SIEMENS

SIMATIC

VS 72x / Spectation

Manual

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Warning
indicates that death, severe personal injury or substantial property damage can result if proper precautions are not taken.

Caution
indicates that minor personal injury can result if proper precautions are not taken.

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Notice
draws your attention to particularly important information on the product, handling the product, or to a particular part of the documentation.

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We have checked the contents of this manual for agreement with the hardware and software described. Since deviations cannot be precluded entirely, we cannot guarantee full agreement. However, the data in this manual are reviewed regularly and any necessary corrections included in subsequent editions. Suggestions for improvement are welcomed.

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Preface

Purpose of the Manual

This manual gives you a complete overview of programming with SIMATIC Spectation. It helps you during installation and commissioning. The procedures involved in creating programs, the structure of user programs and the individual language elements are described.

It is intended for persons who are responsible for the realization of control tasks using SIMATIC automation systems.

We recommend that you familiarize yourself with the Getting Started.

For further information about data exchange with the SIMATIC Automation System refer to the "*VS 72x Communication manual*".

Required Basic Knowledge

You require a general knowledge in the field of automation engineering to be able to understand this manua.

In addition, you should know how to use computers or devices with similar functions (e.g programming devices) under Windows 95/98/2000 or NT operating systems.

Where is this Manual valid?

This manual is valid for the software SIMATIC Spectation V 2.7.

Place of this Documentation in the Information Environment

This manual forms as a PDF part of the CD SIMATIC Spectation.

CE Labeling

VS Link, VS Link-PROFIBUS and SIMATIC VS 72x products fulfil the requirements and protection guidelines of the following EU directives:

- EC Directive 89/336/EWG "EMC directive"

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Further Support

If you have any technical questions, please get in touch with your Siemens representative or agent responsible.

You will find your contact person at:

http://www.siemens.com/automation/partner

You will find a guide to the technical documentation offered for the individual SIMATIC Products and Systems here at:

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The online catalog and order system is found under:

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Training Centers

Siemens offers a number of training courses to familiarize you with the SIMATIC S7 automation system. Please contact your regional training center or our central training center in D 90327 Nuremberg, Germany for details:

Telephone: +49 (911) 895-3200.

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- Your local representative for Automation & Drives.
- Information on field service, repairs, spare parts and more under "Services".

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1 Getting Started

This chapter contains important information for both new and experienced users. New users will benefit from general ideas about machine vision as well as from pointers to other sources of information and training. This chapter starts with an introduction to both the newest family of Vision Sensors, the VS 720 Series, including technical specifications and a brief description of every Vision Sensor in that. It then moves onto how to install the software (SIMATIC Spectation user interface), walks the user through the process of setting up the Vision Sensor and explains how to establish communications with it.

The chapter ends with a brief description of the new features of SIMATIC Spectation 2.7, and a guide to other resources.

1.1 What is Machine Vision?

Machine vision, in layman's terms, is exactly that. It can be defined as machines with their own set of eyes. Using their vision, machines inspect products for defects by detecting presence/absence of parts, taking measurements, reading codes, etc. How it works may seem rather complicated at first glance. However, with a little help from basic optics, it is not. The machine's eye mainly looks for changes in contrast and uses a 2-dimensional plane to do so. Our SoftSensors tell the camera (the machine's eye) how to evaluate changes in contrast and in what direction to evaluate them. The camera then collects this information from the image and evaluates it following the user-defined rules. Because the camera's actions are so dependent upon that change in contrast, it is imperative that you adjust your lighting such that the camera (or machine) can get a consistent and close look at the factory product.

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1.1.1 Imaging and Pixels

Every image from the Vision Sensors can be considered an array of pixels. For standard resolution systems, the image consists of 640 columns and 480 rows of pixels (for a total of over 300,000 pixels). For high resolution systems, the image contains 1280 columns and 1024 rows of pixels (for a total of over 1.3 million pixels!). Every pixel in the image can be considered a source of information, so from a standard resolution image, the system obtains over 300,000 data points. For grayscale systems, every pixel provides a numerical value from 0 to 255 which is normalized to values from 0 to 100. This value is the intensity level of that pixel. An intensity value of 0 corresponds to pure black, an intensity value of 100 corresponds to pure white, and the values in between correspond to 99 different shades of gray. For color systems, every pixel provides 3 different intensity values: one for red, one for blue and one for green. These three values make up the RGB content of that pixel. Virtually any color can be represented by using the appropriate coefficient for the base colors (Red, Green and Blue). Using this information Vision Sensors inspect images to provide the user with feedback regarding the presence or absence of a part, flaw detection, code reading/or verification, etc.

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1.2 What is a Vision Sensor?

The Vision Sensor is your hardware tool for assuring quality in manufacturing, gathering data, and providing information to all levels of your enterprise. This information might take the form of device-level data such as inspection values being sent to a PLC or process-level Statistical Process Control (SPC) data. This information might be as generalized as a PASS or FAIL signal or as specific as position feedback to a motion controller. You can use the SIMATIC Spectation software to divide and conquer these tasks. SIMATIC Spectation was designed to be easy to use for anyone.

1.2.1 Newest hardware platform: The VS 720 Series

The VS 720 family of products consists of the following Vision Sensors:

- SIMATIC VS 721: lowest-cost machine vision solution for factories that need high-end photoelectric sensors that easily adapt to new applications. The SIMATIC VS 721 Vision Sensor combines the industry's latest CMOS imaging technology with SIMATIC Spectation firmware to create an easy-to-use but powerful inspection tool. The grayscale CMOS device has a resolution of 640 by 480 pixels which makes this inexpensive Vision Sensor an excellent option for basic applications.
- SIMATIC VS 722: basic Vision Sensor with a CCD for image acquisition. This grayscale Vision Sensor is similar in functionality to the SIMATIC VS 721 Vision Sensor, but it delivers more precision replacing the image acquisition device with a CCD. This Vision Sensor is better than the SIMATIC VS 721 Vision Sensor for precision measurement applications and analysis of parts that are rich in details.
- SIMATIC VS 723: fastest Vision Sensor available. It consists of a 640 by 480 pixel grayscale CCD and a high speed processor. It combines the quality images provided by a CCD with the power of a fast processor to perform delicate inspections at a very high speed.
- SIMATIC VS 723-2: medium resolution Vision Sensor. It consists of a 1024 by 768 pixel grayscale CCD and a high speed processor. Its CCD offers very good features for capturing images based on the same hardware as VS 723.
- SIMATIC VS 724: high resolution system. It uses a high resolution grayscale CCD (1280 by 1024 pixels) to capture images with an unprecedented level of details. Recommended for cases where ultra high precision is a must.
- SIMATIC VS 725: basic color system. It consists of a color CCD of 640 by 480 pixels which makes the Vision Sensor the best choice for most color applications.
- SIMATIC VS 72x-S: camera systems contained within a stainless steel enclosure. These systems have industrial connector and use industrial cables to achieve an IP68 rating. These systems have 6 configurable digital I/O. The following systems are available with the stainless steel enclosure: VS 723, VS 724 and VS 725.

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Every Vision Sensor of the VS 720 family includes the SIMATIC Spectation software to set up inspections on part presence/absence, positioning, defect detection, precise measurement, 1D and 2D code readers, OCR, Color (can be used for grayscale levels in monochrome systems), and programmable tools to accommodate user needs. Figure 1-1 shows the VS 720 SIMATIC VS 724 Vision Sensor.

Figure 1-1: Member of the VS 720 Series: the SIMATIC VS 724 Vision Sensor

VS 720 Series System Specifications

Size: 112mm x 60mm x 30mm (not including lens) + an additional 50mm cable clearance added to 112mm

- Mounting: Four M4 threaded holes (on back of unit), 7.9mm depth
- Weight: 170g / 6 oz. (without lens)
  - VS 72x-S: 850g / 1.875lb (without lens)
- Power Requirements: A regulated and isolated 24 V DC, (210mA at 24 Volts (equivalent to minimum 5W supply)); power supply is needed (sold separately).
- Operating Temperatures: 0-45° C (32-113° F), non-condensing environment; Maximum 50° C / 122° F
- Electronic Shuttering: 10µs – 1s exposure times (VS 721 supports rolling or global shuttering, rolling shuttering should only be used for indexed applications)
- Optics: CS mount standard, C mount-capable with an adapter (sold separately)
- External Ports: Keyed 10 pin RJ-45 connector (Power and Digital I/O), RJ-45 (10/100 megabit Ethernet communications, TCP/IP protocol connector)
  - VS 72x-S: Industrial M12 x 8 10/100 Mbps Ethernet communications, Industrial M12 x 8 connector for power and digital I/O

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- Digital I/O: 24 Volts DC regulated, 8 configurable inputs & outputs, NPN (current sinking) inputs, PNP (current sourcing) outputs, active high signals. Inputs can sink up to 1.5mA and outputs can source a maximum of 50mA.
  - VS 70x-S: 6 configurable inputs and outputs.

Warning

Users are strongly encouraged to the SIMATIC VS 720 Digital I/O and Power Cable (sold separately).

- Certifications: CE certified

Summary of Image Sensor Information

System	Description	Resolution	CCD Size (Format)	RAM	Flash
VS 721	Grayscale CMOS	640x480	CMOS 5x3.7mm (1/3")	32 MB	16 MB
VS 722	Grayscale CCD	640x480	4.8x3.6 mm (1/3")	32 MB	16 MB
VS 723	High Speed Grayscale CCD	640x480	4.8x3.6 mm (1/3")	64 MB	16 MB
VS 723-2	Medium Grayscale Resolution CCD	1024x768	5.80(H)x4.92(V) mm (1/3”)	64 MB	16 MB
VS 724	High Resolution Grayscale CCD	1280x1024	7.60(H)x6.20(V) mm (1/2”)	64 MB	16 MB
VS 725	High Speed Color CCD	640x480	4.60(H)x3.97(V) mm (1/4”)	64 MB	16 MB
VS 723-S	Stainless Steel Enclosed Grayscale CCD with Fastest Processor	640x480	4.8x3.6 mm (1/3")	128 MB	16 MB
VS 724-S	Stainless Steel Enclosed High Resolution Grayscale CCD with Fastest Processor	1280x1024	7.60(H)x6.20(V) mm (1/2”)	128 MB	16 MB
VS 725-S	Stainless Steel Enclosed Color CCD with Fastest Processor	640x480	4.60(H)x3.97(V) mm (1/4”)	128 MB	16 MB

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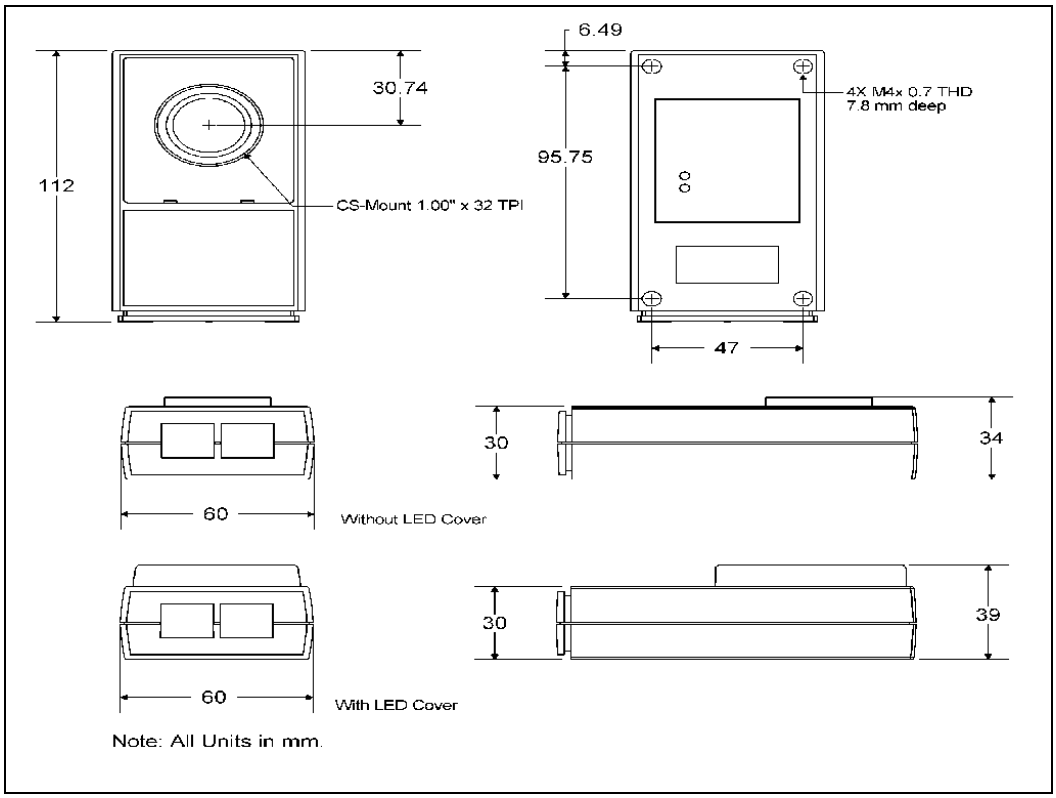
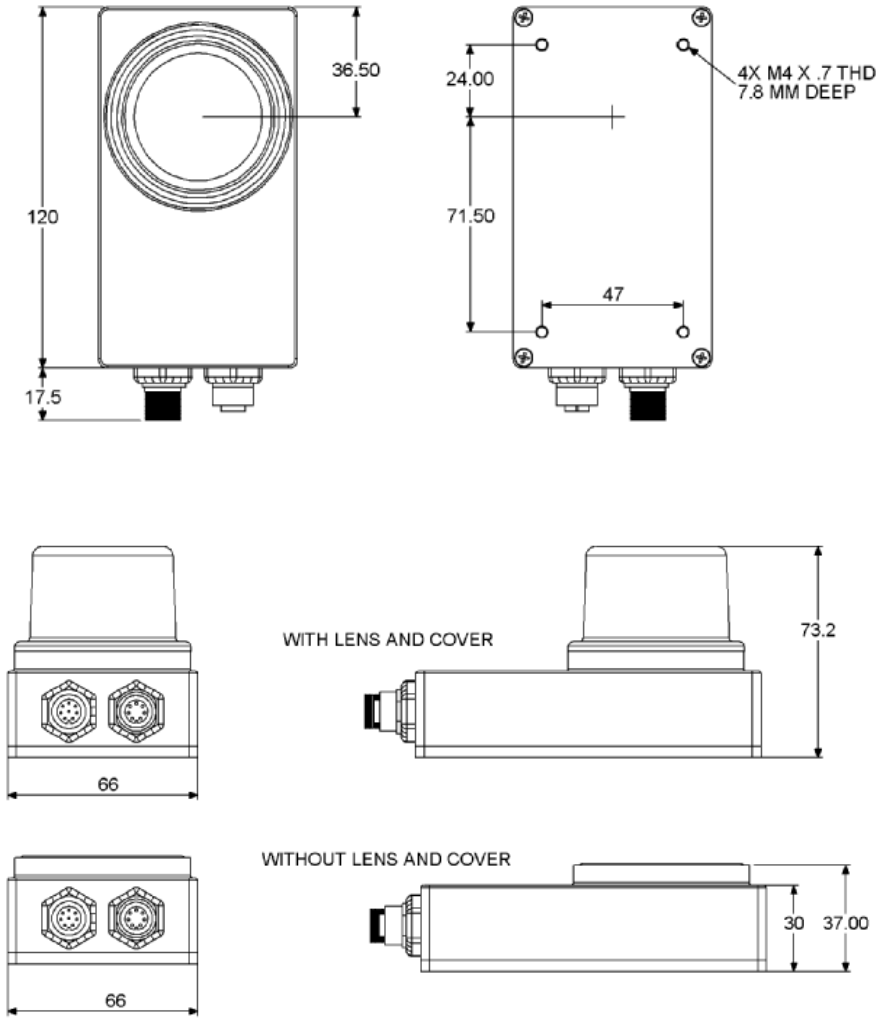
VS 720 Series Vision Sensor Dimensions



VS 72x-S Series Stainless Steel Vision Sensor Dimensions



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Installing SIMATIC Spectation Software

While it may be very tempting to immediately insert the SIMATIC Spectation CD into your computer, please take a moment to ensure that installation will go smoothly. The following is a list of requirements necessary for a proper installation of this version of SIMATIC Spectation.

PC Requirements:

- 400 MHz Pentium-class PC: For best results, we recommend that you use Windows XP on your PC. However the following Windows platform will work as well: Windows 98, Windows NT 4.0 or Windows 2000. A minimum of 128 MB RAM will be required. A faster processor will directly relate to faster updates of images in the SIMATIC Spectation user interface. Note: only Windows NT, 2000, and XP support the new event logging capabilities of Spectation.
- Available Space: Spectation requires a minimum 30 MB hard disk space.
- Ethernet Card: 10/100 megabit Ethernet card with integrated RJ-45 jack. For laptop computers, an Ethernet card with CardBus technology is recommended.

Installing the SIMATIC Spectation User Interface

The steps to follow are:

- Insert the SIMATIC Spectation CD. The SIMATIC Spectation installation should automatically start. However, if the CD does not automatically run, follow these steps:
  - From the Start menu, choose Run.
  - Type D:\InstallSpectation263.exe (substitute the appropriate drive letter of your CD-ROM drive for D) and press Enter.
  - Follow the installation instructions on screen.

Hint

The SIMATIC Spectation installation program leaves intact older versions of SIMATIC Spectation. You will still have access to older versions of SIMATIC Spectation.

For example, the firmware file for SIMATIC Spectation 2.6 release 1 for a SIMATIC VS 725 system is named “Spectation263.VS 725.” These firmware file contains the code that needs to be downloaded to the Vision Sensor. They are the part of SIMATIC Spectation that resides in the Vision Sensor where all the calculations take place.

After installation you can start SIMATIC Spectation with Start\SIMATIC\Machine-Vision\.

1.3 Vision Sensor Hardware Setup

In this section, physical connections to the Vision Sensor are explained. This includes powering the system and connecting the communications cable.

1.3.1 Unpacking and Powering the VS 720 Vision Sensor

	Connect the keyed RJ-45 Digital I/O and power cable to the Vision Sensor (typical part number: 6GF9002-2AD). The cable used for a VS 720 Vision Sensor has a 10 pin RJ-45 connector and no connector on the other end. **Note:** The VS 72X-S Sensor uses an industrial M12 connector 8 pin male connector for power and I/O. The cable used with the VS 720X-S Vision Sensor has an 8 pin industrial M12 female connector with no connector on the other end.
	Connect the Ethernet communications cable. The VS 720 Sensors use the standard 8 pin RJ-45 ethernet connectors. The VS 72X-S Sensors use a special industrial cable communications cable with on M12 male connector and one RJ 45 connector. **Note:** It is recommended that you communicate through an Ethernet switch. However, if you are connecting the other end of the Ethernet cable directly to a PC (as opposed to a hub), make sure to use a crossover Ethernet cable or a crossover connector.

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VS 72x Port Digital I/O Power Supply Assignment (RJ45 connector without LEDs)		
PIN	**Signal**	**Wire Color**
1	DI/DO 1	Yellow
2	DI/DO 2	Violet
3	DI/DO 3	White
4	DI/DO 4	Orange
5	DI/DO 5	Grey
6	DI/DO 6	Black
7	DI/DO 7	Red
8	DI/DO 8	Blue
9	Ground	Green
10	24 V	Brown
		Apply power to the Vision Sensor and wait for the system to boot. The Status light will illuminate with a constant green light when the boot sequence is finished. Note: The status light on the VS 72X-S Sensor is located above the lens and under the lens cover.
		Attach a lens to your camera. If you are using a C-mount lens, you will find it necessary to use a 5mm adapter (6GF9001-1AP). If you have a CS-mount lens, you will not need the adapter.

1.4 Communicating with the Vision Sensor

The Siemens Vision Sensors can use Ethernet and the TCP/IP and UDP/IP communication protocols. This section outlines how to establish communications with the Vision Sensor. In order to communicate with a Vision Sensor, you will need the following:

- PC: A Pentium class PC with the following hardware and software:
  - Windows Operating System: Windows 98, NT, XP, or 2000. (Windows 2000 or Windows XP is recommended)
  - Spectation Software: Siemens Spectation User Interface.
  - Ethernet Network Card: 10/100 megabit Ethernet card. For laptop computers, an Ethernet card with CardBus technology and integrated RJ-45 jack is recommended. The Ethernet card's appropriate drivers should be installed and the TCP/IP communications network protocol should be installed and setup.
  - Ethernet Switch (Hub): Full Duplex 10/100 megabit Ethernet Switch is necessary for connecting multiple Vision Sensors in a network.
  - Ethernet Cable: Category 5 Ethernet Cable with RJ-45 connectors. (Note: a cross-over Ethernet cable should be used when connecting directly to a single Vision Sensor)

The RJ-45 connection on your VS 720 Vision Sensor is designed to communicate between the Vision Sensor and a PC running Spectation. To do this, the PC must have an Ethernet network card running the TCP/IP protocol. Figure 1-2 shows where the connectors are located in the Vision Sensors.

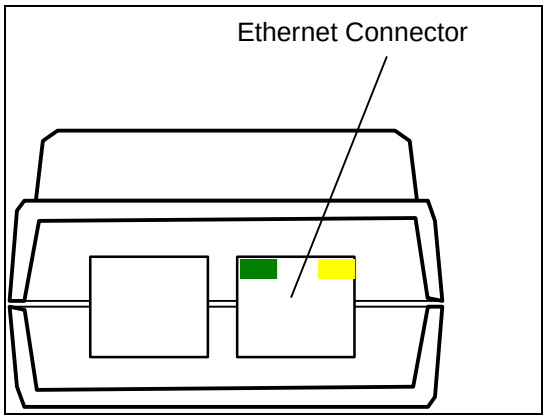

Figure 1-2: The RJ-45 (Ethernet) port is the port on the right with indicator LEDs built into it.

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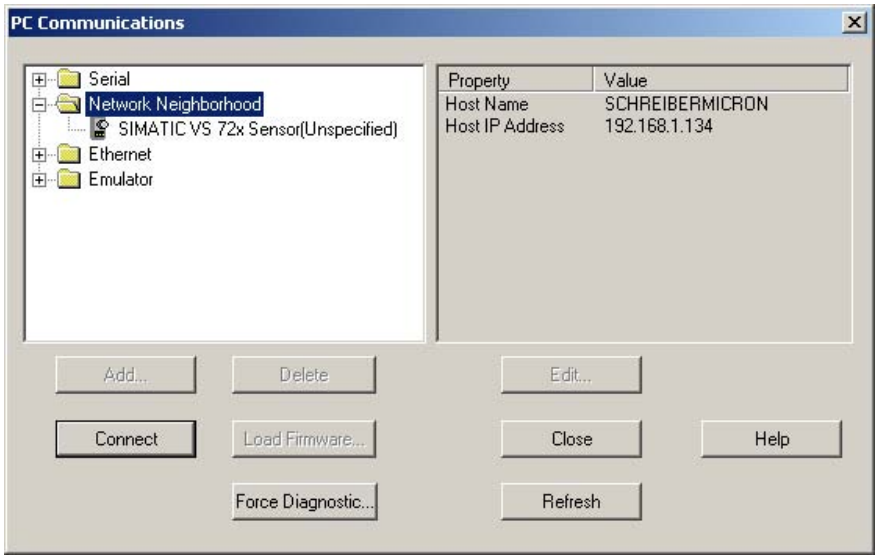
Assigning an IP Address to a Vision Sensor

The PC and Vision Sensor communicate using the TCP/IP and UDP/IP networking protocols. TCP/IP stands for Transmission Control Protocol / Internet Protocol and is based on identifying elements on a network by unique numbers, called IP numbers. In order for two devices to communicate they must reside on the same Local Area Network (LAN), be part of the same sub network, and have unique IP addresses.

All Vision Sensor systems come with a default IP address, which must be changed to a number compatible with both your computer and LAN. An IP address is the equivalent to a telephone number. The Vision Sensor will assign itself a default IP address. You must then re-assign a new IP address that is compatible with your local network. In other words, you must make sure that you have the right phone number to call the Vision Sensor!

Please use the following steps to set your computer and camera up with the correct IP addresses:

- Start Spectation.
- Click and Open the “Network Neighborhood”. Network Neighborhood allows you to identify cameras on a network. Your computer will search your local network for Vision Sensors. When “Network Neighborhood” is highlighted, the right pane will show the current IP address of your computer. Record your computer’s (Host) IP address on a piece of paper. If no camera has been found, wait about 10 seconds and search again. There is sometimes a small delay due to the time it takes for your computer to recognize the camera.

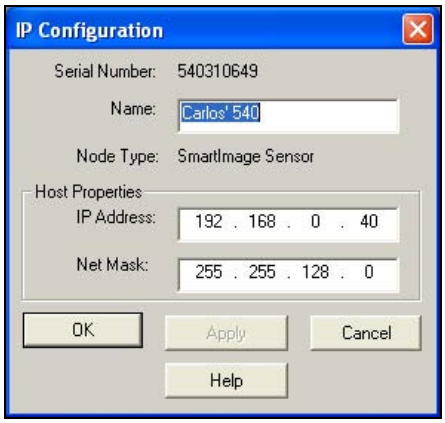


- Highlight the Vision Sensor with the appropriate serial number.

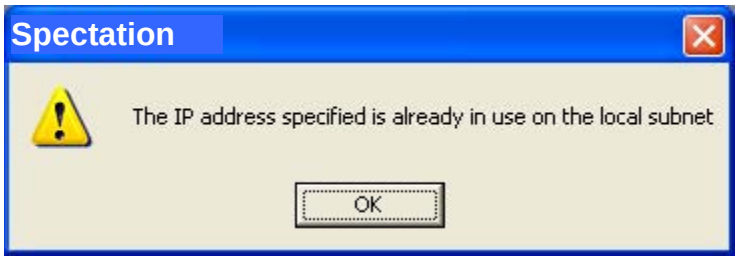
Note

The VS 720 Vision Sensors will have a serial number in parenthesis next their user configurable name. It is easiest to identify these units by connecting directly to them or by the unique random IP that is initially assigned to them. This IP will have the form 169.254.xxx.xxx and will be visible in the right pane when the Vision Sensor is highlighted.

- Click on the edit button. When you do so, the above window will appear. In the Edit dialog box, you can change the camera's IP address, subnet mask and the name of the Vision Sensor. Set the IP address to be same as your computer's IP address except for the last number. For instance, computer: 192.168.1.113; Vision Sensor: 192.168.1.32. When you hit the apply button, the units information will be permanently stored in the unit's flash memory. If you are not sure about which IP address to use you should ask your network administrator.



- If the IP address is already being used by another device, you will receive the following message. Simply go back and edit the systems' IP address once more to a number that is not currently being used.



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- Highlight your Vision Sensor in the Network Neighborhood and click on the Add button. This will add the Vision Sensor to the Ethernet folder, which contains your most commonly used systems.

Hint

After configuring your Vision Sensor with its new IP address, you should affix a label to the camera with the Ethernet properties so that you do not forget this important information

Repeat these steps for each Vision Sensor you have. When complete, the PC and all Vision Sensors will have unique IP addresses. Connect all of the systems to a hub (or multiple hubs) and the hub to your PC. You now have an “Industrial Ethernet network.”

- For more advanced network configurations, you will need to adjust the Sensor Address Mask. For a Vision Sensor and PC to communicate, they must be on the same sub-network. This means that the masked portions of the camera’s IP address must be identical to the PC’s. For example, with the default mask of 255.255.255.0 on your Vision Sensor, only the fourth portion of the PC’s IP address may be different from your Vision Sensor. In this example, a camera at 192.168.0.242 can communicate with a PC at 192.168.0.200, but not with a PC at 192.168.1.200. The following table summarizes the use of the Sensor Address Mask property with Ethernet networks.

Sensor Address Mask	Camera IP Address	Valid Sample PC IP Addresses
255.255.255.0	192.168.0.242	192.168.0.200, 192.168.0.100, 192.168.0.240
255.255.0.0	192.168.0.242	192.168.1.200, 192.168.35.67, 192.168.222.35
255.0.0.0	192.168.0.242	192.25.1.200, 192.222.22.242, 192.0.1.45

Warning

Whenever connecting a node to an existing network, please exercise extreme caution. Connecting a Vision Sensor system onto a network without the Network Administrator’s knowledge is not recommended.

1.4.1 What's New in This Version

Some enhancements have been added to the latest version of SIMATIC Spectation (Spectation 2.7). The major enhancements are summarized here. For more information about each one of them, please see the appropriate section of this User's Guide.

Ability to read new types of Barcodes

In SIMATIC Spectation 2.7, the 1-D and Stacked codes reader SoftSensors were enhanced. Decoding of the following codes was added to this version of SIMATIC Spectation:

- Stacked and truncated versions of RSS-14 (the standard RSS-14 was already supported in SIMATIC Spectation 2.6),
- Micro PDF 417
- RSS Limited
- RSS Expanded (standard and stacked)
- RSS-14 Composite
- RSS Limited Composite
- RSS Expanded Composite
- UPC/EAN Composite
- UCC/EAN-128 Composite
- PLANET

Ability to grade new types barcodes

In addition to the above enhancements, it is now possible to grade some of the barcode types that the SoftSensor can read. Besides the types that already supported grading in the past (USS-128) and UPC/EAN) the following barcode types can be graded: Interleaved 2 of 5, USS-39, Codabar and Code 93)

New 2-D Reader SoftSensor

The new 2-D Reader SoftSensor consolidates DataMatrix, SnowFlake and Vericode (requires a special license) code reading. In addition, the DataMatrix Reader was greatly enhanced through the implementation of new, more robust and faster algorithms. The new DataMatrix reader allows the user to train on a good code and then search for and decode similar codes in subsequent images.

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Dynamic Color Reference

Starting with SIMATIC Spectation 2.7 the reference of a color from a Pixel Counting SoftSensor through the use of the Dominant Color Threshold will be a dynamic process. In the past, the reference of the color data was a static, one-time process that would require the user to explicitly import the new color data every time a color needed to be relearned. Now, this process will occur (like it does with Position Reference) on every inspection. Also, when a merge operation is performed, the colors that are merged still remain on the list but they are set to inactive. A new color entry is created with all color data merged, this color is active.

1.4.2 Getting More from Spectation

In addition to the Spectation Vision Sensors Installation & User's Guide, you can learn more about Spectation software from the following resources:

On-line Documentation & Help Files

After Spectation Software has been installed on a PC, all the necessary documentation is included along with the application software. HTML Help and PDF (Portable Document Format) versions of the written documentation are included.

- HTML Help: the help file is a great source of information about all aspects of Spectation. There are several ways to access the help file:
  - Click on the Help menu and choose Help File Index or press F1.
  - Use the Help buttons located in most dialog boxes (navigates to just the right location in the help file).
  - Hold the Shift key and press the F1 key to get the prompt. From this, click on any part of the user interface for context-sensitive help.
  - The Help file can be viewed independent of a Spectation session. Simply click on the Windows Start menu, choose SIMATIC Applications, and then choose "Spectation Help".

For information visit the web site, http://www.siemens.com/machine-vision.

- From Spectation, click on the Help menu and choose Siemens on the World Wide Web. Start your web browser and type http://www.siemens.com.

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2 A closer look at the system

This chapter describes all the basic principles behind Vision Sensors. The internal structure of the Vision Sensor is described and a brief description about the parameters available at every level is provided. From system level (unique to every Vision Sensor) to SoftSensor level (dependent upon the SoftSensor being used), this chapter illustrates the parameter's use and the functionality these add to the system. Once the user becomes familiar with the internal structure of Vision Sensors, the use of these will become a very simple procedure because Spectation is designed to be an easy to use interface. The Vision Sensor hardware emulator is also explained in this chapter. The hardware emulator is a very powerful tool that simplifies troubleshooting, setup and assists in training.

As mentioned before, Vision Sensors can take images and analyze them to determine whether, based on user defined parameters, that is a good image or not. Based on this output from the Vision Sensor the user can take the necessary action (i.e. reject a part, fix the production process, etc.). The functionality inside the Vision Sensor is yet to be discussed, and is the purpose of this section. Figure 2-1 shows the hierarchical tree determined by inner components of Vision Sensors.

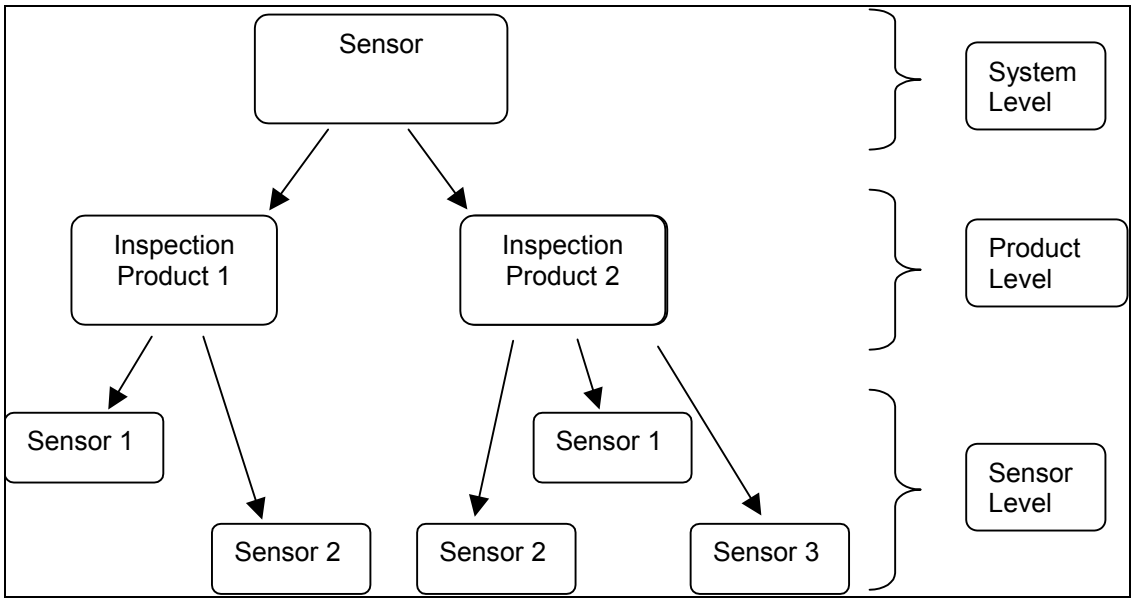

Figure 2-1. Hierarchical organization within the Vision Sensor

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At the top level, we find the system parameters. These parameters are common to every inspection that the Vision Sensor takes, they affect the overall behavior of the Vision Sensor rather than that of a certain inspection. At the product level the user can change parameters that affect a specific inspection such as illumination. Essentially, a product is directly associated with an inspection, so Product parameters affect only one of the inspections that the Vision Sensor is taking. Finally, at the sensor level, the user can set some sensor parameters. Each sensor performs part of an inspection; here is where all the pieces of every inspection are defined. SoftSensors are associated with inspection tasks.

In order to illustrate this functionality let us work with an example. The part in Figure 2-2 needs to be inspected. First, we need to verify that the drillings on the left end are vertically centered, a certain distance apart, and of a certain radius. After that, we need to verify that the label on the right end is centered, aligned and that it contains the correct code. Finally, the specific data from every inspection has to be sent out of the Vision Sensor using Modbus communications. The existence of products inside Vision Sensors simplifies this task. The inspections can be separated into two groups, those that take place on the left end of the part and those that take place on the right end of the part. This will allow the user to trigger the Vision Sensor twice as the part moves in a conveyor from left to right. The first trigger would occur when the left end is in front of the Vision Sensor and the second one when the right end is in front of the Vision Sensor.

Figure 2-2: Sample part to be analyzed in two different inspections.

This would not only add modularity to the process but also would allow for a more precise inspection because now we can zoom in on the part. There is not a need to have the entire part in a single image. The inspections are then separated into products. A product would inspect the left end of the part and another product would inspect the right end. In order to determine if there is a problem with the part, those products would use a number of SoftSensors. For the first product, both Math and Measurement SoftSensors are needed to perform the inspection. For the second product the same SoftSensors are needed and also a label reader SoftSensor (OCR SoftSensor) is needed. Finally, to send out the data, communications, a system level parameter, needs to be configured. Regardless of the inspection taking place, a data transfer will occur.

2.1 System Parameters

As mentioned before, the System level of a Vision Sensor controls the overall functionality of the Vision Sensor. The main system parameters are inspection mode, password protection, I/O configuration, background scripts, power-on-product, trigger source, FOV balance, and communications setup.

2.1.1 Inspection mode

A Vision Sensor can be taking images for the purpose of inspecting them or simply for displaying them in a user interface, so the fact that the Vision Sensor is taking images does not mean that it is inspecting them. The inspection mode determines whether the Vision Sensor is currently inspecting images or not. The difference between these two modes is that when the Vision Sensor is inspecting the images, it sends out the user defined outputs indicating the result of the inspection. The inspection mode requires an inspection product. As it was explained before, every product defines a specific inspection, so for the inspection mode to be on, an inspection product must be selected. If a product is selected as the inspection product and the inspection mode set to running inspections, when the Vision Sensor is triggered, it acquires an image and inspects it according to the sensors that the selected inspection product contains.

2.1.2 Password protection

In order to provide administrators with access control, Spectation allows for the creation of different users. This allows system administrators to give specific control of the system to different users. Each user that is set up is given certain access restrictions, from simply stopping the inspection mode to editing the parameters of every SoftSensor, administrators can choose which tasks each user is allowed to perform on the system. Furthermore, an inactivity timeout can be set to maximize security. Access control is independent of PC being used, that is, the access control information is loaded in the internal flash memory of the Vision Sensor.

2.1.3 Digital I/O Configuration

Vision Sensors have 8 configurable I/O lines. It should be mentioned that the number of I/O lines in the VS 720 Series can be increased to 32 inputs and 64 outputs by using remote Ethernet I/O devices. The I/O lines can be configured to better suit the user’s needs. Vision Sensors do not have a concept of input or output lines. Every I/O line can be configured as an input or as an output depending on the user’s needs. This assignment is a system parameter because another device will be connected to the I/O lines, and this cannot change between inspections.

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Input Functions

Inputs on the Vision Sensor can serve one of 5 functions. The following table summarizes these functions:

Input Function	Purpose
Product ID Bits	Each line will represent a digit to make up the binary code that identifies a product based on the assigned Product ID.
Product Select	Toggled when **Product ID** bits are active to select a Product. This signal tells the camera that the Product ID in binary code is ready for reading.
Inspection Trigger	Turned on to start acquisition of an image for inspection when the system is in external trigger mode.
Digital Relearn	Used by Template, ObjectFind, OCR, Code readers and Color SoftSensors to automatically relearn or reset SoftSensor parameters. Relearning will occur if the Digital Relearn input is held active during the next inspection and the SoftSensor has its Digital Relearn parameter checked.
Input 18-31	Inputs 18-31 are used in combination with SoftSensor scripts and Background Script to monitor inputs. (See the Script Reference Manual for more details and examples)

In addition to assigning specific functions to the I/O pins, the user can specify other parameters to ensure that the inputs are correctly read by the system. The use of these parameters depends on the hardware device providing the connection to the Vision Sensor. These parameters are polarity inversion and debounce times. Polarity inversion is used to change the system lines from active high to active low. Debounce times are used when the signal received by the Vision Sensor is affected by noise. If this is the case, the user can select a period of time for which the Vision Sensor does not look at the line after registering a transition in the state of that line.

Output Functions

Just like for inputs, there is a number of output functions that can be assigned to the I/O lines. The following table summarizes the available output functions and their meaning. Any function may be assigned to any I/O line.

Output Function	Purpose
Pass	After inspection is completed, **Pass** is set to show that all SoftSensors within the Inspected Product passed inspection.
Warn	After inspection is completed, **Warn** is set to show that any SoftSensor within the Inspected Product met its warn condition and no SoftSensors failed.
Fail	After inspection is completed, **Fail** is set to show that any SoftSensor within the Inspected Product failed inspection.
Busy	**Busy** is set after **Inspection Trigger** is read until the inspection result (**Pass, Warn** or **Fail**) is signaled.
Strobe	When active, the corresponding strobe light source will be on during image exposure.
Strobe 2	When active, the corresponding strobe light source will be on during image exposure.
Strobe 3	When active, the corresponding strobe light source will be on during image exposure.
Resource Conflict	Signals a conflict between inspections trying to use the same system resources. Typically, signals that an **Inspection Trigger** was received while the system was acquiring another image.
Select Pass	While **Select** input is active, **Select Pass** signals that the **Product ID** bits signaled a Product ID found in the system.
Select Fail	While **Select** input is active, **Select Fail** signals that the **Product ID** bits signaled an invalid Product ID.
Acquiring	Signaled after **Inspection Trigger** is read, during exposure time and image digitization. Another **Inspection Trigger** cannot be signaled while **Acquiring** is active.
Inspecting	Signaled after the **Acquiring** signal while an image is being processed for inspection. (Note: **Acquiring + Inspecting = Busy**)
Inspection Toggle	Changes state once after each inspection is performed.
User1 – User16	User definable outputs that go active or inactive based on combination of the results of the SoftSensors being used. User Definable outputs are Product-specific.
Wrong Code	Indicates whether any reader SoftSensor in the product failed because of a string mismatch (high) or because it could not read anything (low).
Output24-Output31 Output48-Output64	Outputs that can be set through Scripts. See the Siemens Script Reference Manual for more details.

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Unlike for input functions, in addition to assigning specific functions to the I/O pins, the user can specify other parameters to ensure that the outputs are correctly received by another system. Spectation offers extra flexibility for the outputs to determine when and how the outputs are made available. The use of these parameters depends on the hardware device providing the connection to the Vision Sensor. These configurable parameters are:

- Invert Polarity: any line configured as an output on a Vision Sensor system is active in the high state. The “Invert Polarity” option makes it active in the low state.
- Timing: outputs from the Vision Sensor can be made available immediately after inspection or at a fixed delay after the trigger signal.
- Pulse Width: outputs can remain high until the next inspection, or simply stay high for a predefined period. The user can also force a separation between consecutive outputs (useful when working at very high speeds).

2.1.4 Other Communications Settings

There are several ways to get data into and out of Vision Sensors including Ethernet and serial communications. There is also a number of Drivers for specific robots available. For specific information on these methods see Vision Sensor Integration.

2.1.5 Background Scripts

Background Scripts are system-wide programs that can run independent of the Inspection Product. Some tasks assigned to Background Scripts are Product selection for an inspection, register reading and writing, exposure time control, communications, etc. More information on Background Scripts can be found in the Siemens Script Reference Manual. Contact your Siemens Distributor for more information.

2.1.6 Power-on-Product

The Power-on Product allows the system to begin running inspections as soon as the camera is turned on and “alive”. Only Products that have been saved to flash memory may be assigned as Power-on Products because those which remain in RAM memory will be lost on power-up. The Power-on Product assignment is critical when the Vision Sensor is used as a stand-alone system. Once the system is configured with a PC, the Power-on Product must be assigned in order for the sensor to start running inspections (thus signal digital outputs) immediately after cycling the power.
In selecting the Power-on Product at start-up, the Vision Sensor actually completes 2 tasks. First, the system selects the named Product for inspections (called the Current Inspection Product). Second, the Vision Sensor sets the Inspection State to Running.

Note

A Vision Sensor without a power-on-product will not start running inspections after power-up.

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2.1.7 Trigger Source

Another system parameter is the trigger source. This parameter indicates how the system is triggered. The options are external trigger and internal trigger. External trigger requires that the trigger input function be assigned to an I/O line and that an external device provide a signal on that input whenever an image is to be taken. Internal trigger is an automatic mode, in which the camera takes a new image periodically at fixed user-defined intervals or simply at full speed.

Note

When working at full speed the Vision Sensor may show a slow response to communications because the inspections take priority over other processes.

When external trigger is the option for triggering the system, the user can define a fixed delay after trigger if the detection of the part to be inspected cannot be made at the precise moment that the part is in front of the Vision Sensor. This way, the user can have a sensor detecting the position of the part, and triggering the system, but the Vision Sensor will not acquire an image until the part is precisely in the correct position.

2.1.8 FOV Balance

When the illumination is not uniform and the physical setup cannot be improved, balancing the field of view may be a solution. The user can select to calibrate (automatic process) and activate a balance of the field of view in a certain region of the image (or over the entire image). This will correct the pixel intensities to make the illumination seem even along the image or the selected region. It should be noted that the balancing alters the information in the pixels, thus the image itself. In general, uneven light should be made even by changing the physical setup (position, source, etc.) instead of using this option. This procedure is not recommended for precision measurement applications, in which the information contained in every pixel may be vital for the success of the inspection.

Note

Although the FOV balance calibration is a system parameter, its activation is product-specific.

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2.1.9 Sensor Gain

The sensor gain adjustment makes your Vision Sensor's CCD more sensitive to light. Gain has a maximum value of 25 and is initially set to 2. A Gain of approximately 2 is generally recommended.

Hint

Is your application on a constantly moving conveyor line? Effective use of the gain setting allows you to minimize blur in your images due to relatively long exposure times. With parts moving past the camera, increase the gain, then decrease the exposure time until the images no longer appear blurry.

2.1.10 Reflectance Calibration

The goal of Reflectance Calibration is to have the measured reflectance of the camera to match an external device. Color monitoring, Segmentation and 1-D ANSI barcode grading are the sensors that can benefit from this. Note that Reflectance Calibration can be performed for gray scale cameras as well as color.

There are two reasons why you may need to have Reflectance Calibration for color cameras. One reason is to have more accurate relative color measurements with Color Monitoring and/or Segmentation. The absolute color values themselves would not be accurate but the relative ones are closer to reality. Another reason why you may need Reflectance Calibration is to match two cameras to each other. If they are both calibrated with a single target, the color values they measure will match. For more information in this procedure refer to the integration notes section of the Siemens website or the Spectation help file.

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2.2 Product Parameters

The next hierarchical level inside Vision Sensor is the Product Level. At the product level, we have independent subsystems which are responsible for specific inspections. These subsystems are called products. All the products in a system use a common set of system parameters (as discussed before). Since every product is responsible for a specific inspection, products need to have control over the imaging process. That is why parameters such as illumination, image window, exposure time are Product level parameters. We will now discuss them.

2.2.1 Exposure Time

Exposure time refers to the time that the electronic shuttering mechanism exposes the imaging acquiring device (CMOS device for the SIMATIC VS 721, CCD for the other systems) to light for image acquisition. The longer the exposure time, the more light enters the device. Three factors will determine the exposure time you set for an inspection:

- The overall speed of the parts. For high-speed parts, short exposure times are recommended to minimize blur within the images.
- The overall inspection rate (parts per minute). In situations where the overall part rate is high, exposure time should be minimized to optimize the inspection.
- The available light. Brighter lighting fixtures allow for shorter exposure time whereas dimmer ones require longer exposure time.

There may be instances in which you must reduce your exposure time. You have the following options to help reduce exposure time and still maintain overall image intensity:

- Increase the light aimed at the inspection area.
- Increase the gain on the CCD. Gain is the ratio of output over input, or, in this case, the overall increase in light intensity. Increasing the gain makes the CCD more sensitive to light. Caution: high gain settings may produce a grainy image that may affect sensitive inspections.
- Use a lens with an adjustable aperture. Many C and CS mount lenses have aperture controls.

Note

An aperture is the hole that lets light through the lens onto the imaging surface. The larger the hole, the more light can strike the CCD. Opening the aperture may reduce the depth of field. Doing so will make it more difficult to focus on objects if they vary in distance from the lens.

Warning

Increasing exposure time slows down the image acquisition process and may increase image blur for moving inspections.

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2.2.2 Digitizing Time

This parameter determines the precision of the analog to digital conversions in the image acquisition device. The slower digitizing time allows for more precise conversions. It is recommended to use the default value. Visible changes in the image are not likely to be observed when changing this option. Depending on the system, users can choose between different digitizing times to speed up the process or to get the best possible image. A parameter directly related to the digitizing time is the partial window acquisition (explained below). When partial image acquisition is being used, the acquisition time decreases to a fraction of the selected digitizing time. This fraction is proportional to the size of the image being acquired.

2.2.3 Partial Image Window

Some applications may not need to process the entire image, but just a portion of it (if the part to inspect is consistently located). Vision Sensors allow the user to select a specific window within the image so only that window is acquired.

One portion of the total inspection time is for image acquisition. The Vision Sensor CCD, with a resolution of 640x480 pixels takes approximately 13ms to transfer the image from the CCD into memory. This time is proportional to the number of pixels being acquired. Reducing the acquisition window to 320x240, for example, would cut the acquisition time to approximately ¼ the original value.

2.2.4 Antiblooming

Blooming effect occurs when pixels absorb so much light that they saturate and cause neighbor pixels (mostly in the vertical direction) to saturate even if their original intensity level was below saturation. When Antiblooming is turned on, local spots of overexposure are reduced, thus minimizing streaks and washed out areas of the image. Antiblooming will correct the image but will add to the overall Image Acquisition Time as a result. Antiblooming is not available in color systems.

Warning

Do not enable Antiblooming when working with the Measurement SoftSensor when using sub-pixel computations. Results may be affected by as much as one full pixel when Antiblooming is activated.

2.2.5 Illumination

The illumination signal is a digital output of the Vision Sensor. Strobe light sources from Siemens are designed to use the strobe illumination signal.
Pulse width for the strobe signal is determined by the Product exposure time (which is a Product-specific parameter). These two signals are tied together so the strobe light remains on for the duration of the CCD exposure to light.

However, when more specific lighting is needed, up to three external strobe lights can be controlled using the digital I/O lines.

2.2.6 Product Identification

Every product in a Vision Sensor can be assigned a number. This number, called the Product Digital ID, is used to reference every product in a Vision Sensor. This number enables the user to send a digital signal to the Vision Sensor to indicate which product to use for a specific inspection. In order to do that, a number of I/O lines must be dedicated to the Product ID bit input function. The number of lines dedicated to this function determines the maximum number of products that can be selected externally. Basically, n lines dedicated to Product ID bits will enable the user to select amongst 2^n products. A common configuration for I/O setup involves designating 4 lines as Product ID bits (bits 0 through 3). The following table reviews the binary combinations for 16 Product ID numbers (binary 0-15) using these 4 input bits:

Product ID	**Binary Pattern (Bit 3, Bit 2, Bit 1, Bit 0)**	**Product ID**	**Binary Pattern (Bit 3, Bit 2, Bit 1, Bit 0)**
0	0,0,0,0	8	1,0,0,0
1	0,0,0,1	9	1,0,0,1
2	0,0,1,0	10	1,0,1,0
3	0,0,1,1	11	1,0,1,1
4	0,1,0,0	12	1,1,0,0
5	0,1,0,1	13	1,1,0,1
6	0,1,1,0	14	1,1,1,0
7	0,1,1,1	15	1,1,1,1

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2.2.7 Product Selection

Digitally selecting a Product is a simple process. Refer to Figure 2-3 for a diagram illustrating the following procedure. First, set the binary bit pattern of a Product's ID number on the "Product ID Input" lines. When the Product ID bits are loaded (in this case Product ID 1, which is 01 in 2-digit binary code) the Product Select line should become active. This tells the Vision Sensor to read the data bits from the Product ID bit lines. When this signal is sent to the system, a response could be read indicating a successful/unsuccessful operation. Two outputs are dedicated to alerting the user of the success or failure of the digital selection process: Product Select Pass and Product Select Fail. Reading one of this should be enough to determine the success of the product selection.

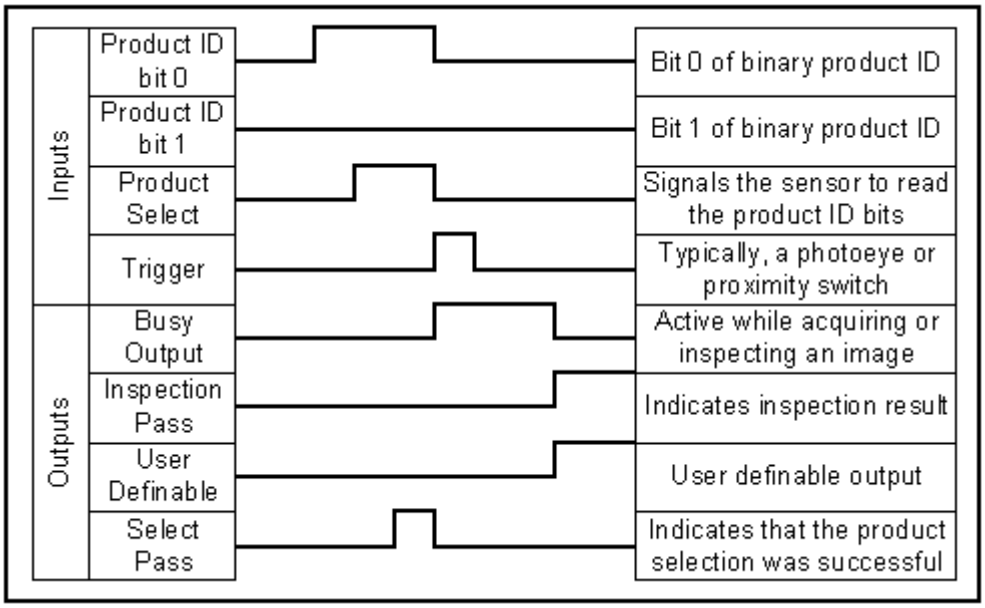

Figure 2-3: Select a Product using the digital inputs. The above diagram shows the I/O timing of the Product Selection process.

For example if a Product ID of 3 is selected but the camera has only products with ID's 0, 1 and 2, Product Select Fail should be high and Product Select Pass should be low. When the product selection has been completed the system can be triggered for an inspection.

2.2.8 Product Graphs

Product graphs help users troubleshoot systems as well as gather statistical data about the inspections. The graphs available at the Product level are: Pass/Warn/Fail, Result Table, Inspection Statistics, Inspection Times, and Digital I/O. These features are made available from the Spectation user interface; they do not reside in the Vision Sensor.

The Pass/Warn/Fail graph keeps count of the inspection results. It Shows the actual counts of Fail, Pass, and Warn outputs as well as an indication of the percentage of the total inspections taken that those counts represent. The graph shows the number of inspections as the abscissa (X axis) and the running percentages of inspection results as the ordinate (Y axis). Figure 2-4 shows a Pass/Warn/Fail graph.

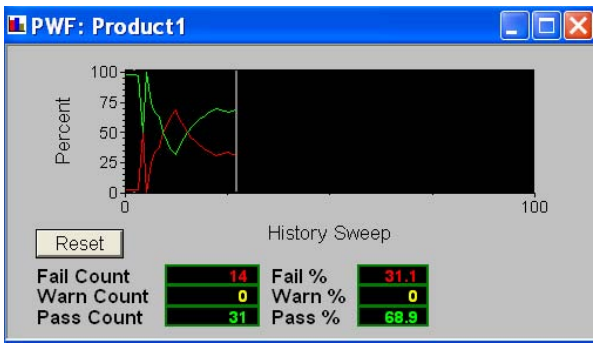

Figure 2-4: Sample Pass/Warn/Fail graph.

The Result Table is a list of all the SoftSensors in the product. It consists of three columns: the name of the SoftSensor, the result for that specific SoftSensor and a customizable third field about that SoftSensor. The user can select what to see in that third column from a number of options: Output Value (the default output of the sensors), Count or Percentage of Pass/Fail outputs for that SoftSensor, Cause of Failure (displayed only when SoftSensor fails), and SoftSensor type. Figure 2-5 shows a sample result table. It indicates the product name, in this case “ORingDetection”, and it shows the SoftSensors being used as well as their outputs.

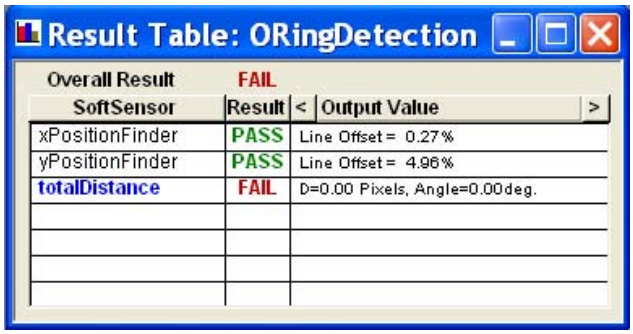

Figure 2-5: Result Table for a product. It lists all the SoftSensors in it as well as their outputs.

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The inspection Statistics graph is particularly useful for troubleshooting. This graph keeps count of total inspections, inspections that timed out (the inspection did not complete in a certain amount of time), and inspections that could not be taken when trigger was received. The last type of count refers to two cases: resource conflict (the Vision Sensor is triggered while it is acquiring an image) and missed count (the Vision Sensor was triggered while the image buffer was full so the trigger was ignored).These parameters help users determine when there might be a timing issue with the inspections. Figure 2-6 shows an Inspection Statistics Graph.

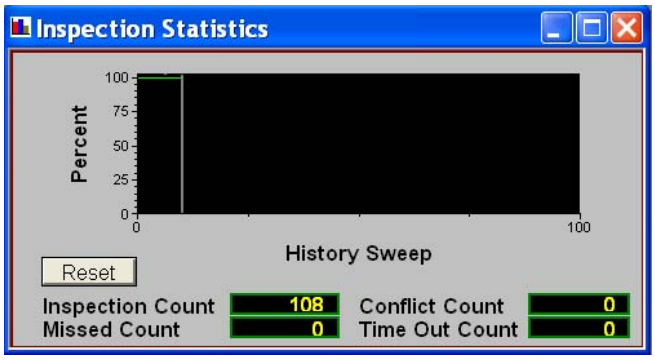

Figure 2-6: Inspection Statistics graph.

The inspection Times graph is a very important graph. It shows how much time every inspection takes showing the maximum and minimum inspection times. This graph should be used when two or more different methods for inspections are being tested. Usually, the time it takes to perform an inspection is crucial, so after setting up different SoftSensors to perform a certain inspection, this graph will tell the user which method is the fastest one. Figure 2-7 shows a screen capture of this type of graph.

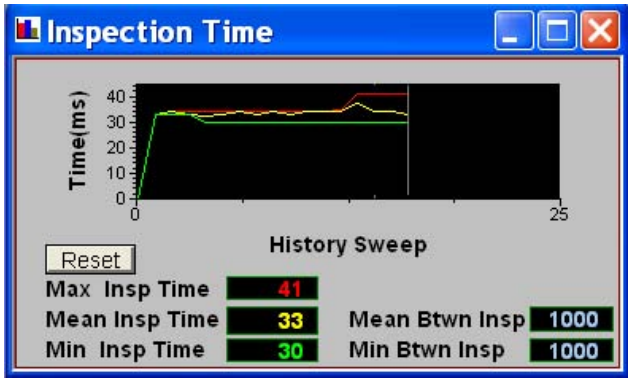

Figure 2-7: Inspection time graph.

Finally, the digital I/O graph works like an oscilloscope. It uses time as the abscissa (X axis) and eight configurable I/O lines as the ordinate (Y axis) to show a timing diagram that indicates when signals go active or inactive. This graph is very useful for troubleshooting communications. Figure 2-8 shows a Digital I/O graph.

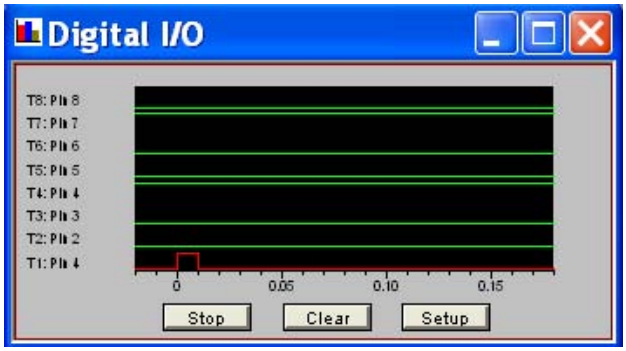

Figure 2-8: Digital I/O graph. The X axis indicates time in seconds.

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2.3 SoftSensor Level

SoftSensors are the “working class” inside Vision Sensors. Each one is assigned a specific task to extract information from the image. The combination of all the tasks performed by the SoftSensors makes up the entire inspection. The main SoftSensor Parameters are the threshold, PASS/WARN conditions, sensor graph, sensor shape, and processing options.

2.3.1 Threshold

SoftSensors use the information from every pixel to inspect images. Every pixel contains a certain intensity level ranging from 0 to 100. Based on application specifications, the user selects a threshold level to classify the pixels contained in the sensor as dark pixels (below threshold) or light pixels (above threshold). There are several ways to compute a threshold:

- **Intensity based, Fixed Value:** this option lets the user manually select the threshold level. This threshold has to be a number between 0 and 100 and it is considered a static threshold because it does not change from image to image.
- **Intensity based, Percent of Path Contrast**: this is a dynamic threshold which places the threshold at some location between the minimum and maximum intensity values based on the value set by the user. This threshold is calculated as follows: $T = (I_{MAX} - I_{MIN}) \times T\% + I_{MIN}$. The T% represents the threshold percent set by the user, Imax and Imin are the maximum and minimum intensity values inside the area that the SoftSensor is set to analyze. This option selects a threshold which can adapt itself from image to image (dynamic threshold) which makes it more robust that any static threshold.
- **Intensity based, Percent of Reference Intensities:** similar to Percent of Path Contrast threshold, described above, the threshold is calculated as follows: $T = (I_{MAX} - I_{MIN}) \times T\% + I_{MIN}$.
  However, Imax and Imin are not the max and min intensity levels along the SoftSensor path. Instead, the user selects references. This option allows users to name other SoftSensors as high and low intensity references from other regions of the image. When this option is enabled, a new menu prompts the user for four options. Two SoftSensors and two intensity levels from those SoftSensors (such as maximum intensity, minimum intensity, etc.) need to be determined. The same SoftSensor can be used for both options.

Note

When using this threshold type, the values reported for the SoftSensor (Contrast, Minimum Intensity, and Maximum Intensity) refer to the selected references, which are the ones used for computation of the threshold.

- **Intensity based, Auto Bimodal:** automatically calculates a single threshold value to use based on the entire histogram. Since it uses all the values in the area to calculate the threshold, the effects of noise and specular reflections are minimized. Auto bimodal thresholding is recommended when there is a distinct foreground and background intensity. The threshold is recalculated for each image.
- **Intensity based, Adaptive:** calculates a specific threshold value for different areas of the image depending on the contrast found in those areas. The user needs to specify a window size in pixels, the software then calculates a threshold (using the percent of path contrast method) for individual windows, making the overall threshold more robust when lighting and contrast are not uniform. This method is the slowest of the thresholding methods.
- **Intensity based, Dominant Color:** type of threshold is used in combination with a color SoftSensor. The color SoftSensor learns a color (it could be a shade of gray if using a grayscale system) which is referenced by another SoftSensor to establish a threshold. Basically, pixels of that color, or shade of gray are considered to be above threshold, the rest of the pixels are considered to be below threshold. This concept will be explained later in the manual.
- **Gradient Based:** this method for calculation of a threshold determines changes in gradient. That is, it compares pixels with the neighbor pixels in the image to determine local changes in intensity. It then produces a gradient graph which peaks where the highest changes are located. The user needs to specify a threshold to separate the main edge(s). The methods for determination of the threshold are: Fixed Value, Percent of Path Contrast, and Percent of Reference Intensities. These methods work in the same way as for Intensity based threshold (as explained above).

Note

This method uses pixel interpolation to calculate the best position for the edge providing sub-pixel accuracy.

- **OCR specific:** the OCR SoftSensor has three extra options for calculation of the threshold that will be discussed later.

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2.3.2 SoftSensor Graphs

Just like at the Product level, Spectation offers graphs to display Sensor-level information. This information is sensor-specific; it could be generic information about the sensor (Pass/Fail, etc.) or very specific SoftSensor information. The latter depends on the SoftSensor being used. The first and most common sensor graph is the Pass/Warn/Fail graph. It serves the same purpose as its product-level counterpart, but the data refers to a specific sensor instead (see product graphs for more information). The rest of the SoftSensor graphs could be classified into two main categories: Data Graphs and Image Graphs.

Data Graph

Data graphs display data over time. That is, they have inspections as their abscissa (X axis) and a specific set of data from the sensor as their ordinate. Some examples of these graphs are Measurement, Intensity/Threshold, and Position. Figure 2-9 shows an Intensity/Threshold graph. Some variation in the values can be observed from the graph, but the current values are displayed at the bottom.

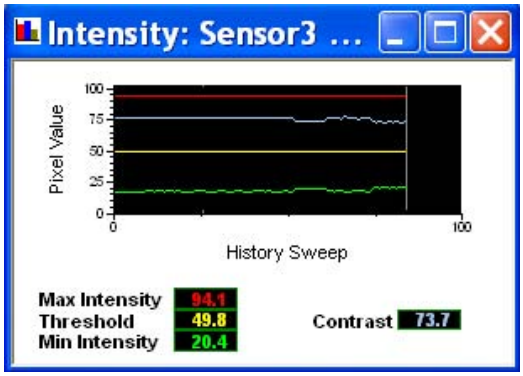

Figure 2-9: Intensity/Threshold graph showing specific information about the area analyzed by the sensor

Image graphs

Image graphs are graphical interpretation of the areas analyzed by the SoftSensors that help the user set a threshold. There are three types of image graphs: Pixel Graph, Histogram and Gradient Graph. The Pixel Graphs is the simplest way of displaying information about a SoftSensor path. It uses the SoftSensor path as the abscissa, and the intensity of the pixels as the ordinate. That is, the range displayed in the X axis goes from the origin to the end of the line SoftSensor, whereas the range in the Y axis goes from zero intensity (black) to 100 (white). Figure 2-10 shows the pixel graph for a SoftSensor with a length 165 pixels.

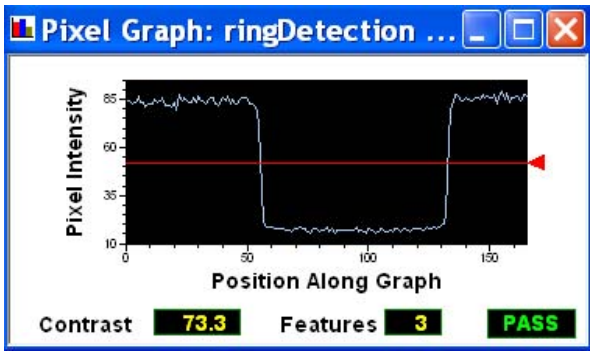

Figure 2-10: Example of a Pixel Graph for a line SoftSensor of 165 pixels in length

As the graph illustrates, the pixels near the origin of the SoftSensor are bright (high intensities), then, a dark region is found so the graph drops down to the low intensities and then it goes back up towards the high intensities as it approaches the end of the SoftSensor.

Histograms are also used to display the intensity of the pixels, but in bar chart format. Unlike pixel graphs, histograms use the intensity levels (ranging from 0 to 100) as the abscissa; for the ordinate, they use the percent pixels. That is, histograms display the percentage of the pixels found at every intensity level. Figure 2-11 shows a histogram for an intensity SoftSensor. The histogram shows two well defined groups of pixels which may represent background (lighter pixels) and the actual part (darker pixels).

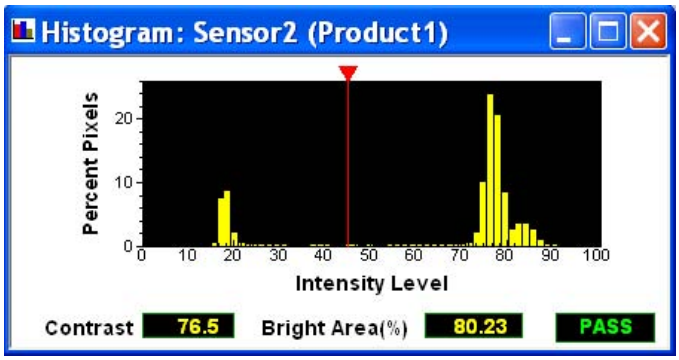

Figure 2-11: Screen capture of a histogram

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The third image graph is the gradient graph. This type of graph plots changes in intensity values from pixel to pixel along the path of the SoftSensor. It does not show the actual intensity value of the pixels, just the changes. Mathematically, this represents the absolute value of the first derivative of the pixel graph. Figure 2-12 shows a pixel graph and a gradient graph for a certain SoftSensor.

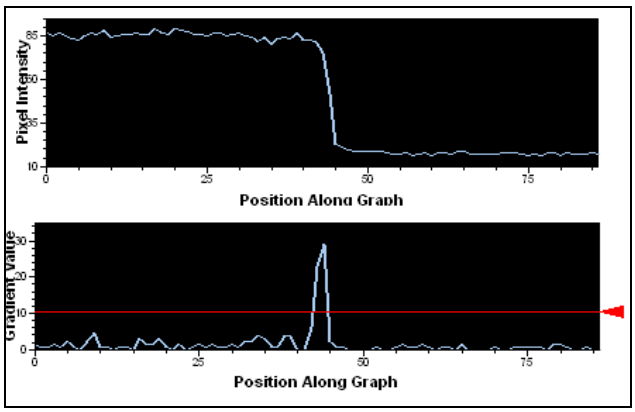

Figure 2-12: Pixel and gradient graphs for a SoftSensor

Notice how the gradient graph peaks where the pixel graph shows the biggest change in intensity levels.

2.3.3 SoftSensor result

SoftSensors can be set to PASS, WARN, or FAIL based on a predefined criteria. Usually, the PASS condition is assigned when the parameter being checked is within the specifications. The FAIL output is reserved for cases where the parameter being checked exceeds the specifications. For cases where the feature being checked by the SoftSensor is approaching the limits of the specification, the user may need a signal to correct the production process without rejecting any parts. In those cases the WARN condition should be used. The WARN output will not reject a part, but it will let the operator know that the production process needs work. Every SoftSensor contains a custom set of rules for the user to set as the PASS/FAIL criteria. Those rules are related to the specific functionality of the SoftSensor. That is, for measurement SoftSensors the condition would be based on maximum and minimum size, for the barcode reader it would be set based on a matching code, etc. However, there is an option that is common to most SoftSensors: Minimum Contrast. The option of Minimum contrast should be used when a dynamic type of threshold is being used. The use of this option will be illustrated with an example. If the user selects for example Percent of Path Contrast as the method for calculation of a threshold, the SoftSensor (as explained before) will determine the intensity levels of the brightest and the darkest pixel, and based on those numbers it will compute a threshold level. This is a very powerful method, but what happens when the part is not present? Only the background is present, so the SoftSensor sees a very low contrast given by the noise present in the background. Based on this contrast the SoftSensor still computes a threshold for the image. Figure 2-13 shows the pixel graph for a SoftSensor illustrating this case.

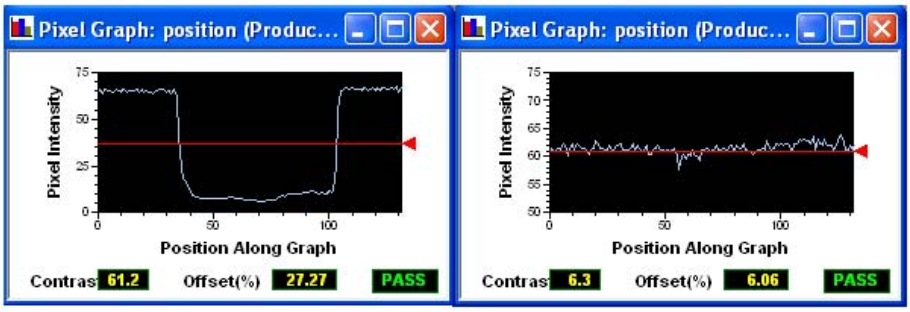

Figure 2-13: Case where the part being inspected (determined by the group of dark pixels in the graph on the left) is not present in the next image. The graph on the right shows that there is still a threshold being calculated

The pixel graph on the left shows the presence of the (dark) part. The threshold is correctly calculated at 50% of the difference between the lightest and the darkest pixel. The pixel graph on the right shows the pixel graph for the same SoftSensor for the case where only background is present in the image with intensity levels between 55 and 63. In this case, there is no part, but the SoftSensor still computes a threshold because it can still find a lightest and a darkest pixel. In order to avoid this case, the user can select the “Minimum Contrast” option and set a minimum contrast that must be matched to even compute a threshold. For the second case explained above, a minimum contrast of about 10 would prevent this SoftSensor from computing a threshold and thus will cause it to fail.

2.3.4 SoftSensor Shape

SoftSensor creation is a very simple point and click process. The first step is to draw a certain shape in the image. The available shapes depend on the type of SoftSensor being used, and the selected shape depends on the part being inspected. The two main categories of SoftSensor shapes are line SoftSensors and area SoftSensors.

Line SoftSensors are mostly used when edges need to be found. These types of SoftSensor scan along lines analyzing every pixel along them. The different types of lines available in Spectation are shown in Figure 2-14. Starting from the upper left corner, the shapes are:

- Horizontal/vertical line: to be used when the SoftSensor is to be drawn perfectly aligned with the pixel grid, either horizontally or vertically.
- Line at an angle: allows the user to draw a line at any desired angle
- Polyline: allows for the creation of a line defined by straight segments, used for analysis of very complicated shapes
- Freehand Line: the line is drawn following the movement of the mouse, used for analysis of very complicated shapes
- Square: draws four sides of a square, good for analyzing the outside of an object with 90 degree symmetry
- Rectangle: draws four sides of a rectangle, good for analyzing the outside of an object with 180 degree symmetry
- Polygon: similar to polyline but it closes the figure, used for complex shapes

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- Circle: draws a circular line, used for analysis of round or highly symmetric shapes
- Ellipse: draws an ellipse, designed for cases where a circle is to be analyzed but perspective errors make circles appear as ellipses.
- Circular Arc: draws an incomplete circle, used for cases where only part of the circular region is to be analyzed
- Elliptical Arc: draws an incomplete ellipse, used for cases where only part of the elliptical region is to be analyzed

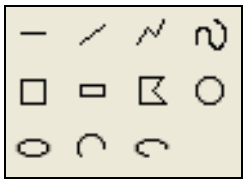

Figure 2-14: available shapes for line SoftSensors

It should be noted that even though some lines are closed, that is, they draw a figure, the SoftSensors are line SoftSensors and they only analyze the edges of those figures. Only area tools analyze areas.

Note

For instructions on how to draw a specific type of SoftSensor select the desired shape and refer to the Spectation status bar for click-by-click instructions.

Area SoftSensors analyze the pixels contained in a specific area of the image. That area is determined when the SoftSensor is drawn. The main types of area SoftSensors are shown in Figure 2-15.

Figure 2-15: Available shapes for Area SoftSensors

As the image shows, the shapes are equivalent to those of line SoftSensors. The different shapes are applicable to different cases, the user should be familiar with the application and the part to be inspected and select a shape accordingly. An important difference between line and area SoftSensors is the processing time. While area SoftSensors might be the best choice to make the inspection reliable, they take more processing time than line SoftSensors. Fortunately, Spectation is designed in a way that this change in processing time is very small and it does not become an issue for most applications.

Note

The main difference between icons for line and area SoftSensors is that those for area SoftSensors are white on the inside, highlighting the fact that they analyze the area delimited by the line.

Besides the basic line and area SoftSensors, Spectation has other specific shapes available for certain applications. Those shapes will be covered as the specific SoftSensors that use them are explained in the next chapter.

2.3.5 Processing Operations

Image quality is always the most important factor for setting up an inspection. Sometimes a minor change in the lighting technique makes a big difference for the image. However, in many cases, users have limited control over the physical setup of the system, so another way to deal with noisy images must be used. For those cases some SoftSensors have a built-in number of operations that process the image before a threshold is applied. These operations do not actually alter the image; they alter the perception of the image for the selected SoftSensor. Since SoftSensors can overlap, altering the actual image would affect the result of every SoftSensor analyzing it. The available operations are:

- Erode: shrinks shapes in the image a user-specified number of pixels. Useful operation when dealing with background noise.
- Dilate: expands shapes in the image a user-specified number of pixels. Useful operation when dealing with noise inside the part.
- Open: combination of Erode operation followed by Dilate operation. This option eliminates background noise and does not alter the sizes of the parts.
- Close: combination of Dilate operation followed by Erode operation. This option eliminates noise inside the part and does not alter the sizes of the parts.

Figure 2-16 illustrates the use of the Erode and the Open operations. In this case, the dark part being analyzed is in presence of background noise.

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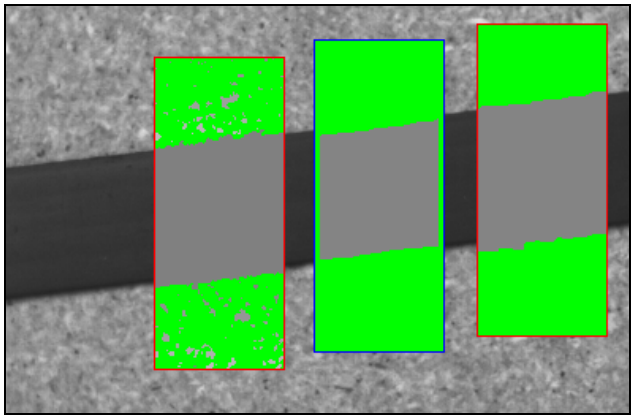

Figure 2-16: Noisy image illustrates use of Erode and Open operations. The SoftSensor on the left uses neither, the one in the center uses the Erode operation, and the SoftSensor on the right uses the Open operation

The use of a SoftSensor with no options of image processing would result in an inspection of the part and the noise as shown in the first SoftSensor. The second SoftSensor uses the Erode operation, it shrinks everything (3 pixels in this case) until the noise is gone, but that affects the original size of the part. The third SoftSensor uses the Open operation, that is, after shrinking the parts it expands them. The result is the noise disappearing and only the part to be inspected being expanded to its original size.

Figure 2-17 shows the inspection of a part with texture. The texture causes some noise inside the part; the first SoftSensor shown does not use any operation, so it picks up all the noise.

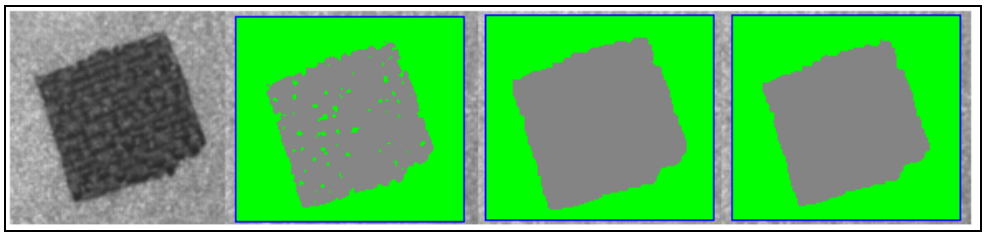

Figure 2-17: Example where the operations of Dilate and Close are used.

The second SoftSensor uses the operation Dilate, which expands the part in all directions. This helps with the noise but alters the area of the part. The last SoftSensor uses the operation of Close and it successfully eliminates the noise and returns the part to its original size.

Note

The user needs to remember that all these operations add some processing time. The operations of Open and Close add twice as much processing time as the other two operations because they perform the basic operations twice.

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2.3.6 Digital Relearn

Digital relearn is an option that is present in many SoftSensors. It refers to cases where the inspection consists of comparing something to a learned version of it. Its use extends to the following SoftSensors: Template Match, ObjectFind, OCR, 1D and 2D Readers and Color. When these SoftSensors are created, something is learned (a shape, a code, a color, etc.). When the SoftSensor performs inspections, it uses the learned model. If the application happens to change the elements being used, there is no need for the user to connect to the Vision Sensors using Spectation and reconfigure the SoftSensor. A simple digital signal to the Vision Sensors indicates that the new element is ready to be learned. In that case, the system takes the element (color, code, shape, etc.) from the next image to be inspected and stores it as the new model.

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2.4 Spectation software

Now that the user is familiar with the system, product and sensor level parameters, we will discuss how to access them. This section explains the basics of the Spectation software. After reading this section the user should be able to access all the parameters explained before and should be more comfortable with the system. Spectation consists of two main parts. One of them is the Spectation firmware which resides in the Vision Sensors. The Spectation firmware is the responsible for all the computations that happen inside Vision Sensors. The user has no direct control over it. The user only programs the user interface and this one translates everything for the firmware to execute. The second part of Spectation is the software. The Spectation software consists of the Spectation user interface and the Vision Sensor hardware emulator. Figure 2-18 shows the relationship amongst the different components of Spectation. The user can only access the components that reside in the PC: the Spectation user interface and the hardware emulator. Using the Spectation user interface the user connects to a Vision Sensor and makes changes to the product or system files loaded in the Vision Sensor. In order to do this, the Spectation user interface queries the Vision Sensor for images and reproduces in the PC what the Vision Sensor does in its internal memory with those images.

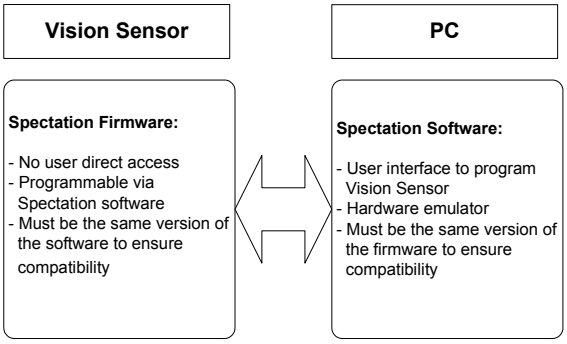

Figure 2-18: Components of Spectation and the relationship among them

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2.4.1 Spectation User Interface

The Spectation User Interface is a Microsoft Windows application used for the configuration of Vision Sensors. The main areas of the interface are the main menu, the expanded toolbar, the SoftSensor toolbar, the SID, the result panel, and the status bar. Figure 2-19 shows a screen capture of the Spectation user interface highlighting these areas.

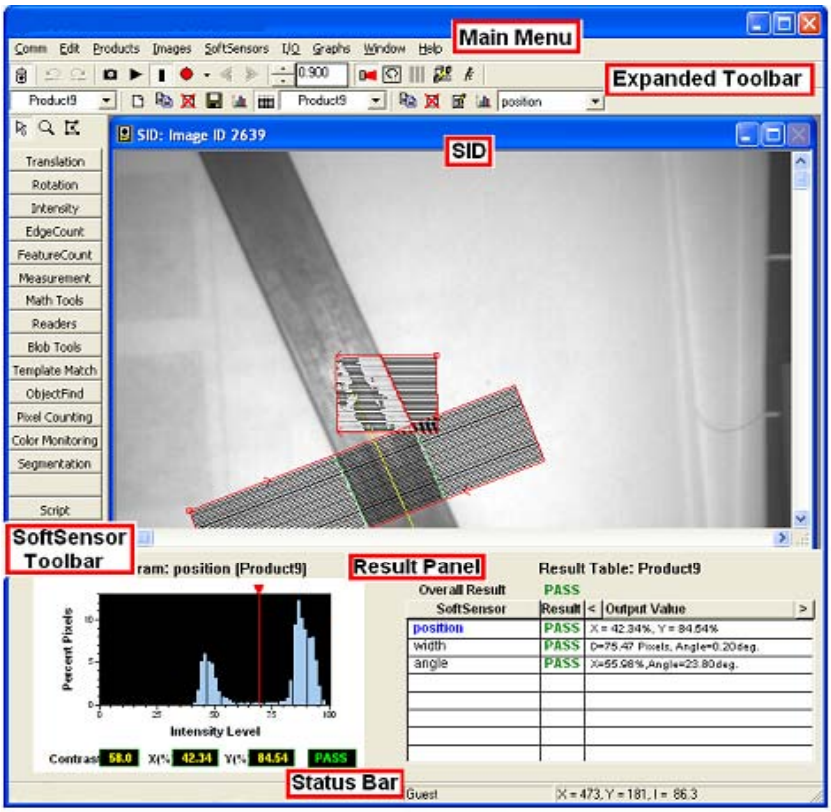

Figure 2-19: screen capture of the user interface highlighting the most important areas

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The main menu contains commands to control most of the parameters discussed so far. Here, we will discuss the functionality of each submenu:

- The “Comm” submenu contains commands to control the connection to the Vision Sensors. From here the user can get to the “PC Communications” dialog box to connect to Vision Sensors or the VSEmulator, as well as manage access control (log in, log out, create users, etc.).
- The “Edit” submenu offers access to the following Spectation features:
  - Background Scripts dialog box: from this dialog box, the user can add, delete, edit, and create background scripts. Please refer to the script documentation for information about background scripts.
  - Terminal Window: opens an Ethernet connection to the Vision Sensor's system terminal (port 3246). The camera can receive a number of commands in this port which allow the user to gain control over it without using Spectation. By using this terminal window, the user can perform the data exchange with the Vision Sensor without exiting Spectation. Refer to the Spectation help files for a complete list of commands that Vision Sensor can receive on the system terminal.
  - Script Debug Window: special window dedicated to receive Debug statements from scripts that help in troubleshooting the code. Please refer to script documentation for more information about it.
  - Options: gives access to advanced features. From this menu the user can enable advanced features for many SoftSensors, set parameters for the Vision Sensor itself, and activate/deactivate buttons from the SoftSensor toolbar.
- The “Products” menu lets the user manage the products in the Vision Sensor as well as create backup copies of products or the entire system. From this menu the user can select the Power-on-product, assign digital ID’s for product selection, store products to flash memory, reclaim flash memory, backup products or systems to the PC’s hard drive as well as restore them back to the Vision Sensor.
- The “Images” menu gives the user control over many imaging parameters. Most options in this menu are very general such as image rotation, display of SoftSensors in the image, copy images from the PC and restore them to the display, go back a number of images (retained images option), and configure image sequences (only applicable to the hardware VSEmulator). The two most important options are:
- Display Parameters: this option brings up a dialog box from where the user can set up recording of images, change the display of images (all images, only failed, etc.), enable/disable image compression for image transfers (to gain speed or concentrate on image quality), and select the type of SoftSensor image marking to display.
- Image Parameters: this option opens a dialog box that offers more control over the system. From this dialog the user can set the type of trigger (internal or external and the period in case of internal trigger), the exposure time, the illumination to use (in case the application uses strobe lights), the sensor gain, product gain, the FOV balance, and the size of the image being acquired.
- The “SoftSensor” submenu offers access to SoftSensor parameters, from here the user can edit SoftSensor settings and create SoftSensors.

- The “I/O” submenu allows the user to set up the communications and assign the digital I/O lines to the desired I/O pins. DataLink, a tool available form Spectation that can be set up to output a configurable string with data after every inspection, is also available from this menu. For more information about communications, see Vision Sensor Integration
- The “Graphs” submenu offers access to both product graphs and sensor graphs (explained before).
- The last two options “Window” and “Help” have standard Windows functionality. The “Window” option is used to customize the user interface. The “Help” menu brings up the Spectation help files which are rich in content and examples.

The Expanded Toolbar contains buttons that offer shortcuts to the most frequently used functions of the software. Every button offers a tool tip, that is, when the cursor is placed over a button, a message is displayed on the screen indicating the functionality of the button. The expanded bar contains three main sections, the upper bar, the product section of the lower bar, and the SoftSensor section of the lower bar. In the upper bar is where the main controls are. It has a button to connect/disconnect from the system, it has spin buttons to change the exposure time (which is displayed in milliseconds), it contains a single button to control the strobe lights, it has the antiblooming control, the white balance control (see Color SoftSensors), and controls for both the Vision Sensor and the user interface. The controls for the user interface contain a “Play” button, a “Stop” button, and a “Record” button. The controls for the Vision Sensor are the “Trigger” button and the “Run/Stop Inspections” button. These two sets of buttons seem to have similar functionality, but they are very different. The ones for the user interface only determine if the Vision Sensor is to send images to the user interface. The fact that the user interface gets images from the Vision Sensor does not mean that the Vision Sensor is inspecting them. The only indication that we have of that is the availability of the inspection results from the Vision Sensor, and the control the user has over this process is the “Run/Stop Inspections” button. If this is enabled, the Vision Sensor is inspecting images, which means that it is making the output signals available. Table 2-1 summarizes the different cases.

Table 2-1: Summary of the relationship between play mode and inspections mode

User Interface	Inspection Mode	Real Time Feedback to user interface	Outputs from the Vision Sensor
PLAY	OFF	Active (updates images)	Not Available
STOP	OFF	Inactive (stopped)	Not Available
PLAY	ON	Active (updates images)	Available
STOP	ON	Inactive (stopped)	Available

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The user should understand the differences between these two options in order to avoid incorrect configurations. The main reason for the independence between these two functions is that the Vision Sensor is a stand alone System. It does not need a user interface connected to it in order to inspect images, so it must not rely on user interface modes to produce inspection results. Likewise, the user does not have to rely on the Vision Sensor running inspections to see images, and it does not have to stop the Vision Sensor from inspecting to observe a particular image. For example, if the inspection mode was tied to the user interface play mode, the Vision Sensor would stop inspecting images every time the user needs to analyze an image in details for which it would be necessary to stop the real time feedback. This would cause a problem when other devices expect the result from the Vision Sensor to reject a part or accept it. It should be mentioned that Table 2-1 summarizes what happens upon triggering the system. That is, when the trigger mode is set to internal with a period, the updating of images/outputs as set by the aforementioned parameters will occur periodically. However, if the trigger mode is set to external, the updating of those parameters will only occur when the Vision Sensor receives an external trigger.

The product section and the sensor section of the lower toolbar contain similar functionality for products and sensors. For products it offers the extra options of showing the result panel (explained below), creating a new product, and saving a product to flash memory. Flash memory is the nonvolatile memory where the product should reside in order to remain in the Vision Sensor after the power is cycled. Both sections of the toolbar contain a pull down menu with the existing products in the system and the SoftSensors that the selected product contains. The remaining toolbar buttons are to duplicate, edit parameters, delete, or access the graphs associated with the product/SoftSensor selected from the pull down menu.

The SID, or Sampled Image Display, is where the images obtained from the Vision Sensor are displayed. The name describes its functionality; not every image from the Vision Sensor is transferred to the user interface. For the Vision Sensor the number one priority is to run inspections, after that and depending on processor usage, it sends images via Ethernet to the user interface. In cases where the Vision Sensor is being triggered very fast, the user interface will only receive some images. This is why the display is called sampled image display; it only displays sample images from the Vision Sensor. Besides the case of the Vision Sensor being busy with inspections, other factors influence the number of images transferred to the user interface such as network traffic, the types of hub being used, the Ethernet card being used, the speed of the processor in the PC, and the type of images being transferred (color, high resolution, etc.). The top bar of the SID displays a number called the Image ID, which is a number assigned to every image which is reset on power-up. This number should only be used to monitor the rate at which images are being transferred.

The SoftSensor toolbar is where most SoftSensors are available. This toolbar represents a shortcut to most options available under the SoftSensor menu of Spectation. All the SoftSensors can be obtained from the toolbar. If the user prefers to use the main menu, the toolbar could be hidden to maximize the work area by selecting the appropriate option for the Window menu.

The result panel is a combination of two elements that have been discussed in this chapter. The result table and the sensor graph for the SoftSensor that is selected from the result table. Figure 2-19 shows three SoftSensors in the result table. The selected SoftSensor is the one highlighted in blue, so the sensor graph to the left of the result table corresponds to this SoftSensor (named position).

The Status Bar, the last section of the user interface contains three main sections:

- Instructions section: this is the left side of the bar. In Figure 2-19 it shows the version of Spectation being used, but when the user selects to create a new SoftSensor, it displays the click-by-click instructions so the user does not need to remember how to draw every SoftSensor.
- User section: this section is related to the Vision Sensor administrator, it shows the username under which the current operator is logged on. Figure 2-19 shows “Guest” because no user has logged on.
- Image information section: this part of the toolbar is used in combination with mouse movements. When the user moves the pointer over the image being inspected, this section of the status bar will show three values for grayscale systems and five values for color systems. The first two values in both cases are the X and Y coordinates of the pixel where the pointer is located; “X” coordinates start at zero on the left edge of the image and increase to the right, and “Y” coordinates start at zero on the top edge of the image and increase downwards. For grayscale systems there is a third value which indicates the intensity of the pixel (between 0 and 100). For color systems there are three values instead of an overall intensity value, these values are the contents of Red, Green, and Blue of the pixel.

2.4.2 Vision Sensor Hardware VSEmulator

The VSEmulator is a program which acts like a Vision Sensor, but it is a software application that runs on your PC. When the emulator application is running, the Spectation user interface can connect to the VSEmulator – just like a connection to a Vision Sensor. Actually, Spectation does not recognize a difference between the actual Vision Sensor and the VSEmulator. The main uses for the VSEmulator are:

- **Education / Training:** With only a PC, users can run the emulator application with Spectation and practice using the tools to learn how Spectation operates.
- **Off-line Setup:** Take development of Product files off of the factory floor. Use the emulator to continue setup work on Products even after you’ve walked away from the machine.
- **Troubleshoot Reliability Problems:** Is your Vision Sensor rejecting too many good parts or passing flawed parts? Save a batch of the images and work off-line to find the problem, and then perform the necessary changes to improve the inspection and reload the product file to the Vision Sensor.
- **Demonstrations:** Show the power of Spectation without the Vision Sensor hardware present.

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Spectation's functionality is opened up only after a connection is established to a Vision Sensor or to the Hardware VSEmulator. When the application starts, the PC Communications dialog box is opened. Users may opt to connect to a Vision Sensor (hardware device) via Ethernet (or serial port for older systems) or to the VSEmulator. Under VSEmulator, the user will find a number of options. Each one corresponds to a different model of Vision Sensor. The selection of emulator depends on the Vision Sensor that the user needs. When the user selects to connect to the VSEmulator, a new windows application launches on the background. The user should not attempt to modify anything in this new application for all the functionality is available from Spectation. The basic steps to work with the VSEmulator are:

- Create a backup copy of the system file or product file that resides in the Vision Sensor. This step is needed only if the user needs to work on the setup of a Vision Sensor. A product file contains all the product parameters (specific for every inspection) whereas the system file contains all the parameters in the System. Figure 2-1 illustrates the difference between product level and system level.
- Record some images from the Vision Sensor. Using the record option, the user can setup Spectation to record images imported from the Vision Sensor to the computer hard drive. By doing this, when Spectation connects to the VSEmulator, the image sequence could be loaded into the VSEmulator and the user could cycle through those images. This step is also optional, given that the user may already have an image sequence to work with.
- Start Spectation and connect to the VSEmulator. Choose the VSEmulator that corresponds to the Vision Sensor used.
- Perform changes to the system/product files as needed. The VSEmulator allows for any type of changes, the user can add or delete SoftSensors and products, setup communications, etc. The only changes that are not reflected are changes that relate to physical setup such as exposure time, illumination, etc. because the VSEmulator works with prerecorded images.
- Back up the product/system file to the PC and restore it to the Vision Sensor.

For a quick tutorial on this process see VSEmulator tutorial.

3 SoftSensor Reference

This chapter explains the main concepts of the Spectation SoftSensors. As it was mentioned before, SoftSensors are the working class inside Vision Sensors. Every type of SoftSensor serves a specific purpose, and the combination of the SoftSensor results represents the overall result of the inspection. The main groups of SoftSensors are Presence/Absence SoftSensors, Positioning SoftSensors and Specific Inspection SoftSensors. Positioning SoftSensors help locate parts to be inspected. In most applications this type of SoftSensor becomes the key to a successful setup because they locate the part to be inspected and pass an internal reference to the remaining SoftSensors indicating the location of the part. Presence/Absence SoftSensors perform basic checks for detection of features. Specific Inspection SoftSensors include 1D and 2D code readers, OCR readers, measurement sensors, math tools, color sensors, pattern matching sensors, geometry finding sensors and programmable sensors.

3.1 EdgeCount SoftSensors

EdgeCount SoftSensors are designed to detect and count transitions between bright and dark pixels (or above and below threshold). These SoftSensors basically analyze the image and determine where the pixel graph intersects the threshold line. Those intersections determine an edge, and the user can select the type of edge to locate (bright to dark, dark to bright, or either edge). Figure 3-1 shows an EdgeCount SoftSensor and its pixel graph.

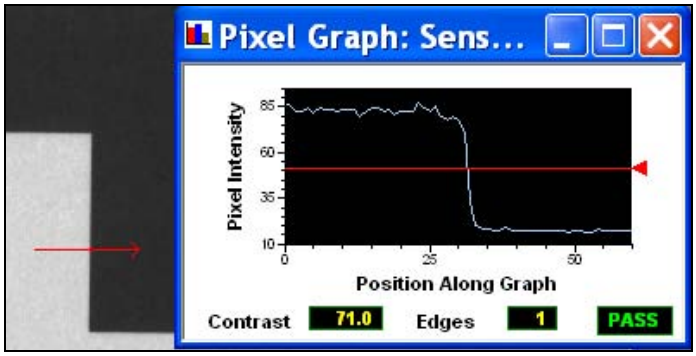

Figure 3-1: Edge Count SoftSensor and its pixel graph. The SoftSensor starts on the bright area (high intensity) and then goes into the dark area (low intensity).

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In this case, the shape of the SoftSensor is a horizontal line, and the direction of scanning is from left to right as indicated by the arrowhead at the right end of the SoftSensor. From the pixel graph the user can determine that the length of the SoftSensor is about 60 pixels and that the edge (transition from bright to dark) is located close to pixel number 32. The output of this type of SoftSensor is the number of edges found; in this case it is one. However, the user must be careful to select the correct type of edge to be located, if in this case the user selects dark to bright edges only, the sensor will return zero edges because there are no such edges in the direction of scanning.

EdgeCount SoftSensors are available only as line SoftSensors because of their purpose. Since they detect edges, they must consist of lines searching for transitions between dark and bright pixels along a certain path. As a consequence, a single dark pixel (like background noise) could make them find extra edges and thus alter the result of the inspection. To avoid this problem, the user can select to increase the scanning. The option of scanning extends the SoftSensor in any direction to make the inspection more robust. Figure 3-2 shows an example where this option is used.

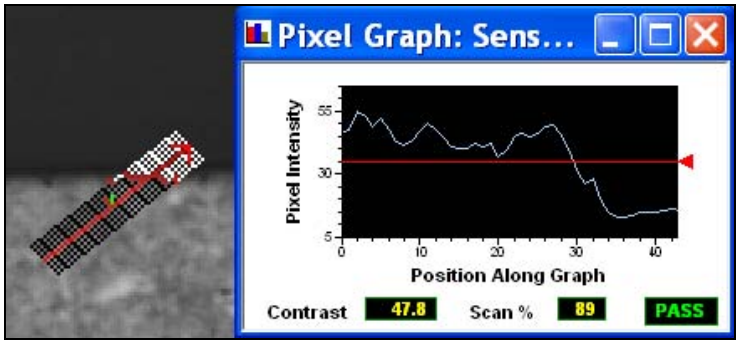

Figure 3-2: EdgeCount SoftSensor analyzing an image with noisy background

The background in this case is noisier than the background in Figure 3-1, so the option of scanning must be used. As the pixel graph shows, some of the noise in the background is very close to the threshold level. If one of those dark pixels in the background reaches the threshold level, a new edge will be found. In order to avoid that problem, the area scanned by the SoftSensor was expanded. In order to do that, the user needed to specify the direction in which the SoftSensor was to be extended (“X” or “Y”) and the number of pixels. Furthermore, a rotation should be indicated to expand the sensor in a very specific direction. In the example shown in Figure 3-2 the axis angle was set to 45 degrees and the SoftSensor was expanded 5 pixels in the “Y” direction. These settings rotated the main axis (X-axis) 45 degrees counterclockwise and then expanded the sensor 4 pixels in both the positive and the negative “Y” direction.

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This option makes the SoftSensor more robust and less sensitive to noise because the user now can select to pass or fail based on the number of scanning lines that need to find the desired number of edges. In other words, a few scanning lines could be affected by noise and the inspection can still be successful. Of course, this option adds some processing time to the system. For cases in which processing time is an issue, another option is available. The user can select to sample those scanning lines instead of analyzing every one. By indicating the scanning density as a percentage of the total lines, the user can select to skip some lines. In the example of Figure 3-2 there are 4 lines above and 4 lines below the sensor. If the user selects 50% of scan density, every other line will be used instead every single one.

This type of SoftSensor can be set to pass, warn or fail based on maximum edge count, minimum edge count, percentage of scanning lines finding the appropriate number of edges, and minimum contrast to find edges.

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3.2 FeatureCount SoftSensors

FeatureCount SoftSensors are designed to detect and count features that make the part being inspected different from the background. A feature, as interpreted by Spectation, is defined by two consecutive opposite edges. For example, a transition from bright to dark, followed by a transition from dark to bright indicates the presence of a dark object in bright background. That object is considered a dark feature. Likewise, a light feature is defined by a transition from dark to bright followed by a transition from bright to dark. The SoftSensors basically analyze the image and determine where the pixel graph intersects the threshold line (edges). Then, they try to group those edges to define features. Figure 3-3 shows a FeatureCount SoftSensor and its pixel graph. It can be observed that the sensor crosses four dark regions and five light regions.

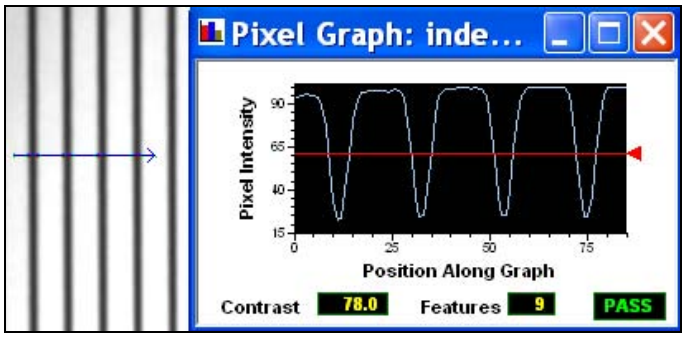

Figure 3-3: FeatureCount SoftSensor and its pixel graph

This is reflected in the pixel graph, where four groups of pixels can be identified below threshold and five above threshold. These groups of pixels represent the features. As the pixel graph shows, this sensor is finding nine features (four dark features and five light features). Depending on the application, different approaches can be taken. The user can select which features to count. If the user selected to count only the dark features, the sensor would report four features instead of nine. Likewise, if light features were selected, five features would be reported. The default option, and the one used in this example is to count both light and dark features. If the image to be inspected is not as good as the one in Figure 3-3, the user may use some options that will make the SoftSensor less susceptible to noise.

The first option to handle noise is to expand the scanning region, and it works in the same way as it does for the EdgeCount SoftSensor (explained before). The second option is a new capability that is unique to SoftSensors that find/count features. It consists of setting a minimum and maximum feature size. When this option is used, the only features that are counted are the ones whose size falls within the specified range. Figure 3-4 shows a sample image with a sensor in it and a pixel graph. The SoftSensor is trying to detect the presence of the dark mark but the dark dot on the outside is another feature. According to the pixel graph, more than one dark feature should be found. However, it can also be observed that whereas the size of the feature to be located is about 80 pixels, the rest of the features do not exceed 20 pixels in size.

Figure 3-4: Filtration of noise using feature size

In this case the user can select a feature size above fifty pixels and only one dark feature should be reported by the sensor. This makes the SoftSensor less susceptible to noise and thus makes the inspection more reliable.

This type of SoftSensor can be set to pass, warn or fail based on maximum feature count, minimum feature count, percentage of scanning lines finding the appropriate number of features, and minimum contrast to find features.

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3.3 Intensity SoftSensors

Intensity SoftSensors calculate the percentage of bright pixels in a given region of the image. It could be a line or an area. The major purpose of this SoftSensor is to determine the presence or absence of image features. The SoftSensor analyzes the pixels and determines how many of them are above threshold (light pixels) and how many of them are below threshold (dark pixels). Figure 3-5 shows an example of its use.

Figure 3-5: Use of an Intensity SoftSensor to verify the presence and correct position of a label

The SoftSensor in this case is detecting the correct placement of the label in the computer disk. This particular example uses a line SoftSensor. The pixels along that line are grouped based on their intensity levels. The histograms, illustrate the pixel analysis of the image. For the first case, the label is present, so most pixels along the line are light. This is reflected in the histogram which shows above ninety percent of the area as bright area. For the second case all the pixels are dark (below threshold) so the SoftSensor reports no bright area. This example only required the verification that the label reached a certain point, so the line SoftSensor was adequate, but if the inspection consisted on the verification of the entire label, a rectangular area SoftSensor should have been drawn over the label.

This type of SoftSensor can be set to pass, warn or fail based on the amount of bright area or the level of contrast found in the image. For the example above, a minimum bright area should be established to determine what is acceptable and what is not. A minimum bright area of 90% would cause the SoftSensor to pass when the label is correctly placed and to fail when the label is incorrectly placed.

3.4 Translation SoftSensors

Translation SoftSensors are designed to locate the absolute position of an element in an image when the position changes due to a translation in any direction. There are two types of Translation SoftSensors: Lines and Fiducial finders.

Translational lines determine the position of an edge or a feature (edges and features were explained under EdgeCount and FeatureCount SoftSensors). The option to locate features should be used when the application allows for it because by selecting a minimum and maximum feature size, the user can make the SoftSensor less sensitive to noise. This type of SoftSensor reports a distance as a percent offset from the origin of the SoftSensor. It searches the pixels from the origin in the direction of scanning (set by the direction in which the SoftSensor was drawn). When it finds the edge/feature that the user indicated, it reports the distance from the origin of the SoftSensor to the location of the edge/feature as a percentage of the total length of the SoftSensor. Figure 3-6 shows a translation SoftSensor and its pixel graph. The pixels graph shows that the length of the SoftSensor is approximately 110 pixels and the light to dark edge is found at approximately 62% of the length of the SoftSensor from the origin.

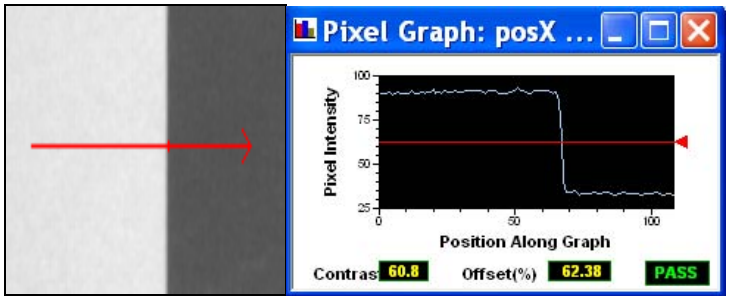

Figure 3-6: Translation SoftSensor and its pixel graph

The output of this SoftSensor will be 62.38% of offset provided that the user specified that this type of edge was an acceptable reference. However, users should tend to use features because of the advantages they offer when dealing with noisy images (see FeatureCount SoftSensor for more details).

This SoftSensor is needed to correct for movement in one direction. However, in most cases the part needs to be tracked in two directions of translation. When that is the case, another SoftSensor of this type needs to be created and a reference between them needs to be assigned. That is, the user needs to create a Translation SoftSensor to determine the translation in one direction and a second Translation SoftSensor to determine the translation in another direction. The second one need to reference the first one and the inspection SoftSensors should reference the second one to create the chain of references as explained before.

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Fiducial SoftSensors are the area tools of the Translation SoftSensors. They scan areas from the top, bottom, right and/or left looking for a specific region (dark fiducial or light fiducial). The user must specify what type of fiducial needs to be found and which directions of scanning are to be used. Usually, two directions of scanning are enough to determine the position of the part. Figure 3-7 illustrates the difference between using two scanning lines and four.

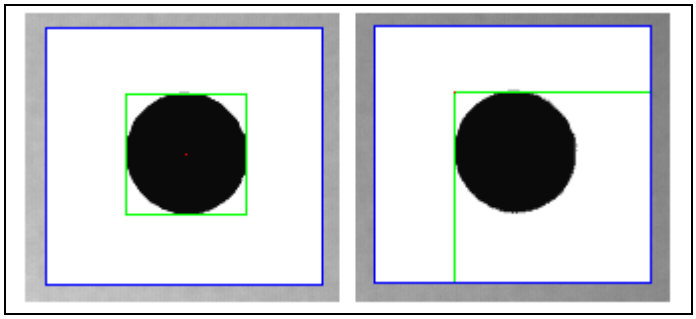

Figure 3-7: Two different ways to locate a part using the same SoftSensor: scanning from all four sides (first case) or only from the left and the top (second case)

In this example, the use of four scanning lines is redundant, because the part can be easily located using two scanning lines. Furthermore, the use of extra scanning lines means more processing time. The output of the SoftSensors changes when different number of scanning lines is used. When four scanning lines are used, the reported output is the position of the center of the green bounding box. That bounding box is determined by all four scanning lines. When two scanning directions are used, the output is the position of the intersection between the two scanning lines used. In all cases, the point used as the position is marked with a red dot. Figure 3-7 also illustrates image marking. The area inside the Fiducial SoftSensor is being binarized. Pixels above threshold appear white, whereas pixels below threshold appear black. This image marking helps the user determine if the threshold needs to be adjusted by letting the user see what the sensor sees.

Another application for fiducial SoftSensors is the replacement of translation lines in a chain of references. Figure 3-8 shows an example where the vertical position is being tracked.

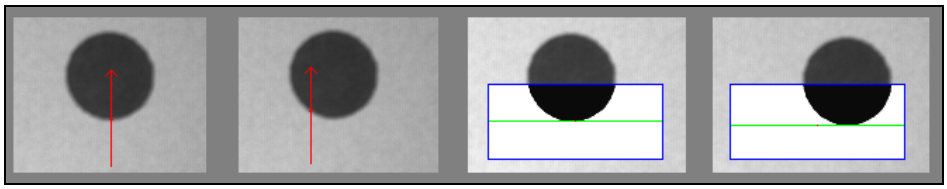

Figure 3-8: replacement of translation line with translation fiducial SoftSensor to increase reliability

With the setup of the first image, as the part shifts right or left, the SoftSensor will report a change in vertical position because the intersection of the line SoftSensor and the edge of the part seems to shift up. This negative effect is illustrated in the second image, where the part shifted to the right but the SoftSensor intersects the edge at a different point. This will cause the SoftSensor to report a change in the vertical position. In the third image a different setup is used where a Fiducial SoftSensor tracks the vertical movement of the part. This allows for some horizontal movement without effect on the vertical position being read. The fourth image shows that this setup is not affected by horizontal movement of the part.

Besides providing a position reference for other SoftSensors to perform the inspection, translation SoftSensors can be used to inspect a part. In applications where the position of a certain feature decides whether the part passes or fails, translation SoftSensors can be used to actually determine the final result. They can be set to pass or fail based on how much the part has moved in the image.

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3.5 Rotation SoftSensors

Rotation SoftSensors are designed to compute the angle of rotation of objects in the image. Like Translation SoftSensors, Rotation SoftSensors allow for different positions of an object without failing the part for being in an unexpected position or location. In other words, other SoftSensors can reference the output of Rotation SoftSensors in the same manner as with Translation SoftSensors. There are two types of Rotation SoftSensors: arc-based and parallelogram-based.

Arc-based Rotation SoftSensors are often applied when the position of an object is known to have fixed radius and center of rotation. For example, the ball bearings in a race can be moved around a circle, but are restricted from moving up and down independently. A Rotation Circular Arc can be drawn to locate one bearing and other SoftSensors can reference the position output of the Circular Arc. Basically, the arcs used to track rotations work like translation lines do. They search along the arc for a specific edge or a specific feature. Then, they report the percent offset from the origin of the SoftSensor. The difference with translation lines is that besides that percent offset, there is a center of rotation associated with the angle being reported. That center coincides with the center of the tool as drawn. Thus, when this tool is used to track the rotation of a part, the closer the center of the tool is to the true center of rotation of the part, the more accurate results will be obtained. Figure 3-9 shows an example where the incorrect placement of the rotation tool causes a problem with the inspection. In the upper left image, we see an intensity tool at the tip of an arrow. Since the center of the arc does not coincide with the center of rotation of the arrow, as the arrow changes position, the arc tracks it incorrectly. It finds it but it uses its own center as the center of rotation. In the third image the arc is correctly placed, so as the arrow changes position, the arc tracks it correctly and it passes a good reference for the intensity SoftSensor which performs the inspection at the tip of the arrow as expected.

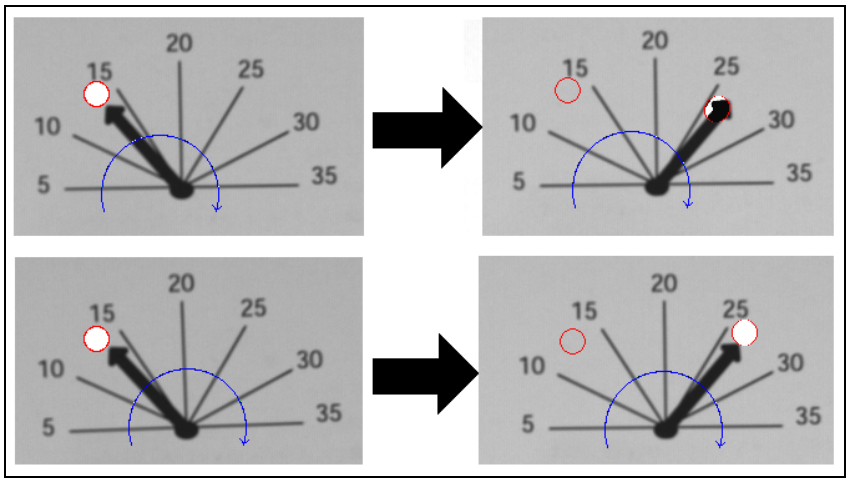

Figure 3-9: Incorrect and correct uses for a rotational arc

The second rotation SoftSensor is the Find Edge tool (this is a parallelogram-based SoftSensor). This SoftSensor is used when an object with straight edges is not fixed in orientation. The SoftSensor fits a line along the straight edge and tracks the rotation of the line. A comparison between the arc and the parallelogram is shown in Figure 3-10.

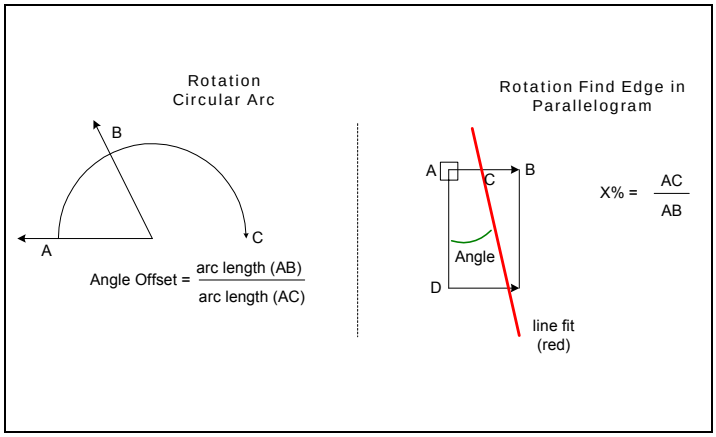

Figure 3-10: Output calculation for Arc (left) and Parallelogram (right) Rotation SoftSensors

As the figure indicates, besides the angle of rotation the parallelogram outputs a distance. That distance illustrated as X% in the figure is obtained from the origin line of the SoftSensor. That is, the first line that the user draws for this SoftSensor acts as a Translation SoftSensor. Furthermore, the direction in which that line is drawn indicates the direction of the scanning lines. This SoftSensor consists of a number of parallel scanning lines. Those lines look for edges or features (according to user specifications) and each one determines a point where they intersect the selected edge/feature. The SoftSensor then fits a line along those points and tracks its rotation. The intersection of that line with the original SoftSensor line is used for translation output. Figure 3-11 shows a sample image where the parallelogram tool is used. The square in the upper left corner of the tool indicates where the user started drawing the SoftSensor. The arrows indicate the direction of scanning, so this tool was drawn starting on the upper left corner going right, then it was expanded down to indicate the height.

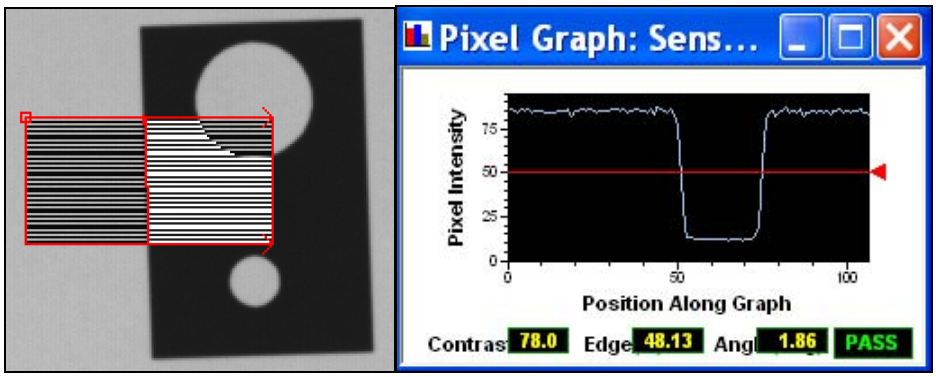

Figure 3-11: Use of the Parallelogram tool of the Rotation SoftSensors. The pixel graph associated with this SoftSensor illustrates the pixels along the origin line (top edge in this case)

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The top line then becomes the origin line and works like a translation SoftSensor. The SoftSensor pixel graph corresponds to the origin line. As it was discussed before, pixel graphs are only compatible with line SoftSensor; however, in this case we have an area SoftSensor and a pixel graph associated with it. Since the most valuable region of the SoftSensor is the origin line, that is the line used for the pixel graph. The pixel graph then shows a numerical value for both the angle of the part and the position of the edge or feature.

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3.6 Specific Inspection SoftSensors

The third group of SoftSensors is the specific inspection SoftSensors. These SoftSensors perform many tasks from very specific inspections to a user defined task (programmable). These SoftSensors are:

- Measurement SoftSensors: take measurements from parts for inspection or simply to gather data
- Math Tools: perform mathematical calculations based on information from the measurement SoftSensors
- Readers: perform readings of 1D and 2D codes as well as OCR (Optical Character Recognition). They can be used for recognition, verification, and in some cases for grading.
- Blob Tools: search the image for specific shapes to track their movement or simply count them.
- TemplateMatch: learn a model and then verify that the model is present in subsequent images, if the model is defective it reports the amount of error.
- ObjectFind: geometry-finding algorithm used to locate, count and classify parts even if they are overlapping.
- Pixel Counting: color matching tools. Learn colors and determine their presence in subsequent images.
- Color Monitoring: ultra precise color verification tools.
- Segmentation: versatile tools used to learn color patterns, detect defects, or count parts.
- VS Link: used to create tables with data to send out to VS Link hardware for monitoring purposes.
- Script: programmable tool that can access other SoftSensors for data gathering, etc.

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3.7 Measurement SoftSensors

Measurement SoftSensors are used to take measurements from the parts being inspected. This measurement will be in pixels unless a scale factor is created and calibrated (see Math Tools for scale factor). There are two types of Measurement SoftSensors: line based and area based. In this case, the area based SoftSensors consist of a number of scanning lines. That is, they collect data from many lines in order to produce a more accurate result. Typically, each scan line will produce a data point by finding an edge. The SoftSensor then uses all those data points to perform calculations (e.g. fit a line or a circle). All the measurement SoftSensors can use gradient based methods for threshold besides the intensity based types. When a gradient based threshold is being used sub-pixel accuracy can be easily achieved, and some advanced SoftSensor parameters become available: Edge Width, Use Best Edge, and Hi-Res Mode. These options were added to this version of the software to make it less sensitive to noise and this is how they help the SoftSensor perform the inspection:

- Edge Width: This option lets the user indicate how many pixels determine the edge to be used. If the images are not well focused, the edges will not appear as sharp. In those cases the user needs to give the SoftSensor an idea as to how wide the transition is to better calculate edge positions. Figure 3-12 illustrates more the use of this option. The SoftSensor finding the top edge faces a sharp transition while the one finding the bottom edge needs to overcome the effects of a fuzzy image. In this case, the edge width is set much higher for the SoftSensor in the bottom edge.

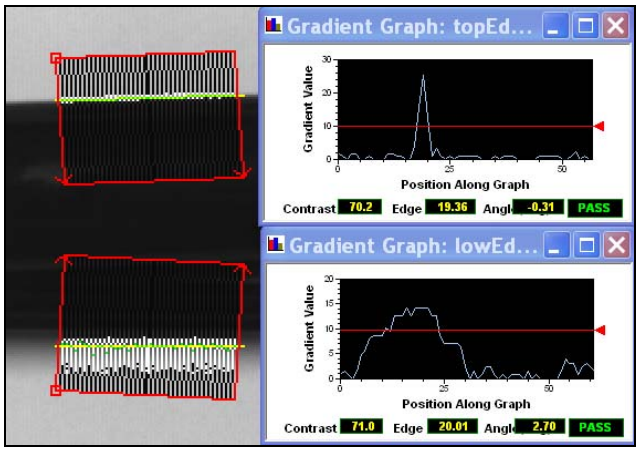

Figure 3-12: Area Measurement SoftSensors in presence of sharp and fuzzy edges. The gradient graphs indicate the width of the transition.

- Use Best Edge: This option is for noisy images. Sometimes background noise determines minor peaks in the gradient graph. In cases where those peaks happen to reach levels above threshold, this option will discard them and keep only the highest peak. The use of this option is illustrated in Figure 3-13. In this example, if the option was not selected, the SoftSensor would report the edge close to pixel number 20, which is where the first peak (above threshold) is located. The use of this option makes it report the true edge instead because it is a better defined edge. The SoftSensor on the left is not using this advanced option and the data points generated by the presence of noise make the output line be at an incorrect location. The second SoftSensor uses the option and the output line is correctly drawn over the edge of the part.

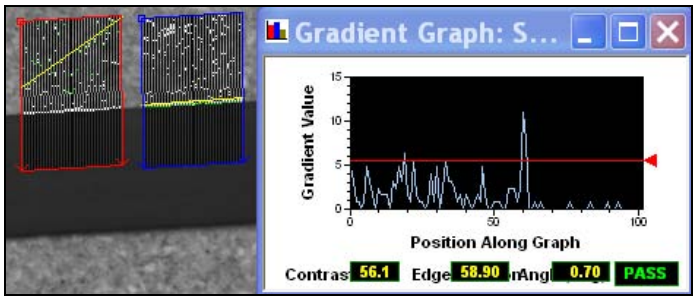

Figure 3-13: Effect of the use of the best edge option. The SoftSensor on the left fails to locate the edge because of the background noise, whereas the one on the right looks for the best edge (the highest peak in the gradient graph).

- Hi-Res mode: This option increases the sub-pixel accuracy of the measurements when the scanning lines are not drawn parallel, perpendicular or at a 45-degree angle with respect to the pixel grid. It compensates for angular error given by the shape of the pixel grid. By using this option the user should obtain more repeatability in the measurements.

All these options increase the processing time of the inspection, so if timing is an important issue, the user should avoid the use of these options by improving the image based on changes to the light or the lens being used.

If sub-pixel accuracy is not a requirement, the SoftSensors should use intensity based threshold. This option increases repeatability in the measurement and it adds some advanced options to deal with noisy images as well. The user has the option to select two of the SoftSensor processing operations (Erode, Dilate, Open or Close). For more information on these operations see under 2.3.5 Processing Operations SoftSensor parameters.

Besides the specific parameters discussed so far, some measurement tools include extra options to make the SoftSensor more precise. When area Measurement SoftSensors are being used, more parameters become available: Scan Density, Max Iterations, and Outlier Distance.

Scan Density lets the user change the number of scan lines being used for the particular SoftSensor. These scan lines run parallel (for rectangles/parallelograms) or towards the center of the SoftSensor (for circles). The more scan lines are used, the more data points are obtained for the measurement. In some cases, increasing the number of scan lines gives a better estimate of the location of the edge of the part being inspected.

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The Max Iterations option lets the user indicate how many times to recalculate the line/circle being interpolated using the data points. After every calculation, points are assigned a certain weight for the next calculation based on the distance from them to the computed output (line/circle). By doing this, the algorithm puts more emphasis of true edge points and less on noise. Figure 3-14 illustrates the use of this option. Image (a) shows the output line calculated with no iterations. As the image illustrates the output line is not on the edge because of the imperfection of the part. Images (b) and (c) show the same SoftSensor after 2 and 5 iterations.

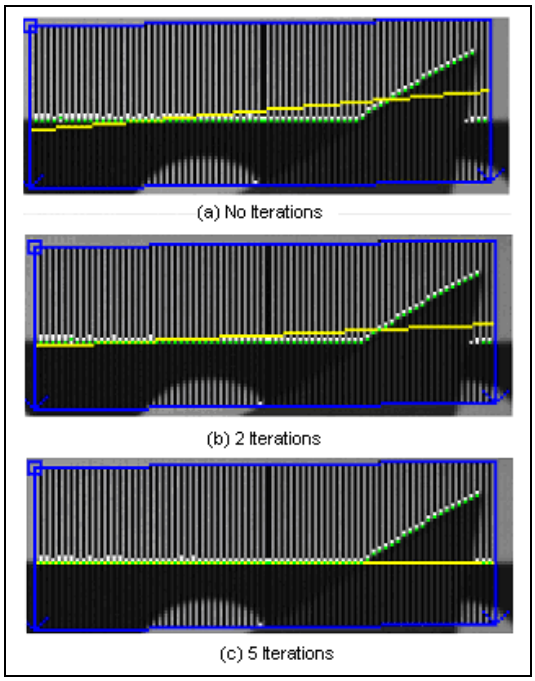

Figure 3-14: Use of the number of iterations to overcome imperfections/noise in the part.

Image (c) is the only one that finds the edge of the part regardless of the imperfections that the part presents.

The Outlier Distance option is used after the iterations and it discards points that are more than a user defined number of pixels away from the output line/circle. This option helps find the right edge of the part and also makes the SoftSensor give a more accurate output regarding how well defined the edge is.

There are four main measurements that the SoftSensors can take: line offset, caliper measurement, line fit, and calculation of a radius.

The line offset Measurement SoftSensor works just like translational lines do. That is, it looks for a specific characteristic (edge or gradient level) and reports the distance from the origin of the SoftSensor to the pixel where the characteristic is found. Unlike the translation SoftSensors, line offset tools report the distance from the origin of the SoftSensor in pixels instead of a percentage. The main advantage of this SoftSensor over the translational line is that since it is a Measurement SoftSensor it can use the gradient based threshold and achieve sub-pixel accuracy.

The caliper-type measurements can be performed using a line or an area SoftSensor. In both cases the SoftSensor can scan inside out or outside in (just like using a caliper). The scanning lines start scanning from the ends of the SoftSensor or from the center until they find the specified characteristic. This characteristic could be a peak value in the gradient graph (when using gradient computation) or a specific type of edge (when the threshold type is intensity based). The output of the SoftSensor is the distance in pixels between the edges of the part. Figure 3-15 shows the use of both line and area based SoftSensors. Line SoftSensors (called Measure Across Line) can only measure the distance along the line.

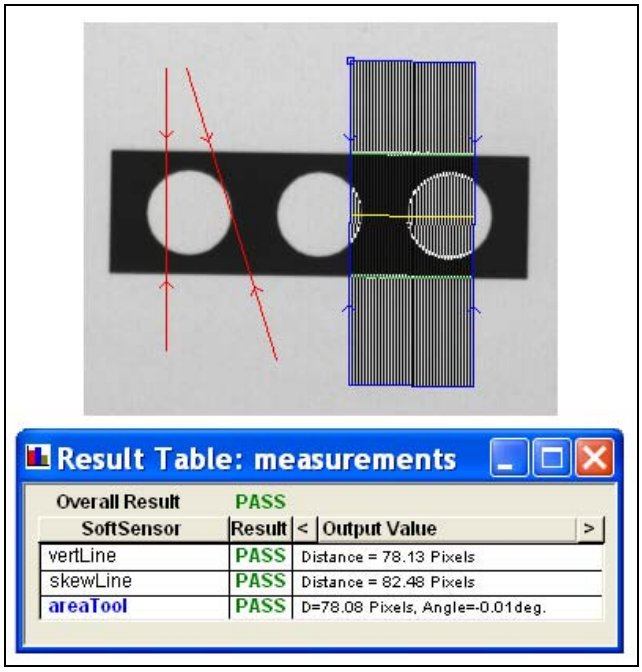

Figure 3-15: Caliper type SoftSensors measuring the height of a part.

As the figure illustrates, more precision can be achieved using the area SoftSensor (called Measure Across Area). Line SoftSensors require that the SoftSensor be drawn at a perfect 90-degree angle with respect to the edge of the part. None of the line SoftSensors in the image is drawn in such way, so the reported distance is greater than the actual distance. Area SoftSensors on the other hand use many scanning lines and each scanning line provides a data point. The algorithm then fits a line along each set of points and reports the distance between those lines as well as the angle between them. If the angle is other than zero degrees, the algorithm averages the maximum and minimum distances that it can calculate from the data points in the SoftSensor. Obviously, the area SoftSensor requires more processing time because not only it consists on many scanning lines, but it requires further processing for the line fitting calculation. One way to reduce the processing time is to reduce the scan density. Scan density is reported as a percentage; for 100% every single line in the SoftSensor will be used, for 50% every other line will be used, and so on. The user can select this value anywhere from 0 (only the 2 edges) to 100 (every single line inside the SoftSensor plus the two edges). Higher scan density is associated with more reliable measurements, so the user should only reduce this number if the image contains very little noise.

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The line fit SoftSensor (called Area Edge Line SoftSensor) is another area SoftSensor. It works just like the area caliper tool only that it scans in one direction. It consists of many scan lines (a number that the user can specify like in the Measure Across Area SoftSensor). Every scan line intersects the edge of the part being inspected and determines the intersection point. The algorithm then interpolates those points into a straight line which is the output of the SoftSensor. This type of tool is the one shown in Figure 3-12, Figure 3-13, and Figure 3-14.

The Measurement SoftSensors that calculate radii are the Find Circle and the Segmented Find Circle. They have the same functionality; they differ only on their applications. A Find Circle tool should be used when the circle to be measured is a complete circle. The segmented version of this tool is used when there is not a full circle. Figure 3-16 illustrates the use of these two different tools.

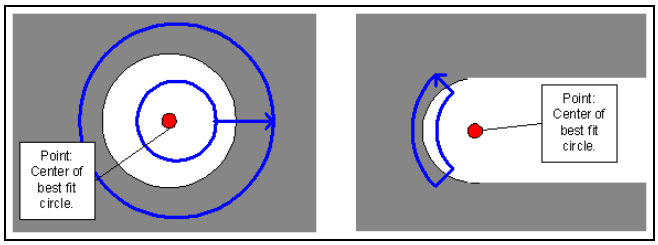

Figure 3-16: Different uses of Find Circle and Segmented Find Circle tools

These tools determine two circles, one inside the part and one outside. Then, scanning lines will go from the first circle drawn towards the second one looking for the edges of the part. The intersections of the scanning lines with the edge of the part will determine data points which are used by the algorithm to interpolate a circle through those points.

Different outputs can be obtained from the area based tools. The user can select minimum, maximum, or average distance (or radius depending on the tool being used). These tools can be set to pass or fail based on specifications for the distances being measured (min radius, max offset, etc.) when the inspection consists of the determination of a correct size. Another feature that the user can select for quality control is the overall roundness/straightness. Depending on the area tool being used, there will be an extra output that indicates how spread out around the output line/circle the data points are. A perfect edge would produce a very small straightness (roundness for a circle) whereas a noisy edge would produce a high straightness (roundness for a circle). In this case, the outlier distance helps a lot in presence of noise. When noise produces data points for the final line, they can increase the straightness a lot. That is, one single data point caused by noise far from the edge will increase the straightness dramatically. Outlier distance will discard those so the calculation for straightness concentrates on edge data points instead of noise. Figure 3-17 illustrates the use of this option. The figure shows a dark part and a noisy background. The dark pixels of the background cause some scan lines to determine data points far from the edge.

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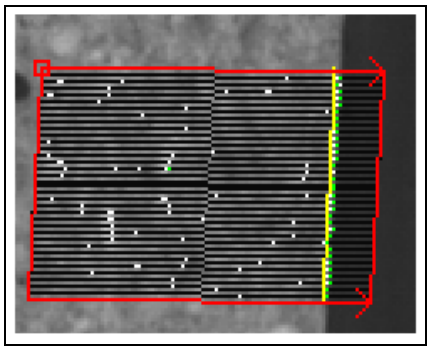

Figure 3-17: Effect of Outlier distance on Straightness for noisy images.

When a number of iterations is selected to correct that effect, the edge is correctly located. However, the data points caused by the noise are still active, so the SoftSensor reports a straightness of 49 pixels. When the outlier distance is used to discard points located more than 5 pixels away from the line the data points produced by the noise are discarded and the straightness drops down to 1.92 pixels. This type of pass/fail condition could be used to verify the quality of a cut or a drilling in a part.

Another use for the Measurement SoftSensors is positioning. Even though Spectation has a dedicated number of SoftSensors for position reference, Measurement SoftSensors can provide a position reference as well. Since Measurement SoftSensors use gradient based threshold and offer a wide range of options to overcome image deficiencies, they can be more precise than the Positioning SoftSensors. In cases where the positioning of a part needs to be very precise, the user can select a Measurement SoftSensor instead of a Positioning SoftSensor as the position reference.

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3.8 Math Tools

The Math Tools toolbox offers an assortment of SoftSensors. Unlike any other tools, when using the Math Tools SoftSensors, no additional drawings are required. Math Tools use references to other tools previously used on the object. Usually, they reference measurement and other math SoftSensors to use their outputs (lines and points) for the calculations. There are three types of Math SoftSensors. The first type performs basic calculations based on other SoftSensors outputs. Table 3-1 shows a list of these SoftSensors and indicates the type of reference that the SoftSensor needs and the output it produces.

Table 3-1: Summary of Math SoftSensors used for basic calculations.

Math Tool	References	Returns
Distance	Two points	The distance between the reference points
	Two lines	The distance between the reference lines
	A point and a line	The perpendicular distance from the reference point to the reference line
Angle	Two lines	The angle between the reference lines
Intersection	Two lines	The coordinates of the intersection of the reference lines
Midpoint	Two points	The coordinates of the midpoint between the reference points
	A point and a line	The coordinates of the midpoint between the reference point and the reference line
Midline	A point and a line	A line parallel to the reference line through the midpoint of the reference point and the reference line
	Two lines	The bisector of the angle determined by the reference lines
Line through two points	Two points	A line through the reference points
Perpendicular Line	A point and a line	The perpendicular to the reference line through the reference point

The second type of SoftSensor is the scale factor. For cases where a distance in pixels is not enough, the user can create a scale factor SoftSensor to convert pixels to units. There are two ways to compute a scale factor: static and dynamic. The static scale method computes the scale factor once and uses it for subsequent images. The user needs to create a SoftSensor to measure a known distance in the object being inspected or in a calibration target. That distance is then indicated to the scale factor SoftSensor which based on the distance in pixels that the measurement SoftSensor reports, computes a scale factor in user units per pixel. This conversion factor is used for every image. The dynamic method requires that an object (or calibration target) with a known size remain in front of the Vision Sensor as long as images are being inspected. The size of this object in pixels is calculated in every inspection and a new scale factor is computed in every inspection. This makes the system more reliable but it takes more processing time. It should be used in cases where there is variation in lighting or working distance (distance from the lens to the part being inspected).

The third type of math SoftSensor is the coordinate transformation type. These SoftSensors are used to set up a coordinate system different from the pixel grid or for correction of lens distortion. The user needs to select a minimum of 5 points in the image (which can be produced with Measurement or Math SoftSensors). The Coordinate Transformation SoftSensor then uses those points to compute the new coordinate system based on their original coordinate (pixels) and the new coordinates (user defined). After this procedure is completed, any SoftSensor can reference the new coordinate system to output a location based on user defined coordinates. That is, any location in the image will have the original coordinates and the option to report the user defined coordinates. The main application of these tools is the interface with a robot. Pixels coordinates need to be transformed to robot coordinates before transferring the data.

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3.9 Readers

Spectation contains a number of SoftSensors dedicated to reading codes, labels, etc. These are the Reader SoftSensors. These SoftSensors consist of the 1D Barcode Reader, 2D Reader (DataMatrix, SnowFlake and Vericode) and OCR SoftSensor (used for Optical Character Recognition and Optical Character Verification).

3.9.1 One Dimensional Barcode Reader

The 1D Barcode reader consists of two types of SoftSensors: a line SoftSensor (arc or straight) and an area based SoftSensor. The line SoftSensor (arc or straight) must be drawn on top of the barcode. Both versions of the SoftSensor have an extra option to include sub-pixel calculation, making it more powerful when the image quality is not the best and the line reader crosses the barcode at an angle other than 0º or 45º. This option makes the SoftSensor more reliable, and the impact on processing times is negligible so it should be used almost every time the above conditions exist. The types of barcode that this tool can read are Interleaved 2 of 5, USS-128, USS-39 (Code 39), UPC/EAN (found on most consumer products), Codabar, Code 93, POSTNET, PLANET, PharmaCode, BC412, PDF417, Micro PDF417, RSS-14 (regular, truncated, stacked and stacked omnidirectional), RSS Limited, RSS Expanded (regular and stacked), RSS-14 Composite, RSS Limited Composite, RSS Expanded Composite, UPC/EAN Composite and UCC/EAN-128 Composite. The SoftSensor can be programmed to auto detect the type of barcode (if the code is one of the first eight codes mentioned above) being read or to always search for a specific type of barcode. The automatic option adds some processing time and should be used only if the barcode type is unknown. The second option can be set manually (the user indicates which type of code is to be read) or automatic (sets the type of barcode upon read of the first instance of the barcode). Usually, applications need to read a certain type code which does not change, what changes is the encoded message that the SoftSensor needs to read. Therefore, the usual setup for this SoftSensor is to set the barcode type upon read (auto-detect) if the user expects one of the seven types mentioned above; otherwise the type should be specified. Figure 3-18 shows sample barcodes. PDF417 is the one on the left; it can be observed that it is a very different type of barcode: it is a stacked barcode. When this is the case, the SoftSensor creates more scanning lines to read the different levels of the stacked barcode.

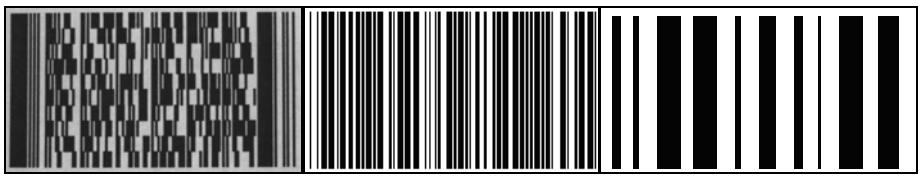

Figure 3-18: Comparison of PDF417, Code 39, and PharmaCode types. The first is a stacked barcode.

The last two barcodes in the image are Code 39 and PharmaCode. For most users it is impossible to visually determine the type of code being used, for they have very similar appearance. In those cases the user should rely on the SoftSensor to determine the type.

Since this type of SoftSensor consists of a line, it is susceptible to noise. To overcome situations where the noise causes codes to be misread, the SoftSensor contains an option to increase the scan lines. By increasing the scan lines, the user can rely on the output from most of the lines instead of all of them. This will allow for some lines to misread the code with the SoftSensor still getting the desired result. This option basically creates a number of copies of the SoftSensor parallel to the original one at a user defined distance and groups all those SoftSensor into one.

A new option available in Spectation 2.7 is the barcode grading. This SoftSensor can be used to grade the quality of the barcode being printed. The method follows ANSI/ISO standards and produces a full report for every barcode analyzed. For more information in this procedure refer to the integration notes section of the Siemens website or the Spectation help files. This procedure is very sensitive to illumination, before using the SoftSensor for barcode grading, system reflectance calibration must be performed (see the Spectation help files for more information on Reflectance Calibration).

3.9.2 Two Dimensional Code Reader

In Spectation 2.7, there is one SoftSensor for all 2-D codes. This is a rectangular-shaped SoftSensor and the user will specify, under the “Options” tab the type of code that will be presented: DataMatrix, SnowFlake or Vericode (for Vericode, a license is needed). The DataMatrix reader has the following features:

- Support for all ECC format DataMatrix codes, including ECC 200. ECC 200 codes can be identified by the even number of rows and columns (result is a white pixel in the corner opposite to the intersection of the solid dark edges or vice versa).
- Automatic detection of symbol size starting at 10x10 (including rectangular code densities).

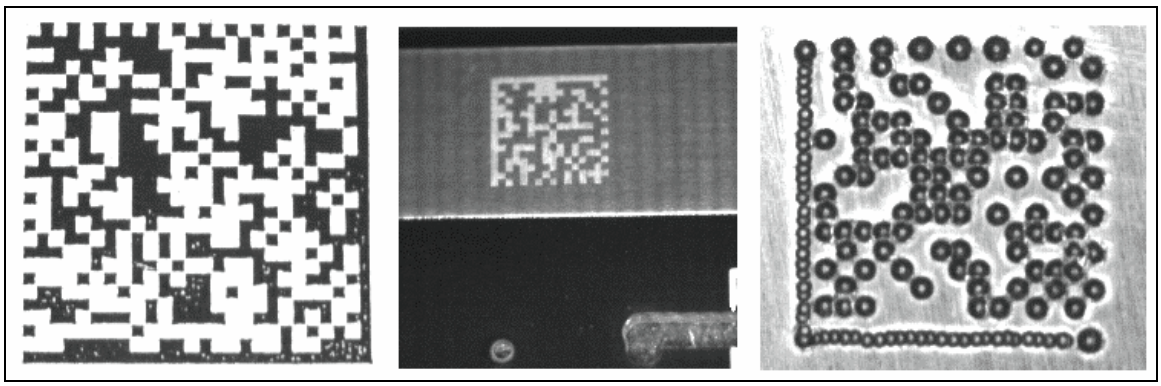

Figure 3-19: Different examples of DataMatrix applications: labels (left) printed circuit boards (center) and other metal parts (right).

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There are two different DataMatrix SoftSensors: fixed and searching. The fixed SoftSensor, which consists of a quadrilateral, must be located just outside the DataMatrix to be read. If the code moves from this location, the SoftSensor will fail. The edges of the quadrilateral must coincide with the edges of the DataMatrix every time. The search tool (which could be a rectangle, an ellipse or a polygon) searches for a DataMatrix inside the area. That is, the code does not have to be consistently located in the same place every time. The SoftSensor will search for it and decode it as long as it is inside the SoftSensor. This tool takes more processing time because of the searching being performed. In order to reduce the processing time when performing a search, the user can specify known values for the DataMatrix. There are many parameters associated with this type of code (ex: cell size, matrix size, etc.). When some of those parameters are known, they can be indicated in the SoftSensor options so the search is limited to a search for a DataMatrix with those features. This makes the SoftSensor faster and more reliable. Figure 3-20 shows a screen capture of two different inspections. The SoftSensor on the left is the fixed SoftSensor, which will not search for the DataMatrix code, the code has to be exactly where the SoftSensor is or it will fail. Of course the SoftSensor can use a position reference to inspect the code where it is located, but it needs another SoftSensor to provide that reference. The second SoftSensor is the searching tool. It searches inside the area delimited by (in this case) the outermost rectangle and it finds the DataMatrix regardless of position as long as it is within that outer rectangle.

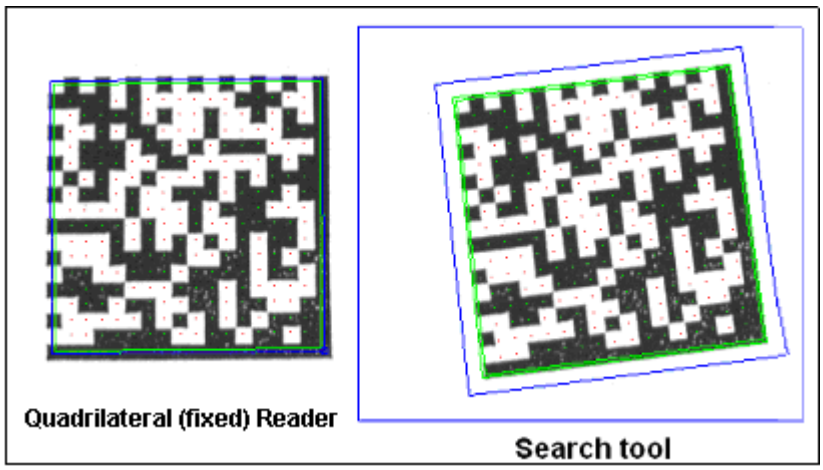

Figure 3-20: Two different methods to read a DataMatrix code: using a fixed tool or a searching tool.

This type of SoftSensors has intensity based thresholds and the user can perform image processing operations (Erode, Dilate, Close, Open) before trying to decode the DataMatrix. This is a helpful feature for cases where the image does not offer the necessary contrast. Figure 3-21 shows the use of the searching SoftSensor and the image marking that can be obtained from a DataMatrix SoftSensor.

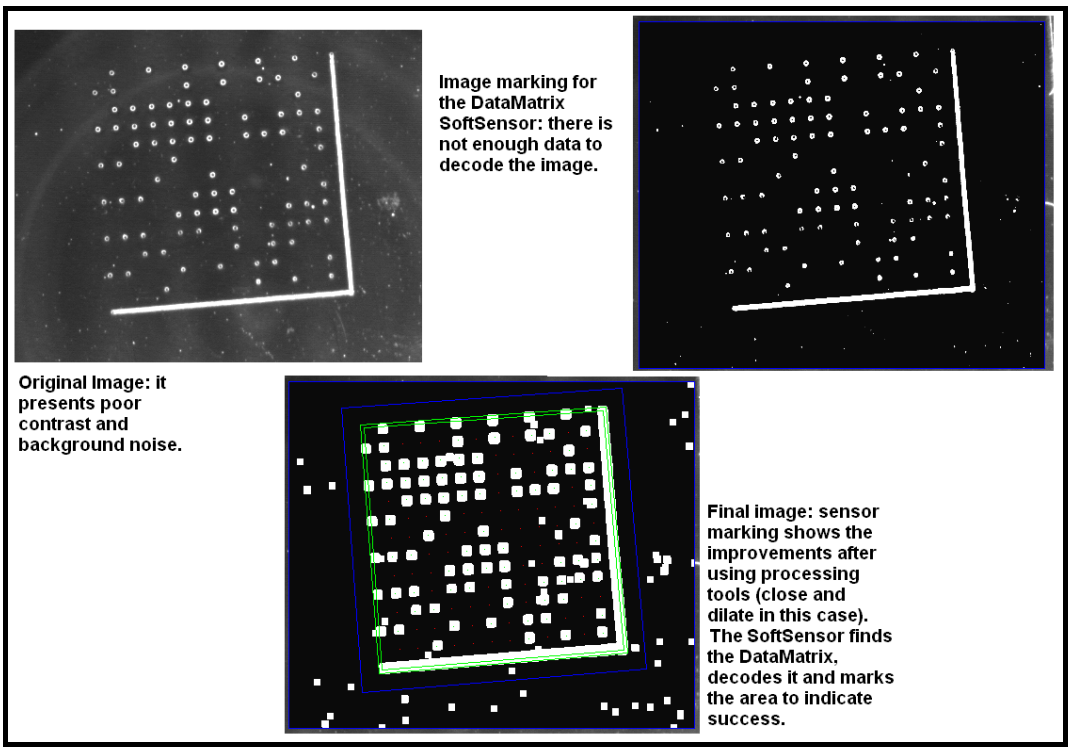

Figure 3-21: Use of the DataMatrix search SoftSensor to decode a noisy image

The image marking for this SoftSensor is unique. It marks with double green lines the edges of the DataMatrix code, and it marks with a color dot the center of each cell. Red indicates that the cell is dark, and green indicates that the cell is light. Since this SoftSensor can read the DataMatrix even if up to 30% of it is missing, the user can select to change the marking to green for cells that were correctly identified and red for cells with error.

These SoftSensors can be set up to simply read, decode and output the code, or to verify that certain string is present in the code. For the second case, the SoftSensor will fail when the string is not matched. It also includes a digital relearn option. That is, if the string to be decoded changes, a signal could be sent to the Vision Sensor to relearn the matching string. The DataMatrix code can also be graded.

The 2-D reader SoftSensor can be set to read SnowFlake codes. Again, the code does not have to be consistently located in the same place every time. SnowFlake codes are designed for fast printing applications and dot matrix printers are generally used. Figure 3-22 shows two examples of such codes.

Figure 3-22: Examples of SnowFlake codes.

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Several parameters can be set to improve the processing speed of the SoftSensor. The density, format, and type of error correction can be auto-detected. However, if these parameters are known, they should be manually specified to obtain faster reads. Other parameters that can be set include code symmetry, dot size and color (dark code on light background and vice versa). The SnowFlake Reader SoftSensor can be set to pass based on a match string.

3.9.3 Optical Character Recognition (OCR)

Siemens OCR (Optical Character Recognition) is a powerful industrial reading tool that provides robust character reading and verification capabilities. It is designed for reading lot codes, serial numbers, labels, product IDs and symbols in the industrial environment. It is not designed to be a page reader that reads scanned-in documents.

The Siemens OCR SoftSensors are based on feature extraction that is more powerful and reliable than normal-correlation algorithms that are used in most low-end readers. Feature extraction computes the features of a graphical object and compares them to features of the trained or learned character set. Since Siemens' OCR uses feature extraction, it has several advantages over normal correlation based systems.

The feature extraction is a faster process; it can handle scaled and rotated characters. Feature extraction is fully trainable which means even symbols, foreign characters, or mixed font sets can be read. This is a very important feature; the SoftSensor is not limited to OCR fonts, which are fonts designed to be read by standard OCR readers. This tool can be used to read anything, the user only needs to train it first, in other words show the SoftSensor what needs to be read. In addition, it can be trained on a sequence of characters so that it can be used as an OCV SoftSensor. Instead of simply reading a code, it can also verify that certain code is present. Unlike normalized correlation, it can handle any type of character marking including dot matrix, laser etching, laser marking, ink jet, video jet, dot peening, etc.

The OCR SoftSensor can be trained on any type of character with any type of font; however, some font styles work better than others. Special OCR fonts have been developed to make reading easier by making characters with the same width (i.e., II and WW are `II` and `WW`) and by making similar characters as different as possible (i.e., 8 and B are `8` and `B`). Other factors that will help you achieve the most reliable and robust readings are:

- Achieve high contrast between the characters and the background
- Make sure characters have good separation
- Maintain a character height of between 20 and 30 pixels.
- Try to minimize noise in your image background.
- Keep characters as similar to the learned characters as possible.

This type of SoftSensor has two different types of threshold: intensity based and OCR. Intensity based threshold methods include the previously discussed types (static, dynamic, and color reference). The OCR threshold is a type of threshold unique to OCR SoftSensors. It is designed to maximize the extraction of the characters for more accurate readings. There are three options for the use of the OCR threshold:

- OCR Computed: Automatic intensity based threshold that makes an intelligent decision as to what text is and what background is and sets the threshold level to better separate those two. It calculates a single threshold level for the entire area of the SoftSensor.
- OCR Linear: Same as OCR Computed but designed for uniform variations in light. It computes an individual threshold for the first and last characters and applies a linear variation of those values for the characters in between. The user needs to specify how many characters (blocks) the SoftSensor is supposed to read.
- OCR Nonlinear: Same as OCR Linear but for cases where the variation of the illumination is not uniform. The SoftSensor in this case computes one individual threshold for each character. This is the option that requires more processing time.

This SoftSensor is very flexible; the user can customize it to the application. A great feature of this SoftSensor is the available shapes it has. The SoftSensor comes in three different shapes: rectangle, parallelogram, and arc. The rectangle is used for text is standard position. The parallelogram is used for text that is inclined, like italics or text written at an angle. The arc is obviously for text in an arc. Figure 3-23 shows four cases where the different shapes are being used.

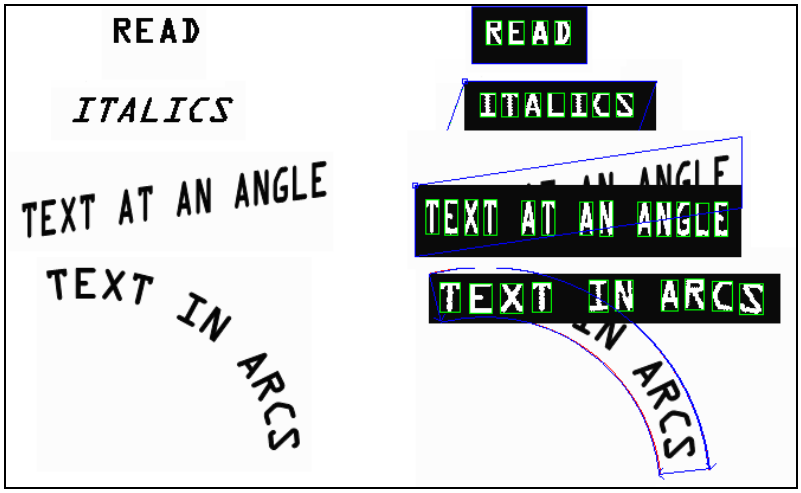

Figure 3-23: Uses of the different shapes of OCR SoftSensor. The top line uses a rectangle, the second and third lines use a parallelogram, and the last line uses an arc.

As the image shows, besides reading the letters in many positions, the SoftSensor offers image marking that straightens the text so the user can read it as well.

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After the SoftSensor is drawn and the threshold is set, the user needs to isolate every character. That is, every character must have a red bounding box around it. When that is not the case, the user can change the extraction parameters which limit the size of the characters in width and height, filter the image to eliminate noise, eliminate loose pixels, etc. The extraction section of the SoftSensor is a combination of very powerful processing options. As the user selects many of them the processing time for the SoftSensor is incremented, so a general rule is to improve the image as much as possible to make the inspection more reliable and to minimize the processing time. Figure 3-24 shows an image containing non-conventional characters. This type of character is very difficult to read because of the deformation that it contains. The first image shows the text itself, and the second one the first attempt to isolate the characters.

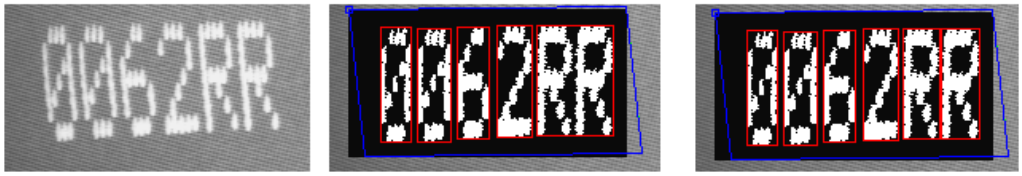

Figure 3-24: Use of the extraction tools to separate individual characters.

As the image shows, the last two letters share the same red bounding box. That means that the algorithm failed to correctly isolate every character. When the extraction parameters are being used (in this case maximum character width and advanced maximum character width) the SoftSensor makes a better decision as to where the characters end and they are correctly isolated.

The next step in the use is the training phase. The SoftSensor needs to be told what the extracted characters represent. This option is very powerful because anything can be trained, from user's handwriting to stroke characters. The only characters that are not trained are the spaces, the SoftSensor ignores them. Also, for applications where the speed of the process causes the characters to vary, several instances of each character could be trained to maximize reliability. As characters are trained, a font list is created and kept in the SoftSensor. This font list can be backed up to a PC for security purposes. If another system is to be reading the same labels, the font list could be loaded into the new system without the need of training all the characters again. Figure 3-25 shows a screen capture of the training tab for the OCR SoftSensor of the example in Figure 3-24. It shows the characters being trained (the string typed by the user), and images of the characters being learned with some information about them. This is the font list that can be backed up to the PC and shared with other Vision Sensors.

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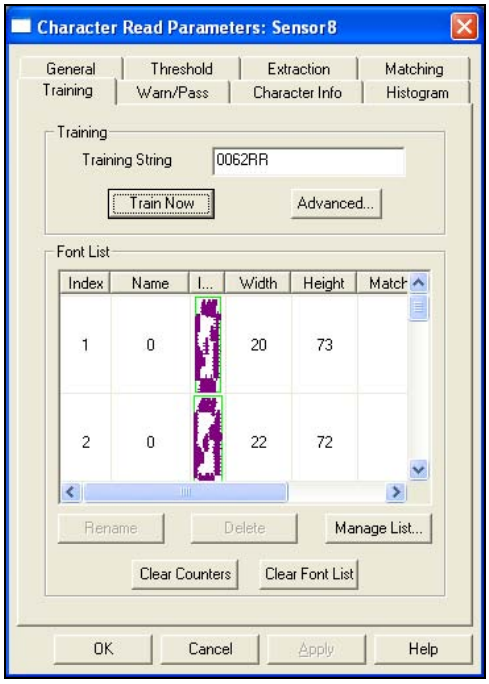

Figure 3-25: Training tab of the OCR SoftSensor. The list of characters is kept in memory as a font list.

After training the characters, the user needs to establish the acceptance threshold that the characters being read need to match in order to be identified as one of the learned characters. When the SoftSensor has successfully learned a character or matched it to a learned one, the bounding box around the character changes from red to green. The user needs to specify a matching threshold which dictates the percentage of similarity that the characters need to have to be considered the same character. For sharp images with even illumination and very distinct characters, a high percentage could be set. As the image quality decreases or variation between similar characters increases due to a poor printing process, the matching threshold must be reduced. In cases where some characters tend to be deformed but still need to be read, the characters should be trained as new characters for not matching the learned model. In those cases the font list will increase for the SoftSensor will learn many instances of every character (for example 4 different uppercase A's). As the font list gets longer, the processing time for this SoftSensor increases due to the increased number of comparisons that it has to make. In order to overcome that increase in processing time, the SoftSensor offers two options: changes in resolution and auto fielding.

The SoftSensor has three different resolution levels: high, medium and low. They differ from each other in the number of features they extract from a character. High resolution mode extracts about 1600 features from the character, medium extracts about 800 and low extracts 200. The selection of medium or low resolution reduces the processing time at the expense of reliability in the identification of the characters. It should be mentioned that the different modes apply only to comparisons. That is, the characters are always learned in high resolution mode to make the comparisons more reliable. The second option to reduce the processing time, increases reliability as well and is called character fielding. Character fielding allows the user to specify the type of character to look for in the different positions of the string to be read. When the application allows for it, the user can specify what type of character to look for in every position of the string (code) to be read. For example, if a particular code consists of two upper case letters and two

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numbers, the user could specify that in the SoftSensor parameters. This will tell the algorithm to check the first two digits against all 26 upper case letters and the last two digits against all 10 numerical characters. This reduces the processing time by reducing the number of comparisons and makes it more reliable (ex: number 8 will not be confused with letter B because it is not being compared against it).

Another powerful feature of this SoftSensor is that it can search for characters. Once the SoftSensor learns some characters, it can be set to find one or all of the characters. This could be used for position reference for other SoftSensors (even for a second OCR SoftSensor). Before starting a search, the SoftSensor scans the list of trained objects to determine the maximum and minimum height and widths. From this, it creates a search window that is moved inside of the region of interest. When a “potential” edge of data is found, the SoftSensor moves through the font list, one object at a time, placing a “window” the size of that trained object at the location of the “potential” edge. The edge is assumed to be the lower left hand corner of the window. As each window is placed, a read is made attempting to match whatever is in the window with any trained object. If more than one object matches, the object with the highest score is returned. If no object matches, the search window continues from where it was last, progressing bottom to top, left to right.

Searching has significant advantages and some significant disadvantages. The major advantage is the ability to find multiple targets from multiple trained objects. The major disadvantage is speed. Careful consideration must be given when evaluating the benefits of using the OCR search versus other search and translation options. Although the OCR SoftSensor does return its location, it does not return a sub-pixel value and does not provide any rotational information. Depending upon the quality and variability of the images, location values may be only “coarse” positions. DO NOT USE THE POSITION VALUES FOR ANY PURPOSE OTHER THAN LOCATING ANOTHER SOFTSENSOR. Since the search algorithm creates a box the exact size of the trained objects, searching will not find objects larger than what was trained. It can find objects that are smaller, however. When searching for text, the acceptance level is generally set higher than normal. This will result in additional training. When searching for patterns, the acceptance level is generally set lower than normal. This will allow for a wider variability. When training patterns, place the ROI as tight to the pattern as possible before training to minimize the effects of noise.

This SoftSensor can be set to pass or fail based on a string to be matched, one or more characters not being read, and a character being read but with a low score. The score represents how well the character matches the learned character. Scores range from 0 to 1000 to show how well the character is matched, a score of 1000 represents a perfect match.

3.10 Blob Tools

Blobs in Spectation are defined as areas of connected pixels of similar intensity. Blob tools are SoftSensors designed to find, count, or track blobs. The blob tools consist of two SoftSensors: the Blob Generator and the Blob Selector.

The blob generator analyzes the image and isolates the blobs based on user options (threshold level and type of blob to locate). Once the blobs are located, the image processing options (Erode, Dilate, Close and Open) can be performed to eliminate noise in the image. If the image requires more dedicated processing options, the user can make those available from the Spectation SoftSensor settings (advanced options under the “Edit” menu). These advanced options consist of features like image processing options in only one direction and filters to extract blob edges instead of the entire blobs. When the image contains noise, the number of blobs reported by the SoftSensor may be affected by it. When that happens not only the SoftSensor becomes less reliable, but also the processing time for the SoftSensor increases because of the extra blobs being processed. In order to overcome this type of situation, the user can limit the blob size. By doing this, blobs caused by noise (usually very small) can be filtered out of the SoftSensor. Using this size feature of the blob generator saves a lot of processing time because the blobs are filtered out before any heavy computation is performed on the blobs found.

This SoftSensor has a very specific image marking. Green corresponds to background. Gray corresponds to blobs that are being counted. Red corresponds to boundary blobs, or blobs that touch the edges of the SoftSensor. In the case of the boundary blobs, the user selects whether those blobs have to be counted or discarded. If the option is to count them, they will be marked in gray just like regular blobs. Finally, black and white corresponds to blobs that have been discarded because of their size: black blobs are undersized blobs, and white blobs are oversized blobs.

The blob selector is used to isolate blobs created by the blob generator. The main use of this SoftSensor is to help the user find the blob(s) that the application requires by calculating a number of parameters about the blobs(s). If the objective is to track a part for rotation and translation, a particular blob must be isolated and its position must be calculated. When this is done, other SoftSensors can reference the blob selector for position reference. If the objective is simply to count the blobs or to verify their correct size/shape, the SoftSensor can do that automatically. This SoftSensor does not have to be drawn; it simply references the blob generator and uses the area delimited by the boundaries of it. As a consequence, it does not have a threshold to set; it simply extracts the blobs from the blob generator and performs calculations based on them. The parameters that the SoftSensor can extract from every blob are: angle, position, area, bounding box size, eccentricity, compactness, perimeter, average intensity, and radius. The user can select to calculate some or all of these parameters to help discriminate between the desired blobs and other blobs in the image. The SoftSensor can display the value of the selected parameters for every blob in the image.

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The image marking for this SoftSensor is different from the blob generator. The background is black, and blobs are highlighted in gray. The blob used for position reference is highlighted in white. Discarded blobs are shown in a darker shade of gray.

Note

The user must set the SoftSensor parameters to select only one blob when doing position reference. That is, if a part needs to be tracked, the position of that part only has to be passed to other SoftSensors.

Figure 3-26 shows an example where the blob selector is being used for position reference. The blob generator passed 4 blobs to the blob selector and this one selected only the blob that represents the part to be inspected. This particular selection was based on compactness and eccentricity of the blobs.

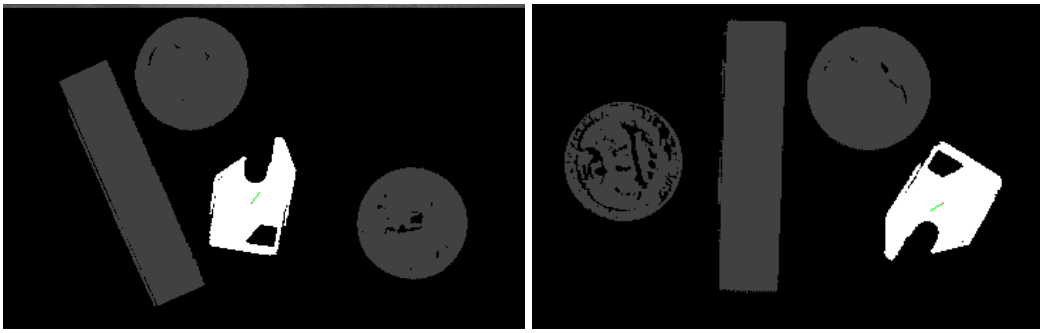

Figure 3-26: Use of the blob selector for position reference.

As the figure shows only one blob is being selected and used for position reference (highlighted in white). The image also shows the marking for the orientation of the part, the mark at the center of it. This mark consists of a green line (which indicates the angle) starting from a red dot (which marks the center of the blob).

Figure 3-27 shows an example where blob tools are used for flaw detection and part counting. The first image shows four pills. The second image shows the image marking for the blob selector when all four pills are being found. In this case the SoftSensor can be set to pass based on pill count.

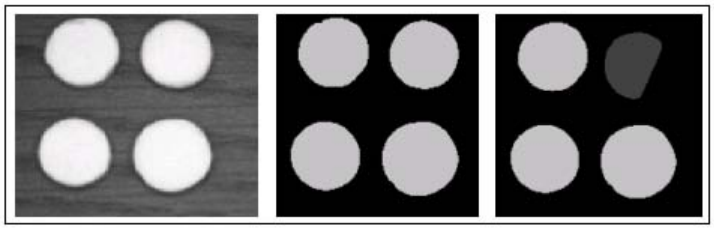

Figure 3-27: Example of use of blob tools for flaw detection/part counting

The last image shows the marking for a case where one of the pills is defective. The damaged pill is discarded so the SoftSensor only finds 3 pills. In this case the SoftSensor should fail based on the blob count. Notice that in this case, since there is no positioning reference being used, the SoftSensor does not mark the center and orientation of the blobs.

Tabelle 3-1: Meaning of the parameters associated with the blob selector.

Parameter	Description	Example
Angle	Measured from clockwise from 3 o'clock position. Must check "Calculate Blob Angles" to then select blobs in range.	$A_1<A_2$
Position	Position of blob centroid as measured from image origin (upper left corner). Must check "Calculate Blob Positions" to then select blobs in a certain range.	Blob 1 (142, 83); Blob 2 (140, 96) $X_1>X_2$; $Y_1<Y_2$
Area	Measured in pixels. Selecting blobs based on area is a very common way to sort shapes.	$A_1<A_2$
Bounding Box	BB is the width and height of the rectangle that encloses a blob.	$B_{1x}<B_{2x}$
Eccentricity	Measures symmetry of a blob. 0-1 scale with most eccentric shapes near 0 (very asymmetrical) and least eccentric near 1 (very symmetrical). Independent of scale.	$E_1>E_2$
Compactness	A measure of blob density. 0-1 scale with least compact shapes near 0 (less dense) and most compact near 1 (more dense). Independent of scale.	$C_1>C_2$
Perimeter	Measures the total length of all edges around the blob, including interior edges.	$P_1<P_2$
Avg. Intensity	Measures average intensity value of the connected pixels.	$I_1<I_2$
Radius	The average radius in pixels of a shape. For non-circular blobs, this value represents the distance from the center of the blob to the point that is farthest away from it.	$R_1<R_2$

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3.11 Template Match SoftSensor

Template Match SoftSensors are used to check pixel patterns against a learned template. The main function of this SoftSensor is defect detection. There are two Template Match SoftSensors from which to choose: Template Match: Fixed SoftSensor and Template Match: Searching SoftSensor.

The Fixed Template SoftSensor assumes a consistently placed part or a position reference from another SoftSensor. This SoftSensor learns the pixel pattern contained in the rectangle (only available shape for this area SoftSensor) and compares the subsequent images to the learned one. This SoftSensor can use any intensity based type of threshold to determine which pixels are light and which are dark. The user then selects whether the light, dark or both groups of pixels are used for the comparison. The selection of one of the groups of pixels decreases the processing time, but it is recommended to use both groups of pixels for reliability. Figure 3-28 shows an image sequence where the part that is present in the first image is being inspected for errors. If only the dark pixels are selected for the inspection, the SoftSensor will verify that all the original dark pixels are present in subsequent images.

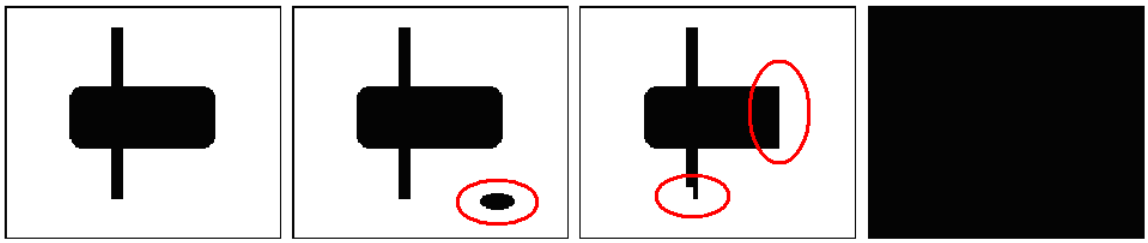

Figure 3-28: Sample images that illustrate the use of only dark pixels for the inspection.

As the SoftSensor inspects the second image, it finds no errors because all the dark pixels of the part are present. The background noise is not picked up because it means error in the originally light pixels. When it inspects the third image, it detects both errors in the part. When it inspects the last image, it reports no errors because basically all the dark pixels from the original image are still dark. This image sequence illustrates why both pixel groups should be used.

A powerful option that this SoftSensor offers is the option to discard pixels near edges. There are minor differences between images, which can be observed by zooming into the image and observing the pixel intensities. This SoftSensor is powerful enough to detect those changes as well, and the areas that are most sensitive to those changes are the part edges. Therefore, the SoftSensor is likely to report some error near the edges even if the part is flawless. To overcome this issue, the user can select a number of pixels near the edge to be disregarded in the inspections. This operation is performed before checking for errors in the template in order to minimize processing time. If the object contains fine details, the user should select to keep the skeleton when disregarding pixels (available from the advanced option). This option will ensure that the geometry of the object is preserved. Figure 3-29 shows an example where the option of keeping the skeleton of the part is used to keep the overall geometry while still disregarding some pixels.

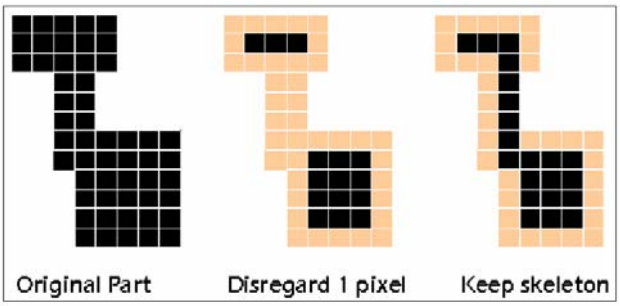

Figure 3-29: Use of the keep skeleton feature to overcome drastic geometry changes when using the option to disregard pixels near the edge.

Unlike most SoftSensors, the Template Match SoftSensor does not offer threshold based image marking. That is, the user should not expect to see any image marking until inspections are being taken. At that time, areas of the image that are different from the original image will be highlighted in red to indicate areas where the part is potentially defective. The only marking drawn with the SoftSensor is the segmentation of it. The area inside the SoftSensor is automatically divided into segments (rectangles). The reason for this is that this SoftSensor can be set to pass or fail based on the amount of error, being the number of pixels or a percentage of the total pixels. When the option being used is the percent total, a small error may be a very small percentage of the entire SoftSensor. In those cases, the user can limit the per-segment error which will always be a higher percentage than it is for the entire SoftSensor.

Note

Although this SoftSensor can be attached to a positioning SoftSensor to inspect the correct location, it can only translate. That is, the SoftSensor will not inspect the part correctly if this one has rotated.

The Template Search SoftSensor performs the same inspection as the fixed type, except that first it searches for the template in a predefined area. The SoftSensor consists of two rectangles: the inner rectangle is the template to be learned and inspected, and the outer rectangle consists of the search region, or where the user expects the template to be located. In this case, the division into segments of the template region has a different meaning. When the SoftSensor is drawn, the template region is divided in segments. After that, the SoftSensor determines how rich in features the segments are, assigning a certain importance to each one of them. There are two ways to select the important segments: monotony based (gives high importance to corner points) and variance based (gives more importance to image details). This process extracts the two most important segments and marks them different from the others. The most important segment is marked with a green plus sign inside a red bounding box at the center of the segment. The second one is marked with a green plus sign inside a green bounding box at its center. The remaining segments are marked with a green or red plus sign at their centers. Green indicates that the segment is very rich in details/corners; red indicates that it does not contain as many details/corners. Figure 3-30 shows a Template Search SoftSensor. The inner rectangle was automatically divided into 4 segments. The third segment from the left is the most interesting one whereas the second one is the second most interesting segment. In

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this case the SoftSensor allows for some translation in the X and Y directions. If the Siemens logo changes the position but stays within the outer rectangle, the SoftSensor should find it and inspect it at that location. This SoftSensor does not track rotations, so if the part rotates a different SoftSensor should be used.

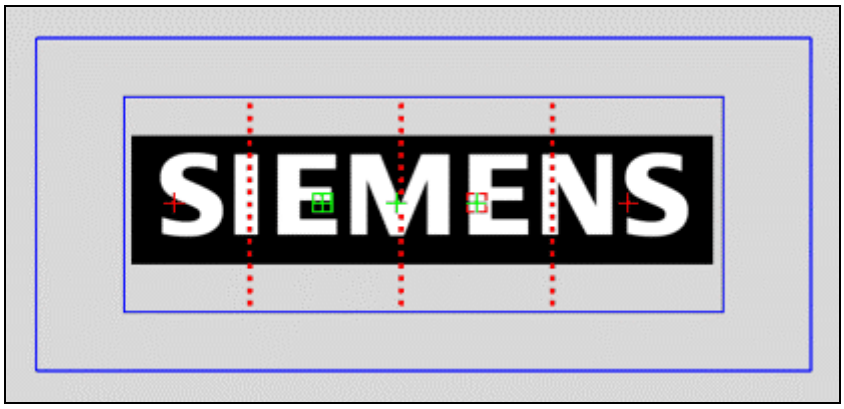

Figure 3-30: Template Search SoftSensor finding the Siemens logo and verifying that no errors are present.

For this specific SoftSensor, the division of the area to be inspected into segments serves yet another purpose. When the SoftSensor searches for the template, it does not search for the entire pixel pattern because that would require a lot of processing time. It searches for the most interesting segments instead. Once it finds a few potential locations for the template it then compares the remaining segments based on the location they should have with respect to the potential locations of the most interesting ones. The user has a few options to speed up the process such as skipping some pixels in the original search and fine tuning the position found by moving the template a number of pixels in all directions starting from the potential location generated by the first search until the best match is found.

Like the fixed template SoftSensor this SoftSensor can be set to pass or fail based on the amount of error detected inside the SoftSensor or inside the segment that contains the most error.

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3.12 ObjectFind SoftSensor

ObjectFind SoftSensors use advanced algorithms to learn the characteristics of an object and find occurrences of that object in subsequent images. ObjectFind SoftSensors can be applied in a variety of Vision Sensor applications, including:

- **Flexible feeding, motion control, robotics:** Parts could be presented in any orientation and may overlap.
- **Short product runs:** The key to these applications is quick setup because a large variety of parts are manufactured.
- **Position finding/referencing:** ObjectFind's learning ability means quicker setup when compared to using Translation, Rotation, or even Blob Tools.

When the SoftSensor is drawn it binarizes the image based on the threshold selected. Then, it analyzes the dark or bright object present (according to user selection) and extracts a number of features that describe the geometry of the object. The list of features is kept in memory and the SoftSensor uses that list as the learned model. In subsequent images, the algorithm searches for the features contained in the model to determine the presence of the learned object. There are two types of ObjectFind SoftSensors: single area and double area. The single area type must be drawn around the object and when the SoftSensor learns the features of it, it can be resized to cover the area where the object could potentially be located. The double area SoftSensor determines two areas; the inner area is for learning the object and should be drawn just outside the object. The outer area indicates the region where to search for the object. Both SoftSensors perform the same task, but the double area SoftSensor is preferred in cases that an object that changes the position over the entire area needs to be relearned using the digital relearn signal. In order to do this, the new object to be learned must be placed within the inner rectangle.

ObjectFind SoftSensors have a number of parameters that the user can set to better find the objects. First, it can be set to find a single object (when used for position reference) or to find multiple objects (when used for part counting). In order to minimize processing time, the user can limit the movement that the objects are to have. That is, when the application allows for it, the user could limit the movement in the X, and Y direction as well as the rotation, so the search for the object does not take much processing time. The distances and angles indicated by the user are relative to the position that the object had when its model was learned. Likewise, when the SoftSensor is set to look for multiple objects, the user can specify a minimum object separation in pixels (translation) and in degrees (rotation). When this option is used and objects are found within the minimum allowed, only the object that better matches the learned model is reported. If the distance between the objects and the lens tends to vary, objects will seem to vary in size. For these cases, the SoftSensor offers a scaling tolerance parameter which the user can select to identify objects when they are proportionally bigger or smaller than the learned model.

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Another important parameter that ObjectFind SoftSensors have is flexibility. The user can set the SoftSensor to be more or less flexible. The SoftSensor should be less flexible when the object to be located does not vary in size/geometry. If the parts are neither defective nor overlapping, the SoftSensor should only recognize the presence of an object when many features of the learned model are present in the area. This option makes the SoftSensor less susceptible to noise. For the opposite case, when objects tend to overlap or even change in geometry, the SoftSensor should be made more flexible. This will allow the SoftSensor to find objects where there are only a few characteristics of the learned model. The user should keep in mind that the more flexible the SoftSensor is, the more susceptible to noise it becomes. That is, if background noise or even other parts in the image present some of the features that the learned model contains, those regions will be identified as a new object. The parameters that allow the SoftSensor to be more or less flexible are:

- **Scale Tolerance:** allows the SoftSensor to find bigger and smaller objects
- **Object Matching Parameters**: Indicates a minimum percent of features and perimeter that must match the learned model for the object to be indicated as a match
- **Feature Matching Parameters:** lowering these allows for some deformation in the part being analyzed and still consider it a match
- **Polyline Parameters:** determines how the polygon that follows the contour of an object is drawn as well as the minimum perimeter that an object feature must have to avoid being discarded (to filter out noise)

All these categories consist of a number of different parameters, for explanations about each one and how to change them please refer to the Spectation help files. For an idea as to how much to change the values please refer to the SoftSensor properties, under object info the SoftSensor displays a number of parameters corresponding to every object that is found in the image.

Image marking for this SoftSensor is different from the others. The user can customize it by choosing among four options: intensity levels (black and white), edges found in the image (highlighted in red), edges of objects found (highlighted in green), and model reference point (center and orientation of the object). Figure 3-31 shows the image marking for the SoftSensor will all four options enabled. First, all the edges determined by changes in intensity level (above or below threshold) are marked.

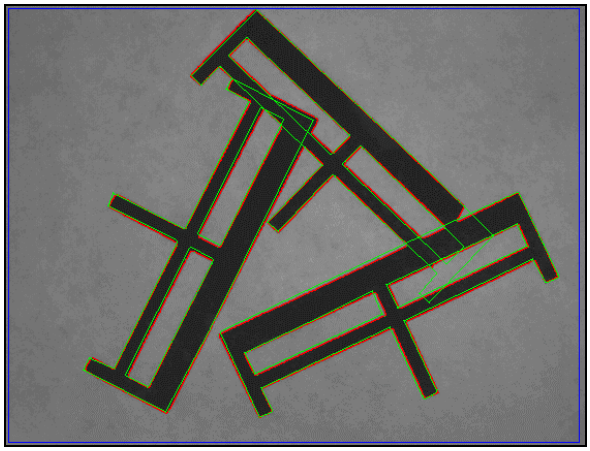

Figure 3-31: Image marking for the ObjectFind SoftSensor

This marking is red; it corresponds to any transition from bright to dark. A second marking (in green) can be observed over the edges of the objects even when they are incomplete of overlapping. This marking corresponds to the learned model and it indicates that an object was found in this position. Even though the object in the image does not match the model point by point, most geometric characteristics of the model are found in this object, so it is being identified as a match. These two types of marking are unique to this SoftSensor. It can also mark the intensity levels (white for areas above threshold and black for areas below threshold) and the center of the object. There is another type of marking available from the edges of the objects. Based on user defined parameters, the algorithm sets a number of corner points along edges which are part of the object model. Those corner points are highlighted in blue and they are on top of the red marking that separates the object from the background.

This SoftSensor is mostly used for position feedback, to another SoftSensor or to a robot. However, if the application consists of counting the parts, the SoftSensor can be set to pass or fail based on the number of objects found.

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3.13 Intro to Color SoftSensors: the RGB color space

In order to better understand the functionality of the Color SoftSensors the color space should be explained. As it was mentioned before, color systems report four different values from each pixel. Those values refer to the color content and the intensity level. The color content is broken into three different coefficients to indicate the content of each basic color: Red, Green, and Blue. Any color can be created using the correct amount of Red, Green, and Blue, so by having the system report the contents of all three basic colors, any color can be represented in the system memory. The fourth parameter that is reported is the intensity level. This parameter would be the equivalent to the intensity as discussed for grayscale systems, and is computed from the values obtained for the basic colors according to certain weight associated to each one (based on the wavelength of the color). All four parameters (R for Red, G for Green, B for Blue and I for Intensity) range from 0 to 100, so color identification occurs in a three-dimensional space of R, G, and B coordinates whereas the intensity is an independent value. Figure 3-32 shows this color space. The X, Y and Z axis are the R, G and B components. A certain color could be defined by three coordinates; however, that will give a very specific color. In practice, colors are defined by ranges of R, G and B. This defines a volume instead of a point as shown in the figure. Points inside that volume are of that color, points outside that volume are not of that color.

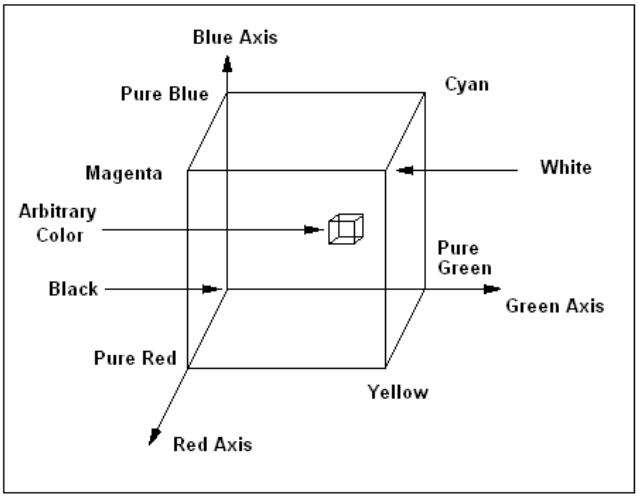

Figure 3-32: Three-dimensional color space defined by the basic colors Red, Green, and Blue.

This definition of the color space defines a new method for thresholding the images. The boundaries of the volume that defines the arbitrary color are the new threshold. Colors inside that volume are defined to be above threshold. Likewise, colors outside that volume are defined to be below threshold. As an example, if an image contains a number of objects of different colors, the user needs to learn the desired color. Once that happens, the user can use the Dominant Color type of threshold to interconnect the threshold to the learned color. By doing this, the object of the learned color will be identified as above threshold (highlighted in white). Likewise, the other objects will remain below threshold (outside the volume) and will be marked in black.

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3.14 Pixel Counting SoftSensor (Color SoftSensor)

The Pixel Counting SoftSensor is the basic Color SoftSensor. It is called Pixel Counting to emphasize what it does and to highlight the fact that its use is not limited to color systems. This SoftSensor learns a color (or many colors) and determines the number of pixels of that (those) color(s) that are found on subsequent images. If a grayscale system is used, the SoftSensor learns a shade of gray and uses it as if it was a color. There is not a concept of threshold in this SoftSensor. The SoftSensor is drawn and based on three parameters it learns a color. Those parameters are:

- Sigma Factor: changes the size of the volume that represents the color in the 3D color space. Increasing it will include more (similar) colors in the volume. Decreasing it will make the color selection more specific.
- Matte Areas: help the user select darker and lighter shades of the same color. In the 3D color space the matte line starts at coordinates 0, 0, 0 and passes through the selected color. The darker shades of the color are located between the color and black, the lighter shades are located on the other side.
- Highlight Areas: are used to include areas of the color that contain direct reflection of light. The areas affected by reflections tend to be white, so the highlight line goes from the selected color to white (coordinates 100, 100, 100).

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Figure 3-33 illustrates the effects of the use of these parameters; the first diagram shows a learned color. The color occupies a limited volume in the RGB space. The image on the upper right corner shows the effect of increasing the sigma factor. The volume increases in all directions bringing similar colors together. At this time the color SoftSensor recognizes any color inside the new volume as the learned color. This makes the color selection more general. If the user wanted to make it more specific, the sigma factor should be decreased to reduce the size of the original volume.

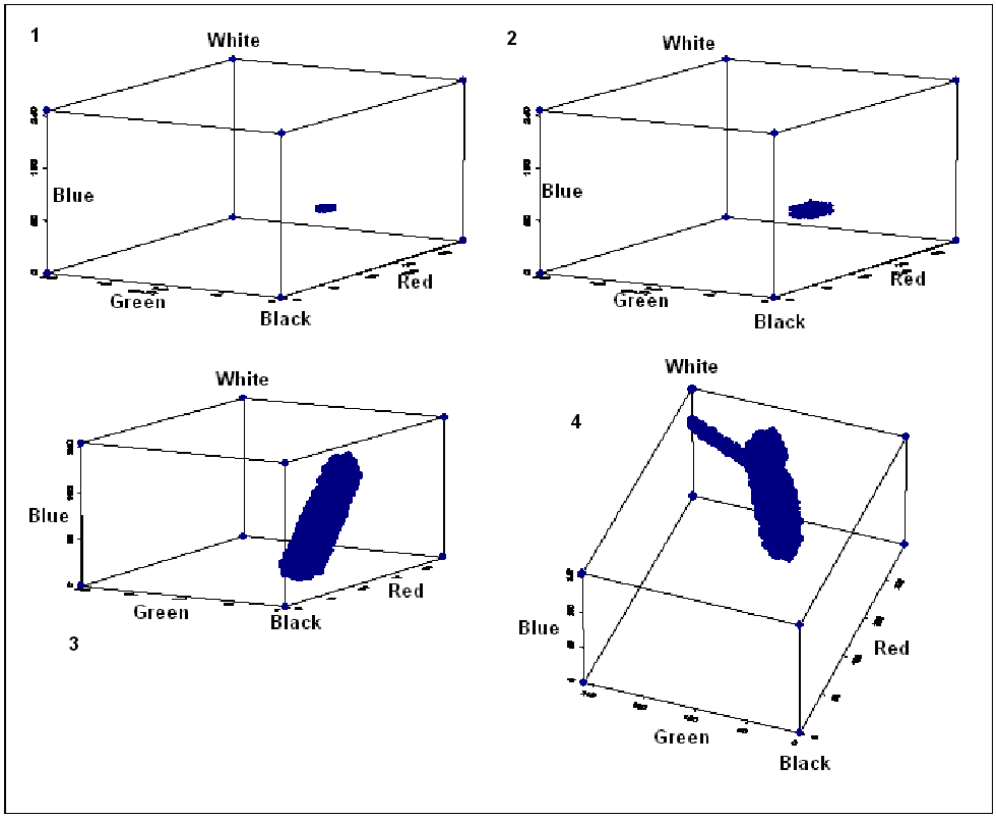

Figure 3-33: Three dimensional illustration of the effect of the color SoftSensor parameters. The first image shows the learned color, the second one the effect of increasing the sigma factor. The third one shows the effect of increasing the matte areas, both for darker and brighter shades of the color. The last image shows the effect of increasing the highlight areas.

The third diagram (lower left corner) shows the effect of using the matte areas. The volume is expanded towards black (coordinates 0, 0, 0) to pick up darker shades of the color or away from black to pick up brighter shades of the color. The user can select how much to extend the volume and in which direction (darker, brighter or both). Finally, the last diagram illustrates the use of highlight areas. This option is intended to include shades of the color that are caused by reflections, so those shades are between the original color and white (which would be a full reflection of the light). Increasing this factor expands the original volume towards white.

Figure 3-34 shows an example of the use of the sigma factor. The color SoftSensor learns only the light orange on the left end. It is then expanded over all the colors and image marking shows where the color is identified. For the example on the top row, it happens to be only over the learned color. This example uses a sigma factor

of two. For the second example, the sigma factor was doubled. For a sigma factor of four, it identifies other colors as well. The last two examples represent sigma factors of seven and ten respectively. The SoftSensor is able to pick up different colors, colors that do not reside inside the original matte line, but as the sigma factor is expanded, those other colors are included in the volume that identifies the learned color.

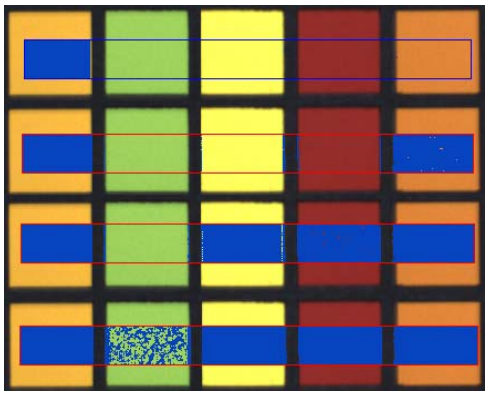

Figure 3-34: Illustration of the use of sigma factor to include other colors in the selection.

This SoftSensor can learn colors one by one or many at a time. When the SoftSensor is used to learn colors one by one, it must be resized to cover only the area where the desired color is present. This procedure should be repeated to learn as many colors as necessary. The SoftSensor will keep a list of all the learned colors. For complex objects where the colors are not well defined, the user should select the clustering mode. In this mode, the user specifies the minimum cluster size which indicates the minimum number of pixels that a color must have in order to be added to the list. When the user learns clusters, the SoftSensor learns all the colors in the specified area and makes a list of them. The user can then manage the color list by merging some or all colors into one, or deleting colors that are no longer needed. One important consideration about this SoftSensor is that whereas the single color learning adds colors to an existing list, clustering mode (multi-color learning) replaces the existing list with a new list of the colors extracted from the part. Another feature that these SoftSensors present is the digital relearn. They can be programmed to expect an external signal (digital relearn), and when the signal is received, the SoftSensor learns a new color. That signal can be used to change the match color as well. The match color is the color against which every image is being compared to determine a PASS/FAIL result.

The uses for this SoftSensor are:

- To detect the correct color: the SoftSensor can be set to pass or fail based on color variation
- To detect the right amount of color: the SoftSensor can be set to pass or fail based on changes in the amount of a certain color
- To identify parts: the SoftSensor can be used to determine which part is in front of the camera based on the “best match” feature, which tells the user which color from the list best matches its original size in pixels
- To export colors: the SoftSensor can learn, merge and export the colors to another SoftSensors to be used as threshold by those SoftSensors.

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3.15 Color Monitoring

The Color Monitoring SoftSensor is another type of Color SoftSensor. It is a much more precise SoftSensor than the Pixel Counting SoftSensor. This SoftSensor can tell amongst approximately 16.7 million colors whereas the Pixel Counting SoftSensor can tell amongst about 65000 colors. As a result, the SoftSensor is used mostly to identify different colors when they are very similar. This SoftSensor reports the difference between colors. If many colors have been learned, the SoftSensor reports the color difference with respect to the closest color. The SoftSensor can be setup to work in the following color spaces:

- RGB is the default color space. Color difference is calculated as the Euclidian distance between two points. If Matte Line is selected, distances are measured to the matte line instead of the saved average color.
- Optical Density is the second option; in this case the color difference will be computed on a base 10 logarithmic scale. This color space is mostly used in the printing industry. RGB shows the reflectance of the measured sample, but Optical Density shows the absorption. The average Cyan, Magenta, and Yellow density is displayed. The reported color deviations represent the change in optical density of CMY components compared to the Closest Color. Color Difference is the maximum of DC, DM, DY
- La*b*ΔE, this is CIE LAB. Please note that La*b* values are approximate. Standard formulas are used to compute these values.
- LC*h°ΔE_{cmc}, L is the Luminance or Intensity component of the sample. C* is the Croma or Saturation component and h° is the Hue angle. Color difference is ΔE_{cmc}.

During Inspection the average color of pixels under the sensor shape is found and displayed in the result panel. Depending on the color space used the distance between this point and every color in the list is computed. The “ClosestColor” is the one with the smallest distance. This distance is displayed in the results panel as Color Difference. Figure 3-35 illustrates how the distance is reported in the RGB space. The SoftSensor computes the Euclidian distance from the color found in the image to all the learned colors to determine the closest color. Once this color is found the SoftSensor reports the color difference in each channel (R, G, and B) besides the overall distance shown in the image.

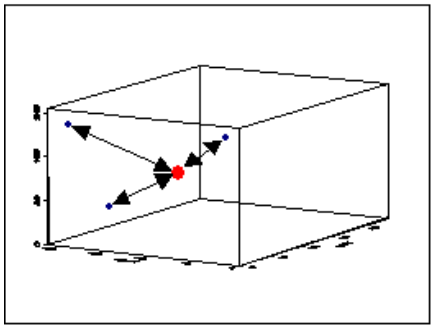

Figure 3-35: Illustration of the output (color difference) as the Euclidian distance in the RGB space. The SoftSensor reports the distance to the closest of the three colors that in this case have been learned.

An important consideration about this SoftSensor is that it does not mark the image. When the SoftSensor is drawn, all the pixels inside it are taken into account for the computation of the average color. The user is supposed to utilize this SoftSensor only over uniform areas of the color. For that reason image marking is not used (because it would mark every single pixel inside the SoftSensor every time). This lack of marking is another feature used to identify the Color Monitoring SoftSensor.

This SoftSensor can be set to pass or fail based on five different criteria:

- Maximum Change in Color Data 1: Depending on the color space used it can be the maximum allowable change in Red reflectance, Cyan density, or Luminance.
- Maximum Change in Color Data 2: Depending on the color space used it can be the maximum allowable change in Green reflectance, Magenta density, a* or C*.
- Maximum Change in Color Data 3: Depending on the color space used it can be the maximum allowable change in Blue reflectance, Yellow density, b*, or h°.
- Maximum Color Difference: Is the maximum allowable distance between the sample color and the ClosestColor. The Color Difference is computed depending of the color space as explained above.
- Match Color Name: This allows the user to select one of the colors in the learned list. The name of the ClosestColor should now match the selected color or the SoftSensor would fail.

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3.16 Segmentation SoftSensor

Segmentation is the process of grouping pixels into distinct sets based on intensity changes. Each set has its own characteristics including color, pixel size, and position. Unlike blob tools, this SoftSensor does not threshold the image; it uses fuzzy logic to detect gradient changes between pixels, which determine segment edges. That is, the SoftSensor analyzes the area and determines gradient levels; if those are above a certain level, the SoftSensor marks them as a separator between different sets of pixels. These edges become segment boundaries. During the segmentation process, the pixel on the upper left corner of each segment used as a seed. The seed pixel is then grown in four directions for area sensors and along the line for line sensors based on color/intensity tolerances. Neighboring pixels can merge with the growing segment based upon pre-defined conditions of color tolerance. In many applications, Edge Contrast is enough to separate different segments from each other. If there is a missing edge pixel, the growing segment can “leak” into the neighboring segment. To prevent the leak a coarser seed type can be used. There are five different seed types for area sensors the finest one would get through the smallest opening that a boundary could present, while the coarsest one will “seal” the small openings in the boundaries Figure 3-36 shows the use of segmentation SoftSensor. In this case the SoftSensor has to count the objects in the FOV. When the SoftSensor is drawn, it determines some limits based on gradient rules. That is, the SoftSensor specifies areas where the gradient exceeds the maximum specified by the user.

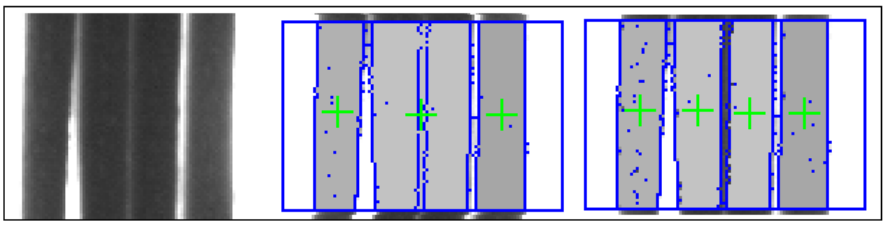

Figure 3-36: Use of the Segmentation SoftSensor to separate and count objects.

In some cases that delimitation is not enough as the second image shows. In this case there are openings in the boundaries of the segments causing two of the segments to be merged into one (second image). In order to overcome this issue the user can select a different gradient threshold or increase the size of the seed. A coarser type of seed cannot get through the smallest openings so the segments are correctly identified as in the third image. In some applications sharp edges do not exist between objects. To segment this type of images, an additional parameter called Color Tolerance can be enabled and configured, which takes color into account in the segment growing process. Based on the Color Tolerance setting, when a particular pixel varies in color from the seed color (the color of the first detected pixel) by a certain amount and still belongs to the same segment, the algorithm will set a limit to exclude it from the segment. If the boundary openings of Figure 3-36 were too big for the coarsest type of seed, color tolerance could be used to establish the limits between different segments.

This SoftSensor has two different modes: relative and absolute mode.

The example shown above uses absolute mode. The SoftSensor only finds and counts the segments. It has the same functionality as the blob tools, but since it uses gradient based calculations instead of a regular threshold, it is more precise when there is poor contrast (like in the example above). In those cases the use of a threshold is very difficult, as the image shows the separation between the two center segments is hard to determine.

The second mode is the relative mode. When working in relative mode the SoftSensor learns a set of segments and detects their presence in subsequent images. The SoftSensor can verify that the segments are present, and how much they have changed in position, size and color. In this case the SoftSensor adds a manager tab to its parameters and it shows a list of the learned SoftSensors in it. The user can then select some rules to determine whether the segment is acceptable or not. The available rules are maximum movement in the X direction, maximum movement in the Y direction, maximum change in size, and maximum change in color. This SoftSensor is used a lot for printing processes where the print register needs to be correct or one of the colors will be printed off the position it should. Figure 3-37 shows two images of a print register. The image on the left illustrates the correct position of all the segments. The image on the right shows that some of the segments have changed position. This would cause a problem with the printouts having some of the colors off their correct position.

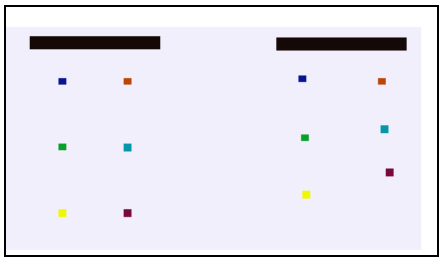

Figure 3-37: Common application for Segmentation SoftSensors: print registers

For these applications the SoftSensor is used in relative mode, so all the segments are learned (size, color and position of each) and the SoftSensor simply verifies that the learned parameters remain within a user-defined range of acceptability.

This SoftSensor can be set to pass or fail based on the number of segments found. For the absolute mode, this relates to the segments found when the image was segmented. In that case there is no further processing. When working in relative mode there is another option. The segments must follow specific user-defined rules in order to be considered segments. In that process some segments are discarded. Those discarded segments make up for the fail count, or the number of segments that failed to follow those rules. In this case, the pass/fail criteria could be based on both segment count and segment fail count.

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3.17 Foreground Scripts (Script SoftSensors)

A foreground Script is a programmable tool that allows the user to write a short program with access to data from other SoftSensors. This program, which uses a very common syntax (similar to Java, C, and C++) is always part of a product and is executed when that product is used to inspect an image, which is why they are called Script SoftSensors. Script SoftSensors can:

- Be set to pass or fail based on certain conditions, except that the user defines those conditions, there is not a predefined set of rules because of the versatility of this type of SoftSensor
- Access data from other SoftSensors and draw a conclusion (pass/fail) based on data from several SoftSensors
- Perform mathematical calculations using built in functions or by letting the user program new functionality
- Access registers in memory to interchange data between different products, with background scripts or even with external devices

For more information, documentation about all the specific functions, and examples about Script SoftSensors please refer to the script documentation and Spectation help files.

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4 Inspection Application Guidelines

This chapter provides major guidelines to approach different inspections. Users should be familiar with the different types of SoftSensors available in order to understand the concepts and issues explained here.

4.1 Dealing with Colors

The main uses of the Pixel Counting SoftSensor (Color SoftSensor) are to detect defects or verify that correct parts are used in an application. Defect detection can be performed by learning the “good colors” of a part and detecting any color not in the “good colors” list in subsequent parts. If the type of defect is known, the “bad colors” can be learned instead and the images can be analyzed by checking the presence of those colors only. Part presence can be performed by learning the colors of a number of parts and verifying that the correct part is being used by inspecting subsequent images and comparing the colors present to the desired color. Another way in which Colors are used is to export them to other SoftSensors. When that is done and another SoftSensor references the color, light areas (referred to as above threshold for grayscale systems) become areas of the imported color, and dark areas (referred to as below threshold for grayscale systems) become areas of other colors. There are two ways to learn colors using the Pixel Counting SoftSensor: single color learning and multi color learning. The process for single color learning is illustrated in Figure 4-1.

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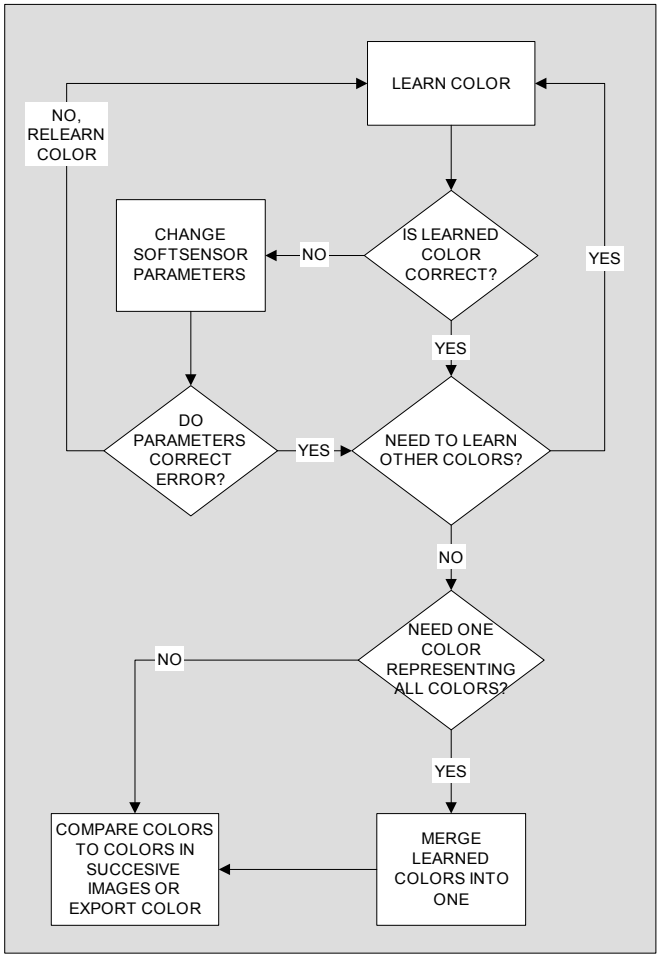

Figure 4-1: Process for single color learning.

As the process in the figure illustrates, single color learning does not mean the use of a single color but the learning of one color at a time. By following this process, the user can end up with a list of colors (or a single color representing the list) that describe a part or a set of parts which can be used to inspect images.

For this process only one color can be seen by the SoftSensor when the colors are being learned. Any attempt to learn a color when 2 or more colors are seen by (are inside of) the SoftSensor will result in incorrect colors being learned.

The second use of the SoftSensor is the multi color learning. This process involves learning multiple colors at the same time. The process is illustrated in Figure 4-2.

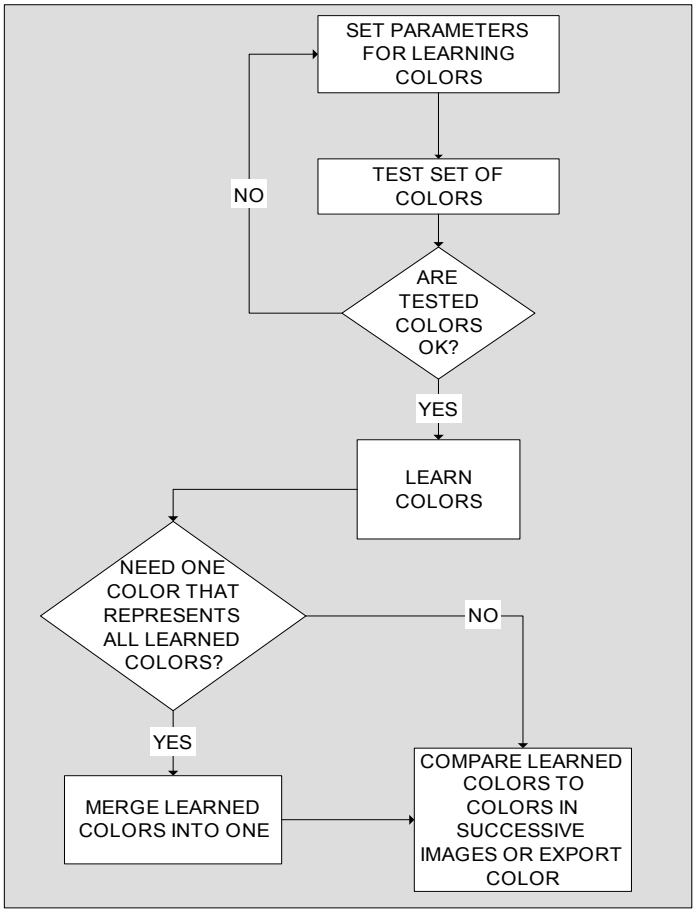

Figure 4-2: Process for multi color learning.

This process is used to learn the colors of a complex part, a part that is not of a well-defined color. The SoftSensor is drawn over the entire area (so all the colors are inside the SoftSensor) and the process begins by setting the parameters. The parameters include the minimum number of pixels that each color must have to be included in the list (Cluster Size) and the maximum number of colors to learn from the part (Maximum Cluster Count). Based on those parameters the image is tested to get image marking showing which colors are learned. Only after the desired colors are marked the user should learn the colors. Since this method learns multiple colors at the same time the list of learned colors replaces any colors previously learned. For more information about color parameters see Color SoftSensors.

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4.2 Dealing with Part Movement

In real world applications, parts to be inspected are not consistently placed in the same position for every inspection. There are many parameters that affect this such as the use of proximity switches to indicate presence/absence of the part. Those switches will only tell whether the part is present or not. For more precise information about the location of the part, proximity switches are not very reliable. Spectation offers a number of tools to help the user locate the part in the image and to create a reference that the inspection SoftSensors can use to track the movement of the part. This set of tools consists of the Translation, Rotation, ObjectFind, Blob, Measurement, Math, Segmentation, and even OCR SoftSensors. These SoftSensors are used to calculate part movement. The user needs to create a reference from the inspection SoftSensors to the positioning SoftSensors so every SoftSensor inspects the correct area of the image every time. Figure 4-3 illustrates how to track the part. The positioning SoftSensor locates the part and calculates the shift in position (with respect to the original position).

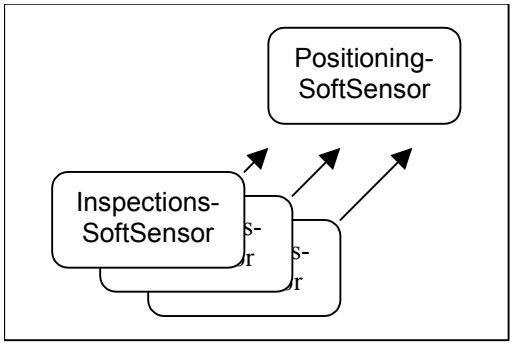

Figure 4-3: position reference mechanism

The inspection SoftSensors then reference the positioning SoftSensor to find out where the inspection is to take place. If the application allows for the use of the most powerful positioning SoftSensors (Blob and ObjectFind SoftSensors) just one SoftSensor can produce all the necessary position references. However, some positioning SoftSensors can only track one type of movement, but in most cases a part translates in both horizontal and vertical directions besides rotating. When that happens and the SoftSensors used do not provide a complete position feedback, the user needs to create a chain of references. SoftSensors may need to find the changes in the location of the part in both X and Y directions and then determine the rotation of it. In those cases, the chain of references is extended to multiple levels. Figure 4-4 shows consecutive images taken from an actual inspection. As the images show, the part moved and if the SoftSensors are to inspect it, positioning SoftSensors need to find it in the image. In this case, the part shifted up, left and rotated counterclockwise.

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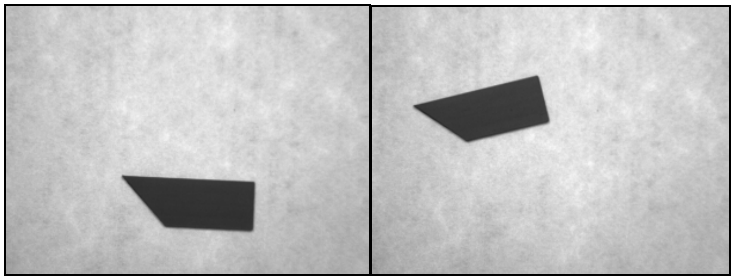

Figure 4-4: Consecutive images of parts to be inspected. The image on the left shows a part in the original position whereas the one on the right shows why positioning SoftSensors are needed.

The procedure in this case would be to find the vertical displacement (the one that changed the most) first. Then, the horizontal displacement, and only then determine the rotation. The diagram in Figure 4-5 illustrates the process.

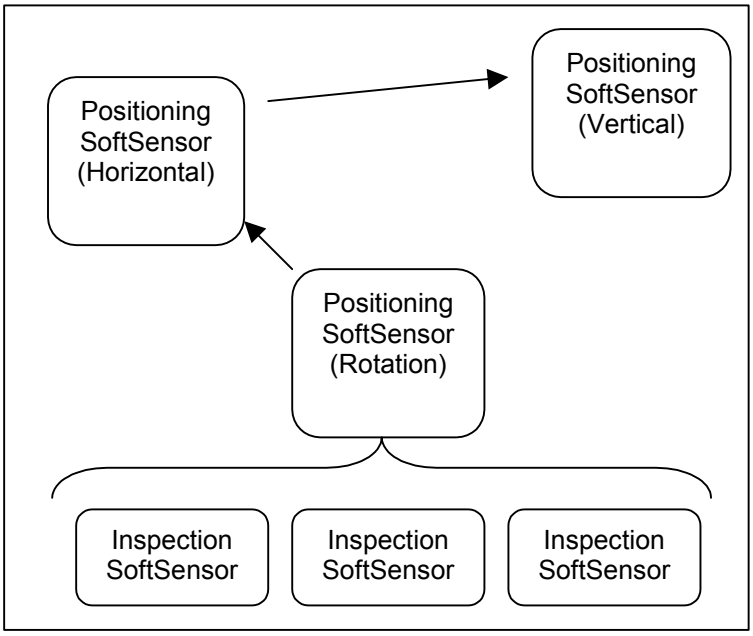

Figure 4-5: Method for passing references

The SoftSensor detecting vertical movement finds the change in position in the “Y” direction. Then, the SoftSensor tracking changes in the horizontal position uses that information to look for the part in the upper region of the image. Once it finds the part it automatically records the change it detected plus the change obtained from the other SoftSensor and passes both as a position reference to the SoftSensor detecting rotation. This SoftSensor shifts up and to the left to analyze the rotation in the right location and adds it to the chain of position references. When the inspection SoftSensors request information from this one, they obtain the changes in position generated by all three positioning SoftSensors. This method simplifies the setup process because position references are automatically concatenated and the inspection SoftSensors need only reference one of the positioning SoftSensors.

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As mentioned before, just one Blob or ObjectFind SoftSensors could have been used at the expense of some processing time. Blob and ObjectFind SoftSensors are area tools, that is, they scan an entire area looking for a shape. This process takes more processing time than a line scan like the one performed by line Translation SoftSensors.

As mentioned before, OCR SoftSensors can be used for positioning. This is a very powerful method of doing positioning because the SoftSensor limits its search to trained characters only, making it less sensitive to noise.

Note

If any of the SoftSensors in a chain of reference is altered (changes size, position, threshold, etc.) all the SoftSensors that come after it in the chain of references will be altered. This will require that the reference be reset by placing the SoftSensor in the desired location and disabling and re-enabling the reference to the SoftSensor that changed.

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4.3 Presence/Absence Inspections

Presence/Absence inspections involve inspecting a part for specific features to make sure the feature is present or absent. The locations of the features of interest in a Presence/Absence inspection are generally known. Many of the SoftSensors within Spectation can be used to inspect for the presence or absence of features of an object. Intensity, EdgeCount, FeatureCount, Blob, ObjectFind, TemplateMatch, and Color (PixelCounting) SoftSensors can all be used to detect for the presence or absence of a part feature. Each one of these SoftSensors has different advantages and disadvantages. Intensity, FeatureCount, and EdgeCount SoftSensors are the ones that take the least processing time, but they are more sensitive to noise. Blob, ObjectFind, and TemplateMatch SoftSensors take more processing time but they offer a number of features to filter out noise. In every case, image contrast plays a very important role. The objective of the physical setup of the application should be to maximize contrast between features to be inspected and the background. Figure 4-6 shows an example where the use of a different lens, correction of working distance, and use of appropriate light source increases the contrast between the part and the background.

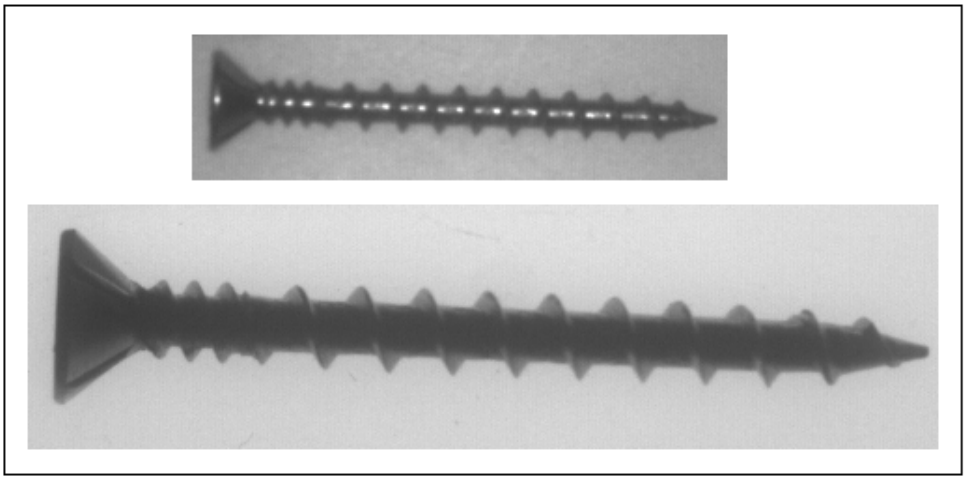

Figure 4-6: Importance of physical setup of the application to maximize contrast between part and background.

The image on the bottom is a better image given by the higher contrast between part and background, the absence of reflections (no pixels are saturated) and the part is defined by sharper edges than the image on the top.

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4.4 Flaw Detection Inspections

Flaw Detection inspections typically involve looking for a general flaw on the surface of a part where the location of the flaw is unknown. SoftSensors that can be used for this type of inspection are Intensity, Blob, Template, Measurement, Segmentation, Color Pixel Counting or FeatureCount SoftSensors. The choice of SoftSensor depends on the application. Template Match SoftSensors can be used if the part contains a certain pattern that can be learned and searched for in consequent images. This SoftSensor takes a lot of processing time as well as system memory given that the SoftSensor needs to keep the learned model in memory. Segmentation SoftSensor computes gradient instead of using a threshold, so when the flaw cannot be isolated using a threshold, this tool should be used. It takes a lot of processing time as well. When the flaw can be isolated using a threshold level, the other tools can be used to find it. Intensity and FeatureCount SoftSensors are the ones that take the least processing time.

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4.5 Counting Inspections

Counting applications require parts or features of a part to be counted. Several SoftSensors can be used for counting applications including EdgeCount, FeatureCount, Blob, Segmentation and ObjectFind SoftSensors. EdgeCount and FeatureCount should be used to identify features along a line, arc, or another predefined shape. These SoftSensors scan along that line counting the edges or features found. They take little processing time, but they require that the pattern in which the features are arranged be known. Blob SoftSensors should be used when counting parts that change the position and that do not touch each other. The way that Blob SoftSensors work would count two parts as the same one if they were in touch. If the parts are separated, this type of SoftSensor offers a very reliable solution at a relatively high speed. When parts can be touching or even overlapping, the ObjectFind SoftSensor should be used for it learns the shape of the part even if the entire shape cannot be found. In this case the SoftSensor will report that there is a part when a certain number of features learned from the part are found in the image. The user can select the acceptance level to discard parts that are barely visible or severely damaged.

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4.6 Measurement Inspections

Measurement applications involve measuring diameters, widths, height, and other key measurements of an object. Usually, a combination of Math and Measurement SoftSensors solves the problems. When more operations are needed, scripts can be used. In fact, scripts offer the flexibility needed to maintain running averages between inspections.

4.6.1 Techniques for Better SubPixel Measurements

Lighting

Backlighting should be the option for measurement applications. This technique consists of placing the part over a plane of light to highlight its contour. The image produced by such arrangement simplifies the job for measurement tools and makes them more precise, too. When Backlight is used on objects with curved surfaces, the light should be masked or collimated to obtain better results. Figure 4-7 shows examples of the use of masks and collimators. The image on the left uses standard backlight. Since the object being inspected has curved sides, the light produced at the far ends of the light source bounces on the upper regions of the part and is directed towards the Vision Sensor. This causes the Vision Sensor to see fuzzy edges making the measurements less reliable. When this happens, edges tend to be defined by transitions of as many as 10-20 pixels. The second example shows the effect of masking the backlight. Masking simply means covering the areas not used, or the areas farther away from the edges of the part. This will make the edges of the part appear sharper (transitions of 3-4 pixels) thus making the measurements more precise. When there is part movement and the light cannot be masked a collimated light should be used; this is shown in the third image. The presence of the collimator filters the light and only rays perpendicular to the surface of the light source get to the Vision Sensor causing a similar effect as masking the light.

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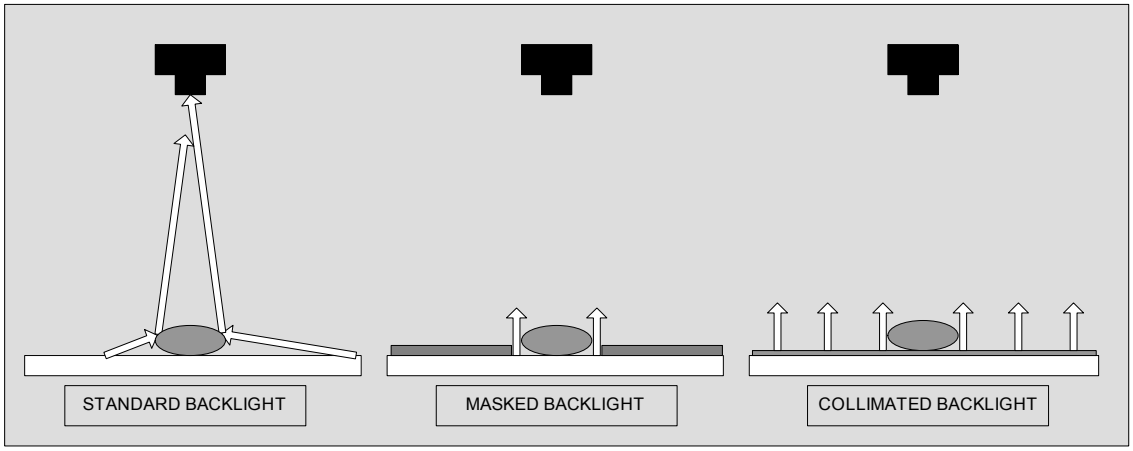

Figure 4-7: Examples of the use of masks or collimators to enhance part edges when using backlight.

Another important consideration to obtain precise measurements is to avoid altering the intensity levels in the image. There should be no saturated pixels (pixels reporting 100% intensity level) and AntiBloomong should not be used for it adds noise to the image.

Lensing

The type of les used for measurement applications should minimize lens (or barrel) distortion. The best choice is to use telecentric lenses. These lenses minimize distortion and perspective error. Using a telecentric lens the part size and shape should not vary if it moves within the FOV or even farther and closer to the lens. This type of lenses is very expensive as the part size increases. An inexpensive alternative consists of zero distortion lenses. Most lens manufacturers carry a number of this type of lenses.

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4.7 Positioning Robotics Applications

Applications requiring the position of an object to be obtained involve SoftSensors that can generate the location of a part feature and conversion from Image coordinates to Robot/Real World coordinates. SoftSensors used for these types of applications are generally Measurement/Math SoftSensors with a Coordinate Transformation SoftSensor for converting to real world coordinates. ObjectFind and Blob SoftSensors can also be used if general position location is desired. These two SoftSensors require more processing time because they scan entire areas searching for objects. The Coordinate transformation can be used both to change pixel coordinates to robot coordinates and correction for lens distortion (require previous calibration). The second correction can be minimized by using a better type of lens.

4.7.1 Setting up a Coordinate Transformation SoftSensor

The steps to create and calibrate a Coordinate Transformation are explained below:

- Select specific points (minimum 5 for simple coordinate transformation recommended over 10 points if lens distortion is also being corrected) for which the robot coordinates are known.
- Create a SoftSensor that generates a point as its output (usually the FindCircle SoftSensor is used) for each one of those points to get the pixel coordinates of them.
- Create a Coordinate System SoftSensor (under Math Tools) and use the SoftSensors created in the previous step as the calibration points. To add the calibration point one by one the user only needs to specify the robot coordinates of the point. By clicking the button to update the coordinates, the pixel coordinates will be automatically entered.
- Create a SoftSensor to track the part being inspected. Usually a Blob or ObjectFind SoftSensor is used.
- Create a New Coordinate Transformation SoftSensor to transform the SoftSensor tracking the part based on calculations performed by the Coordinate System previously calibrated. This SoftSensor should output the position of the part using robot coordinates.

4.8 Color Sorting Applications

Color Sorting applications generally involve monitoring the color(s) of an object to determine which object it is. The best match / worst match features in the Pixel Counting or Color Monitoring SoftSensors must be used. Basically, for gross differences the PixelCounting SoftSensor should be used. For parts that offer very little color difference and when the PixelCounting SoftSensor does not offer the reliability needed, a Color Monitoring SoftSensor should be used. This SoftSensor requires that the area to be analyzed be of a uniform color, no color variations are allowed.

4.9 Part Identification

Identifying a part is a very broad type of application which generally entails defining differences between the parts and identifying them using SoftSensors. There are several different techniques for achieving part identification and they depend mostly on the part being inspected. They can be implemented using one or many different SoftSensors to detect the differences between parts. Some SoftSensors which can be used by themselves to identify parts are Blob, ObjectFind, Color (PixelCounting), Reader, Segmentation, and TemplateMatch SoftSensors. Blob SoftSensors should be used when the parts can be identified based on general geometric features (Area, Radius, Eccentricity, Compactness, etc.). When a more precise identification needs to be done, ObjectFind should be used at the expense of some extra processing time. Segmentation and TemplateMatch SoftSensors should be used when the features of interest cannot be separated from the background based on a threshold level. The extra precision comes with an extra processing time. Pixel Counting SoftSensors should be used when the difference between parts is based on color. Finally, reader SoftSensors should be used when the difference is in a barcode, DataMatrix, or a label with characters. In those cases, the user needs a SoftSensor to read the data from the label on part in order to determine which part it is.

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4.10 Lot Code and Data Code Applications

Lot Code and Data Code Reading can be accomplished with any one of the Reader SoftSensors. The OCR (Optical Character Recognition) SoftSensor is used to read human readable characters. The 2-D and 1-D Readers are used to read information symbols printed on the product.

4.10.1 OCR

The OCR SoftSensor can be trained to read any character (besides letters and numbers). Usually this type of application requires positioning. That is, the label is not located always in the same location. This problem requires more SoftSensors to provide a position reference. As mentioned before, the OCR SoftSensor itself can be used for position reference. The user simply needs to create an OCR SoftSensor to locate the first character and another SoftSensor to read the code. This option of finding the first character makes the positioning very independent of noise for the SoftSensor will be looking for a specific learned character, not an edge or a feature.

4.10.2 1D Reader

The 1D Reader SoftSensor scans along a line trying to read a certain bar code. The user has a few options to speed up the process or to make it very thorough. When the application consists of the same type of code every time, the user can set the SoftSensor to look for that specific code. This will reduce the processing time because the SoftSensor does not need to attempt to decode the data using other methods. When the application determines that different types of barcode are to be used, the user must select the option to remain in auto detect. In this case the SoftSensor not only reads the code but it also determines that type of code it is. This option requires more processing time.

4.10.3 2D Reader

There are two types of DataMatrix readers: fixed and searching. The fixed SoftSensor takes less processing time, but it requires that the code be consistently located in the same area every time. A minor change in position would cause it to fail. In some cases, this SoftSensor can be linked to a position reference so the SoftSensor inspects the area where the data is. In cases where images present too much noise this option should be avoided because this tool requires very precise positioning. The other type of SoftSensor available for DataMatrix searches for the code in a predefined area. Even if the code rotates, the SoftSensor will find it and read it. This option takes more processing time because the SoftSensor needs to search for the code in what usually is a noisy image (typically the code is surrounded by text). In order to speed up the process, the user should indicate the SoftSensor as many parameters as possible about the type of code to search for, so the searching process is faster.

Starting in Spectation 2.7, two versions of SnowFlake readers are provided: a rectangular shape and an elliptical shape reader. They are both searching readers.

5 Vision Sensor Integration

This chapter discusses the different ways in which the user can send data to the Vision Sensor or get data out of it. The most common method is the digital I/O lines, which was explained under system parameters. This chapter explains how to implement Modbus transfers, how to set up DataLink, how to set up the built in drivers, and how to enable/disable different operational modes. It also mentions the types of communications that Vision Sensors support.

5.1 Transferring Data from a Vision Sensor

The most important factor to consider before setting up a data transfer is the timing. Information about an inspection needs to arrive in a certain way for the receiving system to interpret it correctly. There are two ways to transfer data, synchronous and asynchronous.

Synchronous transfers of data happen after every inspection. The user sets up the data to be transferred and that data is sent out after every inspection. This ensures the receiving system that new data is transferred as soon as it becomes available. The methods of communication that support synchronous transfers are the digital I/O (discussed under system parameters), and DataLink.

Asynchronous transfers of data happen at a certain rate. In most cases, the user selects the rate and blocks of data are continuously transferred whether they contain new data or the same data that was already transferred. An example of this method of data transfer is the Modbus master transfer available from Spectation.

It should be mentioned that because of their flexibility, scripts allow for both types of data transfers, but in this case the user needs to implement the transfers. For more information about scripts see the script documentation and help files.

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5.1.1 DataLink

DataLink is a built-in tool used to send data out of the system and even receive a limited number of commands from another device. This tool is product specific, that is, every product has its own DataLink that can be configured depending on the inspection and the SoftSensors being used. DataLink consists of a number of ASCII strings that are created based on information from the SoftSensors. The user selects a set of rules under which those strings are to be sent out. Those rules are created using logical operators (and, or) acting on SoftSensor results. For example, if the positioning SoftSensor fails a certain string can be sent out, but if this one passes DataLink could look at the result from another SoftSensor to determine which string (if any) to send out. Figure 5-1 shows a screen capture of DataLink (a dialog box within Spectation). In this case the user selects three different messages. The first one, “String 1” will be sent out when the SoftSensors that measure the inner and the outer radius of a part indicate a successful result (PASS) and the SoftSensor reading a lot code fails.

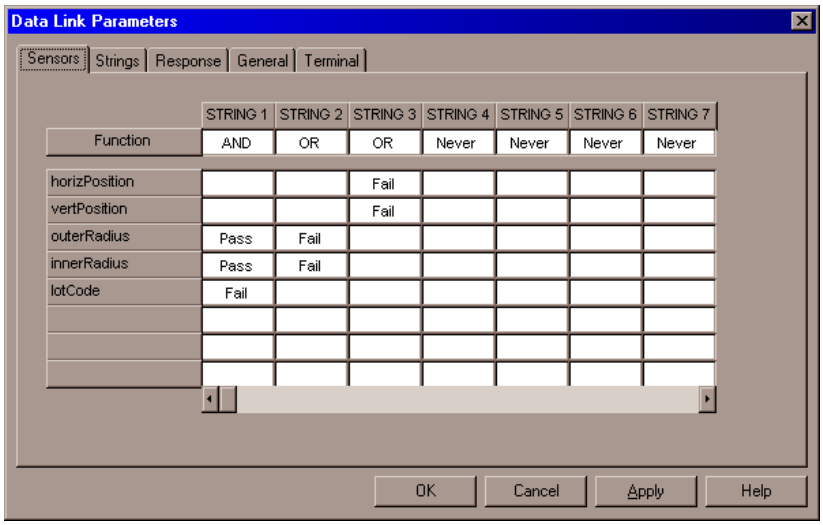

Figure 5-1: Screen capture of DataLink. In this case three different messages are requested from the system based on the inspection results

The second one “String 2” will be sent out when any of the SoftSensors measuring the radii fail. Notice the “OR” operator at the top of the column. The last one (“String 3”) will be sent out when either or both positioning SoftSensors fail, which could indicate that the part has moved too far away from the original position or that it is not present in the image.

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Once the conditions are indicated, the strings need to be created. This is a simple point-and-click process that gives the user access to data from every SoftSensor in the product plus the possibility of typing some extra characters. Figure 5-2 shows a new screen capture of DataLink with the correct setup for the message “String 1” as selected before. This message was supposed to be sent when only the lot code reader indicates a failure (it failed to read anything); therefore, the message should indicate the code being read. The string was setup using text (“The lot code read was: “) then a reference to the SoftSensor that contains the information to be sent out (in this case lotCode is the SoftSensor and its string is what contains the data, so “lotCode.String” will reference the desired data).

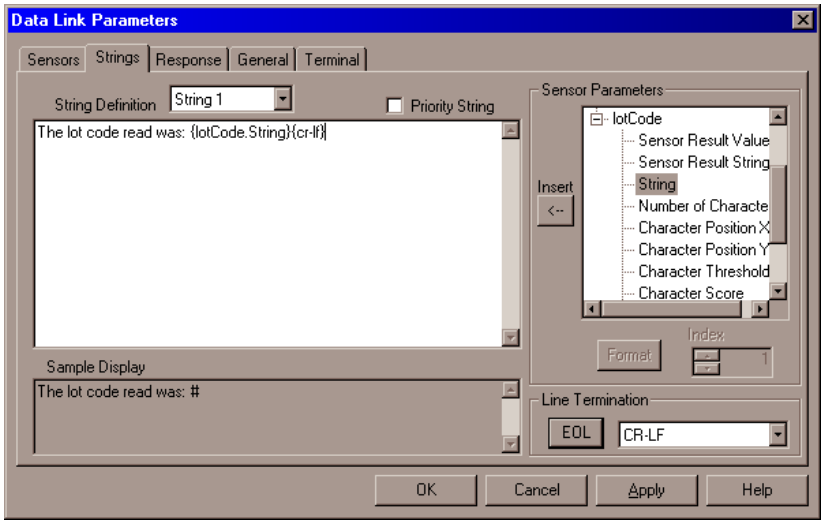

Figure 5-2: String setup for DataLink

The last section of the string is the “end of line” character, which is available for the menu shown, in this case {cr-lf} was selected which gives a carriage return followed by a line feed.

Depending on the output from every SoftSensor, one of the selected messages (Strings) will be sent out or, in some cases, no string will be sent out (ex: if all the SoftSensors pass). This will give the user the tools to determine where the flaw is in the process and allow him to take immediate action. The fact that every string is fully configurable gives the user the flexibility needed to implement an effective inspection. In order to read the data sent out from DataLink, the user needs to establish an Ethernet connection using TCP protocol to port 3247.

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5.1.2 Modbus Transfers

A very efficient way to share data among Vision Sensors or between a Vision Sensor and an external device is to perform a Modbus transfer. Modbus transfers, as implemented in the Spectation user interface, take a number of registers from one system and copy those registers into another system. Using this simple procedure, one Vision Sensor can make a decision based on the result from other Vision Sensors or gather data from other Vision Sensors and send it out to an external device. In a Modbus network we have master devices and slave devices. Vision Sensors can be enabled to be a Modbus slave, which will make the system expect a connection on port 502 (Modbus standard). The Modbus Master initiates the connection and decides the type of operation to perform (write data to the slave or read data from it). Figure 5-3 shows two possible configurations to share data using Modbus transfers. The first configuration uses Modbus transfers to exchange data between Vision Sensors. There are four Vision Sensors in the industrial Ethernet network, three of them are being used as Modbus slaves and the fourth one acts as the master. This Vision Sensor queries the slave Vision Sensors for data and based on the data from all three slaves and its own data draws a conclusion. The final output of the inspection is made available to an external device using either Modbus or any other type of communications. It could even be a single I/O line indicating a PASS or FAIL result. The second configuration shows a slightly different setup. In this case, an external device is acting as a master and the Vision Sensors performing inspections are acting as slaves. The external device has direct access to the internal memory of the Vision Sensors so it can easily query the individual inspection results from each.

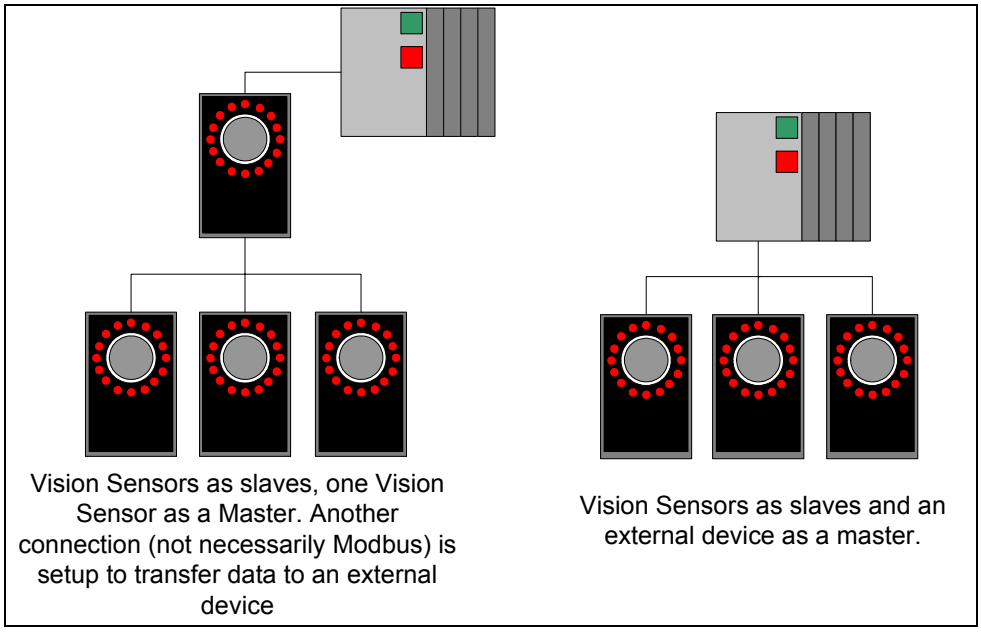

Figure 5-3: Two different configurations to share data among many devices.

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In order to make a Vision Sensor behave as a master, a Modbus master transfer must be created from Spectation. This transfer will indicate the slave IP Address, the operation to be performed (read/write), the block of registers to use, and the polling rate for the transfer. In order to specify the block of registers to transfer, the user must be aware of the difference between Siemens registers and Modbus registers as well as the size of the different data types used by the Vision Sensor.

Siemens registers are 8-bit registers whereas Modbus registers are 16-bit registers. This difference poses a problem that the user must solve in order to implement a successful transfer. Since the rules for the transfer must be expressed in Modbus registers, the user needs to convert the register numbers to Modbus register numbers. Fortunately, this happens to be a very simple procedure which will be illustrated by an example. Let's say the user needs to transfer the data in registers 112 to 117 of the slave to registers 30 to 35 in the master. It is a total of 6 Siemens registers which means 3 Modbus registers. Instead of starting at Siemens register 112 of the slave system, the user has to specify the starting register as 56. Finally, the master register to write to is Siemens register 30, so the user needs to specify Modbus register 15. In order to simplify the process, Spectation provides feedback of the register selection to ensure that the correct registers were selected. Figure 5-4 shows the actual Spectation dialog box used to set the register numbers. The user selects the Modbus registers using the editable text box on the left.

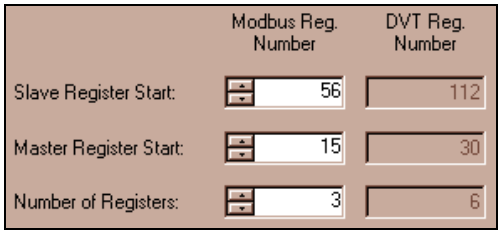

Figure 5-4: Sample register setup for a Modbus transfer

Once the numbers are set, Spectation shows the equivalent SIMATIC VS registers in the non-editable text field on the right. The particular setup used in the image refers to the previous example.

The second important issue to take into account is the size of the different Siemens data types. This becomes a very important issue when trying to transfer data. Different data types occupy different numbers of registers in memory. If a certain value is saved to memory using a script tool and that particular piece of data needs to be transferred to another system, the user has to know the exact number of registers that the piece of data occupies in memory. Table 3-1 shows the size that every different data type occupies in memory. For example, if a measurement tool outputs a float, that number will occupy 32 bits or 4 Siemens registers. If that number needs to be transferred to another system using a Modbus master transfer, the user has to specify that 4 Siemens registers need to be transferred. According to the size of the Modbus registers (explained above) this requires the transfer of 2 Modbus registers.

Table 5-1: Size of the different data types in bits and Siemens registers

Name	Size (bits)	Size (registers)
byte	8	1
short	16	2

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integer	32	4
long	64	8
float	32	4
double	64	8
string	8 per char +1	1 per char + 1

If the transfer of data needs a more explicit process, Modbus transfers might not be the best approach. In those cases a background script should be used. From a background script, the user can create a Modbus transfer object which can perform a number of standard Modbus functions as specified in the open Modbus protocol. For more information about this see the script documentation.

5.1.3 Ethernet Terminal Controller (ETC)

The Ethernet Terminal Controller (ETC) allows the user to set up different Ethernet configurations for communication using the TCP protocol. This converts Vision Sensor into a TCP server or client. Depending on the application, the user can select the Vision Sensor to be a client (connect to another device) or a Server (expect a connection from other devices). In both cases the connection will be established using a user-defined port. Using this connection the following drivers can be used to communicate with different devices:

- System Driver: redirects the data exchange at the system level that normally happens on port 3246
- DataLink Driver: redirects the data exchange from DataLink that normally happens on port 3247
- Robotic Drivers including Fanuc, Motoman, ABB, Reis, and Kawasaki Robots.

The user can set the system up as either a TCP/IP server or client and specify the preferred port. The user can also set the Ethernet port for communication as well as the type of communications driver needed to use on the port from this selection. Figure 5-5 shows two different configurations for the ETC. The first one makes the Vision Sensor a TCP server, expecting a connection on port 5003. In this port it exposes the System Driver, which is the driver that receives most Ethernet commands to control the system. The second configuration is as a TCP client. In this case the system connect to a server with IP address 192.168.0.242 on port 5004 and sends DataLink strings to that server. This is indicated by the selection of the DataLink Driver. This example summarizes the two possible configurations (server/client).

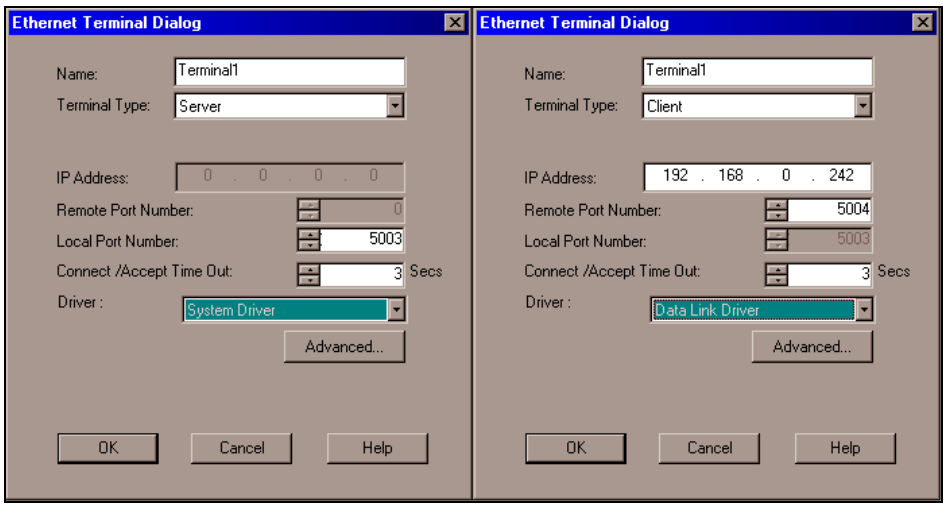

Figure 5-5: Different configurations for Spectation's ETC.

After this is properly setup the communications should be established when the Ethernet Terminal Controller is started or on power-up.

5.1.4 Industrial Protocols

SIMATIC VS 720 systems support PROFIBUS communications through the VS Link ProfiuBus Hardware Module. For more information about this type of connectivity please refer to the VS Link Manual.

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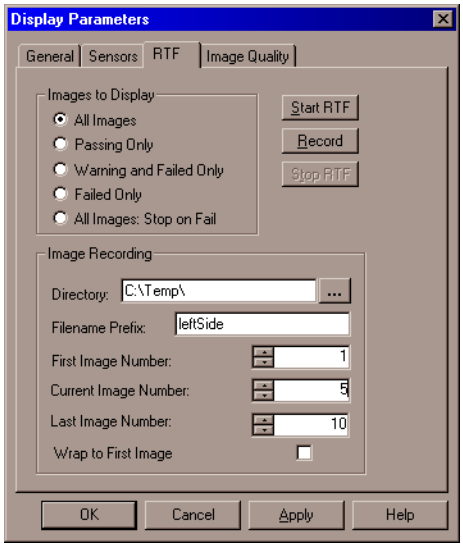
6 VSEmulator tutorial

A closer look at the system explains the basics about the use of the VSEmulator. This appendix walks the user through a full example on how to work with it. Every step is explained and the Spectation dialog boxes are included for reference. If the user already has a set of prerecorded images and a product or system file the first 2 steps should be skipped.

Step 1: Connect Spectation to the Vision Sensor and create a backup copy of the System or Product files. In order to do this, the user must select the desired option (“Backup Product to PC” or “Backup System to PC”) from the “Products” menu. This will prompt the user for a file name just like in any Windows application. A file will be saved to the computer hard drive with the name specified by the user and an extension indicating if it is a system file (extension “sys720”) or a product file (extension “prod720”).

Step 2: Record images from the Vision Sensor. In order to do this the user must select “Display Parameters” under the “Images” menu and select the “RTF” tab (RTF stands for real time feedback). The dialog box is shown below. This dialog box lets the user select the directory where the images are to be saved, the name for the images and the number of images to record.



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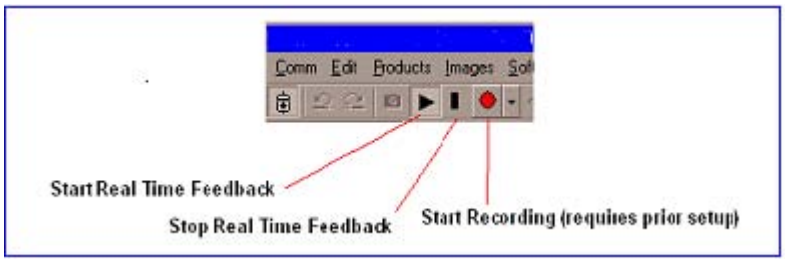
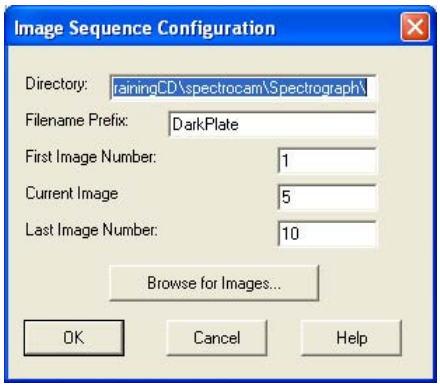
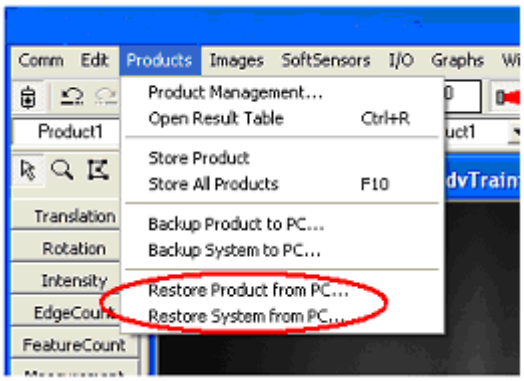
The user must specify the number of the first image in the sequence, the number of the current image (the next image to be recorded) and the last image to record. The last option “Wrap to First Image” indicates whether to stop on the last image or start overwriting from the first one. This will create a number of bitmap images in the selected directory with the name and 3 digits indicating the image number. The particular setup shown in the dialog box above would save the following images: leftSide005.bmp, leftSide006.bmp, leftSide007.bmp, leftSide008.bmp, leftSide009.bmp, and leftSide010.bmp in the “C:\Temp” directory. This procedure saves every image that Spectation brings from the Vision Sensor. From the top portion of the dialog box, the user can select which images to bring to the user interface. So if only the failed images are to be saved, the user should select to display only those. Once this setup is completed, the user should exit it using the “OK” button for the changes to take place and the real time feedback should be started as usually from Spectation. When the user wants to start recording, the “Record” button should be pressed from the expanded toolbar as shown below. If this toolbar is not available it should be selected from the “Window” menu.



Step 3: Once the product or system file and the images are available from the hard drive, the user can start Spectation and connect to an emulator. The emulator should be selected to match the Vision Sensor from where the images or product/system files were originated. Upon connection to the VSEmulator, Spectation will show the SID and make the standard editing options available. At this point the user can load the image sequence and the product or system file. In order to load the image sequence, the user needs to select the option “Configure Image Sequence” under “Images” and the following dialog box will appear:



Here the user has two options, type everything manually or click on the “Browse for Images…” button to find the desired images. In order to load the product or system file the appropriate action should be selected from the main “Products” menu. To load a product file the user needs to select “Restore Product from PC.” Likewise, for a system file, the user should select “R4estore System from PC.” The menu is shown below and both options are highlighted.



With the images loaded, the user can make any change (that does not depend on physical setup) to the system just like if Spectation was connected to a Vision Sensor. When the user is done, step 1 should be repeated but in this case for the VSEmulator. A system or product file can be saved from the VSEmulator in the same way that it can be saved from the camera. This procedure allows the user to set up the inspection parameters in the VSEmulator, and then load those as a system or product file into the Vision Sensor.

Note

If users want to run the VSEmulator but they have no images, a standard graphics program could be used to create some images. The images need to be 256-color bitmaps of the same resolution as the Vision Sensor to be used (640 by 480 or 1280 by 1024). The naming convention should be followed as well.

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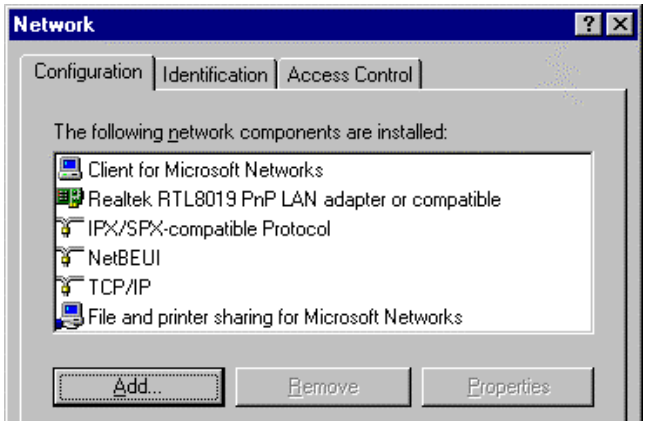
7 Basic TCP/IP Setup

In this section, we will step through setting up the TCP/IP protocol on a PC. TCP/IP stands for Transmission Control Protocol / Internet Protocol and is based on identifying elements on a network by unique numbers, called IP numbers.

We will assign our PC with one IP number and any Vision Sensor with another. There are several methods of connecting PCs and Vision Sensor systems.

For Windows 98:

- Click on the **Start** menu in Windows, select **Settings**, then **Control Panel**.
- Double click on the **Network** Control Panel icon (shown above right).
- Check the list of installed network components for TCP/IP (as shown below). If TCP/IP is on the list, click **Cancel** and skip to the Communicating with the Vision Sensor section.
- If TCP/IP is not on the list, click the **Add** button.



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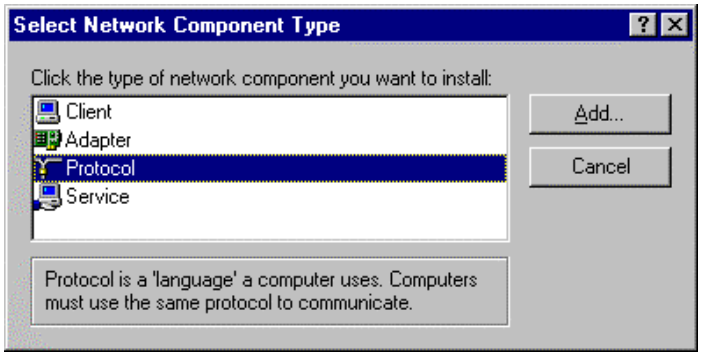
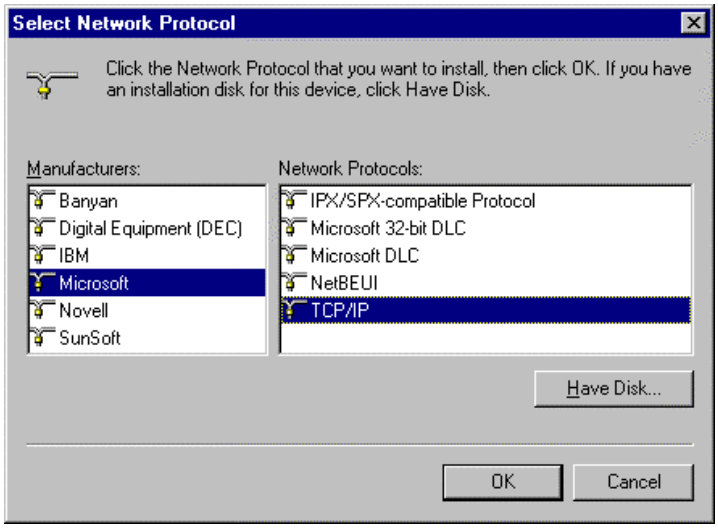
- Click on **Protocol**, then **Add…** (shown below).



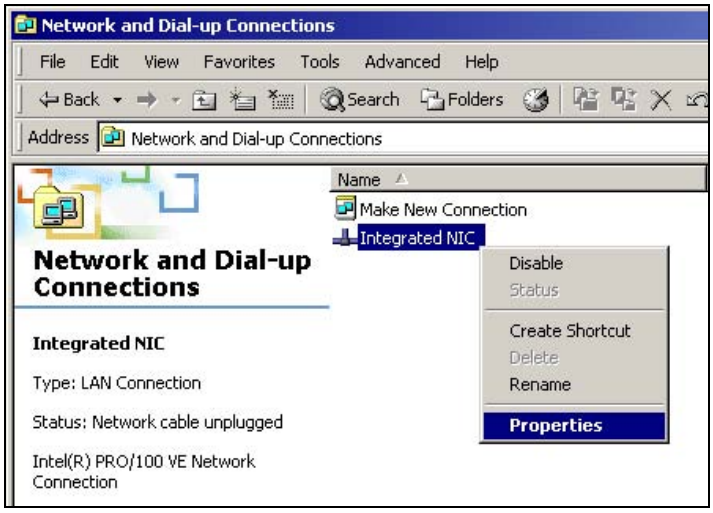
- Under Manufacturer, click Microsoft and under Protocol, click TCP/IP then click **Ok** (see below).



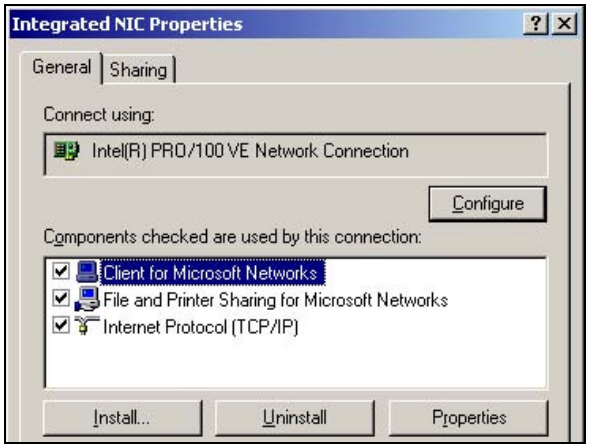
Windows will then install the protocol and return you to the Network control panel. During this installation process, the PC may ask for the Windows 98 CD-ROM and will copy relevant files to the PC's hard drive. After this is done, restart your PC and continue to the Communicating with the Vision Sensor section.

For Windows 2000 (Windows XP will be similar):

- Click on the **Start** menu in Windows, select **Settings**, then **Control Panel**.
- Double click on the **Network and Dial-Up Connections** Control Panel icon (shown above right).
- To check for the list of installed network components for your network card, right-click on it and select **Properties** (as shown below). If TCP/IP is on the list in the corresponding dialog box, click **Cancel** and skip to the Communicating with the Vision Sensor section.



- If TCP/IP is not on the list, click the **Install…** button.



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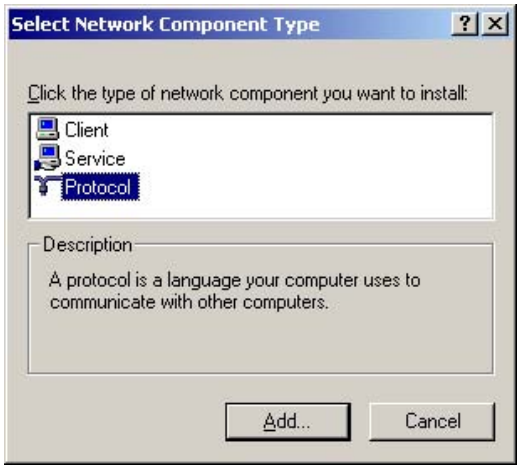
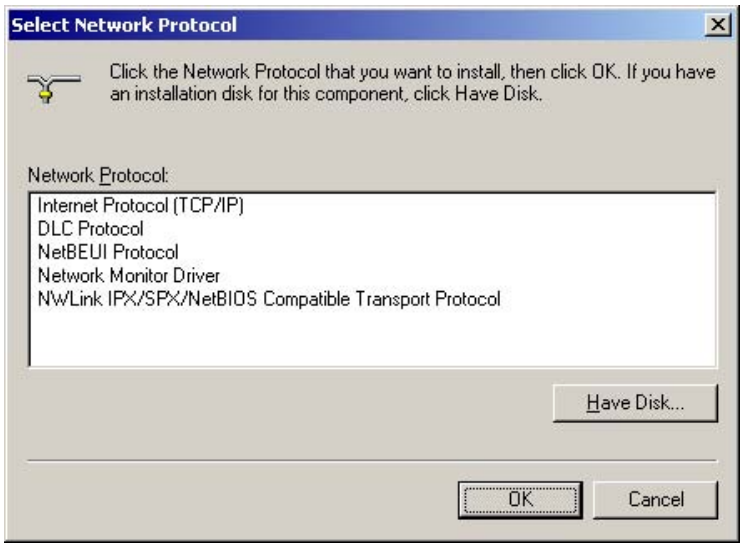
- Click on **Protocol**, then **Add…** (shown below).



- Select **Internet Protocol (TCP/IP)** then click **Ok** (see below).



Windows will then install the protocol and return you to the Network control panel. During this installation process, the PC may ask for the Windows 2000 CD-ROM and will copy relevant files to the PC's hard drive. After this is done, restart your PC and continue to the Communicating with the Vision Sensor section.

8 Advanced TCP/IP

The Vision Sensor runs TCP/IP over an Ethernet (RJ-45 only) connection. This Appendix provides some advanced information about this setup that may be useful to Network Administrators.

8.1 TCP/IP Installation Tips

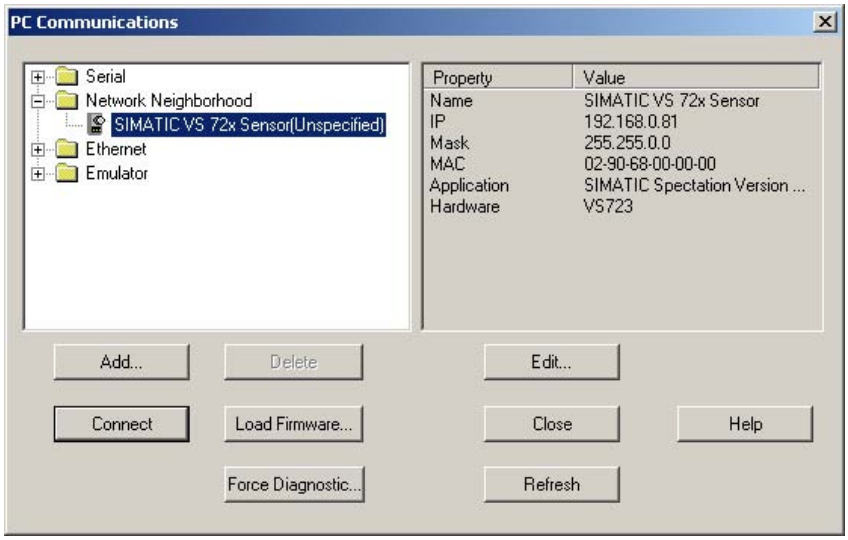
Vision Sensors are shipped with a random IP address, which must be changed according to your network. When assigning an IP address to the Vision Sensor, you need to make sure that it is one that has not already been assigned to another device on the network and that.

Currently, Vision Sensors do not support DHCP.

Vision Sensors do not require a Default Gateway to be set. For more information on what a Default Gateway is, please refer to the respective section later in this Appendix.

Typically, when connecting your PC to the Vision Sensor, the network masks must match.

The IP address can be changed from Spectation software (**Comm** menu, **Image Sensor Communications** selection), or from the Network Neighborhood Browse in Spectation 2.3 or greater (see below).



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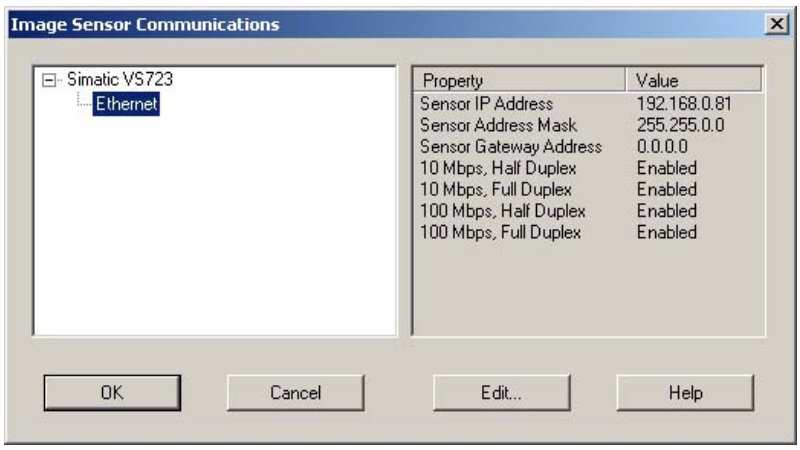
Highlighting **Ethernet** in left pane of Spectation's **PC Communications** dialog box gives the PC (host) IP address (see below).



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8.2 TCP/IP Troubleshooting Tips

IP addresses for each PC (and for each network card installed on the PC) and each device that uses the TCP/IP protocol (such as the Vision Sensor) is required to have a unique IP address.

IP addresses should not use 0 or 255 as the last value (e.g. 192.168.1.0 and 192.168.1.255, respectively). These are reserved and have special meaning:

- Addresses that end in 0 specify all addresses for a particular subnet.
- Addresses that end in 255 specify a broadcast packet that is sent to all hosts on the network.

With both PC and Vision Sensor using the Subnet (or Address) mask of 255.255.255.0, the IP addresses of PC and 600 must be identical for the first three values and unique in the fourth value. **Example**: Vision Sensor (IP: 192.168.0.242) & PC (IP: 192.168.0.240). Please refer to the section on subnetting later in this Appendix.

Query the Vision Sensor for its IP address in two places. 1) Run Spectation, click **Comm**, **Image Sensor Communications**, select “Ethernet – Port A” in the left pane and view the IP address in the right pane. 2) From a terminal command line (serial communications, HyperTerminal @ 38400 baud, 8-N-1, no flow control), the ‘#Cn’ command queries the Vision Sensor for its IP address and address mask.

Type ‘ping ###.###.###.###’ (replacing # with numbers) to check if an IP address is connected to the network. This command can be useful in determining if a node is powered up, operational, and physically connected to the network.

Type ‘arp –a’ from a DOS prompt to view the ARP (Address Resolution Protocol) table. The response should look something like this:

C:\WINDOWS>arp -a

Interface: 192.0.0.111

Internet Address	Physical Address	Type
192.0.0.211	00-90-68-00-00-42	dynamic
192.0.0.212	00-90-68-00-00-42	dynamic
192.0.0.253	00-60-97-4f-c0-45	dynamic

The “Internet Address” column refers to the IP addresses you’ve recently communicated with. The “Physical Address” column contains the corresponding Ethernet Addresses for the IP’s in column 1. Siemens Vision Sensors will have Physical Addresses starting with “00-90-68”. In the case above, 192.0.0.253 is not a Vision Sensor, but another PC on the same network as the named Interface. The ARP table is cleared approximately every two minutes. The ‘arp’ command is useful in determining if an IP address belongs to a Vision Sensor system or another node on the network.

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8.3 TCP/IP Subnetting

Please note that the creation of custom subnets is beyond the scope of this appendix and so will not be discussed. This section will only discuss default subnets (i.e. 255.0.0.0, 255.255.0.0, and 255.255.255.0), some key terms relating to subnetting, and some basic rules on setting up IP addresses with the default subnet masks.

Subnetting is a common technique among network administrators to segregate a network so that network traffic remains in certain areas (or subnets). If a device in one subnet needs to communicate to another device in another subnet and both devices reside on the same physical network, a router will be required (see the definition of a Default Gateway) to provide that link between the two areas. However if the two devices reside in the same subnet, then no router is required and the two devices can communicate with each other. As a rule of thumb, if the subnet mask is 255.255.255.0 on all devices, then the first three numbers of an IP address, which is the Network ID (e.g. **192.168.203**.1), will need to be the same and the last number, which is the Host ID (e.g. 192.168.203.**1**, 192.168.203.**2**, 192.168.203.**3**, etc.), will need to be unique in order for those devices to communicate with each other. Similarly, if the subnet mask is 255.255.0.0 on all devices, then the first two numbers of an IP address will need to be the same and the last two can be different.

Below are some key terms related to subnetting:

- Physical Segment – A Physical Segment (or subnet) is a portion of the network that can receive a broadcast packet. All computers within a specified Physical Segment will share a common Network ID. Physical Segments are separated by routers because routers cannot forward broadcast packets; they can, however, traverse hubs, switches, and bridges.
- Network ID – The Network ID is the part of an IP address that is common to all computers on a specified physical segment. The Network ID is equivalent to the area code of a phone number.
- Host ID – The Host ID is the part of an IP address that uniquely identifies the device on a specified physical segment. The Host ID is equivalent to the phone number.
- Default Gateway – A Default Gateway is typically a router that provides a route between two Physical Segments. It does not forward broadcast packets. So, if your Vision Sensor resides in one Physical Segment and your PC resides in another Physical Segment, then you will need to setup a Default Gateway to provide a route between the two Physical Segments. You would then need to setup up your Vision Sensor and your PC to point to that Default Gateway. Specifying a Default Gateway is not required, especially if both your Vision Sensor and your PC reside on the same subnet.
- Subnet Mask (SNM) – A Subnet Mask is the second element required in TCP/IP communications, along with the IP address. Without a subnet mask, communication will not be able to take place between two network devices. The Subnet Mask also helps you to identify what is the Network ID and what is the Host ID in an IP address.

9 Upgrading or Reinstalling VS 720 Series Vision Sensor's Firmware

Before installing Spectation on your PC and upgrading the firmware file in the Vision Sensor, take the time to backup the existing system to the PC.

9.1 To back up a Vision Sensor system to a PC:

- Run the older version of Spectation and connect to the Vision Sensor.
- Click on the **Products** menu.
- Choose Backup System to PC.
- When prompted, provide a filename.
- Exit Spectation.

Now that the old system has been fully backed up, Spectation may be installed on the PC.

To install Spectation on a PC:

- Insert the Spectation CD. The installation should automatically start.

If the CD does not automatically start, do the following:

- From the **Start** menu, choose **Run**.
- Type **D:\Setup.exe** (substitute the appropriate drive letter of your CD-ROM drive for **D**) and press **Enter**.

OR

- Run the installation file downloaded from the Siemens website
- Follow the installation instructions on screen.

After Spectation has been installed on the PC, the firmware file on the Vision Sensor must be upgraded.

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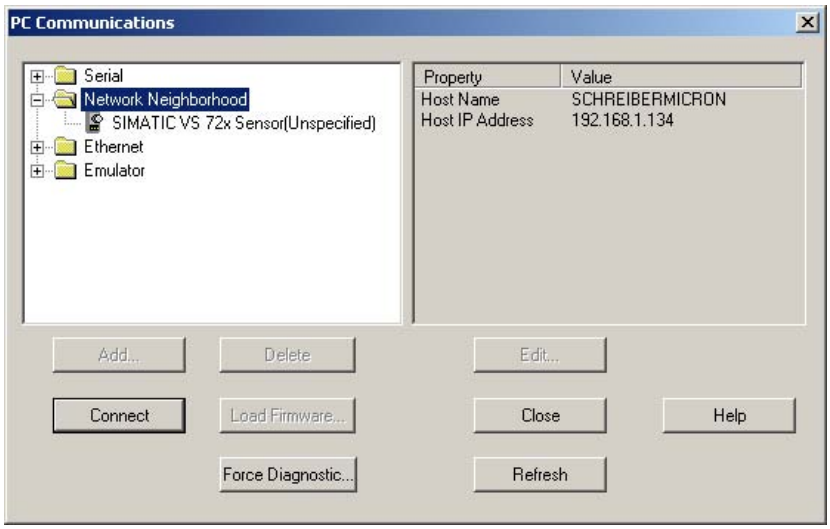
9.2 Upgrading Spectation firmware on a VS 720 Series Vision Sensor

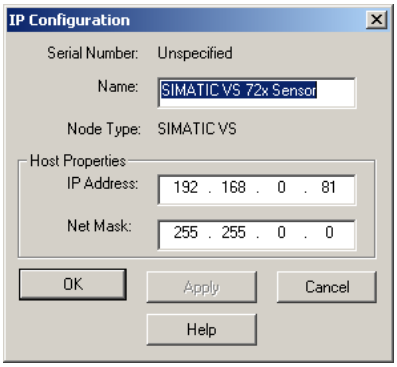
Note

The Vision Sensor is a stand-alone unit that runs the firmware. All Vision Sensors arrive from the factory with Spectation firmware installed. This step should not be necessary unless reinstalling or upgrading firmware.
Before upgrading, start Spectation and click Help|About to verify the version of the software being used.

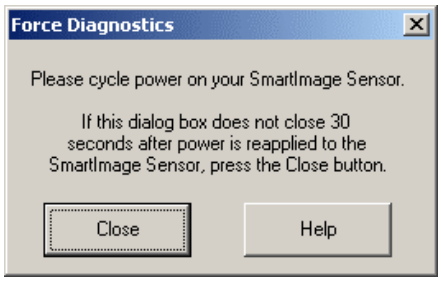
- Start Spectation. The "PC Communications" dialog box will come up.
- Select "Network Neighborhood". This will search your local network for Siemens systems.



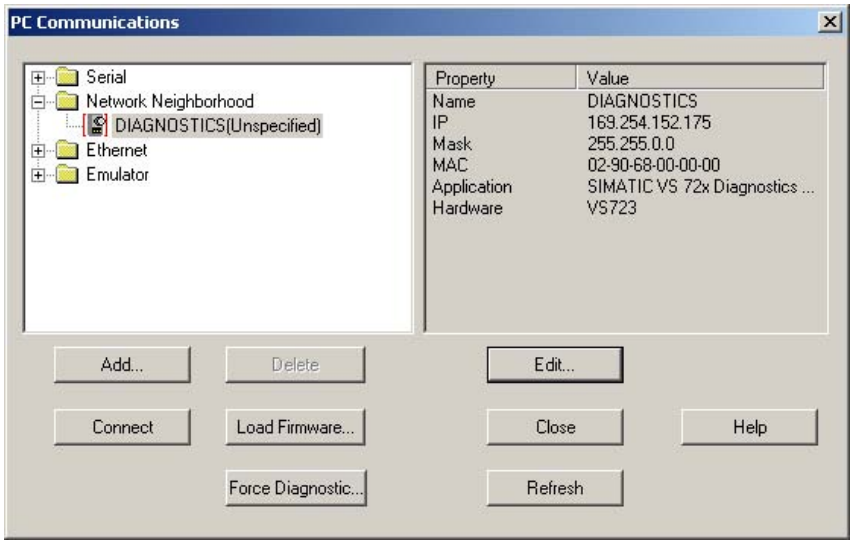
- Highlight the appropriate sensor by choosing the system with the matching serial number and make sure the IP address and subnet mask are compatible with your computer's IP address and subnet mask.
- If you need to change the IP address and/or the subnet mask of the Vision Sensor, click on the edit button. The following dialog box will come up and you will be able to change these parameters and the name with which this particular Vision Sensor is identified.



- It is recommended that before loading firmware into the system, the user erases the content of flash memory. This will avoid potential problems that could arise when loading different firmware versions on top of one another. The first step to do this is forcing the system into diagnostics mode. Select the appropriate Vision Sensor under "Network Neighborhood" and click on the "Force Diagnostics" button in the "PC Communications" dialog box. Spectation will instruct you to cycle power on the system you are trying to upgrade.



- After the system boots up it should be in diagnostics mode. You can check this by verifying that the "Status" LED on the back of the Vision Sensor is blinking red. Also under "Network Neighborhood", the system should appear now as "DIAGNOSTICS".
- When the system is forced into diagnostics mode, it resets its IP address. This means that at this point you would need to select the system, click on the "Edit…" button and reassign the appropriate IP address and net mask.
- Now that the system is in diagnostics mode you can proceed to erase flash memory. While the Vision Sensor is in diagnostics, select it under "Network Neighborhood" and look at the right hand pane of the "PC Communications" dialog box to identify the diagnostics version of the system.



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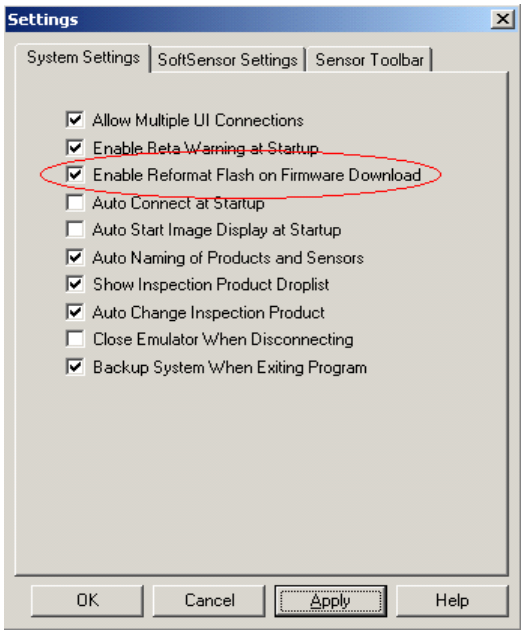
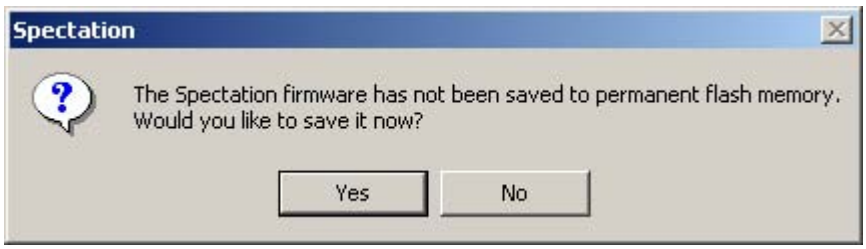
- If this version is 0.28 or a more recent release (like in the case above) you would be able to erase flash memory and load the new firmware version from Spectation. If your system has an older diagnostics version go to the section "Erasing flash using Telnet" at the end of this document and then continue on step 11. The mentioned section explains a fail-safe method to erase flash memory; so if your system has a recent diagnostics version but the procedure that will be described below to accomplish this task did not work, you can still refer to the technique covered at the end of the document to achieve your objective of clearing the contents of permanent memory.
- Before proceeding, make sure that the option "Enable Reformat Flash on Firmware Download" is enabled in Spectation. You could verify this by closing the "PC Communications" dialog box and clicking on "Options…" under the "Edit" menu in Spectation. The option is indicated in the next figure.



- On the "PC Communications" dialog box accessed through the "Comm" menu, click on "Network Neighborhood", select the Vision Sensor on the list and click on the "Load Firmware" button. Select the firmware version that you want to load based on your model. The firmware files for all the systems are included in the Spectation installation and their extensions would identify the sensors for which they were designed. At this point, if you are erasing flash from Spectation, you should select "Yes" when the message shown below appears.

- Wait for approximately 30 seconds if the progress bar closes before that, make sure the correct Vision Sensor is highlighted in the left hand pane and click the "Connect" button.

- Before getting into Spectation, the program will ask you if you would like to store the firmware to Flash Memory. Choose Yes. It will take a few seconds to store the file to flash memory. Then the Sampled Image Display will appear in the User Interface of Spectation.



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9.3 Erasing flash using Telnet

This is a fail-safe method to erase flash memory. You should read this section and follow the instructions explained if the diagnostics version of the system you are trying to upgrade is older than version 0.28 or if the procedure covered in steps 10-11 above did not work.

After forcing the system into diagnostics mode and reassigning the appropriate IP address and net mask, you could proceed to clear the contents of flash memory. You would use telnet or any other terminal emulator to connect to the Vision Sensor through Ethernet on port 23 (which is the default port for telnet.) Telnet is included as an accessory in all versions of Windows.

- Click on "Start" then "Run…"
- Type "telnet" and press Enter.

In Windows 2000, XP and NT telnet is included as a DOS-based program. In this case you will see a DOS console appear. At the prompt, type "open" followed by a space and then the Vision Sensor's IP address.

In Windows 98 and ME telnet is a Windows-based application. When the program comes up, click on the "Connect" menu, then select "Remote System…" In the dialog box that appears type the IP address of your system under "Host Name", select "telnet" as the "Port" and for "Term Type" choose "VT100".

- After you are connected, you will see some information about the system displayed. At the question mark prompt, type the following command without the quotes: "*F1bdc" (You might not see what you are typing if you do not have local echo enabled in the telnet program.)
- You should see the message "Erasing Flash". After the process is completed, you will receive the question mark prompt. At this time, permanent memory has been erased and you could close the telnet program.

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