed. This is useful when you need to determine the distance across a blob, or the difference between the gray levels of a blob and its background (to determine an appropriate threshold). The distance can be displayed in calibrated or uncalibrated units depending on whether you select the pixels or world option respectively.
- If **Pixels** is selected, the X and Y pixel values from the uncalibrated image are displayed in the graph.
- If **World** is selected, the X and Y world units from the calibrated image are displayed in the graph.

Regenerating the profile window

If you close the profile window, you can have it automatically regenerated for profile objects by selecting the object in the image.

Adjusting profiles

Once the profile's graphic object or ROI is drawn, it can be moved, resized, or rotated. When you make any of these changes, the profile window will be updated accordingly. Adjusting the profile object or ROI is useful when comparing pixel intensities of two edges.

Adding profiles to a graph window

To add profiles to a graph window, move, resize, or rotate an existing profile while pressing the **Ctrl** key. The graph window is updated to display the new profile. Therefore, all profiles for an image can be associated with a single graph window.

❖ You can associate up to 20 profile datasets to a graph window.

To switch between the different profiles, place your cursor anywhere in the white portion of the graph window and click the right mouse button. Select **Visibility** from the context menu, then select the graph data set you want to view. Note that despite the data set you select to display the grey portion of the graph always displays the data values of the first graph.

❖ Note that you cannot add profile ROIs to a graph.

Features of histogram/profile graph windows

There are several features common to the histogram and profile windows. Specifically, when a histogram or a profile window is active, you can:

- **Zoom vertically**. To zoom in/out on a graph in the vertical direction, use the **View Zoom** command. Note that, when you zoom vertically, the entire vertical axis is not visible. You can use the scroll bar to scroll through the vertical axis. Alternatively, you can have Inspector automatically adjust the size of the graph so that the maximum vertical value within the two slider bars is visible. This is known as interactive zoom mode and can be useful when you are interested in only a range of the histogram/profile. To access interactive zoom mode, select **Zoom Interactive** from the **View** menu or from the graph's context menu.
- **Zoom horizontally**. To zoom in/out on a graph in the horizontal direction, adjust the width of the graph window.
- **List data**. To view the entire list of resulting values in text format, select **View Data** from the **View** menu or from the graph's context menu. Note that this command is useful when you want to transfer text to other software packages.
- **Move graph markers in single steps**. To move the markers on the graph in single steps, select the required marker using the mouse, and then use the arrow keys to move the markers.

- **View required components**. To view only the required components of a color image, select **Visibility** from the graph's context menu, then deselect viewing of a particular component by clicking on that component's letter. To reselect a component, click on its letter again. Note that displayed components have a check mark beside their letter.

  This view allows you to compare component results between more than one histogram or profile.

- **Plot as bars or line**. To view the histogram/profile as a bar graph, select **View as BAR** from the **View** menu or from the graph's context menu. In bar view, you can display each entry with at least one screen pixel, ensuring that all resulting values are plotted. This is useful when displaying in low resolution and when trying to figure out the drop across an edge. To display each entry with at least one screen pixel in bar view, select **Fit 1 Value/Pixel** from the **View** menu. To go back to line view, select **View as LINE** from the **View** menu or from the graph's context menu.

- **Print/export**. See *Analyzing images with Inspector*

- **Resize**. Histogram/profile windows can be resized, maximized, minimized, and dragged.

- **Markers**. Markers in graph window are vertical bars, that you can drag to values and obtain the X and Y or Count in a profile or histogram graph respectively.

- **Dynamic updates**. If you want the graph window to update as you modify the graphic object, select **Dynamic updates** from the graph window's context menu. If you deselect this option, the graph window will be updated only at the end of a graphic object modification.

- **Copy**.You can use this to copy a histogram or profile graph to a new image.

  Note that when graphs are copied to the clipboard they are copied as normal bitmaps. However any other images copied to the clipboard from Inspector are copied as DIB bitmaps. When pasting the copied image to a new image the DIB bitmaps have priority in Inspector, and therefore these images will be pasted into the new image. To copy your profile or histogram graph to another image when there are DIB bitmaps copies to the clipboard, you need to clear the clipboard of any DIB images.

Taking measurements using graphic objects

Using the **Drawing Tools** available in Inspector, it is possible to take quick on-the-spot measurements of any object in any type of image. When the **Measure** check box is enabled in the **Drawing Tools** toolbar, all graphic objects drawn in the overlay or as a profile, are measured and these results are placed in the **Quick View - Measured Object Properties** dialog box (graphic objects drawn directly in an image (buffer) cannot be measured). Once measured, the graphic object's positional results can then be transferred to the measurement table, and the graphic object's keypoints used for further calculations. Using graphic objects provides an easy and efficient way to quickly measure various image features, such as distances, angles, or areas.

Finding average intensities using graphic objects

When you take quick measurements of graphic objects in an 8-bit or 16-bit unsigned image, the minimum, maximum, and mean values the pixels under the graphic object will be calculated and placed in the **Quick View - Measured Object Properties** dialog box.

Taking measurements between result objects

A variety of measurements can be taken between result objects in the measurement table. All result objects in the measurement table contain keypoints. Keypoints are points within a result object from which measurements can be taken. Different types of result objects have different sets of keypoints.

If you select two or three result objects in the measurement table, and click on calculate, only measurements that can be taken using the selected objects are available. For objects which have more than one keypoint, a drop-down list box allows you to choose the required keypoint. Calculation results are automatically placed in the measurement table as new result objects.

Chapter 9: Pattern matching

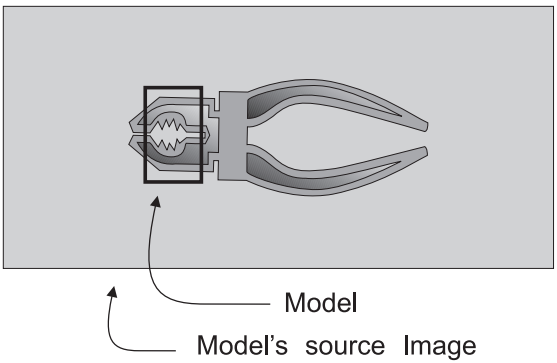
This chapter describes how to define a pattern matching model, and how to search for that model in an image.

Pattern matching

In many applications, it is useful to know where, in an image, something is located. In a machine guidance application, for example, a mechanical device might need to know where mounting holes are located on a circuit board so that screws can be inserted properly. In the semi-conductor industry, finding fiducial markers is required to determine the orientation of objects. In these cases, exact positions must be calculated: a minor deviation could cause problems during assembly.

With Inspector's pattern matching operations, you can perform such searches quickly, reliably, and with sub-pixel accuracy. These operations are implemented using normalized grayscale correlation.

Inspector refers to the pattern for which you are searching as the *search model* and the image from which it is extracted as the *model's source image*. The image being searched is called the *target image*.



To obtain the best search model, you should test several models created from images acquired over the full range of expected conditions for the target image (for example, lighting and angular displacement). A collection can help you keep track of these models and images. For information on collections, see Chapter 3: *Collection Files*.

Models defined in Inspector can be used in other pattern matching applications that have been built with MIL development tools.

See the *pattern.scr* demo, for an example of a simple pattern matching application.

Steps to performing a search

The basic steps to search for a model in an image are:

1. Define your search model. You can manually create the model or you can have Inspector automatically select a unique one for you.
2. Fine-tune the model. This might involve masking regions of the model and/or redefining the model's hot spot (reference point).
3. Set the model's search constraints.
4. **Preprocess** the model. If required, save the model.
5. Search for the model in an image.

Once you save a model, you can load it from disk for future searches. In such a case, you won't need to perform steps 1 to 4 unless the model requires adjustment.

Note that, in some cases, the orientation of a model and/or target image can play a factor in the search operation. To simplify matters, these issues are discussed after the basic steps are covered, under the *Rotation* section.

❖ The define and search operations can only be performed on 8-bit images. If you try to perform these operations on an image that is not 8-bit, Inspector creates an 8-bit copy of the image on which to perform the operations.

Defining a search model

The first step in performing a search is to define a search model. There are two ways you can define your search model:

- You can manually create it by selecting an area in an existing image, using the ROI drawing tool in the model's source image, followed by the **Analysis Pattern New Model** command.
- You can have Inspector automatically select a unique one for you (called an automodel) using the **Analysis Pattern New Automodel** command. In this case, Inspector searches, in an existing image, for the most-suitable unique area of a specified size, and creates a model from this area. Automodels are most useful in alignment applications.

Note, the search model is always rectangular in shape. When using non-rectangular ROI drawing tools to define a search model, the model will be created using the ROI's bounding box. In this case, a mask might be necessary to exclude those pixels outside the non-rectangular ROI.

See the *Mosaic.scr* demo, for an example of an application which uses an automodel.

Saving a model

Once you have set the model's search constraints, you can save the model (using the **.mod* extension). When you retrieve this model at a later time, the **Model** dialog box appears, with all tabs exactly as they were when the model was saved. The model does not have to be redefined or its constraints reset; if a model has been rotated or masked, these changes are saved with the model.

Note, Inspector can also retrieve model files created using MIL (*.mmo files).

Fine-tuning the model

Once you have defined your search model, you might need to fine-tune it. This might involve masking certain regions of the model and/or redefining the model's hot spot in the **Dimension** tab of the **Model** dialog box.

Masking a model

Often, your search model contains regions that you need Inspector to ignore when searching for the model in the target image. These regions might be noise pixels or simply regions that have nothing to do with what you are searching for.

In these cases, parts of the search model can be masked. Inspector then ignores the regions under the mask when searching for occurrences of the model. Note that the ROI has to be at least as large as the model.

For example, to mask edges in a model, perform an edge detection operation on the same region as that from which the model was extracted, then binarize the resulting ROI, and then use it as a mask, as shown below:

Defining a mask using the mouse

The mouse is usually used to mask noise pixels or pixels close to the boundaries of the model. Left-clicking on the mouse will mask the pixel or pixels (depending on the size of the brush); you can hold down the left mouse button and drag to continously mask. Right-clicking on the mouse unmasks pixels.

Defining a mask using an existing ROI

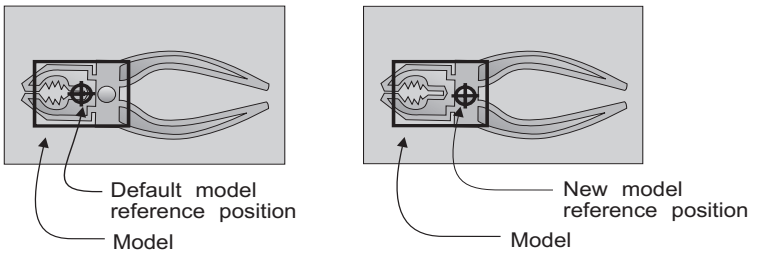
You can also use an existing ROI to mask or unmask a model. To do so, binarize the image you want to use as a mask, that is, set all "mask" pixels to 255, and all other pixels to 0. Activate

the model's dialog box and select the **Analysis Pattern Get New Mask** command. All corresponding "mask" pixels will be masked in the search model. To erase the mask, use the **Analysis Pattern Clear Mask** command.

Redefining a model's hot spot

The returned coordinates of a search are the coordinates of the model's hot spot (reference position). These coordinates are relative to the origin of the image being searched (calibrated or non-calibrated). By default, a model's hot spot is at the model's geometric center.

If there is a particular spot from which you would like results returned you can change the model's hotspot, interactively by clicking on the mouse button in the **Dimension** tab of the **Model** dialog box and using the cursor to place the hotspot, or by entering the required X and Y coordinates in the appropriate fields. For, example, if your model has a hole and you want to find results relative to this hole, change the model's hot spot accordingly.



Setting a model's search constraints

Once you define a search model, it is assigned a set of default search constraints. You can change these constraints, using the various tabs of the **Model** dialog box, in order to:

- Set the number of occurrences to find.
- Restrict the search to a specific region of the target image.
- Set the threshold for acceptance and certainty.
- Set the positional accuracy.
- Set the search speed.

In most applications, the above search constraints are all you need to adjust. Inspector provides more advanced search contraints for cases where you want to customize the search strategy, however this is not recommended unless absolutely necessary. Refer to the *The pattern matching algorithm (for advanced users)* section for details.

Number of matches

With Inspector, you can specify how many matches to try to find. If all you need is one good match, set it to one (the default value) and avoid unnecessary searches for further matches. If a correlation has a match score above the certainty level, it is automatically considered an occurrence (default 80%), the remaining occurrences will be the best of those above the acceptance level.

Search region

When searching for a model in an image, the search region can be all, or only a part, of the image. The search region is actually the region in which to search for the model's hot spot; therefore the search region can be smaller than the model. If you have redefined the model's hot spot, make sure that the search region covers this new reference position and takes into account the angular search range of the model.

Search time is roughly proportional to the area of the search region. If speed is a consideration, make the search area as small as possible.

The acceptance level

The level at which the correlation between the model and the pattern in the image is considered a match is called the acceptance level.

You can set the acceptance level for the specified model in the **Search** tab of the **Model** dialog box. If the correspondence between the image and the model (referred to as the *match score*) is less than this level, there is no match. The acceptance level affects the number of results returned, because only those matches with a score greater than or equal to the acceptance level will be counted.

A perfect match is 100%, a typical match is 80% or higher (depending on the image), and no match is 0%. If your images have considerable noise and/or distortion, you might have to set the acceptance level below the default value of 70%. However, keep in mind that such poor-quality images increase the chance of false matches and will probably increase the search time.

Note that perfect matches are generally unobtainable because of noise introduced when grabbing images

When multiple occurences are found, they are returned in the measurement table in decreasing order of match score.

Setting the certainty level

The certainty level is the match score (usually higher than that of the acceptance level) above which the algorithm can assume that it has found a very good match and can stop searching the rest of the image for a better one. The certainty level is very important because it can greatly affect the speed of the search. To understand why, you need to know a little about how the search algorithm works.

Since a brute force correlation of the entire model, at every point of the image, would take several minutes, it is not practical. Therefore, the algorithm has to be intelligent. It first performs

a rough sub-sampled search to quickly find likely match candidates, then checks out these candidates in more detail to see which are acceptable.

A significant amount of time can be saved if several candidate matches never have to be examined in detail. This can be done by setting a certainty level that is reasonable for your needs. A good level is slightly lower than the expected score. If you absolutely must have the best match in the image, set the level to 100%. This would be necessary if, for example, you expect the target image to contain other patterns that look similar to your model. Unwanted patterns might have a high score, but this will force the search algorithm to ignore them. Symmetrical models fall into this category. At certain angles symmetrical models might seem like an occurrence in the target image, but if the search was completed, a match with a higher score would be found. Set the certainty level in the **Advanced** tab of the **Model** dialog box.

Often, you know that the pattern you want is unique in the image, so anything that reaches the acceptance level must be the match you want; therefore, you can set the certainty and acceptance levels to the same value.

Another common case is a pattern that usually produces very good scores (say above 80%), but occasionally a degraded image produces a much lower score (say 50%). Obviously, you must set the acceptance level to 50% otherwise you will never get a match in the degraded image. But what value is appropriate for the certainty level? If you set it to 50%, you take the risk that it will find a false match (above 50%) in a good image before it finds the real match that scores 90%. A better value is about 80%, meaning that most of the time the search will stop as soon as it sees the real match, but in a degraded image (where nothing reaches the certainty level), it will take the extra time to look for the best match that reaches the acceptance level.

The positional accuracy

You can set the required positional accuracy to:

- **High** (typically ± 0.05 pixel)
- **Medium** (typically ± 0.1 pixels)
- **Low** (typically ± 0.2 pixels)

Note that the actual positional accuracy achieved depends on the quality of the model and the target image.

The less accuracy you require, the faster the search will be. Low positional accuracy can help speed up the search, but can also produce match scores that are slightly lower than usual. Positional accuracy is also slightly affected by the search speed. If a precise match score is important for your application, use medium or high accuracy.

The search speed

When searching for a model in an image, you can increase or decrease the search speed. As you increase the speed, the robustness of the search operation (the likelihood of finding a match) is decreased slightly, and match scores might be a little less accurate. You adjust the search speed using the drop-down list box found in the **Search** tab of the **Model** dialog box. This command has four settings:

- **High.** As expected, the high speed settings allow the search to take all possible shortcuts, performing the search as fast as possible. The high speed setting is recommended when searching on a good quality image or when using a simple model, since accuracy might be slightly affected otherwise. Note, the search might have a lower tolerance for rotation when using this setting.
- **Medium.** This is the default setting and is recommended for medium quality images or more complex models. A search with this setting is capable of withstanding up to approximately 5 degrees of rotation for typical models.
- **Low** or **Very Low.** Use these settings only if your image quality is particularly bad and if you have encountered problems at higher speeds.

Preprocessing the search model

Once you are ready to search for the model (normal or automodel), you must preprocess the model by enabling the **Preprocess** checkbox. This ensures that, for time-critical applications, preprocessing is done and is performed outside of the search operation.

The preprocessing stage uses the known model to decide on the optimal search strategy for subsequent search operations. Preprocessing should be performed after all search constraints have been set. To do so, enable the checkbox found on the either the **Advanced** tab or **Angle** tab of the **Model** dialog box.

If you save a model to disk after preprocessing it, preprocessing changes are stored with the model; it is not necessary to preprocess it again after restoring it. However, you must *preprocess again* if the following constraints are modified:

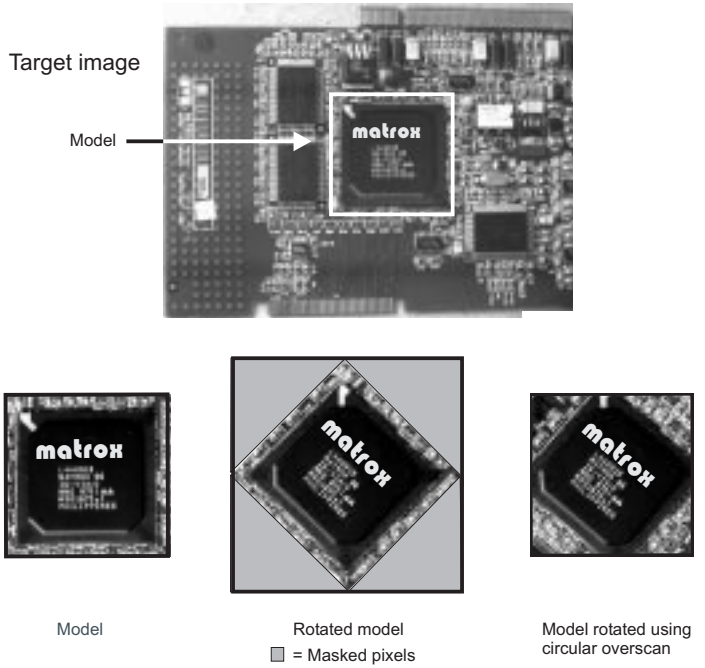
- Speed
- Advanced tab (all constraints)
- Angle tab (all constraints)
- Mask
- Positional accuracy

Rotation

By default, the angle of the search is 0^o. However, you can specify a rotational range of up to 360^o, as well as the required precision of the resulting angle and the interpolation mode used for the rotated model.

There are two ways to search for a model that can appear at different angles:

- **Rotated model search.** Search for rotated versions of the model.
- **Circular overscan model search.** Search for models taken from the same region in rotated images.



Inspector's implementation of a circular overscan search is faster and more accurate than that of a rotated model search when performing an angular search. A rotated model search

should only be used when the pixels surrounding the ROI follow no predictable pattern (for example, when searching for a bolt in an image of loose nuts and bolts.

Rotated model search

To perform a rotated model search, follow the same procedure as you would when manually creating the model, using the **Analysis Pattern New Model** command, making sure the **Use Circular Overscan** command is disabled. Check the **Enable search with rotate** checkbox found in the **Angle** tab of the **Model** dialog box to set the search angle of the model, and the **Delta negative** and **Delta positive** of the angular range, if necessary (discussed in greater detail later in this section). Angles are expressed in degrees and floating-point values are accepted.

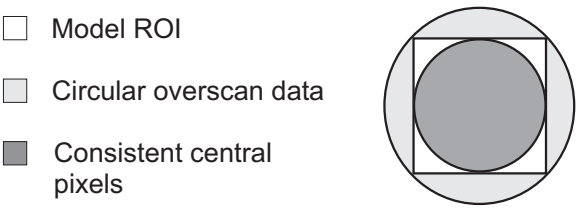
When a non-circular overscan model is preprocessed, Inspector will internally create different models by rotating the original model at the required angles, masking the corners of the model automatically so that these pixels are ignored during the search.

Note, you can also use the **New Rotated Model** command to search for a model at one specific angle. However, in this case, you should not also specify a range of angles; this will ensure that you keep the number of masked pixels to a minimum.

Circular overscan model search

To perform a circular overscan model search, follow the same procedure as you would when performing a rotated model search, except enable the **Use Circular Overscan** command.

When a circular overscan model is created, overscan data outside the ROI is also extracted from the source image. Specifically, Inspector extracts the region enclosed by a circle which circumscribes the model's ROI.



When a circular overscan model is preprocessed, Inspector will internally extract different orientations of the model from the overscanned model.

It is recommended that the model's source ROI be as square as possible: the longer the rectangle, the smaller the number of consistent central pixels in every model. Therefore, this type of model should only be used when the model's distinct features lie in the center of the region, so that they are included in all models when rotated.

In addition, the pixels surrounding the ROI should be relevant to the positioning of the pattern (that is, the model should appear in the target image with the same overscan data) or relatively uniform.

Finally, the model must not be extracted from a region too close to the edge of the model's source image: an error will be generated if circular overscan data extends beyond the boundaries of the image.

Searching for a model within a range of angles

When an angular search range has been specified, the preprocess operation creates a model for every *x* degrees within the range, where *x* is specified by the **Tolerance**. After the approximate location is found, Inspector fine-tunes the search, according to a specified **Accuracy**. To be effective, you must set the degree of accuracy to a value smaller than that of the rotation tolerance. When searching within a range of angles, you should use as narrow a range of angles as possible, since the operation can take a long time to perform.

Tolerance defines the full range of degrees within which the pattern in the target image can be rotated from a model at a specific angle and still meet the acceptance level.

When creating the internal models, Inspector rotates according to the specified interpolation mode. These settings can influence the speed of the preprocessing operation significantly. The accuracy of the search can also be influenced.

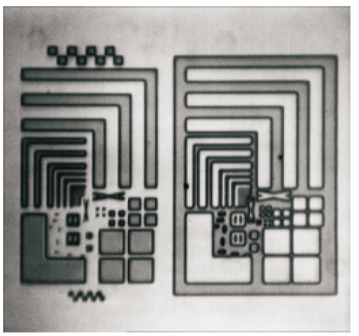
❖ Once a search has started, it cannot be stopped by simply pressing on **Esc**; you must shut down Inspector.

Quickly finding the orientation of an image or model

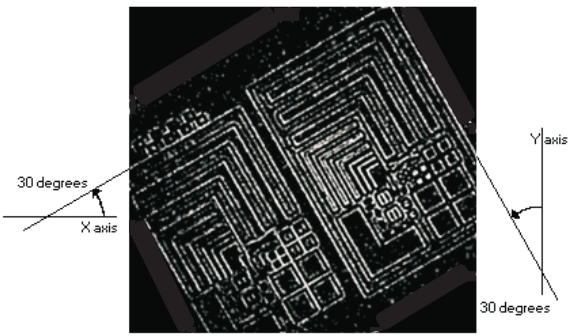
You can find the angular displacement of a target image, or of an object in that image, in a number of ways. The choice of method will depend on whether whole-image or object orientation is required, the shape and distinctiveness of the object, the complexity of the image background, and the degree of angular accuracy that is required.

Image orientation

With the **Analysis Pattern Find Image Orientation** command, you can quickly determine the orientation of an image based on the dominant edges in the image and their angular displacement from the image frame. The image can have either uni-directional dominant edges (such as parallel stripes) or bi-directional perpendicular dominant edges. The operation is designed for images with smooth edges, usually obtained when grabbing an image with a camera. It will not work well on an artificially generated image unless the lines and edges are anti-aliased.



typical image



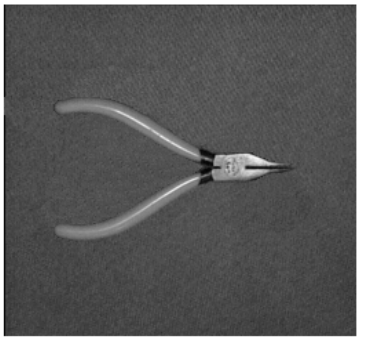
edge detection on a 30 degree rotated image

Once the orientation of a target image is found, the angle is returned to measurement table, and an angular search can be performed within a narrow range of the angle.

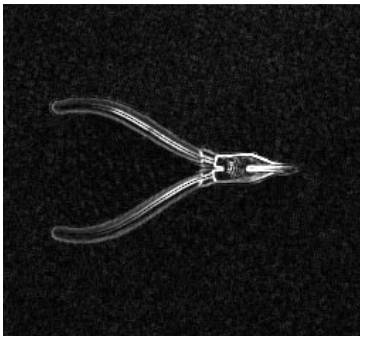
Note that, if an image does not have dominant edges, its orientation might not be found properly. In addition, if the image's background contains perpendicular edges, the orientation of these edges might be found instead.

Model orientation

The orientation of a single large object on a smooth uniform background can be found using the **Analysis Pattern Find Model Orientation** command. This searches for the general contours of the object in a target image. The model should be created from an image with a smooth uniform background, so that the contours of the object can be properly defined, thereby making the operation more effective. The operation returns the angle of the object in relation to the model, as well as the match score between the object and the model. However, the coordinates of the occurrence are not returned.



Typical image



Contours are well defined

Speeding up the search

To ensure the fastest possible search, you should:

- Choose an appropriate model.
- Set the search speed constraint to the highest possible setting for your application.
- Set the search region to the minimum required. Search time is roughly proportional to the region searched, so don't search the whole image if you don't need to.
- Search the smallest range of angles required.
- Select the lowest positional accuracy that you need.
- Set the certainty level to the lowest reasonable value (so that the search can stop as soon as a good match is found).
- Search for multiple models at the same time, if possible.

Choose the appropriate model

The size of a model affects the search speed. In general, small models take longer to find than larger ones, although very large models can also be time-consuming. In general, the optimal size is approximately 128 x 128 pixels if you are searching a large region (for example, most of the image). Small models are found quickly when the search region is not too large.

Adjust the search speed constraint

You can adjust the algorithm's speed. As you increase the speed, the robustness of the search operation (the likelihood of finding a model) decreases. Higher search speeds reduce the positional accuracy very slightly.

Effectively choose the search region and search angle

You can improve performance by not searching the whole image unnecessarily. Search time is roughly proportional to the region searched; set the search region (target image size) to the minimum required. You can also improve performance by selecting the lowest positional accuracy. In addition, for an

angular search, select the smallest range required, in combination with the highest **Tolerance** setting possible and lowest angular **Accuracy** setting possible. Actually, keeping the **Accuracy** option disabled is best (when disabled, the accuracy is equal to the tolerance).

The pattern matching algorithm (for advanced users)

Normalized grayscale correlation is widely used in industry for pattern matching applications. Although in many cases you do not need to know how the search operation is performed, an understanding of the algorithm can sometimes help you pick an optimal search strategy.

Normalized Correlation

The correlation operation can be seen as a form of convolution, where the pattern matching model is analogous to the convolution kernel. In fact, ordinary (un-normalized) correlation is exactly the same as a convolution:

$$r = \sum_{i=1}^{i=N} I_i M_i$$

In other words, for each result, the N pixels of the model are multiplied by the N underlying image pixels, and these products are summed. Note, the model does not have to be rectangular because it can contain masked pixels that are completely ignored during the calculation. When the correlation function is evaluated at every pixel in the target image, the locations where the result is largest are those where the surrounding image is most similar to the model. The search algorithm then has to locate these peaks in the correlation result, and return their positions.

Unfortunately, with ordinary correlation, the result increases if the image gets brighter. In fact, the function reaches a maximum when the image is uniformly white, even though at this point it no longer looks like the model. The solution is to

use a more complex, normalized version of the correlation function (the subscripts have been removed for clarity, but the summation is still over the N model pixels that are not "don't cares"):

$$r = \frac{N\sum IM - \left(\sum I\right)\sum M}{\sqrt{\left[N\sum I^2 - \left(\sum I\right)^2\right]\left[N\sum M^2 - \left(\sum M\right)^2\right]}}$$

With this expression, the result is unaffected by linear changes (constant gain and offset) in the image or model pixel values. The result reaches its maximum value of 1 where the image and model match exactly, gives 0 where the model and image are uncorrelated, and is negative where the similarity is less than might be expected by chance.

In our case, we are not interested in negative values, so results are clipped to 0. In addition, we use r^2 instead of r to avoid the slow square-root operation. Finally, the result is converted to a percentage, where 100% represents a perfect match. So, the match score returned is actually:

$$Score = max\ (r, 0)^2 \times 100\%$$

Note, some of the terms in the normalized correlation function depend only on the model, and hence can be evaluated once and for all when the model is defined. The only terms that need to be calculated during the search are:

$$\sum I, \sum I^2, \sum IM$$

This amounts to two multiplications and three additions for each model pixel.

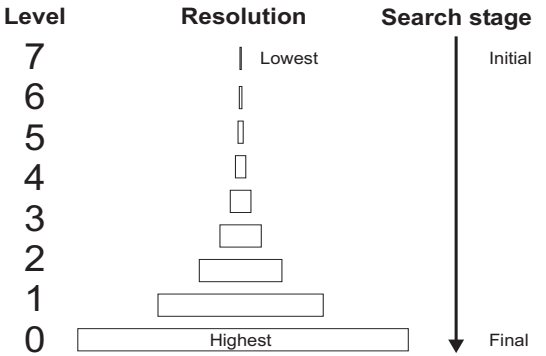
On a typical PC, the multiplications alone account for most of the computation time. A typical application might need to find a 128x128-pixel model in a 512x512-pixel image. In such a case, the total number of multiplications needed for an exhaustive search is $2x512^2x128^2$, or over 8 billion. On a typical PC, this would take a few minutes, much more than the 5 msec or so the

search actually takes. Clearly, Inspector does much more than simply evaluate the correlation function at every pixel in the search region and return the location of the peak scores.

Hierarchical Search

A reliable method of reducing the number of computations is to perform a so-called hierarchical search. Basically, a series of smaller, lower-resolution versions of both the image and the model are produced, and the search begins on a much-reduced scale. This series of sub-sampled images is sometimes called a resolution pyramid, because of the shape formed when the different resolution levels are stacked on top of each other.

Each level of the pyramid is half the size of the previous one, and is produced by applying a low-pass filter before sub-sampling. If the resolution of an image or model is 512x512 at level 0, then at level 1 it is 256x256, at level 2 it is 128x128, and so on. Therefore, the higher the level in the pyramid, the lower the resolution of the image and model.



The search starts at low resolution to quickly find likely match candidates. It proceeds to higher and higher resolutions to refine the positional accuracy and make sure that the matches found at low resolution actually were occurrences of the model. Because the position is already known from the previous level (to within a pixel or so), the correlation function need be evaluated only at a very small number of locations.

Since each higher level in the pyramid reduces the number of computations by a factor of 16, it is usually desirable to start at as high a level as possible. However, the search algorithm

must trade off the reduction in search time against the increased chance of not finding the pattern at very low resolution. Therefore, it chooses a starting level according to the size of the model and the characteristics of the pattern. In the application described earlier (128x128 model and 512x512 image), it might start the search at level 4, which would mean using an 8x8 version of the model and a 32x32 version of the target image. You can, if required, force a specific starting level or last level, using the **Search** levels section of the **Model** dialog box's **Advanced** tab.

The logic of a hierarchical search accounts for a seemingly counter-intuitive characteristic of the pattern matching search operation: large models tend to be found faster than small ones. This is because a small model cannot be sub-sampled to a large extent without losing all detail. Therefore, the search must begin at fairly high resolution (low level), where the relatively large search region results in a longer search time. Thus, small models can only be found quickly in fairly small search regions.

Search Heuristics

Even though performed at very low resolution, the initial search still accounts for most of the computation time if the correlation is performed at every pixel in the search region. On most models, match peaks (pixel locations where the surrounding image is most similar to the model, and correlation results are largest) are several pixels wide. These can be found without evaluating the correlation function everywhere. When the **Preprocess** option is enabled, Inspector analyzes the shape of the match peak produced by the model, and determines if it is safe to try to find peaks faster. If the pattern produces a very narrow match peak, an exhaustive initial search is performed. The search algorithm tends to be conservative; if necessary, you can force fast peak finding by enabling the **Fast find** option.

The **Extra-candidates** option allows you to set the number of extra peaks to consider. Normally, the search algorithm considers only a limited number of (best) scores as possible candidates to a match when proceeding at the most sub-sampled stage. You can add robustness to the algorithm, by considering more candidates, without compromising too

heavily on search speed. In addition, you can use the **Coarse acceptance** option on the **Search** tab to set a minimum match score, valid at all levels except the last level, to be considered as an occurrence of the model. This ensures that possible models are not discarded at lower levels, yet maintains the required certainty during the final level.

At the last (high-resolution) stage of the search, the model is large, so this stage can take a significant amount of time, even though the correlation function is evaluated at only a very few points. To save time, you can select a high search speed, using the Speed drop-down list box. For most models, this has little effect on the score or accuracy, but does increase speed.

Sub-pixel accuracy

The highest match score occurs at one point, and drops off around this peak. The exact (sub-pixel) position of the model can be estimated from the match scores found on either side of the peak. A surface is fitted to the match scores around the peak and, from the equation of the surface, the exact peak position is calculated. The surface is also used to improve the estimate of the match score itself, which should be slightly higher at the true peak position than the actual measured value at the nearest whole pixel.

The actual accuracy that can be obtained depends on several factors, including the noise in the image and the particular pattern of the model. However, if these factors are ignored, the absolute limit on accuracy, imposed by the algorithm itself and by the number of bits and precision used to hold the correlation result, is about 0.025 pixels. This is the worst-case error measured in X or Y when an image is artificially shifted by fractions of a pixel. In a real application, accuracy better than 0.05 pixels is achieved for low-noise images. These numbers apply if you select high-search accuracy, using the **Accuracy** drop-down list box in the **Search** tab of the **Model** dialog box, in which case the search always proceeds to resolution level 0.

If you select medium accuracy (the default), the search might stop at resolution level 1, and hence the accuracy is half of what can be attained at level 0. Selecting low accuracy might cause the search to stop at level 2, so the accuracy is reduced by an additional factor of two (to about 0.2 pixel).

Chapter 10: Analyzing blobs

This chapter describes how to perform a blob analysis operation.

Blob analysis

Blob analysis is a branch of image analysis that allows you to identify aggregated regions of pixels (known as **blobs**) within a grayscale image. Once these regions are identified, you can calculate selected features of these regions, automatically discard regions that are not of interest, and classify the remaining regions according to the values of the features.

Segmentation

Inspector must be able to identify these regions as blobs. This is done by segmenting the image so that the regions to be recognized as blobs are in the same logical pixel state-foreground state. Pixels not part of a blob make up the image's background. The segmented image is known as the segmentation mask (also known as the blob identifier image).

Inspector uses the segmentation mask for both the identification of blobs and the computation of their binary features. For grayscale features, the segmentation mask is only used for the identification of blobs, while the source region's pixel values are used to calculate the feature.

By default, when you use the **Analysis Blob New** command, Inspector extracts the segmentation mask from the source region and allows you specify the threshold between foreground and background, separate touching blobs using a watershed algorithm, and fill the holes in the blobs. However, if your active region is difficult to segment, you can segment it using some of Inspector's other processing operations, and then import it into blob analysis. When you import this image (segmentation mask), it is automatically binarized using a threshold of one.

❖ An imported segmentation mask cannot be segmented from within the blob settings (**BLOBSET**) dialog box.

Source and mask images

If you need to use the same blob settings for several images, you can easily change the source region for the segmentation mask and grayscale values, or only for the grayscale values.

Performing blob analysis

When performing blob analysis, you might not know which features are relevant to your application. If you are trying to distinguish between two objects, for example, some features might show a more notable difference than others. Blob analysis, therefore, is usually an iterative process, whereby the features to calculate are added and removed, until you determine which features are relevant to your application.

Steps to perform a blob analysis

The steps to perform a blob analysis depend on the nature of your image, as well as the information you need. Therefore, some blob analysis applications require only a few simple steps, whereas others require most of the blob analysis functionality included in Inspector.

The image you start with is easy to segment if the grayscale values of the objects are distinct from those of the background. To ensure this, use a background with very different grayscale values from those of the objects when acquiring the image. When the grayscale values of the objects are not distinct from the background, you can use the processing operations to segment the image, and then the segmented image can be used in the blob analysis by importing it as a segmentation mask.

Blob analysis applications

The following are some typical blob analysis applications.

- **Presence detection**. The purpose of this type of blob analysis is to count all blobs in an image (usually one type of blob), and to calculate some blob features which can then be used, for example, to determine each blob's orientation. If the calculated features are position-type features (such as the centroid of a blob), their values can then be transferred to a measurement table for further analysis.
- **Advanced presence detection**. The purpose of this type of blob analysis is to count each type of blob in an image (two or more). To do so, each blob first has to be identified by type, using classification.

- **Inspection of mechanical parts**. The purpose of this type of blob analysis is to identify faulty parts by comparing calculated blob features with a set of expected feature values. This generally involves using blob filters, statistics, and tolerances.
- **Tissue and material analysis**. The purpose of this type of blob analysis is to analyze complex tissue (such as biological tissue) to determine any of the following: existence of certain types of blobs, number of blobs in an image, or distribution of the blobs.

  The image used in this type of application is usually very difficult to segment and thus requires sophisticated segmentation techniques. For example, the image might contain touching objects that must be separated before they can be counted accurately. Therefore, it might be useful to segment a specific region of interest (ROI) of the image, import the mask into blob analysis, extract the required information, and then change the source image and mask to another region of interest in the image.

  To avoid counting the same blobs twice when *moving* the ROI, you can disable counting blobs that touch two of the ROI border edges. For example, if you are moving the ROI across the image in a left-down pattern, you can disable counting blobs that touch the top and left edges to avoid double-counting a blob.
- **Sequence analysis**: The purpose of this type of blob analysis is to study a set of images acquired over a known period of time. During this period of time, one or more factors might be variable, for example, the number of objects in the camera's view (in the case of moving objects). In general, this type of analysis requires changing the source image but using the same set of blob analysis parameters. It also involves maintaining statistics on the different sources to determine changes such as position, count, or size of object(s) in an image.

Performing the same blob analysis on different images

Inspector allows you to perform the same blob analysis operation on several different images, without saving and closing the existing blob settings and then re-loading these settings with a different active image. This is useful when you want to perform blob analysis on images grabbed from a camera, from a collection, or on a grayscale sequence. It is also useful when you want to collect blob and measurement statistics from several different images.

The following are examples of when and how you would perform blob analysis on different images:

- In the simplest case, when grabbing images from a camera, Inspector's blob analysis operations automatically recognizes if the data in the source image has changed. For an example, see *camblob1.scr*.
- In some operations, it might be useful to create a work image. You can use the work image as the source image of your blob analysis operation. For an example, see *camblob2.scr*.
- When you have several images open and you want to switch to another source region for your segmentation mask and/or grayscale values, you can use the **Source** and/or **Mask** button in the **Segmentation** tab of the **Analysis Blob New** command. For an example, see *camblob3.scr*.
- When you use a script to move an ROI to specific areas in an image, and then use this new region as the source. For an example, run the *MissingBlobDemo.bas*

Note that blob operations always needs a valid source image, so you must switch to the next source image before closing the current source image. The *camblob3.scr* uses a temporary image to get around this. Also note that the new source region must be the same size as the existing one.

Selecting blob features

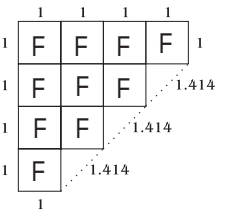
In Inspector, most features fall into one of four main groups:

- The area and perimeter of a blob.
- The dimensions of a blob.
- The shape of a blob.
- The location of a blob.

The following sections discuss some of the blob features available for selection. To select blob features in Inspector use the **Feature** tab of the **Analysis Blob New** command. The names of specific features, as they appear in the **Feature** tab are listed in the following sections in bold-face.

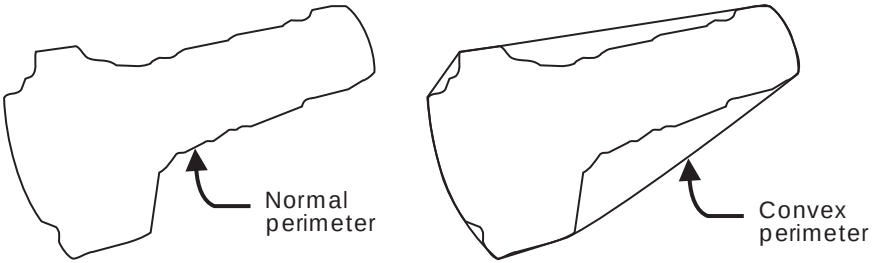
Area and perimeter

Since blob calculations assume a pixel is 1 unit wide and 1 unit long, the area of a single pixel is equal to 1 and the perimeter is equal to 4. The area (**Area**) of a blob is then the number of square pixels in the blob (excluding holes), and the perimeter (**Perimeter**) is the total number of pixel sides along the blob edges (including the edges of holes). Note that, when calculating the perimeter, an allowance is made for the *staircase effect*: the pixel side of diagonally adjacent pixels is considered to be 1.414, rather than 2. For example, the following blob (where F represents foreground pixels), has a perimeter of 14.242.



The convex perimeter

In addition to the normal perimeter, you can calculate the convex perimeter (**Convex Perimeter**) of the blobs. The convex perimeter is an approximation of the perimeter around the blob's convex hull (see below).

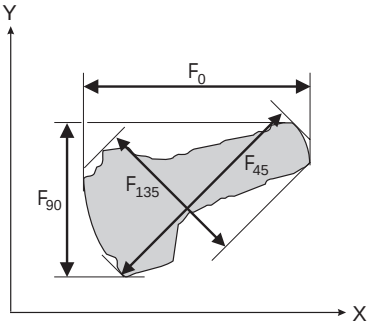


The convex perimeter is derived from several Feret diameters of the blob.

Dimensions

The Feret diameter

The dimensions of a rectangular object are its length and width. Most blobs, however, are not rectangular. Therefore, to get an indication of a blob's dimensions, you need to look at other features (such as the Feret diameter). The Feret diameter of a blob is the diameter of a blob at a given angle. Several Feret diameters are illustrated below. Note that the angle at which the Feret diameter is taken (relative to the horizontal axis) is specified as a subscript to the F.



Calculating different Feret diameters

With Inspector, you can calculate the Feret diameter at 0° (**Feret X**) and 90° (**Feret Y**). You can also determine the minimum, maximum, and mean Feret diameters of the blob (**Feret Min. Diam**, **Feret Max. Diam**, and **Feret Mean Diam**). The length of a blob can then be defined as its maximum Feret diameter and the width of a blob as its minimum Feret diameter.

Diameters are determined by checking the Feret diameter of the blob at a specified number of angles. Increasing the number of angles tested increases the accuracy of the results, but also increases the amount of processing time. Note that the maximum Feret diameter is not very sensitive to the number of angles, and 8 angles usually gives an accurate result.

With Inspector, you can also determine the angles at which the minimum and the maximum Feret diameter were found (**Feret Min. Angle** and **Feret Max. Angle**) and the ratio of the maximum to minimum Feret diameter (**Feret Elongation**).

Long thin blobs

Note that the minimum and maximum Feret diameter of a long, thin blob is not very representative of its dimensions (especially if the blob is curved). This is true even if the minimum and maximum Feret diameter are checked using the maximum number of angles (64). For long, thin blobs and long thin curved blobs, the following features are better:

- **Length**
- **Breadth**

These features are derived from the area and perimeter, assuming that the blob area is equal to the [*length x breadth*] and the perimeter is equal to [*2(length + breadth)*]. Note that these calculations are not valid for most blob types; however, they do hold for long, thin blobs since such blobs have approximately constant breadth along their length. Note that you can also determine the ratio of the length to the breadth (**Elongation**).

Determining the shape

When trying to distinguish between blobs, the shape of the blobs can be an important feature. This is because two blobs can have similar sizes but different shapes because of a different number of holes, curves, or edges.

For example, in the above illustration, the blobs have similar sizes, but can be distinguished by the shape of their holes. Note that, to measure the shape of the holes in the above illustration, you would have to identify non-zero pixels as blob pixels.

Compactness and roughness

The following features will tell you something about a blob's shape:

- **Compactness**
- **Roughness**

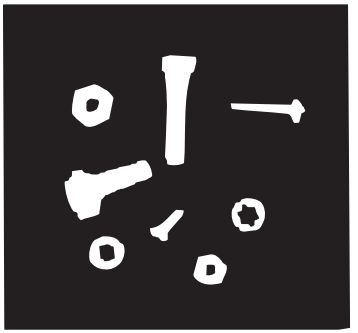
The compactness is a measure of how close pixels in the blob are to one another. It is derived from the perimeter and area. A circular blob is most compact and is defined to have a compactness measure of 1.0 (the minimum); more convoluted shapes have larger values.

The roughness is a measure of the unevenness or irregularity of a blob's surface. It is a ratio of the perimeter to the convex perimeter of a blob. The minimum roughness value is 1.0 because a blob's perimeter will always be equal to or greater than its convex perimeter. A blob with many jagged edges will have a much higher roughness value because its perimeter will be much larger than its convex perimeter.

Note that **Compactness** is quicker to calculate than **Roughness** since it is derived using only the area and perimeter.

Holes

In some cases, you can also distinguish blobs by the number of holes that they have (**Number of Holes**). For example, you could distinguish between bolts and nuts by counting their holes.



However, this is not a very robust measurement, since a single noise pixel in the wrong place is counted as another hole.

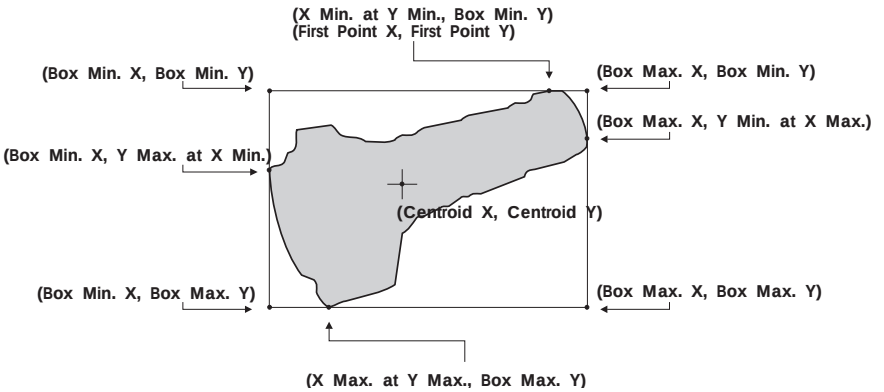
Finding blob locations

Finding the location of blobs in an image can sometimes be more useful than finding their shape or size. For example, if a robotic arm needs to pick up an object, it can use the location of that object in an image as a guide.

You can also use the blob location to determine if a blob touches the image borders. If there are any such blobs, you might want to adjust the camera's field of view so that all objects are completely represented in the image, or you might just want to exclude these blobs (since certain features, such as the area of the blob, would be misleading).

Blob points

You can determine the following blob points:



The blob points are relative to the entire image (calibrated or uncalibrated).

In addition, the center of gravity (**Centroid X**, **Centroid Y**) can be calculated in binary or grayscale mode.

Chained pixels

Pixels bordering blobs or delimiting holes are referred to as chained pixels. Chained pixels always form a closed chain. This implies that the starting pixel in the chain is also the closing one. If your blob has regions which are 1 pixel wide, these pixels are chained twice, once in the forward direction and then in the opposite direction.

Using Inspector you can only obtain the coordinates of pixels bordering blobs, not for holes in blobs. To obtain the bordering chains of blobs, use the *BlobGetOutlinePoints()* function.

You can use the chained pixel coordinates to create a chain code. A chain code is a directional code that records an object's boundary as a discrete set of vectors, where each vector points to the next pixel in the chain.

Moments

Using blob analysis operations, you can also calculate the moments used to find the center of gravity, as well as other grayscale or binary moments.

You can calculate either central or ordinary moments. Central moments use coordinates that are relative to the center of gravity of the blob. Ordinary moments use coordinates relative to the top-left corner of a calibrated or uncalibrated source image (not the entire image) and are therefore dependent on the blob's position within the source image.

Segmenting an image

There are two ways to select your segmentation mask:

- You can either create it from your source image, based on a few specified settings.
- Use a specific image.

From a source image

To create a segmentation mask from a source image:

1. Process your image, so that blobs are as separate and distinct as possible (from each other and the background).
2. Select the image as your source image by setting the option in the **Mask** tab of the **Blob Settings Properties** dialog box.
3. Binarize your image from within the **Segmentation** tab view. This tab allows you set pixel values between two selected thresholds to 0 and all other pixel values to 255.

For more information see the on-line topic *To create a mask from the source image*.

Importing a segmentation mask

Often, the image on which to perform blob analysis requires more sophisticated segmentation techniques than straightforward binarization such as separation and/or filling holes. In such cases, you can segment your image using some of the processing operations available in Inspector, and then import the segmented image into blob analysis as a mask.

When you specify an image as a mask, the region used to create the mask is binarized automatically; all grayscale values greater than or equal to 1 are changed to 255.

❖ The region from which to create the mask must be the same size as the existing source region.

To import a segmentation mask, make sure that the source region from which to create the mask is active. Then, open the **Blob Settings Properties** dialog box one of the following ways:

- Clicking on the **Mask** button from the **Segmentation** tab or the **Properties** button from the **Settings** tab of the **BLOBSET** dialog box.
- By using the **BLOBSET** dialog box or **All Results** window's context menu and selecting **Properties** from the displayed menu.
- When the **BLOBSET** dialog box or **All Results** window is active, select **Properties** from the **View** menu.

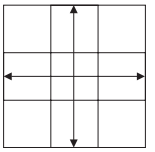
In the **Mask** tab select the **last active ROI** option. The data from this ROI is used as the permanent mask.

Specifying your segmentation preferences

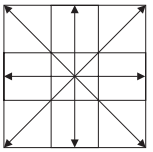
With Inspector, you can control how certain aspects of your segmentation mask are interpreted. You can control:

- Which pixel value (0 or 255) is considered a foreground (blob) pixel (**Foreground** options in the **Settings** tab).
- The minimum and maximum area of a blob (**Min area** and **Max area** options of the **Settings** tab). Blobs whose areas are not in this range are excluded from calculation.
- Whether to exclude from calculation (either automatically or explicitly) blobs touching the segmentation mask borders (**Touching** options of **Settings** tab).
- Whether to exclude from calculation blobs whose specified features are outside a specified range (refer to the *Filtering blobs based on features* section).
- Whether two diagonally adjacent pixels are considered touching (**Settings** tab of the **Blob Settings Properties** dialog, accessed using the **Properties** button). In Inspector, horizontally and vertically adjacent pixels are considered

touching. You can specify whether diagonally adjacent pixels are considered touching by selecting **8 neighbors** in the **Settings** tab.



If diagonally adjacent pixels are not considered touching, a blob has 4 "neighbor connections".



If diagonally adjacent pixels are considered touching, a blob has 8 "neighbor connections".

For example, the following is considered one blob if diagonally adjacent pixels are considered touching, but is considered two blobs if they are not.

Counting and calculating selected blob features

Once you have segmented your image and specified the features to calculate, you can count the blobs in the image and calculate their features.

To do so, click on the **Count** button from the **Settings**, **Features**, or **Segmentation** tab of the **BLOBSET** dialog box. Alternatively, select **Count** from the **BLOBSET** dialog box's context menu. The results of all blob calculations are returned in a result table.

Blob calculations assume a pixel is 1 unit long and 1 unit wide. If you have calibrated your source image, results can be accessed in calibrated or non-calibrated units.

When the pixel aspect ratio of an image is not 1:1, pixels are not square, so the results of blob calculations can be misleading. In this case, you should either resize or calibrate the image before performing blob analysis.

❖ Note that the maximum number of blobs Inspector can count is 10000. As Inspector reaches the maximum number of blobs that it can count, it will take more time.

If your image contains more than 10000 blobs, define an ROI which contains less than 10000 blobs, import it into blob analysis to generate the mask, calculate the required information from the mask, and then change the source image and mask for another ROI in the image. You can repeat this procedure until you analyze the entire image.

Sorting results

Once you have selected features to calculate, you can select the order in which to sort the feature results. Using the **Analysis Blob Sort** command or **Sort** button of the **Features** tab, the feature results can be sorted in ascending or descending order, by a maximum of three features, assigned as sorting keys.

After you have selected the sorting keys, you can perform a **Count** operation and your blob results will be displayed sorted in the **All Results** table.

Analyzing

After calculating features, you will probably want to analyze results. All blob feature results are displayed in the **All Results** table. To view the results for a single blob, double click on the blob within the source image. Results for that blob are returned in the **One Result** table.

You can also analyze results using the statistics of the blob analysis operation. You can view the statistics for all blobs, or only for those blobs of a specific class. For more on statistics, refer to the *Statistics and tolerances* sectionlater in this chapter.

Exporting/transferring

Once you have the required results, you can export these results and/or transfer positional results to the measurement table.

To transfer positional results to the measurement table, select the row(s) to transfer and then click on the **Transfer** button. If the blob result table does not contain any positional results, the **Transfer** button is disabled.

Saving and loading blob settings

Once you have determined the appropriate features for calculation and selected your segmentation mask setting, you might want to save these settings.

After saving, you can load the blob settings from disk to analyze other images. In this case, you won't need to add or remove features, or re-define blob filters or classes. In addition, you can apply these blob settings to several typical images to determine appropriate tolerances for automated checking. When you load this file at a later time, the **BLOBSET** dialog box appears, with each tab exactly as it was when you saved.

Filtering blobs based on features

In addition to filtering blobs outside a specified area range, you can also filter blobs based on the result of a specified feature. In other words, you can exclude from the results any blob whose specified feature is above, below, different, or equal to a specified value. In addition, you can also exclude blobs whose specified feature is between or outside a specified range of values. All values or ranges of values must be specified in calibrated units if image is calibrated.

❖ You can select whether or not to calculate the statistics for filtered blobs.

Defining a filter

To define a filter first make sure the required image and corresponding blob settings are loaded. Then open the **Blob - Edit Filter** dialog box in one of the following ways.

- Clicking on the **Filters** button from the **Settings** tab.
- Opening the filter file name (*.cls*) from the **Settings** tab.
- Selecting **Filters** from the **BLOBSET** dialog box or **All Results** window's context menu.
- Use the **Analysis Blob Filter** command.

In the **Blob Edit - Filter** dialog box, you can select the feature(s) and specify the value or range of values for the blobs to remove for the corresponding feature. For a description of the elements in the **Blob - Edit Filter** dialog box, see the on-line topic **Blob - Edit Filter Dialog Box.**

Filter options

To set the filter options, open the **Blob - Filter Options** dialog box by clicking on the **Options** button from the **Blob - Edit Filte**r dialog box.

You can set the following options:

- **Number of bars**: Specify the maximum number of bars to use when displaying feature results in the frequency histogram.
- **Number of criteria**: Specify the maximum number of features that can be used to define a filter.
- **Apply after count**: Specify whether to apply the filter immediately after performing a blob count. When this check box is enabled, the statistics for excluded blobs are not calculated.
  - You can also set this option from the **Settings** tab of the **BLOBSET** dialog box, or the **Settings** tab of the **Blob Settings Properties** dialog box.

Saving and loading filters

Once you have defined your filter, you might want to save it. If you save your **Blob Settings** (**.bst*) file, the filter is automatically saved with these blob settings. However, if you plan to use the same filter with different blob settings files, you can save the filter in its own (**.cls*) file, and then load it into the required **Blob Settings** dialog.

To load a filter from a blob settings file, click on the **Open** button in the **Blob - Edit Filter** dialog box.

Classifying blobs

With Inspector, you can classify blobs; that is, you can define categories in which to group blobs that have similar specified features.

You can classify the blobs by defining a blob class using the bins, filter, or training set methods. The method you select depends on several factors, such as the feature distribution of the blobs in the image and the information you have about the blobs.

Since you can automate the classification process, you no longer have to perform this repetitive task manually, which can lead to errors.

General steps for classifying blobs

The general steps for classifying blobs are:

1. Define the blob classes using the bins, filter, or training set methods (explained below). Then use any combination of these classes to classify the blobs in an image.
2. Set display options for the blobs in each class.
   - These settings apply only if you have chosen to display blobs using graphic objects (refer to the *Specifying your segmentation preferences* section).
3. Select whether or not to apply the classes immediately after a count. To apply the classes immediately after a count select the **Apply after count** option using the **Option** button of the **Segmentation** tab. Otherwise, you must explicitly classify the blobs in an image.
4. Specify other options specific to the types (bins, filter, or training set) of the blob classes in your application.
5. Classify the blobs. Note that you have to perform at least one blob count operation before you can classify the blobs.

   For a step by step procedure see the on-line topic *To perform a blob classification*. You can set several options on classifying blobs and how to display classified blobs. To select classification options see the on-line procedure *Setting classification options*.

- You can view the statistics for all blobs, or for only those that belong to a specific class. Refer to the *Statistics and tolerances* section.

Bins method

The bins method is used to sort blobs into several sub-classes of a single feature (main class). In general, the blobs in the image cover a wide range of values in the selected feature.

To define a bins class, you must select a blob feature (which defines the main class) and then specify the range of values of this feature for each required bin (sub-class). For more information see the on-line procedure *Bins method*.

Filters method

The filter method is used when a known combination of features can be used as criteria to determine which blobs should be included in the class.

To define a filter class, you must specify the value or range of values of the selected blob feature(s) to use as criteria for filtering blobs. The blobs that meet the specified criteria are then included in the class.

Define class filters the same way you would define blob filters (refer to the *Filtering blobs based on features* section). The only difference in the class filters method is that the blobs **passing** the criteria are **included** in the class.

For more information see the on-line procedure *Filter method*.

Training set method

The training set method is used when you can determine, by looking at the blobs and/or their position in the image, which should belong to the class (without knowing the actual combination and values of the features for these blobs).

To define a training set class, you must select one or more blobs whose selected features ultimately will be used to define that class.

The blobs included in the class depends on the selected measure of similarity (set using tolerances or specified ranges). To set similarity, refer to the on-line procedure *Setting classification options*.

Once the required blobs are selected, the statistics for all features are extracted from the blob count results. If the standard deviation for a feature is small, this feature might be a significant one to define the class (since the selected blobs have similar values for this feature).

❖ You can use any Inspector feature(s) to define a class training set. In other words, features used to define a class do not have to be enabled as one of the features for calculation (in the **Features** tab of the **BLOBSET** dialog box).

For more information see the on-line procedure *Training set method*.

Saving and loading classes

Once you have defined one or more classes, you can save them. If you save your **Blob Settings** file (**.bst*), the classes are saved with these blob settings. However, if you plan to use the same class settings with different **Blob Settings** files, you can save the classes in its own file (**.cls*), and then load this file from the required **Blob Settings** file.

You can save each class to its own separate file, or you can save a set of classes in one file.

Weight of a feature

To make selecting the appropriate features more intuitive, a weight for each feature is also calculated, as follows:

$$w = 1 - \frac{\sigma}{x} \quad \text{if} \quad \sigma \leq x \quad \text{AND} \quad w = 0 \quad \text{if} \quad \sigma > x$$

where:

w represents the weight
σ represents the standard deviation
x represents the mean

If a feature has a weight close to or equal to 1, the values for this feature are similar for the selected blobs. Similarly, if a feature has a weight close to or equal to 0, the values for this feature are very different for the selected blobs.

Statistics and tolerances

Inspector maintains a set of statistics for all calculated blob features, as well as a separate set for each specified class. You can view these statistics and compare results against specified tolerances. Setting tolerances can be useful during automation, as results can be read and acted upon immediately. To determine appropriate tolerances, refer to *Keeping analysis statistics* in Chapter 7.

To view statistics, click on the **Statistics** button from the **Settings** tab of the **BLOBSET** dialog box or from the **All Results** table. Alternatively, use the **BLOBSET** dialog box's context menu, then select **Statistics** from the displayed menu. The **StatBl** dialog box, in which statistics are displayed, opens. Then, use the **Results** drop-down list box to select whether to view statistics for all blobs or only those blobs that belong to a specified class. By default, results for all blobs are displayed. Scroll to view statistics and the corresponding distribution or trend graph for the required feature. You can export selected statistics using the **Edit Export** command (see the *Exporting results* section in Chapter 7 for more information). To copy selected statistics to the clipboard, use the **Edit Copy** command.

❖ A trend graph is particularly useful if you want to maintain statistics for a set of images, since a trend graph displays statistics in the order in which blobs are found.

Statistics are also logged in the **Result Log** window if the **Log results** option is enabled. You can also specify tolerances and view statistics in graphical format by clicking on the **Graph** button in the **StatBl** dialog box. For more information on options available in the **StatBl** dialog box. See the on-line procedure *StatBl Dialog Box Options*.

Chapter 11: Finding and measuring edges and stripes

This chapter discusses how to find and measure markers with Inspector.

Finding and measuring edges and stripes

Many industries base decisions on position-type measurement of edges or pairs of edges (stripes). The Inspector measurement tools can perform a variety of these operations with both a high degree of precision and speed. For example, Inspector can be used to measure the width of pins protruding from chips or printed circuit boards and to measure the distance between each pin.

Inspector allows you to find sets of image characteristics or "markers" in an image, based on differences in pixel intensities. Upon finding a marker, the line of the edge(s) and the edge/stripe position are recorded in the measurement table; data such as position coordinates, angle, and contrast are also displayed. Measurements can then be taken between results found for different markers, or other result objects, such as pattern matching positions or graphic objects.

The measurement tools, based on the MIL measurement module, rely on a one-dimensional image analysis. As such, the measurement tools have several advantages over pattern matching when locating relatively simple image characteristics; it is independent of lighting, more tolerant of slight differences, and much faster.

You specify the approximate location and other characteristics of a marker to help locate the marker in an image. The more precisely the marker characteristics are defined, the more likely it is to be distinguished from similar aspects of the image.

The measurement module can operate on 8-bit or 16-bit unsigned grayscale images or on the red component of color images. When using 16-bit images, all 16 bits should contain image data; Inspector will internally convert the image to 8-bits by dividing by 256. Therefore, images containing only 10-bits must be converted to 8- or 16-bit images to be successfully supported by Inspector.

Finally, measurements are made with sub-pixel accuracy and results can be returned in pixels or real-world units.

See the *BrokenGear.bas* demo, for a typical application involving Inspector's measurement operations.

Steps to finding and obtaining measurements of markers

You must first grab or load a target image, in order to enable the measurement commands.

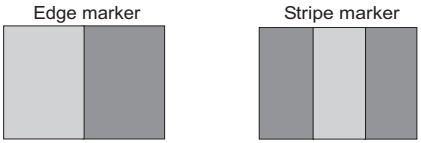
Although there are many types of measurements that can be taken with Inspector, the series of steps outlined below, using the **Analysis Measurement Edge and Stripe** command's dialog box, are usually followed to find and obtain measurements of markers:

1. Specify the type of marker for which to search, by enabling the **Edge** or **Stripe** radio button.
2. For a multiple marker, check the **Multiple** checkbox, and set the number of occurrences of the edge or stripe in the number edit field.
3. Set the processing area, generally referred to as the search box, by clicking on the **Draw the search box** button and drawing the search box in the target image.
4. Set the marker's characteristics.
5. Search for the marker in the target image by clicking on the **Find** button.
6. Read the results found in the measurement table.

Markers: edges and stripes

To find edge and stripe markers with Inspector, you must first define your markers. The marker contains the image characteristics to seek, within a search box, in the target image. There are two types of markers for which you can search:

- **Edge marker**: A marker consisting of an edge or multiple edges. Edges are sharp changes between two or more adjacent pixels.
- **Stripe marker**: A marker consisting of a stripe (two edges) or multiple stripes. Stripe marker edges need not be parallel.



Using edge detection techniques, Inspector can find a predominant edge or stripe in a given image area, based on certain specified characteristics, with sub-pixel accuracy. Inspector records the position and/or line of the edge or stripe in the measurement table. This information is also displayed in the **Result Log window**, if it is enabled.

Multiple marker

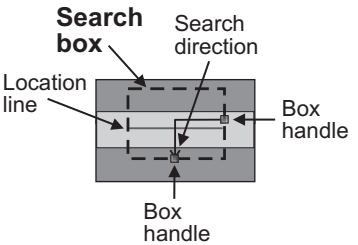
Inspector also allows you to define a multiple edge or stripe marker, so that you can search for multiple instances of the same image characteristics within one search box. For example, a multiple marker could be used to verify if a series of presumed-identical pins are actually of equal width or if the spacing between the pins is within established limits. Finally, a multiple marker is considered to be only one marker that has a specified number of instances of the same characteristics.

The search box

The search box indicates the area of the target image in which to search for the marker. Proper placement of the search box is essential to the success of any **Find** operation. The search box should be limited to as small an area containing the marker as possible, in order to ensure the success of the operation, especially when using a highly detailed or complex target image. In addition, by limiting the processing region, you can accelerate the find marker operation.

The search box can be placed manually on the image by clicking on the **Draw Search Box** button in the dialog box of the **Analysis Measurement Edge and Stripe** command; place the cursor in the required location, left click and drag the search box to its appropriate size and click on **New**. If you do not want to draw the box, click on **New** and a default search box will be drawn using the center of the image as the origin.

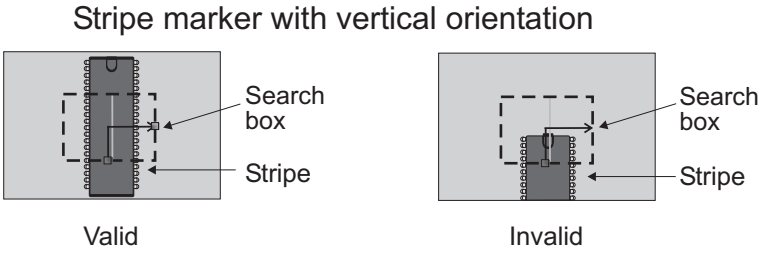
You must adjust the search box's:



- Size and position to specify the area in which to search.
- Angle to ensure the proper search direction. Note that the search takes place in the same direction as the search direction line.
- Adjust the search box's location line to indicate the expected position of the edge or stripe (optional).

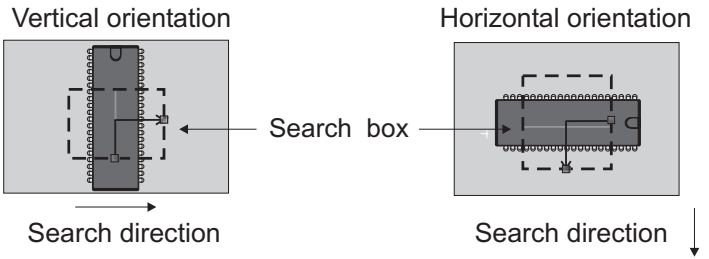
Obtaining valid results

To obtain valid results the edge or stripe must enter and leave by opposite sides of the box. The illustration below is an example of valid and invalid search box definitions.



Orientation

The orientation specifies the angle of the edge or stripe in relation to that of the search box. The initial orientation for a new search box can be set to either vertical or horizontal by toggling the **Vert** checkbox before clicking on the **Draw Search Box** button.



The orientation, and direction of the search, is shown by the arrow within the search box.

These settings can tolerate a certain amount of rotation. The amount is determined by the target image, placement of the search box, and the marker characteristic settings. The greater the degree of rotation from angle of the search box, the greater the chance of not finding the marker and miscalculation of characteristics, such as edge strength and width. If the rotation is too great and you cannot find the marker, the marker's search box should be defined with a range of angles.

Searching within a range of angles

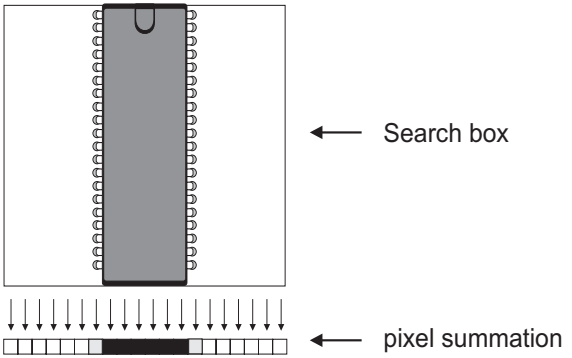
Inspector allows you to search for a marker within a range of angles, rather than at a specific angle, by internally rotating the search box during a **Find** operation. The range is from (search box angle - **Delta Negative**) to (search box angle + **Delta Positive**) and the default center of rotation used is the center of the search box. The approximate location of the edge or stripe is first found by searching at every *x* degrees within this range, where *x* is specified by the *tolerance*. After the approximate location is found, Inspector fine-tunes the search, according to a specified *accuracy*. To be effective, you must set the degree of accuracy to a value smaller than that of the rotation tolerance.

Note that you can specify which interpolationmode to use when rotating the search box to the required angles (see Chapter 4 for a description of the available modes).

If searching within a range of angles causes the search box to be rotated beyond the edges of the image (indicated by a yellow search box), the search box should be repositioned or resized.

Search algorithm

Inspector projects the two-dimensional search box into a one-dimensional line (that is, it takes the box's profile). The pixel summation is performed perpendicular to the search direction. Each sum represents the intensity of all the pixels in that column.



To locate each edge, an edge filter is then applied to the profile. The edge filter first finds the edge value of each profile value. The edge value is the difference between one profile value and the next. The greater the difference, the larger the edge value. The filter rejects as possible markers any edge with an edge value below 2%. For best results, it is recommended that only edges with edge values above 10% be used as markers.

The filter then finds the marker by scoring each possible edge based on geometric constraints that you specify, giving each characteristic a specific weight, or degree of importance. The edge(s) with the highest score is returned as the marker.

Markers: fundamental characteristics

This section describes the fundamental characteristics of edge and stripe markers that are set using the dialog box of the **Analysis Measurement Edge and Stripe** command ot the **Edge and Stripe Settings** dialog box or returned as measurement results in the measurement table.

A stripe marker is simply a marker with two edges, therefore the discussion of edge characteristics applies to each of the stripe marker's edges. However, certain characteristics have special attributes applicable only to stripe markers.

It is recommended that you only adjust marker characteristics if Inspector cannot find the required edge or stripe using the default values.

You can also assign weights to certain characteristics, so that some characteristics have greater influence than others. Again, weights should only be adjusted if Inspector cannot find the required edge or stripe with the default weight settings.

Polarity

The polarity of an edge (or a stripe's edges) is rising or falling. A rising edge denotes a rise in grayscale values and a positive polarity. A falling edge denotes a decrease in grayscale values and a negative polarity. When setting the polarity of a marker, it is important to keep in mind the direction of the search, which is indicated by the search box's search direction line.

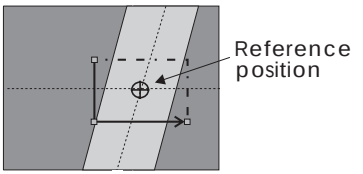
The edges of a stripe marker can have opposite polarities or can have the same polarity. By default, the polarity is set to Auto. In this case, Inspector searches for a strong edge or stripe without considering its polarity.

Position

The marker's position is defined as the X and Y coordinates of the marker's center (the center of the portion of the marker located within the search box). These coordinates are relative to the top-left pixel of the image and are returned to the

measurement table as the reference position of the marker. The reference point coordinates of the marker respect calibration settings on output.

The position of a stripe marker is considered the center between the two edges of the stripe.



When several edges have similar characteristics within the same search box, you can use the location line to specify the approximate position at which to find the required marker's reference position.

Contrast

You can indicate the typical difference in grayscale values between an edge and its background using the marker contrast setting. Contrast is useful in distinguishing between several different edges, particularly when the required edge does not have the largest edge strength (described later), or when the edge is at an angle. The contrast for a stripe marker requires two values, one for each of the stripe's edges.

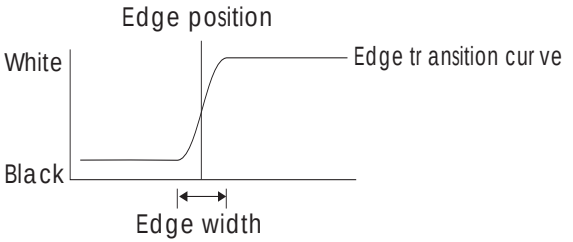
Markers: advanced characteristics

This section describes the advanced characteristics of edge and stripe markers that are available in the **Edge and Stripe Settings** dialog box or returned as measurement results in the measurement table.

Width

Width of an edge marker

Edges are usually gradual shifts in grayscale values over several pixels. The smoother the image, the more gradual the change. The width of an edge can be seen as a measure (in pixels) of this gradual shift in grayscale values. The diagram below illustrates a profile of an edge where the gradual transition from black to white can be seen.

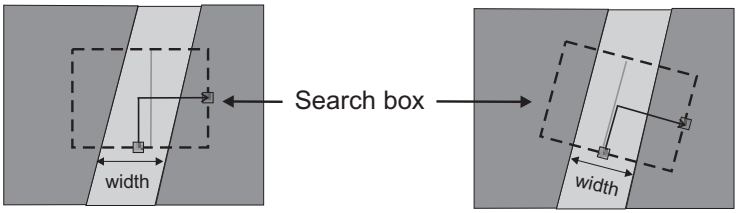


Inspector calculates the marker's position to be in the middle of this width. Note, the more an edge is at an angle the greater the stretching or distortion of its actual width.

Width of a stripe marker

To help find a stripe marker, you can specify the typical distance between both of its edges in pixels. The default is 0, which finds a stripe with any width.

The width of a stripe marker is the average distance in pixels between its edges. Note, if the marker's search box is at an angle, the width is measured according to the orientation of the box, as shown below.



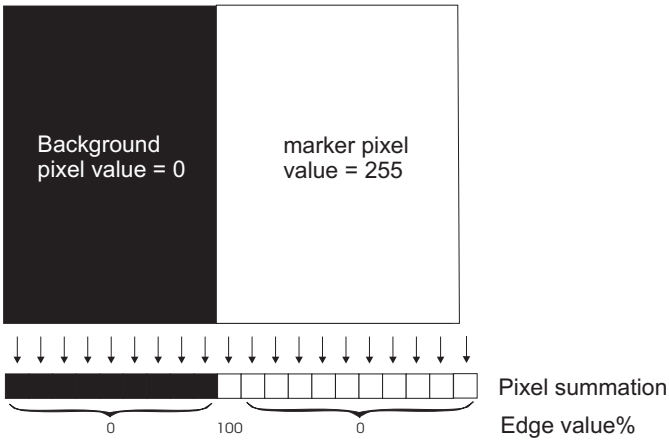
Edge strength

A marker's edge strength is the minimum/maximum edge value along the width of the edge (depending on the polarity of the edge). The edge value is represented as a normalized percentage of the maximum pixel value possible for the specific image buffer. The sign of the edge value represents the polarity of the edge. For example, for a search box with a vertical orientation, the equation for an edge value is:

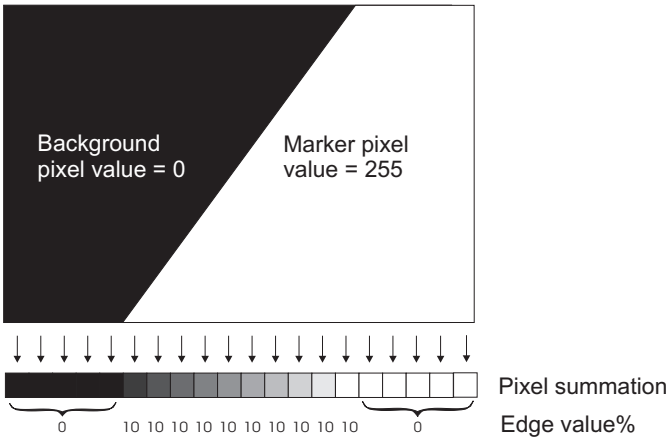
$$\text{edge value\%} = \frac{\Delta \text{ adjacent profile values}}{(\text{box height})\,(2^{\text{buffer depth}} - 1)} * 100$$

For instance, in an 8-bit image buffer the maximum possible pixel value is 255. Therefore, a 50% edge strength in this buffer represents a maximum difference in average adjacent profile values of 128 and a rising edge. The larger the absolute edge value, the greater the edge strength. The default setting finds the marker with the largest edge strength.

The edge in the diagram below has an edge strength of 100%, the maximum edge value possible since the edge is completely vertical and has an edge width of one pixel.



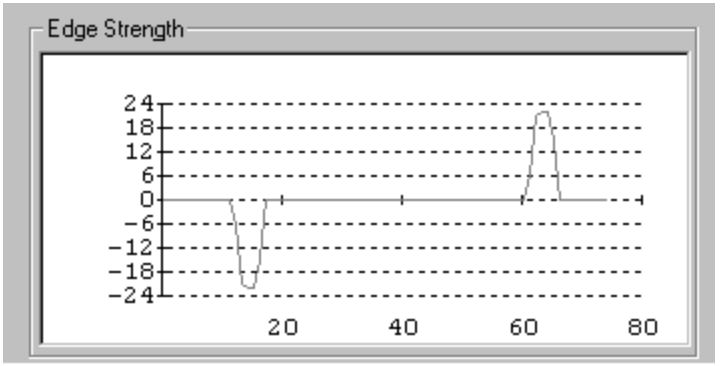
However, with the edge at the angle shown below, the edge profiles are distributed over ten profiles, resulting in a much lower edge strength of 10%:



When the edge strength is not very high, you should specify the contrast. By using the contrast characteristic as a criteria, changes in consecutive edge values are summed, from where the edge starts and ceases (that is, from one region of zero edge value to another), allowing the marker to be located. In general, it is recommended to set the contrast rather than to specify an edge strength, since the edge strength is very dependent on lighting.

Determining the strength of the required edge

To determine the edge strength of the required marker, view the **Edge Strength** graph by clicking the **Graph** button in the **Edge and Stripe** dialog box. This displays the edge values for every profile value of the search box.



Notice that, in this example, the search box is 80 pixels wide so there are 80 edge values that are returned. The two peaks in the graph represent two distinct edges; one negative and one positive, both with edge strengths of approximately 22.

When **Angle mode** is enabled (available through the search box context menu), the **Edge Strength** graph shown is the best projection found for the given angular range and tolerance.

Weight factors

When searching for a marker, the relative importance (weight) assigned to each of the marker characteristics is crucial to the robustness of the operation. By default, 50% of the search weight is assigned to the edge strength; the remaining 50% is

equally divided among all characteristics that can have a weight factor. This makes the edge strength by far the most important characteristic in the search.

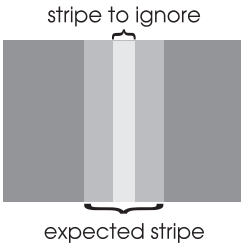
You can override the default weight factors by checking the **Enable weight mode** and adjusting the appropriate values in the **Weight by percentage** section of the **Edge and Stripe Settings** dialog box. However, to better control the search, it is recommended when specifying weight factors that you assign a weight factor to all the enabled characteristics which support weight factors to a total of 100%.

For example, in a case where you must distinguish between two edge markers of different contrast, you can specify the typical contrast of the marker to be found. If you specify only this characteristic, the default search algorithm will assign a 50% weight to the edge strength and the remaining 50% to the contrast. However, if the edge you want to ignore has the higher edge strength, the required edge might not be found. In this case, specifying the weights as 30% for the edge strength and 70% for the contrast will give precedence to the edge with the best match to the specified contrast.

Inside edges

Inside edge

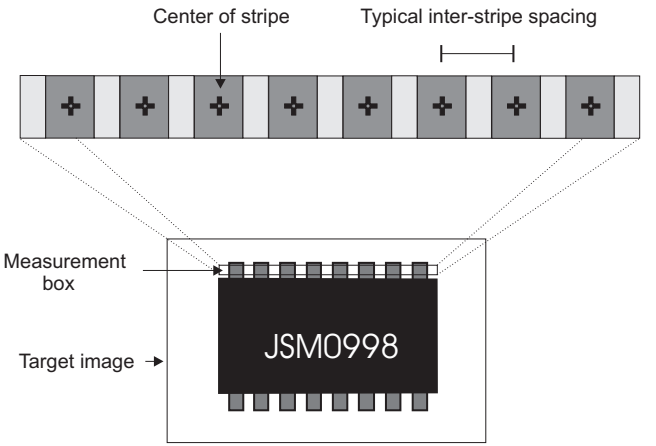
To help find a stripe marker, you can specify the typical number of edges located between the external edges of the stripe marker you are defining. For example, in the following illustration, the two stripes share the same position since their centers coincide.



To find the larger stripe without having to determine and specify its width, specify 2 as the number of inside edges of the stripe marker. To find the smaller stripe, specify 0 (this default setting ignores the possibility of any inside edges).

Multiple marker characteristics

To search for a multiple marker, enable the **Multiple** checkbox in the **Edge and Stripe** dialog box. Set the edge or stripe marker characteristics just as with any marker, except that the expected position and its weight factor are ignored.



Specify the maximum number of edges or stripes to be found in the **Number** edit field (default is 0, meaning that all edges or stripes meeting the established marker criteria in the search box are returned) and the typical spacing between them, if a regular pattern is expected, in the **Spacing** edit field (default is 0, meaning that spacing is not a criteria).

When the **Spacing** setting is enabled, an initial search is performed to find all edges or stripes which best conform to the marker characteristics. This group of edges or stripes are then inspected to ensure that the spacing constraints are met.

See the Inspector *BrokenGear.bas* demo, for a typical application involving a multiple marker.

Measurement results

If an occurence of a marker is successfully located, results are automatically placed in the measurement table. For an edge, there are two result objects: the **Edge** and **Edge Position**. For a stripe, there are three result objects returned: the two edges comprising the stripe and the **Stripe Position**. The edge result object corresponds to the line which follows the edge, with the start and end points found at the boundaries of the search box, while that of the **Edge Position** is that of the center point of this line. The **Stripe Position** is located at the center point between both its edges, and at the midpoint of the search box height. The position result is optional and is only returned when the **Show position also** checkbox is enabled.

When finding multiple markers, a **Multiple Find** result object is returned, in addition to the results for all occurrences found. This result object contains various information concerning the group of located occurrences as a whole, such as the number of occurrences found and their mean angle. Note, however, that if the occurrences found are close to the horizontal axis, the mean angle result might be invalid since the angles can lie both in the first and forth quadrant. For example, while one angle is calculated as 1^{o}, another similar angle is calculated as 359^{o}, such that the average is skewed.

Measurement statistics

Types of statistics

Inspector allows you to maintain statistics on markers and measurements. There are five types of statistics maintained: X and Y positions, distances, angles, and widths. By default, one set of statistics is maintained for each type. However, you can maintain separate sets of statistics for each type, by creating statistic objects. For example, you can maintain separate angle statistics for the top and bottom edges in an image by creating two statistic objects of type angle.

Tolerances

You can assess measurement results against specified tolerances. Setting tolerances can be useful during automation, since results can be immediately read and acted upon. For tips on determining appropriate tolerances, see the *Keeping analysis statistics* section in Chapter 7. Note that Inspector also reports a quick summary of all assessments obtained for a particular marker or measurement.

Viewing in a graph

You can view statistics in a trend or distribution graph. These graphs were discussed in the *Keeping analysis statistics* section in Chapter 6.

Copy to programs or scripts

You can copy statistics to other programs or scripts. For details, see the on-line help.

Note, statistics are not maintained by default; they must be enabled.

Chapter 12: Defining ROIs and annotating images

This chapter describes how to define ROIs of different shapes and annotate an image.

Using ROIs and graphic annotations

Once you have grabbed or loaded an image, you might want to perform operations on localized regions of interest (ROIs) of the image. In addition, you might want to annotate your image with labels and/or drawings, or to record your findings directly on the image. You might also want to manually segment an image that contains touching blobs.

You can use the ROI and annotation drawing tools, available in the **Drawing Tools** toolbar, to define regions of interest on which to perform operations or to add graphic objects to an existing image. The **Drawing Tools toolbar** also allows you to add text, lines, and filled or outlined shapes to your image in any color.

The following image shows an X-ray annotated with text, lines, and a magic wand ROI:

LEGEND

A : Medial Tubercle of the Calcanus
B1 : 1st Metatarsal (anterior)
B2 : 5th Metatarsal (anterior)
B1-A : Medial longitudinal arch span
B2-A : Lateral longitudinal arch span

You can also characterize the shape, and size of any graphic object you draw, and as well as the data under the graphic objects. For example, you can determine the minimum, maximum, and mean pixel value of the data under the graphic object and the profile of its outline.

When annotating your images, you have several drawing options. For example, you can choose whether to draw directly in the image (destructive) or in its overlay (non-destructive), and you can select a drawing color and line style of your graphic objects.

Note that this chapter deals with defining ROIs with the ROI drawing tools; for an in-depth discussion of what ROIs are and how they are used, refer to *Images in general*.

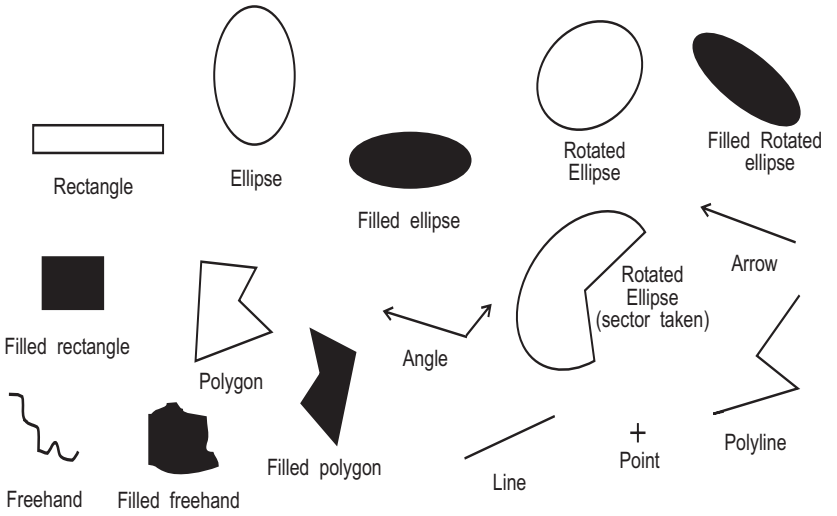
Annotation and ROI drawing tools

The annotation and ROI drawing tools are found in the **Drawing Tools** toolbar. If this toolbar is not visible, enable it with the **View Drawing Tools** command. The tools, available from this toolbar, create graphic objects which can be repositioned and resized. The rotated ellipse and donut can also be rotated, and a sector can be taken of the rotated ellipse.

Note that most of the annotation and ROI drawing tools are recordable. When you are recording, the tools that are recordable appear in blue; tools that are not recordable appear in grey. Note that none of the freehand tools are recordable.

Annotation drawing tools

Inspector includes several drawing tools and a text tool, with which you can annotate your images. The annotation drawing tools allow you to draw the following shapes:



See the on-line procedures, *Drawing graphic objects*.

Adding text to your images

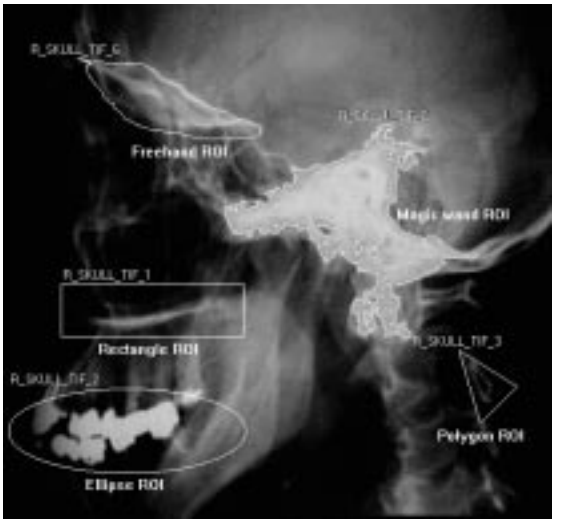
Use the **Text** tool to add captions to your images. When this tool is selected and you click on the image where you want the text to appear, and a dialog box appears, which allows you to type in the required text and specify its font properties. To modify the text, double-click on it to open the dialog box and change its properties.

Note that once you specify a set of font attributes, they are automatically selected the next time you click on the text tool.

See the on-line procedures, *Adding and modifying text*.

ROI drawing tools

Using the ROI drawing tools, you can define ROIs with the same shapes as those possible with the annotation drawing tools. In addition, you can define a rotated donut (toroid) ROI, and a magic wand ROI. Many of these shapes are illustrated in the image below.



❖ Note that some processing operations, such as blob segmentation and pattern matching, use the bounding rectangle of a non-rectangular ROI as the processing region.

See the on-line procedure, *Drawing ROI objects*.

Magic wand ROIs

You might want to define an ROI based on the gray or color values in an image, rather than a specific area. Such an ROI can be created using the magic wand tool. A magic wand ROI includes all pixels that are similar (within a specified range) to the selected pixel value.

See the on-line procedure, *Drawing a magic wand ROI*.

❖ You can also define an ROI based on gray or color values using the **Image Processing Threshold** command and selecting the **Make ROI** option.

Specifying your drawing preferences

You can either use Inspector's default drawing settings or specify your own drawing preferences. You can specify:

- **Drawing destination**: Selects whether to draw in the image buffer (destructive) or the overlay (non-destructive).
- **Graphic object analysis**: Displays a profile of the data underneath the outline of a graphic object, characterizes its properties in a Quick View table, and/or transfers the results to the current measurement table.
- **Multiple mode**: Keeps the current drawing tool selected, until another tool is selected.
- **Outline properties**: Selects a line style and width.
- **Drawing color**: Selects a drawing color.

Drawing destination

You can draw graphic objects in an image's overlay or directly in the image by choosing the appropriate radio button in the **Drawing Tools** toolbar.

When the **Overlay** radio button is selected, graphic objects drawn in the overlay are stored separately from the image. Therefore, any object can be modified, moved, and deleted without affecting the image or other objects. For more information on handling objects in the overlay, see the on-line help procedure, Adjusting graphic objects.

By default, objects are drawn in the overlay. Once you are satisfied with your annotations, you can merge the selected objects into the image by using the **Annotations Convert** command (see *Converting graphic objects*) or the **Annotations Merge to image** command. Note that immediately after merging objects to an image with the **Annotations Merge to image** command, an undo operation will restore the image buffer, but not the graphic objects.

❖ A physical overlay frame buffer is not required to draw in the overlay.

When the **Buffer** radio button is selected, graphic objects that are drawn become part of the image. Once drawn, these objects cannot be modified or deleted (except through an **Edit Undo**). In addition, when you save your image, these objects are saved as well, since they are part of the image. This mode is mostly used to create test images and segment blobs (that is, to separate touching objects).

If you merge color graphic objects into a grayscale image or if you draw directly into a grayscale image, the objects become grayscale. The grayscale color used is derived from the selected overlay color, using a minimum color distance measure between the overlay RGB value and the RGB values in the palette of the one-band image (scaled to match the buffer type, if necessary).

Analyzing graphic objects: Profiles

When the **Profile** radio button is selected, graphic objects are drawn in the overlay, and once drawn, the profile of the pixel values underneath the outline of the object (outlined in yellow) will be generated; the profile is taken in the direction of the arrow. If you are drawing a filled shape, the graph drawn will show the pixel values underneath the edge of the object. See *Chapter 8: Histograms, profiles, and measurements* for more information on profiles.

Analyzing graphic objects: Measuring objects

When the **Measure** check box is selected, graphic objects are drawn in the overlay, and once drawn, a Quick View table, characterizing the object's properties, is generated. When the **Transfer** check box is also selected, the drawing tools become outlined in yellow, and once an object is drawn, its positional properties are also transferred to the current measurement table. See *Finding and measuring edges and stripes* for more information on measuring objects.

Multiple mode

If you plan to use the same annotation or ROI drawing tool more than once, you should enable multiple mode. Multiple mode keeps a tool enabled so you can draw several shapes. When using this drawing mode, the current tool remains selected until you select another tool or deselect multiple mode.

By default, multiple mode is disabled and the current tool returns to select mode once the object has been drawn. To temporarily apply multiple mode to a tool, double-click on it, and it will remain in the pressed state until you click on another tool. You can also enable/disable multiple mode for all the drawing tools by selecting or de-selecting **Multiple Mode** from the drawing tools' context menu. To set **Multiple Mode** as your default, select the **Multiple drawing mode for all tools** from the **Options Preferences - Toolbars tab**.

Selecting a drawing color

For annotation drawing tools, you can select the drawing color from:

- Any displayed image (using the palette viewer or the eyedropper tool).
- The **Color** dialog box.

The current drawing color is shown in the color indicators next to the eyedropper tool. The left indicator shows the overlay drawing color, and the right indicator shows the image (buffer) drawing color. By default, red is the default color in the overlay for RGB images, and black is the default color in the overlay for single-band images. If your image is RGB, both indicators will be of the same color. If your image is a single-band image, the image drawing color can only be a color that exists in its display palette; there are no restrictions on the overlay drawing color.

❖ Note that the drawing color does not apply to all graphic objects (such as ROIs and measurement markers).

Palette Viewer

You can select the required color from the palette viewer. If the palette viewer is not visible, display it with the **View Palette Viewer** command. Clicking on a color in the palette viewer selects that color for drawing.

If you are using an 8-bit display, the palette viewer displays the system palette. If you are using a true color display, the palette viewer displays the current image palette if one exists; otherwise, it displays the default palette.

- To determine the RGB values of any color in the palette viewer, place the cursor over the required color; the RGB values are displayed at the bottom of the window's pane.

Eyedropper tool

You can select the required color directly from the image by selecting the eyedropper tool and then clicking on the image pixel that has the required color.

Selecting a color using the Color dialog box

You can also select a drawing color from the **Color** dialog box, which is accessed by clicking on the color indicators next to the eyedropper tool.

Outline properties

You can specify the style and width of lines created with any non-filled annotation tool. By default, a solid, one pixel wide line is selected. When clicking the **outline style** button on the **Drawing Tools** toolbar, the outline tab will appear, where you can set its properties.

- Outline properties do not apply to ROIs or filled graphic objects. ROIs are always drawn using a solid, single pixel wide, red outline. Profile lines are always drawn in yellow.

Converting graphic objects

The **Annotations Convert** command also allows you to convert graphic objects into other graphic objects. Graphic annotations, graphic objects used to delimit blobs, measurement edge markers, and ROIs can be converted into ROIs, or profiles, or graphic objects merged into the overlay or buffer. When merging objects into the overlay or buffer, you can also change the attributes (color, line style, or filled object) of the object by selecting the appropriate buttons in the dialog box. When converting ROIs, you can choose to keep the ROI label, the R_ identifier.

The **Move** button converts the graphic objects to their new type or drawing destination. The **Copy** button copies the graphic object(s); after the button is selected, select the graphic object and drag to get the copy. The **Select All** button allows you to select all the graphic objects in your image for the purpose of conversion.

Chapter 13: Grabbing images and specifying camera settings

This chapter describes how to grab images with your digitizer and specify camera settings using Inspector.

Cameras and input devices

If you have an installed Matrox frame grabber (digitizer), you can grab from any input device supported by your frame grabber. Since cameras are the most common input device, we refer to input devices as such.

Upon starting Inspector, the **System Allocation** dialog box asks you to select one of the digitizers it has detected. If your system has only one board, you can check the **Don't ask me again** option, and the next time you open Inspector, it will open with the same board. If you have more than one digitizer available, refer to the section, *Using multiple digitizers*.

Specifying your camera settings

Before you can grab images with Inspector (as discussed in Chapter 3), you must specify your camera's type. To do so, select a digitizer configuration format (DCF) file that matches your camera's type, using the **Options Digitizer Settings** command.

The DCF files can be found under your MIL folder in the *\DRIVERS\BOARD NAME\DCF* folder (for example, *D:\MIL\DRIVERS\CORONA\DCF*). In addition, DCF files can be created and edited using Matrox Intellicam, which is shipped with MIL and MIL-Lite.

The digitizer settings that are required to grab from a particular camera are specified in the DCF file. If necessary, you can adjust these settings using the **Options Digitizer Settings** command. You can adjust:

- **The input channel(s)**. These are the channel(s) from which to grab (also known as the active channel(s)). Make sure that your camera is connected to the specified channel. See, *Configuring the synchronization and signal channels*.
- **The grab size**. This is the size of the frame to grab. You can set the size of a grabbed frame to the size of the camera resolution (by grabbing into a new window) or to the size of the current window (by grabbing into that window).

More settings are available, depending on your board and camera. All settings, unless otherwise specified, are saved in the Windows Registry. For board-specific information, refer to the readme.

See the on-line procedure, *Selecting a digitizer configuration format*.

Grabbing

With Inspector, you can grab images one at a time (snapshot mode), grab images continuously keeping only the last frame, or grab a sequence of frames. Sequences are a special case of grabbing, and will be discussed later (see *Sequences*). To start a grab, use the **File Grab** command, or click on the appropriate grab button (Snapshot, Continuous, Sequence) on the **Digitizer** toolbar.

Grab mode

In continuous mode, grabbing is initiated into the window specified with the **Options Preferences - Digitizer** tab. Continuous mode is very useful when adjusting and focusing your camera. Once an image has been frozen, you can continue grabbing one snapshot at a time, or restart in continuous mode. You can select one of three grab continuous modes from the **Grab mode** drop-down list, next to the **Grab Continuous** icon on the **Digitizer** toolbar:

- **Normal**: Grabs directly to the display. If the depth of the image or the grabbed data is greater than 8 bits, the grab will be displayed using the display mapping mode (see Chapter 3 *Dealing with images*).
- **Double buffering**: Grabs so that the digitizer grabs a frame into non-paged (DMA) Host memory (or on-board memory, when applicable) while the previous frame is transferred to the display. This is most useful if you want to display a continuous grab with a pseudo-color palette (for example, the Blue Gray Red palette), since images can only be associated with a palette if Windows is handling their display. When

performing a continuous grab in normal mode and displaying from an imaging board with a display section, Windows is not handling the display.

- **Averaged**: Grabs and displays a running average on a basis of 8 frames, where 7/8 of a given frame is accumulated data, and the remaining 1/8 is data from the new frame.

During a continuous grab, the camera grabs into a live window, and ends when you call the **Grab Halt** command. If your system is not using an imaging board with a display section, a continuous grab is performed in two stages. During the grab, the incoming data is transferred to the display in the fastest way possible given your system configuration. When you call the **Grab Halt** command, a final snapshot is made into system memory, and this data can be used for further processing and display. Due to these two stages, the image quality might be different between the live grab and the final image.

See the on-line procedure, *Continuous grab*.

Setting digitizer controls

During a continuous grab, you might be presented with the **Digitizer Control** dialog box. This dialog box allows you to interactively adjust the various dynamic controls of your digitizer. Use the **Option Preferences** command to specify whether this dialog box should present only standard options, or both standard and advanced options. The standard options appear in the **References** tab of the **Digitizer Control** dialog box. The advanced options appear in other tabs that vary according to your particular frame grabber.

Standard options

The standard options allow you to adjust the black and white reference levels of your frame grabber's analog-to-digital converters, or the hue and saturation of its composite decoder. By reducing or increasing either or both the black and white reference levels, you can affect the brightness of the resulting image. By reducing one reference level and increasing the other, you can affect the contrast of the resulting image. The hue and

saturation should normally not need adjustment unless you need to calibrate to a color standard; one or two points should be sufficient.

Note that the standard options are recordable when scripting. For example, the black and white reference levels can be adjusted through the scripting function *CamSetRef()*. In addition, the standard options are saved in the Inspector GrabControl page of the Windows registry.

Advanced options

The advanced options that are available depend on your particular frame grabber. Advanced options are similar to the functionality of Matrox Intellicam and are described in the *Matrox Intellicam User Guide* (see the *intelcam.hlp* file).

The advanced options cannot be recorded or saved.

More advanced options - LUTs and grabbing with triggers

Although Inspector does not directly support some of the more advanced features of your frame grabber, you can always use a script to call a MIL function that does. For example, you can use this method for triggers and input LUTs.

If your Matrox digitizer supports trigger input, you can grab a frame upon the occurrence of an event. Your camera's DCF file specifies whether or not to perform a triggered grab and exactly how it should be carried out.

You can correct or precondition input data by mapping it through an input LUT when grabbing (if hardware permits). Although there is no direct support for input LUTs in Inspector, you can use the sample script *DigLUTDemo.bas* to call the MIL function.

Grabbing more than 8 bits

If you have a combination of camera, DCF, and digitizer that supports 10- or 12-bit input, Inspector will grab into a 16-bit image. However, because of the display remapping that is required, only snapshot grabs are possible when grabbing into a 16-bit image. To preview the grab at a live rate, you must force the grab into an 8-bit image, by enabling the **Grab Depth** check box in the **Digitizer Info** tab of the **Digitizer Settings** dialog box. An 8-bit grab can also be forced by using the **Options Preferences - Digitizer** tab command, and checking the **Always default to 8-bit grab on new digitizer installation** checkbox. (Note, that unless you have a Matrox Pulsar, this box should remain unchecked.)

Configuring the synchronization and signal channels

If your digitizer supports simultaneous video input connections of the same type, you can switch between the input channels. The channels can be switched using the **Options Digitizer Settings** command. Inspector identifies the channels according to their corresponding label on the board's connection plate; use these identifiers when accessing multiple cameras. Inspector names the channel indentifiers from 0.

Certain digitizers have separate signal and sync channels, and therefore have a channel reserved for either signal or sync input. If you are resetting the input channels and see one missing from the drop down list, it is because that particular channel is reserved. To determine which channel inputs are available on your board, consult your board's installation manual, or see the on-line help topics: Input channels on Corona, Input channels on Genesis, Input channels on Meteor-II, Input channels on Meteor, and Input channels on Pulsar.

Using multiple digitizers

By default, during Inspector's start-up procedure, Inspector automatically detects all digitizers in the system that can be allocated and then presents the **System Allocation** dialog box.

If your system has several boards of the same type, only one board will be listed in the **System Allocation** dialog. Inspector will grab with the first board of the specified system type (M_DEV0). (If you want to re-allocate a digitizer to M_DEV1, see the readme provided in the online help.)

❖ If your system has several different boards and you want to grab with a different board, you must restart Inspector.

Chapter 14: Creating and manipulating sequences

This chapter describes how to create, manipulate, and grab sequences using Inspector.

Sequences

With Inspector, you can grab and playback sequences. Sequences are a set of sequential frames that can be either grabbed from a camera, built from a number of images, or loaded from file, of which there are four supported types (AVI, TIF, RAW, and DICOM).

Sequences are useful in applications that:

- Determine the movement, growth, contraction, replication, and/or metamorphoses of the object(s) in an image.
- Determine at what interval to grab snapshots (when setting up an inspection system) by viewing a longer video tape.
- Capture a transient occurrence.
- Reconstruct a large object from a set of images obtained by panning across the object with a camera.

Sequences can be in one of two forms:

- **Memory sequence**: The frames of this type of sequence are stored in your system's memory. That is, each frame in the sequence is allocated its own memory (image buffer). You can process and analyze the frames in a memory sequence as you would any other image in Inspector. Once a memory sequence is saved, it becomes a disk sequence.
- **Disk sequence**: The frames of this type of sequence are saved to disk, and cannot be rearranged or changed. Only one image buffer is allocated and used for the display of any frame. You can create an image from any frame in the sequence, as well as drag frames into a new or existing memory sequence.

Loading sequences and the sequence window

You can load a sequence file using the **File Open** command, or from a collection window. Sequence files can be of type AVI, multipage TIF, DICOM, or RAW. Sequences are displayed in a window which has two panes: a main playback pane and an optional thumbnail pane. Either of these panes can be closed or made smaller by dragging the vertical edge which separates the two panes. If the sequence you are opening contains more than 150 frames, you will be asked if you want to display the thumbnails. While a sequence is loading, you can press the **Escape** key to stop creating the thumbnails.

The.sequence window displays: the name of the sequence, the current frame, the number of the current frame, and the total number of frames in the sequence. The timing of the sequence, the relative time at which each frame was grabbed, appears in the main pane's overlay. If required, the timing of the frames can be exported using the **Edit Export** command or the script function, *SeqExportFrameTimes()*.

Sequence properties

The properties of a sequence can be viewed by using the Sequence Info tab command of the **View Properties** command:

- **Number of frames**. Indicates the number of frames in the sequence.
- **Playback rate**. Indicates the speed at which the sequence is played, in frames per second; the playback rate is adjustable.
- **Data source**. Indicates the type of sequence.
- **Thumb Size**: Specifies the size of the thumbnails. Changing the size will rebuild the thumbnails in the pane.
- **Keep Image Ratio**. Keeps the pixel aspect ratio when displaying frames as square thumbnails.

- **In/Out**. Shows the number of the first frame and last frame that will be played back in the sequence. You can edit this playback range by typing the required frame directly in the edit fields. Alternatively, you can edit the playback range by right-clicking on the yellow slider, and dragging the ends of the slider to the required frames.
  - Note that although the thumbnail size can be changed, the actual thumbnail is not updated if the frame has been processed or modified.
  - You cannot use the **View View Component** commands on a sequence window.

Opening compressed sequences

The most common file types for sequences are audio video interleave AVI and TIFF. AVI files use many forms of compression. For example, an AVI file can be a keyframed delta file, or the file can be compressed using proprietary compression schemes.

CoDecs (coder/decoders) are sometimes required to open files with specific compression schemes. CoDecs are software modules that implement various compression/decompression schemes. Some CoDecs are installed by default with Windows; others are installed separately. Within the AVI file, there are identifiers which tell Inspector which CoDec to use. If you save an AVI using Inspector, you will be able to reload it in Inspector, but if you get an AVI from another source, you might not have the right CoDec to load it, unless it is in a standard Windows format.

For information about compressing/decompressing files with the MJPEG module, see the readme file.

Playing back sequences

You can view the entire sequence in forward or reverse order by pressing the appropriate **Play** button. In addition, a sequence can be viewed repeatedly by clicking the **Loop** button.

You can display a required frame by single-stepping through the sequence using the **Next** or **Previous** buttons. Alternatively, you can move the slider until the required frame appears. To better view a particular frame, you can zoom in or out on the main pane.

DICOM images, in particular, have much information that can be displayed in the overlay. When playing back a sequence with a lot of data in the overlay, you might want to check the **Optimize grab with overlay** feature in the **Options Preferences** command. This option, when checked, optimizes the displayed sequence so that the overlay does not flash as each frame is played. Although this option improves the sequence's playback, it has a slight effect on the playback speed.

Grabbing sequences

To grab a sequence, you must have your digitizer and camera correctly configured. Once you have configured, you can grab using the **File Grab - Sequence** command, or select the **Sequence** button from the **Digitizer** toolbar. You must select the type of sequence you wish to grab, either a memory type or a disk type sequence, as well as the number of frames to grab. These types of sequences will be discussed later. You can also specify the size of the grabbed frames, and the rate at which to grab frames.

You also have previewing options when grabbing sequences. In the **Timed Acquisition Setup** window, there are two options: **Preview** and **Preview while grab**. The **Preview** button opens a pane and allows you to see what your camera will grab. If the **Preview while grab** checkbox is checked, the preview window will open and remain open during the grab. Note that while previewing while grabbing is necessary in some cases, the time required to re-paint the display reduces the maximum bandwidth available for the actual grabbing of data.

After you call the **File Grab Sequence** command, you are presented with the **Sequence Setting** dialog box, with the **Timed Acquisition Setup** tab showing. In the **Timing** section of the tab, you can select to use the digitizer's timing (which will grab every frame), or you can select to grab every *nth* frame, or every *n* milliseconds.

The sequence is grabbed only when the **Start** button is clicked; if you select the **Stop grab at user request only** checkbox in the **Timed Acquisition Setup** tab, the digitizer will grab into a circular queue until the **Stop** button is clicked. When the stop grabbing command is under your control, the grab is known as grabbing into a circular queue. The grab can be paused by using the **Pause** button.

❖ To optimize your system's performance, free up memory by closing all unnecessary images prior to grabbing a sequence.

See the on-line procedure, To grab a sequence

Grabbing memory type sequences

You can grab a memory type sequence to paged Host memory (system RAM), or on-board memory, or DMA memory (non-paged Host memory). The memory available for the grab determines the maximum length of the sequence; the more memory available, the longer the maximum sequence length. The grab destination determines the speed of the grab, as well as the memory available for the grab.

The speed of the grab affects whether successive frames can be captured; a high-speed grab can grab more successive frames than a grab at a lower speed.

Grabbing to paged Host memory

When you grab to paged Host memory (system RAM), the speed of the grab depends on the transfer rate from your frame grabber to computer memory. This, in turn, depends on the following:

- The maximum transfer rate from the frame grabber to the PCI bus.
- The PCI controller on the path to computer memory (that is, Neptune, Triton, or Orion chip).

The amount of memory available for the grab depends on the combination of the amount of real memory and the size of the swap file.

Grabbing to on-board or DMA (non-paged) memory

Grabbing to on-board memory or DMA memory (non-paged Host memory) is generally faster than grabbing to paged Host memory or disk. As a result, you are less likely to miss frames. However, on-board memory (for example, on Matrox Genesis) is limited. The amount of DMA memory is the amount specified when you installed Inspector.

If you do not have sufficient free memory for the requested number of frames, you can choose to store some of your images in another memory resource, using the **System** toolbar. For more information on the **System** toolbar, see the on-line help topic, The System Bar.

❖ Once you have grabbed a memory sequence, you can save it to disk, but you must ensure that all modifications, or any rearranging or processing of frames are completed before closing the sequence. Once a memory sequence is saved, you cannot make further changes. To change a saved sequence, see *Grabbing disk type sequences*, and *Processing the frames of a sequence*.

Grabbing disk type sequences

When you grab to disk, the specified type of sequence is created (for example, AVI or TIFF), and data is copied to disk from system memory during the grab. Each grabbed frame is temporarily stored in memory before being copied to the disk. In other words, sequences grabbed to disk are double buffered. Usually, when grabbing to disk, more storage space is available, allowing you to grab longer sequences. However, the speed of the grab is generally slow because disk access is slow.

A sequence grabbed to disk is read-only, and the sequence file's content cannot be modified or processed in any way. To make changes to a sequence, the sequence must be grabbed as a memory sequence, and modified before saving, or copy the frames into a new memory sequence. Alternatively, you can create a new sequence and insert frames into the sequence. See, *Creating sequences*.

The actual transfer rate to disk depends on the fragmentation of your disk. To obtain the best transfer rate, check the fragmentation of your disk and then, if necessary, perform a disk defragmentation. For more information, refer to your Windows documentation.

Creating sequences

There are four methods of creating a new sequence. Creating a sequence using the **File Grab Sequence** command was discussed in the previous section *Grabbing sequences*. There are three other methods of creating sequences using the **File New** command.

- You can insert image files into a new sequence using the Sequence Insert Frame command. Inserted images are added to the end of the sequence. When inserting multiple image files at the same time, they are added to the end of the sequence in reverse order, that is the last file selected is inserted first, and the first one selected is inserted last. Sequence frames, once inserted, can easily be rearranged by dragging and dropping the thumbnails.

  See the sample script, *Buildsequence.bas* as an example of creating a sequence and sorting frames by some criteria.

- You can drag and drop open image windows into a new, empty sequence.

- You can drag and drop frames from existing sequences that are open into a new, empty sequence.

Note that the images must be the same type, size, and depth. If you try to insert an image whose attributes do not match those of the frames already in the sequence, an error message will appear.

If you drag and drop frames from an open memory sequence, the frames are moved to the new sequence, not copied. If you want to copy the frames, use the **Ctrl** key, and check for the small plus (+) sign on the mouse cursor when you drag to the new sequence window.

You can drag and drop multiple frames. To select successive frames, press the **Shift** key while selecting them; to select non-successive frames, press the **Ctrl** key while selecting the frames.

Dragging and dropping from an existing sequence takes data but not palette information. If you need to transfer the palette, save the palette in the source sequence using the Palette Editor command, and then load it into the new sequence, again using the **Palette Editor**.

Deleting frames in a sequence

To delete frames from a sequence, you must have a memory sequence. Select the frame you wish to delete, and use the **Sequence Delete Frame** command. Alternatively, you can select the frame's thumbnail and press the **Delete** key.

Frames from disk sequences cannot be deleted. If you must remove frames from a disk sequence, create a new memory sequence, and drag and drop the frames of the disk sequence into it, omitting unnecessary frames.

Saving and compressing sequences

Once a memory sequence is grabbed or created, you can save it to an *.avi or *.tif file using the **File Save As** command. When saving, click the **Compression** button to set compression parameters to compress your frames and reduce the amount of disk space needed to store them.

❖ Note that compression is only supported for AVIs.

If you are grabbing to disk, you are asked to specify the name of the file in which to save the sequence before the grab. Compressing frames during a grab to disk is supported (click the **Compression** button when specifying the disk sequence's filename); however, the grab will be slower. If you have specialized hardware, it will be used.

Unless you have a fast machine with an optimized CoDec, a grab to disk is most suitable for time-lapse applications with a large number of frames being collected at a relatively low rate, for example, growth studies, waiting for mechanical displacements, or surveillance.

Processing the frames of a sequence

Frames of a sequence can be used as a source for any processing or analysis operation.

If your sequence is a memory sequence, you can annotate, process into, or rearrange the frames in the sequence. Use the sequence playback tools to select the frame (or select the frame directly), and perform the required operation. You can also activate the frame by clicking on it, or using the scripting function, *SeqSetCurrentFrame()*.

- If you have a disk sequence which you must analyze, you can create a new memory sequence using the **File New** command, and paste the frames from the disk sequence into the new memory sequence. Then, the frames can be processed like any other image.

Frames of any sequence can be copied to the clipboard or duplicated like any other image, and you can create images from frames of any sequence type. To create an image from a particular frame in a sequence, double-click on it to bring it up as an image. Note that when you create an image from a sequence frame, its identifier changes to I_IMAGE... The **Edit Copy** command or the **Duplicate** command will also create an image. The image is independent of the sequence; that is, changes in the image do not affect the frame in the sequence.

Note that if a frame of a sequence is used as a destination image, the sequence must be a memory sequence if you want to save the results of the operation; sequences grabbed to disk or opened from disk cannot be modified.

Inspector supports dynamic update of histogram and line profile graphs when playing back the frames in the sequence. When you want mapping or thresholding preview to apply to all the frames in the sequence, select the **Lock Live Preview** button of the **Image Processing Mapping** command or **Image Processing Threshold** command.

Locking sequences

If necessary, the active frame of a sequence can be locked as a source or destination image (locking was described in the *Selecting a different source and destination* section Chapter 3). Only the active frame can be locked; you cannot lock two frames from the same sequence. You can, however, create images from specific frames in the sequence and lock these images, or lock frames from two separate sequences.

You cannot use Inspector's **Edit Duplicate** command, or **File Save As** command to reproduce an entire sequence. The easiest way to create two identical sequences, is to copy the saved sequence to another file name, outside of Inspector.

Sequences and scripts

In sequence analysis applications, scripts can be useful since these applications often require performing the same set of operations on a large number of frames. For example, you can create a script that determines the number of frames in a sequence, makes a specific frame active, and then performs operations on that frame. The script can then be used to select and process other frames (see the *TrackingDemo.bas* for an example of how to do this). For more information, refer to the scripting chapters.

Chapter 15: Calibration

This chapter describes how to use Inspector's calibration object.

Calibration

Using Inspector, you can calibrate your imaging setup so that pixel coordinates map to world coordinates. Calibrating your imaging setup allows you to obtain analysis results in world units, view the current cursor position in world coordinates (in status bar of the images), and if necessary, physically correct an image's distortions.

When you get results in world units, you automatically compensate for any distortions in an image. Therefore, you can get accurate results despite an image's distortions.

Types of distortions

You can use calibration if you have one or more of the following types of distortion:

- **Non-unity aspect ratio distortion**: Present when the X and Y axis have two different scale factors. This is evident, for example, if you know that the object in your image should be round and it appears as an ellipse. This type of distortion is often a side effect of the sampling rate used by some older digitizers.
- **Rotation distortion**: Present when the camera is perpendicular to the object grabbed in the image, but not aligned with the object's axes.
- **Perspective distortion**: Present when the camera is not perpendicular to the object grabbed in the image. Objects that are further away from the camera appear proportionally smaller than the same size objects closer to the camera.
- **Other spatial distortions**: Complex distortions, such as pin cushion and fish eye distortions, fall in this category. These distortions can be compensated for by using a large number of small sections in the mapping function. If the number of sections used is big enough and the corresponding area covered in each is small enough, the mapping in each area can be approximated with a piecewise linear interpolation function.

Calibrating in Inspector

Inspector provides two ways to calibrate your imaging setup:

- The **Options Calibration New** command allows for the creation of a *calibration object* that compensates for non-unity aspect ratio and rotation distortions.
- The **Options Calibration New from Grid** command allows for the creation of a calibration object that compensates for perspective and other spatial distortions.

For both of these calibration methods, you can select whether you want to apply the calibration object to the current image or to all new images. If you select the latter, the current calibration object is used for all newly created, loaded, or grabbed images.

You can also load a a previously saved calibration object and apply it to your current image or to all new images, using the **Options Calibration Load** command. You can load a MIL (*.mca*) calibration file that is generated by a MIL 6.0 application or Inspector 3.0, or you can load an Inspector 2.x (*.cal*) calibration file.

When a calibration object is associated to an image, that image is known as a *calibrated image*.

When you associate a calibration object to your image, the image is not physically corrected and therefore it still appears distorted. However, image coordinates are returned in world units; you can position the cursor anywhere in the image and the corresponding world coordinates are displayed in status bar of the image. Also, when you perform any analysis on a calibrated image, your results are returned in world units.

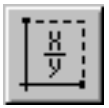
You can physically correct a calibrated image by using the **Image Advanced Geometry Correct** command.

Note that Inspectors scripting functions take values only in uncalibrated units, although they can return results in either calibrated or uncalibrated units. Similarly, it is important to mention that most dialog boxes (for example, measurement and

pattern matching) take positional and measurement data in uncalibrated (pixel) units, while all tables present results in calibrated units.

Calibrating your imaging setup

Non-unity aspect ratio



To compensate for a non-unity aspect ratio distortion, use the **Options Calibration New From Grid** command and uncheck the **Square Pixels** option in its dialog. This creates a calibration object for which you can specify different pixel-to-world scale factors in X and in Y. You can type the ratio of pixels to world units in the edit fields. Alternatively, you can interactively identify the necessary pixel dimensions by drawing a rectangular graphic object using the **Rectangle** button (in the dialog) and typing in the corresponding world dimensions. Once you have clicked on this button, it will flash to remind you to click on it again after you have finished drawing and adjusting the graphic object.

Uniform rotation and scaling

For rotation distortion, or to specify a uniform pixel-to-world scale, you can calibrate your imaging setup using two points in the image, where the distance between these points is a known value. A ruler is often placed in the image so that there is an object of known dimensions. Inspector uses the distance between these as a reference for assigning the pixel-to-world mapping.

To specify a uniform scale, use the **Options Calibration New** command. After ensuring that the **Square Pixels** option is checked, select the Line button to draw a line between the two known points and then specify the scale factor. The line button flashes to remind you to click on it again after you have finished drawing and adjusting the graphic object.

Using the same command, you can also specify the origin and angle of the world coordinates system. Click on the **Origin/Angle** button and then click anywhere in the image to select the origin (0,0). To specify an angle, draw a line from the position that you want to be (0,0) in the world coordinate system

to another point along the world X-axis. Note that if you do not draw a line (zero length line), only the origin is set; the angle remains 0.

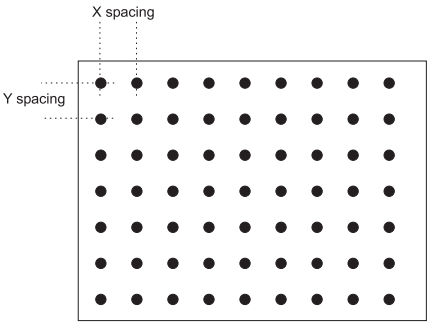
Perspective and other spatial distortions

To correct perspective and other spatial distortions, you can use an image of a user-defined grid or a list of coordinates, respectively.

Calibration from a grid

Calibration from a grid is often used when a number of images will be grabbed using the same camera position and lens configuration.

Using the **Options Calibration New from Grid** command, you can specify the pixel-to-world mapping from an image of a user-defined grid of circles and the world description of this grid. You specify the number of rows and columns, as well as the center-to-center distance between these rows and columns, in real-world units.

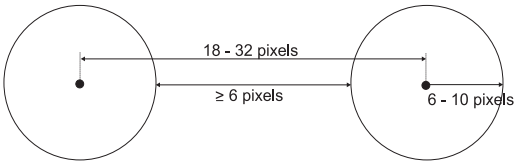


General rules for constructing a grid

You can create a pixel-to-world mapping from almost any grid of uniformly spaced circles. However, to create an accurate (sub-pixel) mapping, your physical grid should meet the following guidelines (at the working resolution):

- The radius of the grid's circles should range between 6 and 10 pixels.
- The center-to-center distance between the grid's circles should range from 18 to 32 pixels (22 pixels recommended).

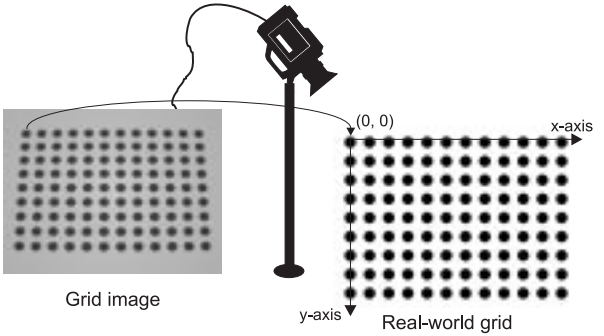
The minimum distance between the edges of the circles should be 6 pixels.



- The grid should be large enough to cover the area of the image from which you want real-world results (the working area).
- The grid image should have high contrast.

Default axes

By default, the circle in the top-left corner of the grid image is associated to the origin, (0, 0), of the *real world coordinate system*, the first column of circles is aligned with its Y-axis, and the first row of circles is aligned with its X-axis.



Offset and Y-axis

If necessary, you can set the top-left circle of the grid image to a different position within the world coordinate system. The origin of the real-world coordinate system does not have to be within the field-of-view.

You can have the positive Y-axis oriented up, 90º counter-clockwise with respect to the positive X-axis (by default, Inspector assumes it is oriented down, 90º clockwise).

Applying the grid calibration object

You can apply the calibration object to your current image, which is your grid, or to all new images. If you want to apply the calibration to an already opened image, save the calibration object and then load and apply it to the opened image.

Calibration modes

When you calibrate from a grid or a list of coordinates (see *Calibrating using coordinates in an image*), you also have to specify the calibration mode. Inspector supports the following calibration modes:

- Piecewise linear interpolation.
- Perspective transformation.

Piecewise linear interpolation

In general, you should use piecewise interpolation mode. This mode can compensate for any kind of distortion. It is very accurate for points located inside the working area (the area of the image from which you want real-world coordinates). However, it is less accurate for points outside the working area. The piecewise linear interpolation mode fits a piecewise linear interpolation function to the set of image coordinates and their real-world equivalents.

Perspective transformation

The perspective transformation mode can compensate for rotation, translation, scale, and perspective distortions. For such distortions, the perspective transformation mode is accurate for points inside and outside the working area. This mode cannot compensate for non-linear distortions such as lens distortions. The perspective transformation mode best fits a global perspective transformation function to the set of image coordinates and their real-world equivalents.

Calibrating using coordinates in an image

In situations where it is not possible to grab an image of a calibration grid to define a complex mapping, it might still be possible to calibrate your imaging setup by using a list of pixel coordinates and their associated world coordinates. Although Inspector does not support this directly, you can use a script that calls MIL's *McalList()* function. Use *McalList()* to specify the list of coordinates and the calibration mode. The sample script *CalibGrid.bas* shows how to calibrate an image using a list of coordinates.

The list of pixel coordinates and their associated real-world coordinates define the pixel-to-world mapping. The more coordinates you specify, the more accurate the mapping. You

use a list of coordinates to calibrate when you explicitly know the real-world coordinates for a given set of pixel coordinates. The specified pixel coordinates should cover the area of the image from which you want real-world coordinates (the working area).

In the case of perspective distortion, knowing the world coordinates of 4 points in the image gives sufficient information to create a mapping function. To create a good mapping for a radial distortion requires a larger number of coordinates (for example, more than 30) distributed over the image.

Relative coordinate system

A relative coordinate system is a cartesian coordinate system defined within the world coordinate system. By default, the relative world coordinate system is aligned with the world coordinate system. However, to get results relative to some object, it can be moved anywhere within the world coordinate system and rotated by any angle. Its unit of measure is the same as the world coordinate system.

The relative coordinate system is generally used to allow measurements to be made relative to a particular object in the field of view, especially when there are several such objects in the field of view. For example, the following is an image that was calibrated from a grid using the default settings. By default, the relative and world coordinate system's top-left circle in this image is 0,0. However, to get results relative to the origin of the object, the relative coordinate system is at (2, 1).

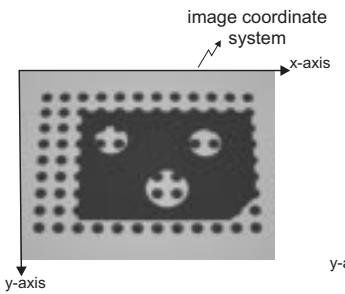
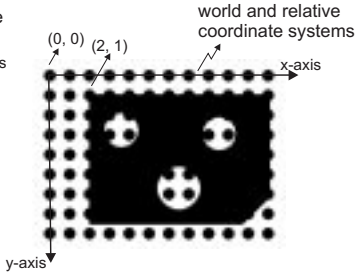
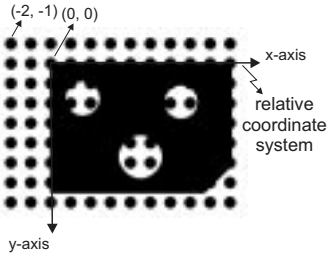


Image of an object.



The object's position within the real-world.



The relative coordinate system can be moved to align it with the top-left corner of the object.

Note that this image is for illustrative purposes only. In general, the object should not be placed over a grid because if the grid of circles and the object are not differentiated when performing the processing operation, then erroneous results will be returned.

To move and/or rotate the relative coordinate system of the current or all subsequent images, use the **Options Calibration Relative Origin** command. Once you change the origin and/or orientation of the relative coordinate system, world coordinates will be returned in this relative coordinate system.

Saving

After you create a calibration object, you can save it using the **Options Calibration Save** command. You can choose to save the calibration object of the current image, or the default calibration object used of all newly created images.

By default your calibration object will be saved in a MIL calibration format (*.mca*). You can also save your calibration object in an Inspector 2.2 format. However, the Inspector 2.2 format only supports non-unity aspect ratio distortion (no rotation or distortion). If you have a more complex calibration mapping and you choose the 2.2 format, only the average X and Y scaling factors will be saved.

Displayed world units

The position of your cursor in an image is displayed in the status bar. By default, the position is displayed in calibrated units. You can position the cursor anywhere in your calibrated image to see corresponding calibrated units in the status bar. If you do not want the status bar to display positions in calibrated units, then uncheck **Show Calibrated** from the **View Properties Display tab**.

Returned results

Measurement and analysis results of a calibrated image are returned in calibrated units, in the **Quick view-Measured Object Properties** dialog box, Measurement table (T_TABLE), and Blob table (AllRes).

Note that script functions that access results have the option of retrieving uncalibrated or calibrated results. To retrieve calibrated results, add the CALIBRATED predefined constant to functions such as *MeasGetResult()* and *BlobGetResult()*.

Note that even though results can be accessed in calibrated or uncalibrated units, script function parameters must be given in uncalibrated units. For example, the parameters for drawing functions, ROIs, and search boxes are in pixel units.

Processing calibrated images

Depending on the type of operation performed on the calibrated image, the destination image is associated with the following calibration object:

- When performing processing operations into new images, the new image is associated with the same calibration as the source image.
- For geometrical operations, the new image uses the default calibration object, which might not be the calibration object that the source image uses.
- When you perform a **Image Advanced Geometry Correct** operation on a calibrated image, the new image coordinates will still be returned in world units. As is expected, the image features in the destination image have the same world coordinates as they had in the source image, despite the fact their pixel coordinates have changed.

  For example, after calibrating the source image below, the world coordinate system of the bottom-left circle is (5,6). When you correct your image, the world coordinates of the bottom-left circle in the corrected image are also (5,6), even though it is evident that the pixel coordinates are different for the bottom-left circle in the source and corrected images.