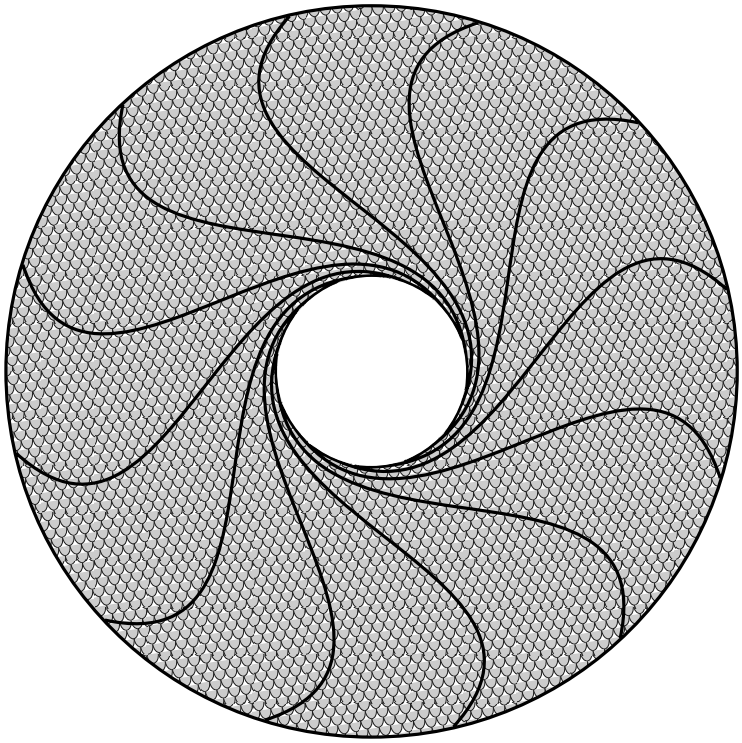
# AdeptVision VME

## User's Guide

**Version 11.0**



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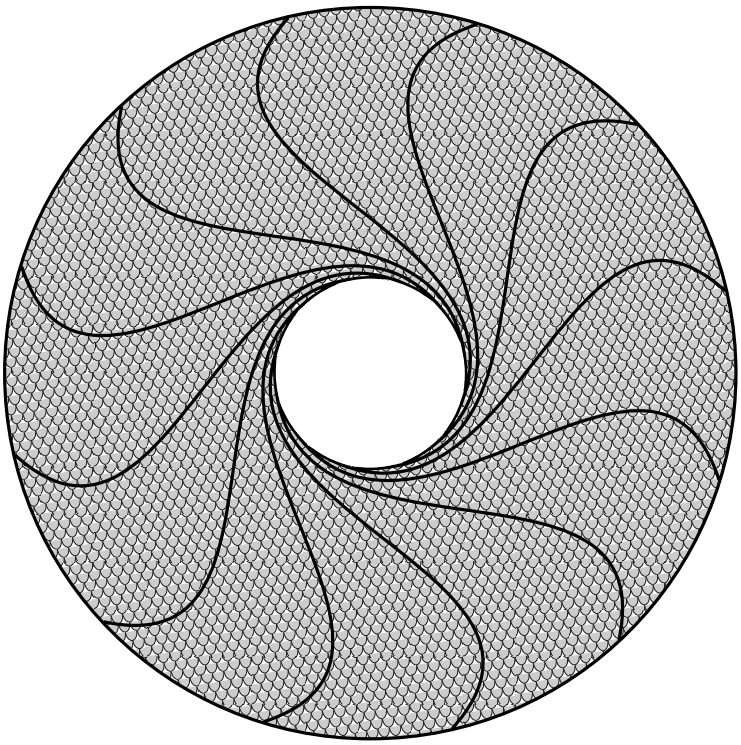

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Printed in the United States of America

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# Introduction

# Compatibility

This manual is for use with V+ systems equipped with the AdeptVision software and hardware options. The system version must be 11.0 or later.

This manual is intended primarily for vision application programmers. If your system includes the optional VisionWare or MotionWare with vision software, you do not need to read this manual. However, many principles of machine vision and AdeptVision VME processing are covered in greater detail here than in the VisionWare or MotionWare user's guides, so a general review of this manual may be useful.

# How to Use This Manual

## Organization

Material in this manual is presented in a step-by-step fashion. Each chapter expands on and relies on information in the preceding chapters. If you are new to machine vision systems, this manual will take you from the conceptual basis for machine vision to advanced programming techniques in computer vision applications. Here is what you will find in each of the chapters:

| | |
|---|---|
| Chapter 1 | presents an overview of machine vision principles and introduces vocabulary and concepts you will need when reading the other chapters. |
| Chapter 2 | shows you how to physically set up the AdeptVision VME system hardware. |
| Chapter 3 | shows you how to perform all the initialization tasks necessary to get your system ready to start developing vision applications. |
| Chapter 4 | introduces vision processing. It describes how to acquire and process an image. You will learn to fine-tune the images you produce so your vision applications run as efficiently and predictably as possible. |
| Chapter 5 | describes the first vision processing strategy, boundary analysis. You will learn where vision data is stored and how you can influence the data the vision system gathers. |
| Chapter 6 | describes the second vision processing strategy, vision tools. You will learn to use rulers, finders, and inspection windows. |
| Chapter 7 | describes the vision modeling process, including prototype recognition, optical character recognition (OCR), and correlation templates. |
| Chapter 8 | presents a sample program. You will learn how to combine the knowledge gained in the previous chapters to program an inspection vision application. |
| Chapter 9 | covers using the vision system to guide a motion device. You will learn how to set up and calibrate cameras that will locate, acquire, and place parts. If you do not have a motion device, you can skip this chapter. |

Chapter 10 discusses advanced topics in vision processing. High speed inspections, part-relative inspections, and conveyor operations are covered.

## Before You Begin

AdeptVision VME is an extension of the V+ operating system and language. In order to use the AdeptVision VME extension you must be familiar with the basic V+ operating system and language. In particular, this manual assumes that you:

- Are familiar with the Adept A-series graphical user interface.
- Can use the SEE program editor to create and edit programs.
- Are familiar with V+ programming, including control structures, data types, and subroutine principles.

The V+ operating system and graphical user interface are covered in the *V+ Operating System User's Guide* and the *V+ Operating System Reference Guide*. The V+ language is covered in the *V+ Language User's Guide* and the *V+ Language Reference Guide*.

## Related Manuals

There are several manuals you should have handy as you use this manual. They are:

The *Release Notes for V+ 11.0,* which contains late-breaking changes not in the manuals, a Summary of Changes, and a section on Upgrading Pre-11.0 code.

The *V+ Operating System User's Guide*, which covers operating system tasks such as copying files, executing programs, and using the graphical interface.

The *V+ Operating System Reference Guide*, which details the operating system commands (known as monitor commands).

The *V+ Language User's Guide* and the *V+ Language Reference Guide,* which contain a complete description of the commands, instructions, functions, and other features available in the V+ language. These manuals are essential for advanced applications programming.

The *AdeptVision Reference Guide,* which contains a complete description of the vision enhancements to the V+ language. This manual is a companion guide to the *AdeptVision VME User's Guide.*

The *Instructions for Adept Utility Programs,* many of which are referenced in this manual.

The *Advanced Camera Calibration Program User's Guide,* which details the camera calibration procedures.

The *Adept MV Controller User's Guide*. This manual contains information on installing, maintaining, and configuring the physical controller hardware.

The user's guide for your robot or motion device (if your system includes a motion device). This manual contains information on installing, maintaining, and calibrating the motion device.

The manuals for any options you have purchased with the system (such as VisionWare), or purchased separately to use with the system.

## Safety

### Reading and Training for Users and Operators

Adept systems may contain computer-controlled robot mechanisms that are capable of moving at high speeds and exerting considerable force. Like all robot systems and most industrial equipment, they must be treated with respect by the user and the operator.

This manual should be read by all personnel who operate or maintain Adept robot systems, or who work within or near the robot workcell.

We also recommend you read the *American National Standard for Industrial Robot Systems - Safety Requirements*, published by the Robotic Industries Association (RIA), in conjunction with the American National Standards Institute. The publication, ANSI/RIA R15.06 - 1986, contains guidelines for robot system installation, safeguarding, maintenance, testing, start-up, and operator training. The document is available from the American National Standards Institute, #13THF, 11 West 42nd Street, New York, NY 10036-8002.

> **NOTE:** This manual follows RIA definitions of "user" as the responsible person or company and "operator" as a person who starts, stops, or monitors robot operation.

This manual assumes that the user has attended an Adept training course and has a basic working knowledge of the robot system. The user should provide the necessary additional training for all personnel who will be working with the system.

### System Safeguards

Safeguards should be an integral part of robot workcell design, installation, operator training, and operating procedures.

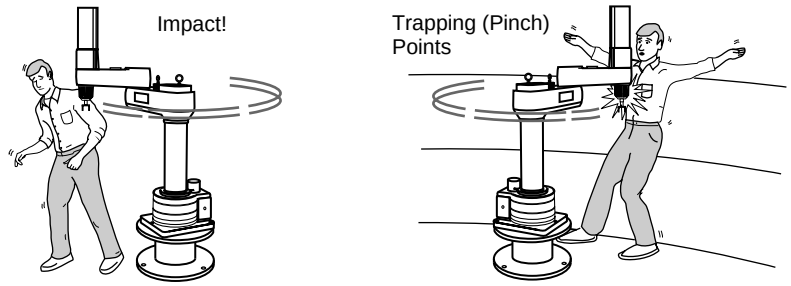
Adept robot systems have various communication features to aid in constructing system safeguards. These include remote emergency stop circuitry, and digital input and output lines. These features are described in the controller user's guide.

Because Adept robots are computer-controlled, the program that is currently running the robot may cause it to move unexpectedly. When the amber HIGH POWER and the blue "Program Running" lights on the optional Adept front panel are lit, the robot might move. When these lights are lit, no one should enter the workcell, because they cannot predict when or where the robot might move. The LAMP TEST button allows this light to be periodically checked (see the controller user's guide).

In addition, these systems can be programmed to control equipment or devices other than the robot. As with the robot, the program controlling these devices may cause them to operate unexpectedly. It is critical that safeguards be in place to prevent personnel from entering the workcell when a program is running. The blue PROGRAM RUNNING light on the front of the optional front panel indicates the program is running. The LAMP TEST button allows this light to be periodically checked.

**WARNING:** Entering the robot workcell when either the HIGH POWER or the PROGRAM RUNNING light is on can result in severe injury.

Adept Technology highly recommends the use of additional safety features such as light curtains, safety gates, or safety floor mats to prevent entry to the workcell while ARM POWER is enabled. These devices may be connected using the system's remote emergency stop circuitry. See the *Adept MV Controller User's Guide*.




**Impact and Trapping Hazards**

# Notes, Cautions, and Warnings

There are two levels of special notation used in this manual. They are:

**WARNING:** If the actions indicated in a "WARNING" are not complied with, injury or major equipment damage could result. A warning statement typically describes the hazard, its possible effect, and the measures that must be taken to reduce the hazard.

**CAUTION:** If the action specified in the "CAUTION" is not complied with, damage to your equipment could result.

**NOTE:** A "NOTE" provides supplementary information, emphasizes a point or procedure, or gives a tip for easier operation.

# How Can I Get Help?

## Within the Continental United States

Adept Technology maintains a Customer Service Center at its headquarters in San Jose, CA. The phone numbers are:

**Service Calls**

(800) 232-3378 (24 hours per day, 7 days a week)
(408) 433-9462 FAX

**Application Questions**

(800) 232-3378 (Monday to Friday, 8:00 a.m. to 5:00 p.m., Pacific time)
(408) 434-6248 FAX

**Training Information**

For information regarding Adept Training Courses in the USA, please call (408) 434-5024.

## Within Europe

For European customers outside of France, Adept Technology maintains a Customer Service Center in Dortmund, Germany. The phone numbers are:

(49) 231/75 89 40 from within Europe (Monday to Friday, 8:00 a.m. to 5:00 p.m., CET)
(49) 231/75 89 450 FAX

### France

For customers in France, Adept Technology maintains a Customer Service Center in Paris, France. The phone numbers are:

(33) 1 69 19 16 16 (Monday to Friday, 8:30 a.m. to 5:30 p.m., CET)
(33) 1 69 32 04 62 FAX

## Outside Continental United States or Europe

For service calls, application questions, and training information, call the Adept customer service center in San Jose, California USA:

(408) 434-5000
(408) 433-9462 FAX (service requests)
(408) 434-6248 FAX (application questions)

> **NOTE:** When calling with a controller related question, please have the serial number of the controller. If your system includes an Adept robot, also have the serial number of the robot. The serial numbers can be determined by using the ID command (see the *V+ Operating System User's Guide*).

## Adept Bulletin Board Service (BBS)

Adept maintains a bulletin board service for Adept customers. Adept posts application hints and utilities to this bulletin board and users may post their own hints and application notes. There is no charge for access to the bulletin board. The BBS number is (203) 264-5590. The first time you call you will be able to set up an account right from the BBS. If you have any questions, call (800) 232-3378 and ask about the BBS.

# Overview 1

# 1.1 Introduction

This section presents an overview of machine vision. It gives a brief description of how a vision system “sees”, and what equipment and software tools you have for extracting information about what the vision system “sees”.

# 1.2 What AdeptVision VME Is

### Physical Equipment

A basic AdeptVision VME system consists of:

- A controller equipped with a vision processor board
- A robot or motion device (optional)
- One or more cameras
- The A-series controller option that includes:

  High-resolution color monitor

  AT-compatible keyboard

  Trackball (or other pointing device)

In addition, your system will probably contain special lighting equipment and camera mounting equipment. This vision system is generally integrated with parts delivery systems and other user-supplied equipment to form a workcell that performs the tasks you have designated for the system. The major components an AdeptVision VME system may have are described below. Figure 1-1 shows a typical system.

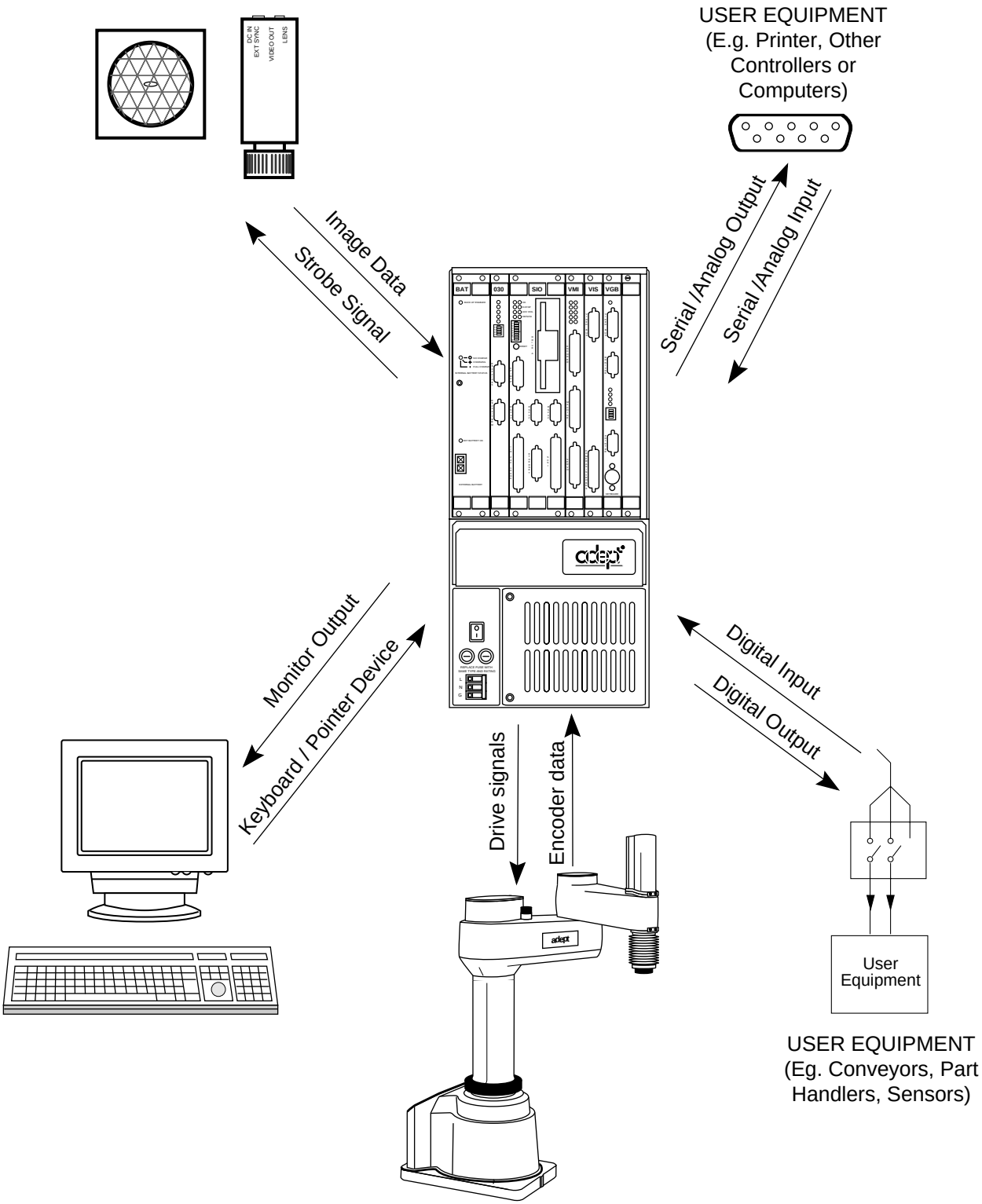



Figure 1-1. **Typical AdeptVision VME System**

## Controller and Vision Processor

The controller contains the logic boards, system and vision processor boards, I/O boards, and camera connector. This hardware system provides an environment for Adept's V+ Operating System and Language that allows you to direct and monitor vision operations. The hardware/software combination is multitasking and contains everything necessary to control:

- Four physical cameras per vision system (32 virtual cameras)
- Strobe lights for two physical cameras (AdeptVision VME provides the connection for a signal pulse for user-supplied strobe lights)
- A graphics monitor
- User-installed serial, digital, and (optionally) analog I/O devices
- User-supplied equipment such as conveyor belts (systems equipped with motion devices)

## Robot or Motion Device

Adept controllers may control robots or other motion devices. This manual describes vision guidance for the standard Adept robots. The principles described for these robots can be generalized to any other motion devices your system may be using.

## Graphics Terminal

The graphics monitor displays all vision system input and output. The system supports multiple windows; the monitor can display output from a camera, input from other cell control equipment, as well as operator input and prompts. The graphics monitor is used along with the keyboard and trackball to develop vision applications. This equipment can also be set up to function as the operator interface during execution of vision applications.

## User Equipment

You can communicate with the controller using serial, digital, and analog I/O. The serial channels support RS-232, RS422, and RS485 protocols which are generally used for printer output and communication with other controllers or computers.

The digital output channels are used to switch the user-supplied current to external equipment. Signaling a part feeder to place a part in the field-of-view is a sample digital output operation.

Digital input channels tell the controller that an event (such as a part being placed in the field-of-view) has occurred, and that your program should either suspend or continue execution (or take any other appropriate action).

The optional analog I/O channels allow you to read from, and write to, compatible analog I/O devices.

See the *Adept MV Controller User's Guide* for details on installing digital, serial, and analog I/O devices. See the *V+ Language Reference Guide* descriptions of IO, SIG, and SIGNAL() for details on programming digital I/O. See the descriptions of ATTACH, READ, GETC, WRITE, and DETACH for details on programming serial I/O. See the descriptions of AIO.IN and AIO.OUT for details on ana-

log I/O. See the description of the utility program CONFIG_C in the *Instructions for Adept Utility Programs* for details on the configuration of digital, analog, and serial I/O.

## 1.3 What AdeptVision VME Does

Quite simply, the AdeptVision VME system looks at something and then tells you what it knows about that thing. The system has software tools that allow you to control how AdeptVision VME looks at objects and what information it gathers about those objects. AdeptVision VME has three primary information processing strategies:

- In the first strategy, boundary analysis, AdeptVision VME looks at the boundaries of whatever is in the field-of-view and calculates information such as the perimeter, centroid, and area of each bounded region.
- In the second strategy, vision tools, you place ruler, window, and finder tools in the field-of-view, and AdeptVision VME returns information based on what it finds with those tools.
- In the third strategy, vision model processing, AdeptVision VME compares each bounded region in the field-of-view with known shapes or models you have placed in memory, and attempts to identify the region. Prototype recognition, OCR, and image correlation are the options in this mode of operation.

**Each of these processing strategies can be used independently or in conjunction with the other two.**

Inspection vision systems will use the results of the various vision options to make quality, gauging, and other measurements of objects in the field-of-view.

Guidance vision systems will use vision options to locate and acquire items in the field-of-view.

## 1.4 Vision Basics

Throughout this manual you will be seeing the object shown in Figure 1-2. We will use this sample object to help explain the features of the AdeptVision VME system.

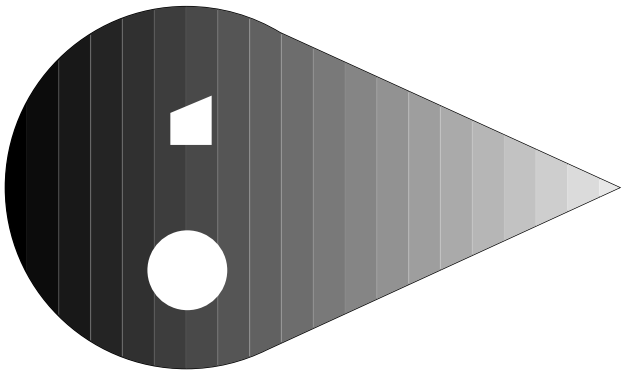


Figure 1-2. **Sample Object**

### Pixel

The basic unit of a vision image is a pixel (picture element). It is the smallest unit of information a vision system can return to you. The number of pixels the system can process determines the system's resolution and affects the computer processing time needed to analyze an image.

A pixel can be thought of as a single cell in a matrix that the camera overlays on the field-of-view. The value that is placed in that cell will be a shade of gray that represents the intensity of the light reflected from the corresponding area in the field-of-view (grayscale vision). Figure 1-3 shows how a 22 x 16 pixel camera would see the object shown in Figure 1-2. (The dashed lines are shown for reference; they are not actually "seen" by the system.)

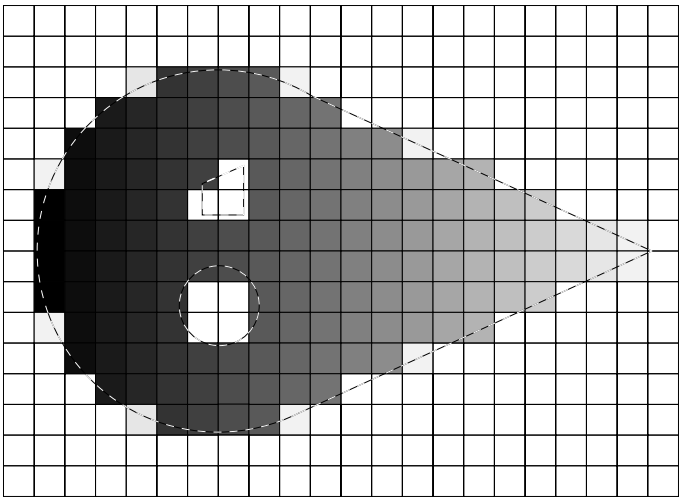


Figure 1-3. **A Grayscale Image**

In addition to grayscale processing, AdeptVision VME can process image data in binary mode. In binary mode, all the cells with a value above a certain value will be seen as white and those below that value will be seen as black. Figure 1-4 shows how the sample object would be seen in binary mode. Chapter 4 discusses the features and uses of grayscale and binary modes in more detail.

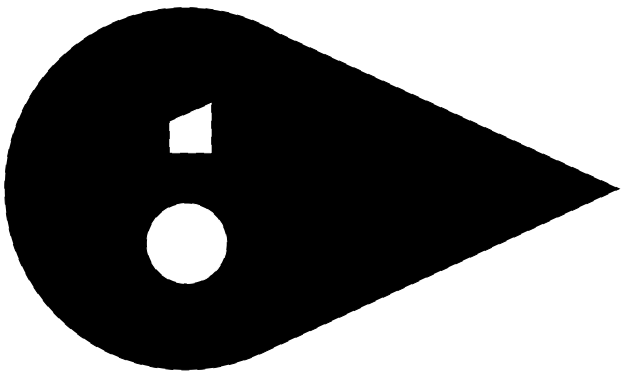


Figure 1-4. **A Binary Image**

## The Camera Imaging Surface

Video cameras used for machine vision replace the film used in a traditional camera with a light sensitive electronic surface. When you instruct the system to acquire an image (“take a picture”), the imaging surface is “exposed” for a short time and the “exposure” is read into the vision processor. The electronic surface is actually an array of photon detectors that store a charge based on the amount of light hitting the detector. The more light that hits an individual detector, the larger the stored charge and the higher the grayscale value that is read into the vision processor. When an image is acquired, all the charges in the imaging surface are zeroed out, the surface is exposed for 1/10,000 to 1/30 of a second, and the value recorded in each cell (pixel) of the imaging surface is

read into the vision processor. The resulting matrix of values is analyzed to locate edges and bounded regions. Vision tools can then be used to measure distances between edges, recognize bounded regions, and extract other information about the image.

## Resolution

The number of rows and columns in the camera imaging surface, the lens focal length, and the distance of an object from the camera will determine the final resolution of whatever you are viewing. Figure 1-5 shows the relationship between focal length and viewing distance. In general, optimum resolution will come when the object of interest fills as much of the field-of-view as possible while still being in focus.

The image representation of our hypothetical 22 x 16 camera shows very poor resolution due to the low density of pixels. The size of the arrays in cameras supported by AdeptVision VME typically ranges from 501 x 485 pixels to 768 x 493 pixels. Appendix C details the steps to selecting the optimum lens focal length, viewing distance, and camera imaging surface.

An important concept that is illustrated by Figure 1-5 is the relationship between a pixel's dimensions and the physical size of an object. A pixel will always have a **relative** relationship to the size of an object. It will have an **absolute** relationship only when you fix your viewing distance and lens focal length, and then calibrate the vision system. The calibration process establishes an absolute relationship between a pixel and the actual dimensions of the field-of-view. "Camera Calibration" on page 28 discusses the utilities Adept makes available to establish this relationship.

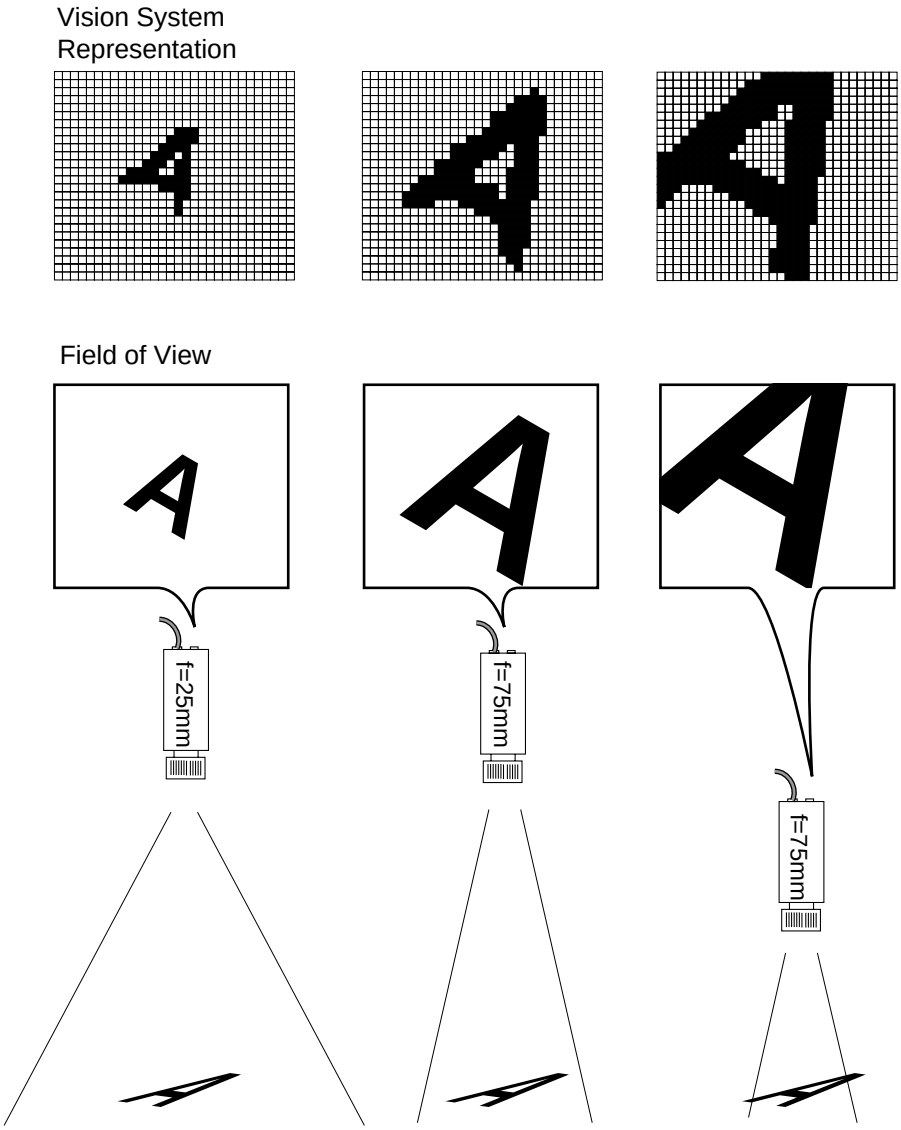



Figure 1-5. **Resolution Factors**

## 1.5 Summary of Software Tools

This section gives a brief overview of the vision tools provided by AdeptVision VME. These tools are detailed in Chapters 5, 6, and 7.

### Boundary Analysis

Boundary analysis locates objects in the field-of-view and returns information about those objects' sizes, locations, perimeters, etc. Boundary analysis locates objects by looking for bounded areas (a contiguous area of light or dark pixels in the binary image). These bounded areas are often called "blobs".

### Rulers

Rulers are inspection tools you place in the vision image that return information based on the values found in the pixels the ruler crosses. Linear rulers return distances between features of an object based on intensity changes (edges) in the field-of-view. Arc rulers return the angular distance between object features. You can set the length, angle, and position of these rulers. Rulers work with both grayscale and binary images. You can place multiple rulers in the field-of-view, inspect multiple objects, and examine the relationship between multiple objects.

### Inspection Windows

Inspection windows provide a quick way of obtaining basic graylevel, binary, or edge statistics about specific areas of an image.

### Finder Tools

These tools allow you to find points, lines, and arcs in an image. The data returned from finder tools may provide all the information you need about an object, or it may provide the basis to perform other inspections.

### Processing Windows

In Chapter 5 you will learn the difference between processed and unprocessed images. In many cases, you can speed up your applications by operating on unprocessed images or by processing only a limited portion of the field-of-view. Processing windows allow you to process a limited area of the field-of-view. (In contrast to inspection windows, processing windows do not return any data about the image: they merely process a portion of an image for use by other vision tools.)

### Modeling

Modeling allows you to store models of different objects in vision system memory and then compare these models with objects in the field-of-view. The system will tell you if an object in the field-of-view matches a model in vision system memory, how close the match is, and where the object is in the field-of-view.

## 1.6 Overview of Guidance Vision

AdeptVision makes use of the tools just described both to inspect objects and to provide information to the motion device about an object's location.

### Frames

All robot motion is based on frames of reference and location variables. Location variables uniquely identify a point within a Cartesian space and the orientation of the robot tool at that point. All robots and motion devices will have a primary reference frame. On Adept SCARA robots the primary reference frame is centered at the base of the robot with the Z axis pointing straight up, the X axis going front to back, and the Y axis going left to right.

The V+ language provides several options for creating new frames of reference that are relative to this primary reference frame. Relative reference frames can also be created with respect to other relative reference frames. It is these relative reference frames that allow the vision system to guide robot motions.

Depending on the camera mounting location, different relative reference frames will be used to relate the camera field of view to the robot work space. Chapters 9 and 10 give the details of creating and using these frames.

## 1.7 Things to Consider When Designing Your Workcell

While designing your workcell, keep in mind the following considerations:

### Consistent Environment

For your results to be consistent and predictable, the environment you operate the vision system in must be as consistent and predictable as possible.

Avoid major changes in temperature and humidity. Mount the cameras so that a constant distance is maintained from the camera to the object.

Isolate the cameras as much as possible from sources of vibration.

### Ease of Maintenance

Periodic maintenance and repair of your system will be necessary. Design your workcell to allow access to all the vision system components as well as any other equipment you may have installed.

### Safety

If there is any moving equipment, such as part feeders or conveyor belts, design the workcell so that all normal operations can take place without the operator coming into dangerous contact with the moving equipment.

## Lighting

Consistent lighting is critical to accurate, predictable vision operations. Appendix D lists the advantages and disadvantages of various lighting systems. Before you select and install a lighting system, experiment with different lighting setups and see which one provides you with the most consistent results. These results should be checked throughout the duration of the shift in which the system will be operated to see how changes in ambient light affect the system.

**Creating an optimum and consistent lighting environment when you design your workcell will save a great deal of trouble later!**

# 2 Installation

# 2.1 Setting Up the Hardware

Your vision system includes the following items:

- An Adept A-series controller equipped with:
  - A System Processor Board
  - Graphics Processor Board
  - Vision Processor Board (VIS) or Enhanced Vision Interface Board (EVI)
  - V+ Operating System and Language (Version 11.0 or later) with the Vision option
- Utility Programs Disk
- High-resolution color monitor
- AT compatible keyboard and pointing device
- One or more cameras

You may be installing the following options:

- Camera lenses, extension tubes
- Strobe lights or other area lighting
- Optical filters
- Camera mounting hardware
- Robot or motion device

## Installing the Controller

Your controller should be set up and configured before you install the peripheral vision system equipment. See *Adept MV Controller User's Guide* for details on setting up the controller. This guide also shows where to connect the monitor, keyboard, and pointing device to the controller.

If you are using digital I/O, pay particular attention to the controller user's guide's instructions on installing and configuring digital I/O in your workcell.

## Attaching Cameras and Strobes

The *Adept MV Controller User's Guide* shows how to connect cameras and strobes and to set any hardware options required by the various cameras and strobes.

Appendix G lists several manufacturers who supply strobe lighting (and general lighting) that is compatible with AdeptVision systems.

### Strobe Compatibility

Adept's strobe signal is TTL compatible with a duration of 120 µsec and an output of 80 - 120 mA (positive going pulse). The stobe signal is normally set "active high", but can be configured using the DEVICE instruction (see Appendix F). Strobe lights have a latency between signal detection and flash. This latency combined with the flash duration should not exceed 100 µsec.

## Cameras Supported by AdeptVision VME

The cameras listed here can be used with AdeptVision VME. Not all features of all cameras are supported by AdeptVision VME. The following highlights the main features of each camera:

**Panasonic GP-CD 40**

This low cost, medium-resolution camera has a resolution of 501 x 485 pixels. It can also be used as an electronically shuttered camera (fixed at 1/1000 sec).

Nonshuttered cameras require about 1/30 of a second to acquire an image. This speed is too slow to acquire unblurred images of moving parts. Shuttered cameras have shutter speeds of 1/1,000 to 1/10,000 sec., allowing them to acquire clear images of moving parts without the use of strobe lighting. With shuttered cameras, the strobe signal is used to latch the external encoders of motion devices simultaneously with image acquisition. Since the timing of a strobe signal used to record encoder positions is different from the timing for a strobe light, cameras used in shuttered mode cannot be used with strobe lights.

When you are using a shuttered camera, images must be acquired in field-acquire mode.

**Panasonic GP-MF 702**

This camera has a resolution of 649 x 491 pixels. This camera can be set up to use the “pixel clock” output of the vision board. This camera uses an MOS array rather than a CCD array for the imaging element. MOS arrays shift data from the imaging element to the vision processor differently from CCD array cameras. Therefore, asynchronous strobe operation will not work.

**Sony XC-77**

This is an electronically shuttered camera with a resolution of 768 x 493 pixels. See the description of the Panasonic GP-CD 40 camera for additional details on shuttered cameras. This camera can be set to operate in standard, nonshuttered mode.

The Sony XC-77 provides both synchronous and asynchronous shuttered capability. When used in asynchronous mode, the maximum number of images that can be acquired per second is 30 (60 is the maximum in synchronous mode).

> **NOTE:** When a camera is used in pixel-clocked, asynchronous, or shuttered mode, the camera must be properly set up to operate in the selected mode. See the camera instructions for details on setting up the camera for different operating modes.

The following cameras are also compatible with AdeptVision VME:

- Hitachi KP-M1
- Panasonic GP-MF502
- Panasonic GP-MF552

Contact your Adept salesperson for details on the cameras sold directly by Adept. Contact Adept Applications for current details on camera compatibility.

### Mounting Cameras

Mount your cameras rigidly and dampened from vibration. Consistent vision results depend on cameras that stay a constant distance from the objects being viewed. Cameras that can skew, change position on their mounts, or lose focus due to vibration or contact will cause problems over the life of your application.

Appendix G lists several suppliers of camera and lighting mounting hardware.

## 2.2 Setting Up the Software

Your vision system leaves the Adept factory with the operating system and vision software installed on a floppy disk. (If your system has a hard drive, the operating system and vision software are also installed on the hard drive [C:].)

To boot the system and bring up the vision monitor, turn on the monitor, place the system disk in drive A, and turn on the controller. If the hard disk option is installed, just turn on the monitor and controller.

After power is turned on, the system will go through a series of self-tests and then load the operating system. When the load procedure is complete, you will see a screen similar to Figure 2-1 showing copyright information and the ID lines. The ID lines contain coded information about the configuration of your system. See the ID command in the *V+ Language Reference Guide* for details on the meaning of these lines.

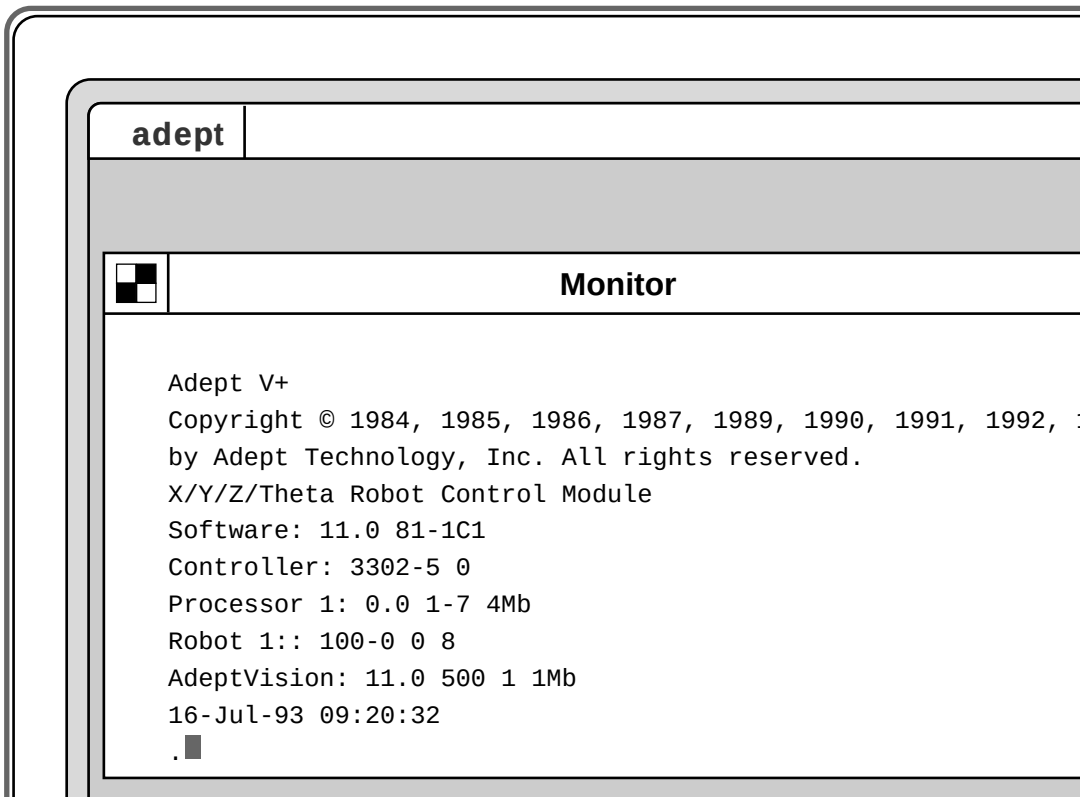



Figure 2-1. **Initial Screen**

When your monitor looks like Figure 2-1, you are ready to begin vision operations and to load vision application programs. See the *V+ Operating System User's Guide* for details on installing application software.

# 3 Getting Started

## 3.1 V+ Syntax Conventions

This manual details V+ keywords (monitor commands, functions, and program instructions). These operations are presented using the following syntax conventions (see Figure 3-1):

- Keywords are typed in capital letters and should be typed exactly as they are shown. For example, **LOAD** should be typed exactly as it appears.
- Arguments are shown in lowercase letters and should be replaced with arguments you provide. For example, **drive** should be replaced with a drive letter you choose.
- Keywords and arguments shown in **bold type** are required; and those shown in regular type are optional. If you omit an optional argument, the system will assume a default value.

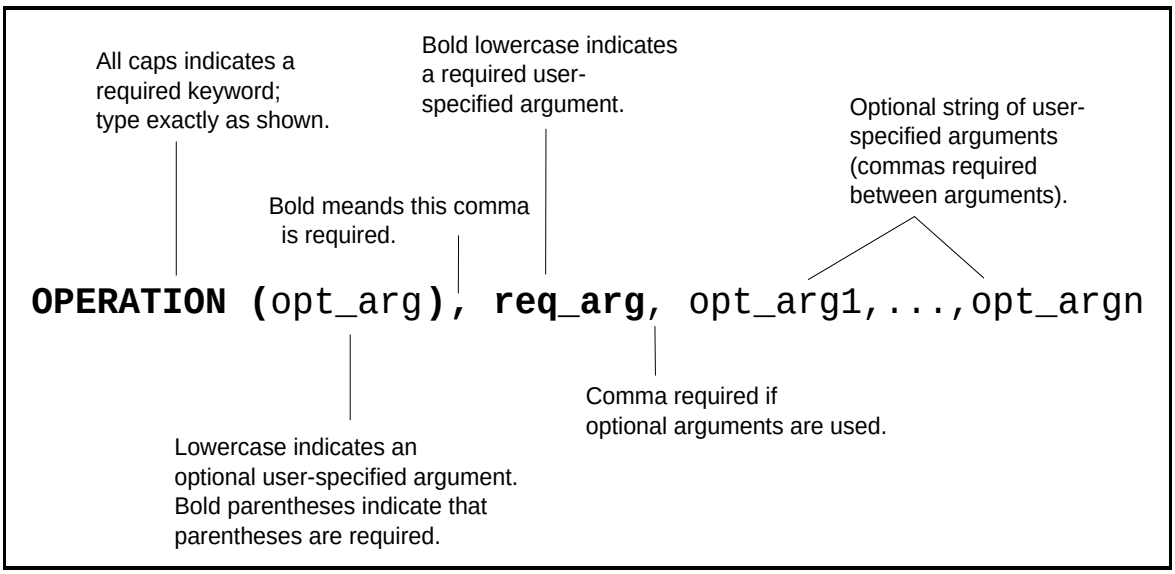



Figure 3-1. **Sample Operation**

**NOTE:** For the sake of simplicity, the operations detailed in this manual do not list all available options. See the *V+ Language Reference Guide* and the *AdeptVision Reference Guide* for a complete description of all keywords.

Remember, AdeptVision VME supplies an extension to the basic V+ programming language. The basic language elements such as control structures, mathematical functions, etc., are detailed in the *V+ Language Reference Guide* and the *V+ Language User's Guide*.

## 3.2 Virtual Cameras

AdeptVision VME allows you to establish several virtual cameras for each of your physical cameras (as long as the total number of virtual cameras does not exceed 32). One of the most important things you will learn in the next three chapters is how to control what a camera sees. You may find that you want to take several pictures of an object with each picture looking at the object in a different way or from a different distance. Virtual cameras allow you to do this. For example, you might want your first picture of an object to look at the perimeter shape and your second picture to look at interior features of the object. By establishing two virtual cameras for the physical camera looking at the object, you can take both types of pictures of the object.

### What Is a Virtual Camera?

The controller allows you to attach four different cameras to each vision processor. These cameras are the “physical” cameras. Associated with each physical camera will be one or more virtual cameras. A virtual camera is a single set of switches and parameters, calibration data, and a vision queue (see Figure 3-2). Switches and parameters are introduced in the next two chapters. The vision queue is introduced in Chapter 5. Calibration is discussed in the next section. A physical camera can have up to 32 virtual cameras associated with it, but the total number of virtual cameras associated with **all** physical cameras can not exceed 32. Each physical camera must have at least one virtual camera associated with it. If you have 4 physical cameras—camera 1 could have eight virtual cameras, camera 2 could have sixteen virtual cameras, camera 3 could have five virtual cameras, and camera 4 could have three virtual cameras. Or they could have any combination of virtual cameras that add up to 32 or less.

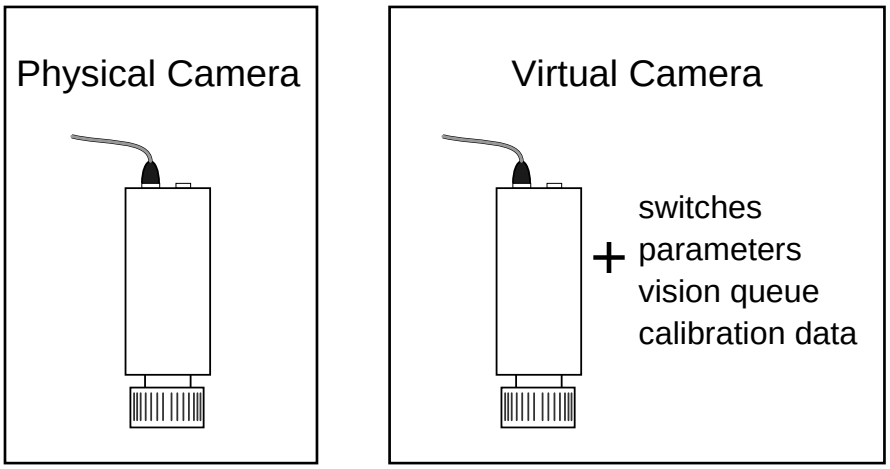



Figure 3-2. **Physical/Virtual Camera Relationship**

### How Are Camera Numbers Assigned?

The physical camera number is determined by the port the camera is plugged into on the vision processor (see *Adept MV Controller User's Guide*). The virtual camera number (and the physical camera associated with it) is determined during camera calibration or when calibration data is loaded. One of the first questions asked during camera calibration is what virtual camera number you want

associated with the physical camera you are calibrating. Your answer to this question determines which virtual camera is being calibrated and which physical camera it will be associated with.

### Why Use Virtual Cameras?

Switches and parameters can be set for an individual virtual camera. Calibration data and prototype groups can also be defined for individual virtual cameras. Virtual cameras allow you to use the same physical camera to look at the same image using different combinations of calibration, prototypes, switches, and parameters simply by specifying different virtual cameras.

For example, you might be inspecting different areas of an object, each of which requires its own switch/parameter settings. Or you might be presenting two (or more) different objects to the same camera for inspection. If these objects are different distances from the camera (but still in focus), you will need different camera calibration data for each object. Since camera calibration is established for each virtual camera, you could use different virtual cameras calibrated for the different distances to inspect the objects.

Unless noted, this manual assumes your system has only one camera and that virtual camera 1 has been assigned to it. **So all references to a camera mean virtual and physical camera 1.**

## 3.3 Camera Calibration

Before you can begin executing vision programs, the system should be calibrated so it has some basic information about the camera and its field-of-view. Two basic pieces of information it needs are: the ratio of the width of a pixel to a millimeter in the field of view (x scale) and the ratio of the height of a pixel to a millimeter in the field of view (y scale). For motion device related cameras, you must also establish the relationship between the camera field-of-view and the motion device. During camera calibration, you will need to focus the lens and adjust the lens aperture (f-stop).

There are two methods for calibrating your cameras. The first is to use the Adept utility, "ADV_CAL". The second is to use the calibration option in the Adept AIM application programs (VisionWare or MotionWare with vision). Instructions for using "ADV_CAL" come with the option package. Instructions for using the AIM calibration option are supplied in the *VisionWare User's Guide.*

### Camera Calibration Results

Camera calibration establishes the following relationships:

- The number of camera pixels per millimeter of the field-of-view. To be able to produce meaningful distance calculations, the system must know how many camera pixels are needed to "see" a millimeter of distance in the field-of-view.
- An option perspective distortion correction, a set of transformations that allow the system to account for fields-of-view that are not parallel to the camera imaging element.
- For motion device related cameras, the camera-to-robot transformation. In order to guide the robot, the system must know the relationship between the camera position/orientation and the motion device end effector.

**NOTE:** Before you can begin the calibration procedures, the camera must be installed in its permanent location. Once a camera has been calibrated, changing camera location or camera lens focus will invalidate the calibration. When you calibrate the camera, you establish a distance relationship between the camera and the field-of-view and between the camera and the motion device. If the distance changes, these relationships will no longer be valid. Changing the camera lens or lens focus affects the size of the field-of-view and, therefore, the distance relationship. Once you have calibrated a camera, you cannot alter the lens focus (lens focus can be set during calibration).

Adept recommends that you tape or clamp your lens focusing ring after you have focused the camera but before you begin calibration. This will help prevent inadverdent focusing of the lens after calibration.

# 3.4 Motion Devices and Calibration

For systems with motion devices, three different types of calibration must be completed before an AdeptVision VME system can be used. The three types of calibration are:

## Motion Device Calibration

This calibration establishes the relationship between the robot's encoders and the actual space the robot works in. On Adept robots, this calibration is performed at the factory and will not need to be repeated unless an encoder is replaced or other major repair is performed. For other motion devices, this calibration is performed with the AdeptMotion VME utility SPEC.V2.

## Start-up Calibration

When a motion device and its controller are first turned on, the device must relate its current location to the motion device calibration data. This procedure is accomplished by entering the commands:

```
ENABLE POWER
CALIBRATE
```

See the robot user's guide or *AdeptMotion VME User's Guide* for more details.

## Camera Calibration

The relationship between the camera field-of-view and the motion device must be established before the vision system can be used to locate objects for the motion device. See the *User's Guide to the Advanced Camera Calibration Program* that came with the calibration package for details on the various calibration configurations.

## The Vision Transformation

Guided vision is essentially the process of putting together several pieces of information to create a transformation. A transformation defines a location a motion device can move to. You must be familiar with the Adept transformation value before you can program motion device applications. See the *V+ Language User's Guide* and the *V+ Language Reference Guide*. The next two sections summarize this transformation for fixe- mount and for robot arm-mounted cameras. Chapter 9 presents detailed information.

### Fixed-Mount Camera Transformation

The transformation value to pick up an object using a fixed-mount camera has the following possible elements:

- The location, in world coordinates, of the origin of the vision reference frame. This location is created by the camera calibration routine and stored in the "to.cam[ ]" array.
- The offset and rotation of the part relative to the vision reference frame. These values are calculated using different vision tools (described in Chapters 5 - 7).
- The offset from the center of the quill flange to the center of the actual gripping location ("TOOL transformation"). See the description of the TOOL program instruction in the *V+ Language Reference Guide* for details.

**Robot-Mounted Camera Transformation**

The transformation value to pick up an object using an arm-mount camera has the following elements:

- The offset, in tool coordinates, from the origin of the vision reference frame to a location on the robot that is fixed relative to the camera (this location varies depending on the joint the camera is mounted on). This transformation is created by the camera calibration routine and is stored in the "to.cam[ ]" array.
- The offset and rotation of the part relative to the vision reference frame. These values are calculated using different vision tools (described in Chapters 5 - 7).
- The offset from the center of the quill flange to the center of the actual gripping location ("TOOL transformation"). See the description of the TOOL program instruction in the *V+ Language Reference Guide* for details.
- The current position of the robot joint the camera was calibrated to. The robot joint that the camera calibration transformation is based on moves. Therefore, the current position of the robot joint must be recalculated each time a picture is taken at a new location. This is a simple calculation that is described in Chapter 9.

The next four chapters will describe the tools and options available to calculate the necessary parts of a vision transformation.

## 3.5 Loading Vision Calibration Data

After you have turned off the controller or zeroed system memory, calibration data is no longer available and will have to be reloaded. There are two ways of loading calibration data to system memory from a disk file. The first is to use the camera calibration program. The second is to call the program "loadarea" from your application program. The *Advanced Camera Calibration Program User's Guide* describes using ADV_CAL to load calibration data.

Loading calibration data by calling "loadarea" from an application program is shown in the programming example in Chapter 8 and described in *Instructions for Adept Utility Programs*.

If you are using VisionWare or MotionWare with vision, the calibration data is automatically loaded when VisionWare or MotionWare is started.

> **NOTE:** In order for loaded calibration data to be valid, the physical camera associated with the virtual camera must be in the same location and have the same lens settings as when it was calibrated. If this is not the case, the system will still return data, but the data may not be valid.

# 4 Teaching AdeptVision to See

# 4.1 Introduction

Your vision system should be installed and turned on (Chapter 2), and the camera should be calibrated and ready to start taking pictures (Chapter 3).

This chapter describes ways of getting the camera to "see" the critical features of an object. The AdeptVision VME system provides several options for "filtering" the information supplied by the camera so that the system analyzes only the features of an object that are important to you. Other options help you produce the clearest, most usable image possible.

Chapters 5 - 7 show you how to gather information from the images that this chapter shows you how to acquire. A thorough understanding of this chapter will help you make efficient, consistent use of the information the system returns to you and the tools the system makes available to you.

Most of the options described in this chapter can be performed from the vision window pull-down menus. This menu system provides you with an excellent development environment that allows you to experiment with the system options before you begin programming vision applications. Use this environment to become as familiar as possible with the effects of all the commands and options before you begin programming. You will write more efficient and accurate programs when you fully understand the vision processes.

Several of the instructions presented in the following chapters are in abbreviated form to minimize confusion. As you become more familiar with the instructions, you will want to explore their full capabilities. These instructions are detailed in the *AdeptVision Reference Guide.*

## Physical vs. Virtual Cameras

AdeptVision VME allows you to establish several virtual cameras for each of your physical cameras (as long as the total number of virtual cameras does not exceed 32). One of the most important things you will learn in the next three chapters is how to control what a camera sees. You may find that you want to take several pictures of an object with each picture looking at the object in a different way. Virtual cameras allow you to do this. For example, you might want your first picture of an object to look at the perimeter shape and your second picture to look at interior features of the object. By establishing two virtual cameras for the physical camera looking at the object, you can take both types of pictures of the object. See "Why Use Virtual Cameras?" on page 28.

For the next two chapters, we assume your system has only one camera and that virtual camera 1 has been assigned to it. S**o all references to a camera mean virtual and physical camera 1.**

### The Point of Origin

Many of the operations you will be learning specify coordinate points within the field of view. These points will be given in Cartesian coordinates with the X/Y origin being at the lower left corner of the screen. This means that:

- In general, only positive numbers are meaningful. (When we introduce relative reference frames, negative values for tool placement are useful, but they must resolve to a positive value relative to the base vision reference frame.)
- The higher the number for the X coordinate, the further to the right on the screen the point is.
- The higher the number for the Y coordinate, the higher on the screen the point is.

These coordinates are in millimeters that refer to the actual distances in the field-of-view, not the dimensions of the monitor. This coordinate frame is referred to as the Vision Coordinate System. Tools placed relative to this coordinate system are in “vision coordinates”.

> **NOTE:** The V+ instructions GTYPE, GARC, etc., have their own coordinate system that is based in screen pixels with the coordinate frame origin at the top left of the vision window. The program instruction GTRANS will automatically convert real-world millimeters to screen pixels so you can specify millimeters for the “G” graphics instructions. The example program on page 131 shows how to use the GTRANS program instruction.

## 4.2 VPICTURE—Getting an Image

The VPICTURE operation (VPICTURE is both a monitor command and a program instruction) accomplishes two primary tasks:

> The first is acquiring an image—getting the camera to transfer an electronic image to the controller.
>
> The second is processing that image—using the software to filter the image data and gather information about the image.

When a VPICTURE operation is performed, the vision system acquires an image into an image buffer. If the processing option has been selected, the image data is examined and basic image data is calculated. Depending on the setting of various vision switches described later in this chapter, the level of data gathered can be controlled. Each time a new VPICTURE is issued, the previous image data is overwritten.[1]

The results of a VPICTURE operation can be displayed in several different ways. The way an image is displayed depends on the selection made from the **Display** menu or with the VDISPLAY command (described in the next section).

[1] See the full description of VPICTURE in the *AdeptVision Reference Guide* for details on storing multiple images.

## VPICTURE Syntax

VPICTURE can be executed either from the monitor prompt or from within a vision program. The simplified VPICTURE syntax is:

**VPICTURE**(cam.virt) mode

`cam.virt` is replaced with the number of the virtual camera you want to take a picture with. Camera 1 is the default value.

`mode` is replaced with:

–1 indicating that a new image should be acquired and processed immediately. This is the default value.

2 indicating that a quick frame grab should be made and boundary analysis and prototype recognition should not be performed.

### VPICTURE Examples

Acquire an image with virtual camera 3 and process it immediately:

```
VPICTURE(3)
```

Acquire an image with virtual camera 3 and hold it for later processing (quick frame grab):

```
VPICTURE(3) 2
```

## Executing VPICTURE From the Menu

To execute a VPICTURE command from the menu:

1. Pull down the **Cam/Frame** menu and drag to the number of the camera you want to take a picture with (only the first 8 virtual cameras can be selected from the menu).
2. Pull down the **Pict** menu and drag to the mode you want the picture taken in. The results will be shown in the vision window.

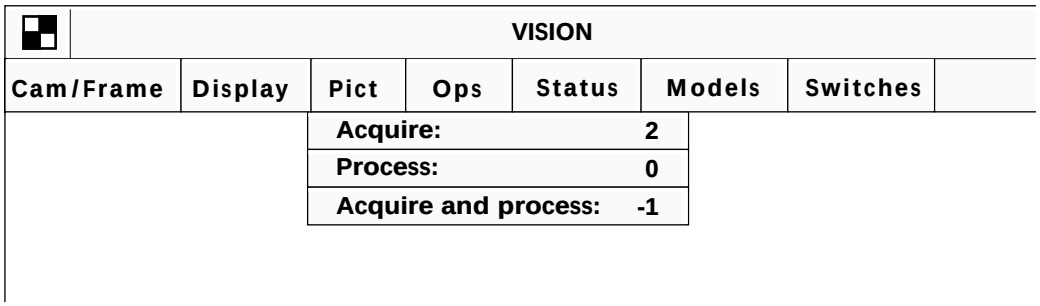



Figure 4-1. **VPICTURE Options**

# 4.3 VDISPLAY—Displaying the Image

AdeptVision VME provides several ways of displaying an acquired image on the screen. You choose a display mode depending on what image characteristics you are interested in, how time-critical your application is, and what information you want relayed to an operator.

## VDISPLAY Syntax

VDISPLAY is both a monitor command and a program instruction. The simplified VDISPLAY syntax is:

**VDISPLAY mode**, overlay

**mode** is replaced with:

- –1 indicating a live grayscale image is to be displayed. This mode displays a live video image that shows you exactly what the camera currently sees (not the last picture that was acquired).
- 0 indicating a live thresholded (binary) image is to be displayed.
- 1 indicating that an acquired grayscale image is to be displayed. (Modes 1 to 4 take effect at the first VPICTURE after VDISPLAY is changed.)
- 2 indicating that an acquired binary or edge image is to be displayed.
- 3 indicating that a graphical representation of a processed image, along with any user-generated graphics, is to be displayed.
- 4 indicating that user-generated graphics should not be erased each time VPICTURE is executed. This mode is useful for graphs or data you want to display continuously.

overlay (used with "**mode**" = –1, 0, 1, and 2 only) is replaced with:

- 0 indicating no user graphics are to be overlaid. This is the default value.
- 1 indicating that any user- or system-generated graphics are to be overlaid on a frozen or live image (**modes** –1, 0, 1, and 2). (In **modes** 3 and 4, user-generated graphics are automatically displayed.)
- 2 indicating user graphics are to be displayed and not erased during successive VPICTURE operations.

### VDISPLAY Examples

Display a live grayscale image with any user-generated graphics overlaid:

```
VDISPLAY -1,1
```

Display a graphical representation of the image, including user-generated graphics:

```
VDISPLAY 3
```

## Executing VDISPLAY From the Menu

Pull down the **Display** menu and select the display mode you want to use. If you select any of the live or frame modes and want a graphics overlay, pull down the menu again and select an overlay. A "✔" indicates the option is selected.

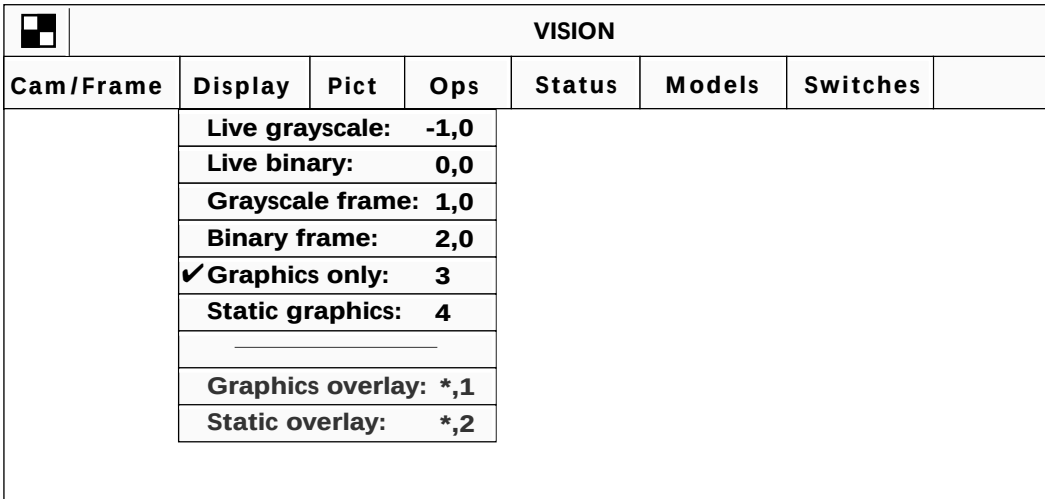



Figure 4-2. **Display Mode Options**

## Using the Different Display Modes

### Live Modes

Use the live modes for setting up your vision cell. These modes allow you to immediately see the effects of changes to:

- Camera lens focus
- Camera lens aperture
- Lighting
- Objects in the field-of-view
- Changes to parameters such as gain, offset, and threshold

### Frame (Frozen) Modes

An acquired image in a frame store is referred to as a "frozen" image. Use the frozen modes to see the actual image the system is currently working with.

### Graphics Mode

The live and frozen modes do not show you the actual edges the system has detected or the graphics that represent the vision tools. To see the processed image, use display mode 3. To see the tool graphics, use a graphics or graphics overlay mode.

Remember, displaying graphics requires processing time and is not essential to many vision operations. If your application is time critical, consider not displaying graphics.

## 4.4 Binary vs. Grayscale Modes

To understand the relative advantages of grayscale and binary modes, it helps to understand what information the camera returns to the controller and how the controller interprets that information. Figure 4-3 shows a magnified section of an array of pixels that might be returned by a camera. In each pixel of the matrix is the grayscale intensity value the camera has registered from the field-of-view.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 88 | 82 | 84 | 88 | 85 | 83 | 80 | 93 | 102 |
| 88 | 80 | 78 | 80 | 80 | 78 | 73 | 94 | 100 |
| 85 | 79 | 80 | 78 | 77 | 74 | 65 | 91 | 99 |
| 38 | 35 | 40 | 35 | 39 | 74 | 77 | 70 | 65 |
| 20 | 25 | 23 | 28 | 37 | 69 | 64 | 60 | 57 |
| 22 | 26 | 22 | 28 | 40 | 65 | 64 | 59 | 34 |
| 24 | 28 | 24 | 30 | 37 | 60 | 58 | 56 | 66 |
| 21 | 22 | 23 | 27 | 38 | 60 | 67 | 65 | 67 |
| 23 | 22 | 22 | 25 | 38 | 59 | 64 | 67 | 66 |

Figure 4-3. **Sample Vision Matrix**

When AdeptVision VME creates a binary image, each value in the matrix is compared with a "threshold" value. All the pixels with a value above the threshold are considered white and all the pixels below this value are considered black. Figure 4-4 shows the binary image that would result from Figure 4-3 using a threshold value of 32. A binary line finder tool[1] would be able to find two lines in this image, the bottom and right edges (assuming the left and bottom edges represent the edge of the field of view).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 88 | 82 | 84 | 88 | 85 | 83 | 80 | 93 | 102 |
| 88 | 80 | 78 | 80 | 80 | 78 | 73 | 94 | 100 |
| 85 | 79 | 80 | 78 | 77 | 74 | 65 | 91 | 99 |
| 38 | 35 | 40 | 35 | 39 | 74 | 77 | 70 | 65 |
| **20** | **25** | **23** | **28** | 37 | 69 | 64 | 60 | 57 |
| **22** | **26** | **22** | **28** | 40 | 65 | 64 | 59 | 61 |
| **24** | **28** | **24** | **30** | 37 | 60 | 58 | 56 | 66 |
| **21** | **22** | **23** | **27** | 38 | 60 | 67 | 65 | 67 |
| **23** | **22** | **22** | **25** | 38 | 59 | 64 | 67 | 66 |

Figure 4-4. **Binary Representation of Sample Matrix**

[1] Line finders are described in Chapter 6.

When grayscale vision tools are used, the software processes image data based on the difference in intensity values found in the neighboring pixels. If the difference found exceeds an “edge strength value”, the system considers the three-by-three area to be part of an edge. Figure 4-5 shows the four edges a grayscale line finder could find if an edge strength value of 20 were applied to the image data from Figure 4-3. (This illustration is somewhat idealized to help illustrate the point.)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 88 | 82 | 84 | 88 | 85 | 83 | 80 | 93 | 102 |
| 88 | 80 | 78 | 80 | 80 | 78 | 73 | 94 | 100 |
| **85** | **79** | **80** | **78** | **77** | **74** | 65 | 91 | 99 |
| **38** | **35** | **40** | **35** | **39** | **74** | 77 | 70 | 65 |
| 20 | 25 | 23 | 28 | **37** | **69** | 64 | 60 | 57 |
| 22 | 26 | 22 | 28 | **40** | **65** | 64 | 59 | 61 |
| 24 | 28 | 24 | 30 | **37** | **60** | 58 | 56 | 66 |
| 21 | 22 | 23 | 27 | **38** | **60** | 67 | 65 | 67 |
| 23 | 22 | 22 | 25 | **38** | **59** | 64 | 67 | 66 |

Figure 4-5. **Grayscale Representation of Sample Matrix**

By comparing these three figures we can make several generalizations about grayscale vs. binary modes.

1. Binary mode uses edge data based on only two states, black or white. Grayscale mode uses edge data based on values in the range 0-127. Grayscale mode examines 3 x 3 sections of pixels when calculating edges. This means binary mode will require less processing time.

2. Binary mode looks for edges based on an absolute intensity value. This means that if the overall brightness of the image changes, binary mode may see the image differently (the edges will move based on the increasing or decreasing brightness of the image). Grayscale mode looks for the relative difference between intensity values in an image. Thus, if the overall brightness changes, the relative brightness should remain similar and the system will see edges in the same place. In general, grayscale mode will be less affected by ambient lighting changes than will binary mode.

3. Since grayscale mode looks for intensity differences, you will be able to identify edges that occur in more than one brightness range. In the examples above, if there had been an intensity change in the range of 80 to 110, binary mode would have considered the entire area to be white and ignored the change. Grayscale mode would have perceived the intensity difference and calculated an edge.

   In the case of an object with several interior features, grayscale mode may be the only way to recognize interior features. You may find, when inspecting a part, that the interior features are not of interest and need to be filtered out, in which case binary mode might be more appropriate.

Some additional considerations when deciding whether to use grayscale or binary mode are:

1. A few AdeptVision VME tools can operate only on binary data. These will be described in the following chapters.

2. All of the grayscale tools can be used even when the picture is processed in binary mode.
3. Grayscale tools can be more accurate than binary tools. Grayscale tools use an algorithm that potentially allows them to locate features with subpixel accuracy.

Each time an image is acquired, both grayscale and binary data is stored. When making a decision about which mode to process in, you are not limited to one mode or the other. You can inspect an image both in binary and in grayscale mode, making use of the unique features of each mode to make different inspections of the image.

## 4.5 Switches and Parameters

Before you can begin using the vision tools to inspect objects, you need to acquire a clear, accurate image that displays the features you are interested in and filters out features you are not interested in. AdeptVision VME has two classes of system variables that control the way it sees objects and what information the system will gather about those objects. The two classes of variables are switches and parameters.

When an image is processed, the effects of the switches and parameters are reflected in the data returned by the vision system. For example, suppose you have a part that has several 6 mm and 13 mm holes, but you are interested only in the 13 mm holes. By setting a combination of switches and parameters you can acquire an image that processes data about the 13 mm holes and ignores the 6 mm holes.

During the development of your applications, care should be taken to set the switches and parameters so that your system produces clear images and processes only the minimum detail needed to accomplish the desired vision task (processing unneeded data consumes processing time and may slow down your applications).

All switches and parameters can be set within a program. This allows you to set the variables for one image, take a picture, process the data, and then change the variables for the next picture or image. Remember, each virtual camera has its own arrays of switches and parameters. This allows you to use different virtual cameras to take pictures using different parameter, switch, and calibration settings, while using the same physical camera.

The switches and parameters can be broken into three main functional groups. The first group influences the way the system initially acquires the image. This group will be presented in this section.

The second group influences the types of processing the system performs and what information it gathers about the objects it finds in the field-of-view. This group will be presented in Chapter 5.

The third group influences the model recognition processes. This group will be presented in Chapter 7.

The entire group of switches and parameters is listed in Appendix A.

## 4.6 Using Switches

Switches are software variables that can take on a binary value—they are either on or off. Switches are referred to as being enabled or disabled. There is an array of switch settings for each virtual camera.

### Enabling/Disabling Switches

Switches are set using the ENABLE and DISABLE monitor commands or program instructions. Their syntax is:

```
ENABLE switch[camera],...,switch[camera]
DISABLE switch[camera],...,switch[camera]
```

| | |
|---|---|
| **switch** | is replaced with any of the switches listed in Table 4-1 (or Appendix A). |
| camera | is replaced with the number of the virtual camera you want to set the switch for. The default value is **all** cameras. If you are using multiple cameras with different switch/parameter settings, make sure you include a camera number in each switch.[1] |

These switches can be set by pulling down the **Switches** menu in the vision window, dragging to the switch you want to change, and releasing the mouse button. A "✔" next to the switch name indicates that the switch is enabled. The switch settings apply to whichever camera is selected in the **Cam/Frame** menu.

The current state of a switch can be read within a program with the SWITCH( ) function.

### Viewing Switch Settings

To see the status of all system switches, issue the command SWITCH from the system prompt. To see the status of the switches from the vision window menu, pull down the **Switches** menu. Switches marked with a "✔" are enabled.

[1] This argument applies only to vision switches and parameters. V+ system switches and parameters do not require this argument.

**SWITCH Example**

The following example will enable the binary switch for virtual camera 4 and then output its current state:

```
ENABLE V.RECOGNITI0N[4]
IF SWITCH(V.RECOGNITI0N[4]) THEN
     TYPE "V.RECOGNITI0N[4] is ON"
ELSE
     TYPE "V.RECOGNITI0N[4] is OFF"
END
```

## Image-Acquisition Switches

Table 4-1 provides a brief description of the switches that affect the way the system sees an object. “Switches and Parameters Used During Boundary Analysis” on page 56 describes the switches that influence what information the system gathers about an object. Complete information on each switch is available in the *AdeptVision Reference Guide*. Appendix A summarizes all the switches available to AdeptVision VME.

Table 4-1. **Image-Acquisition Switches**

| Switch | Effects |
|---|---|
| V.BINARY | If disabled, it will affect the operation of VPICTURE modes –1, 1, and 2 in the following ways:<br>For VPICTURE modes 2 and 1, it will start a VEDGE operation immediately following the completed acquisition into the virtual frame buffer.<br>For VPICTURE mode –1, a VEDGE operation is performed prior to processing of the image. In this case, the VPICTURE instruction will not complete until after the first stage of processing (the computation of run-lengths) is complete. Therefore, the run-lengths are computed on the binary edge image which is the result of VEDGE (see Appendix B in the *AdeptVision Reference Guide* for details on how vision run-lengths are generated).<br>In each case above, the choice of edge operation to be performed (cross-gradient or Sobel) is determined by the value of the system parameter V.EDGE.TYPE. And the edge strength threshold is given by the V.EDGE.STRENGTH system parameter. |
| V.BACKLIGHT | The system has no way of differentiating between background and object unless you tell it which one is dark and which one is light. This switch tells the system which intensity is background and which intensity is object. If the switch is set incorrectly, the system will process the background rather than the object. Disable the switch for a dark background and enable it for a light background. (Applies to binary processing only.) |
| V.BOUNDARIES | Enables or disables boundary analysis. If this switch is disabled, perimeter, edge, centroid, 2nd moment data, and hole data will not be gathered. This switch **must be enabled** for prototype recognition and OCR. |

## 4.7 Using Parameters

Parameters affect the vision system in much the same way switches do, except that parameters can take on a range of values—not just on or off.

### Setting Parameters

Parameters are set by entering the monitor command program instruction:

```
PARAMETER param_name[cam.virt] = value
```

**param_name** is replaced with the name of the parameter you want to set.

cam.virt is replaced with the virtual camera number you want to set the parameter for. The default is **all** cameras. If you are using multiple cameras with different parameter settings, make sure you include a camera number with each PARAMETER command.

**value** is replaced with the new value you want the parameter to have.

#### Parameter Examples

Output the entire parameter list to the screen:[1]

```
PARAMETER
```

Display the value of a single parameter (V.THRESHOLD for example):

```
PARAMETER V.THRESHOLD
```

To return the value of a parameter from within a program, use the PARAMETER function:

```
TYPE "V.THRESHOLD is: ", PARAMETER(V.THRESHOLD[1])
```

### Image-Acquisition Parameters

Table 4-2 describes briefly the parameters that primarily influence how AdeptVision VME sees regions in the field-of-view. Complete information on each parameter is available in the *AdeptVision Reference Guide*. Appendix A gives a brief description of all the parameters available to AdeptVision VME.

[1] The parameter DISP.CAMERA determines how many virtual cameras will have their arrays of switches and parameters displayed.

Table 4-2. **Image-Acquisition Parameters**

| Parameter | Effects |
|---|---|
| V.FIRST.COL | Sets the first column (in pixels) that will be processed by the system. Used to speed processing time by ignoring unwanted areas to the left side of the field of view. Must be less than or equal to V.LAST.COL. (Note: the effect of the first four parameters in this list is generally ignored by vision tools that use the "area-of-interest" option. See section 6.1.) |
| V.FIRST.LINE | Sets the first line (in pixels) that the system will process. Everything below this line will remain unprocessed. Must be less than or equal to V.LAST.LINE. |
| V.LAST.COL | Sets the last column (in pixels) that will be processed. Everything to the right of this column will remain unprocessed. Must be greater than or equal to V.FIRST.COL. |
| V.LAST.LINE | Sets the last line (in pixels) that will be processed. Everything above this line will remain unprocessed. Must be greater than or equal to V.FIRST.LINE. |
| V.MAX.AREA | Sets a value for the largest object (in pixels) the system will process. Useful if a large object is in the same field of view as the object you are interested in. The setting of V.SUBTRACT.HOLES affects this parameter. Must be greater than or equal to V.MIN.AREA. |
| V.MIN.AREA | Sets a value for the smallest object the system will attempt to process. Useful for ignoring small objects you are not interested in and filtering out noise. Must be greater than or equal to V.MIN.HOLE.AREA and less than or equal to V.MAX.AREA. The setting of V.SUBTRACT.HOLES is considered when comparing area values. |
| V.MIN.HOLE.AREA | Sets a value for the smallest hole (in pixels) in an object that the system will process. Must be less than or equal to V.MIN.AREA. |
| V.THRESHOLD | Sets the intensity at which the system divides pixels into black or white. |
| V.2ND.THRESHOLD | Used with V.THRESHOLD to establish a range of intensity that the system will see as black or white. For example, with V.THRESHOLD at 50 and 2ND.THRESHOLD at 70, all pixels between 50 and 70 would be seen as black. |
| V.EDGE.STRENGTH | Sets the threshold at which the system recognizes an edge in grayscale processing. If the variation in pixel intensity across a region exceeds this parameter, an edge is recognized. |
| V.GAIN | AdeptVision VME recognizes 128 degrees of intensity. V.GAIN works with V.OFFSET to maximize the use of these 128 values. V.GAIN scales the incoming analog video signal. |
| V.OFFSET | Works with V.GAIN to maximize the range of intensities that the system recognizes in your objects. V.OFFSET is applied to the incoming video signal. |

## 4.8 Examples of Switch and Parameter Settings

The examples in this section show the effects of changing switches and parameters. The examples were taken with a VPICTURE ( ) –1 instruction and with VDISPLAY mode set to 3.

This is the object that is being placed in the field of view. This is the sample object that was introduced in Chapter 1.

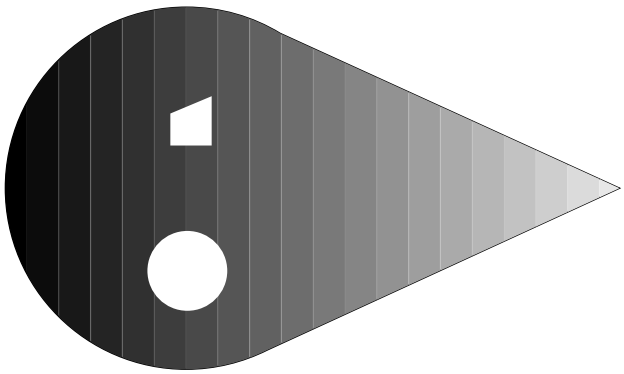


Figure 4-6. **Sample Object**

One of the first things you will notice about VDISPLAY mode 3 is that the object is rendered in white and the background in black, regardless of the actual intensities of the object and background.

In “Switch and Parameter Example 1”, the switches and parameters are set to obtain the best possible image. This image was obtained with the following switch and parameter settings:

| **Switches** | | | | | |
|---|---|---|---|---|---|
| ✔ | V.BINARY | ✔ | V.BOUNDARIES | ✔ | V.BACKLIGHT |
| **Parameters** | | | | | |
| 1 | V.FIRST.COL | 1 | V.FIRST.LINE | 640 | V.LAST.COL |
| 480 | V.LAST.LINE | 307,200 | V.MAX.AREA | 16 | V.MIN.AREA |
| 100 | V.OFFSET | 90 | V.GAIN | 8 | V.MIN.HOLE.AREA |
| 55 | V.THRESHOLD | 0 | V.2ND.THRESH | 20 | V.EDGE.STRENGTH |

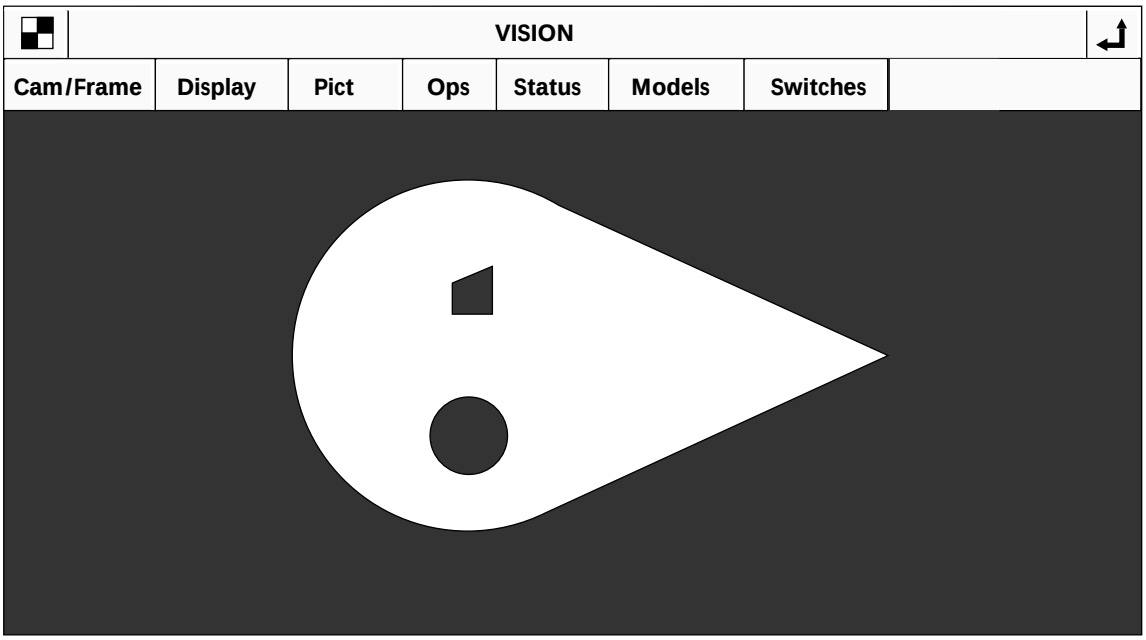



Figure 4-7. **Switch and Parameter Example 1**

In the following examples, the switches or parameters that have been changed are marked with a shadow.

> **NOTE:** If you are experimenting with the sample object, remember that parameter settings are sensitive to ambient lighting. Therefore, your parameter settings may be different to obtain the same image.

In “Switch and Parameter Example 2”, V.BINARY is disabled, resulting in an edge image. When the system processes this image, it will operate on the edges generated using the parameter V.EDGE.STRENGTH rather than the binary image generated using the parameter V.THRESHOLD.

The settings for “Switch and Parameter Example 2” are:

| **Switches** | | | | | |
|---|---|---|---|---|---|
| | V.BINARY | ✔ | V.BOUNDARIES | ✔ | V.BACKLIGHT |
| **Parameters** | | | | | |
| 1 | V.FIRST.COL | 1 | V.FIRST.LINE | 640 | V.LAST.COL |
| 480 | V.LAST.LINE | 307,200 | V.MAX.AREA | 16 | V.MIN.AREA |
| 100 | V.OFFSET | 90 | V.GAIN | 8 | V.MIN.HOLE.AREA |
| 55 | V.THRESHOLD | 0 | V.2ND.THRESH | 20 | V.EDGE.STRENGTH |

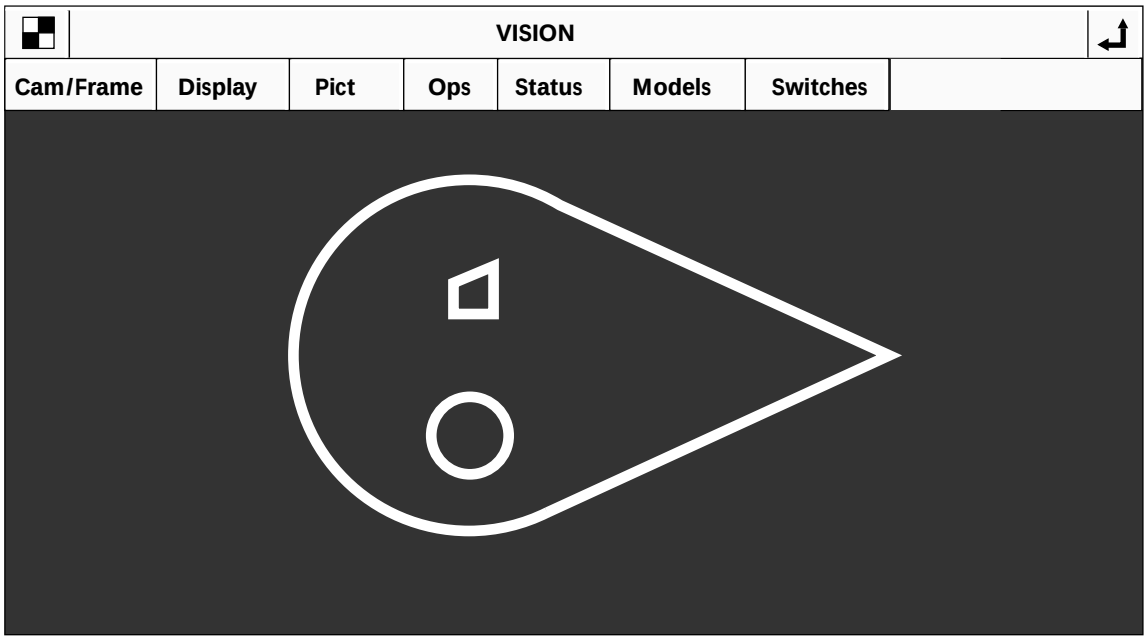



Figure 4-8. **Switch and Parameter Example 2**

Changing the value of V.EDGE.STRENGTH to 40 causes the system to fail to recognize an edge at the tail end of the object. The change in intensity values at the tail of the object does not exceed the value of V.EDGE.STRENGTH so edges are not detected in that area. “Switch and Parameter Example 3” shows the effects of changing this parameter.

The settings for “Switch and Parameter Example 3” are:

| **Switches** | | | | | |
|---|---|---|---|---|---|
| | V.BINARY | ✔ | V.BOUNDARIES | ✔ | V.BACKLIGHT |
| **Parameters** | | | | | |
| 1 | V.FIRST.COL | 1 | V.FIRST.LINE | 640 | V.LAST.COL |
| 480 | V.LAST.LINE | 307,200 | V.MAX.AREA | 16 | V.MIN.AREA |
| 100 | V.OFFSET | 90 | V.GAIN | 8 | V.MIN.HOLE.AREA |
| 55 | V.THRESHOLD | 0 | V.2ND.THRESH | 40 | V.EDGE.STRENGTH |

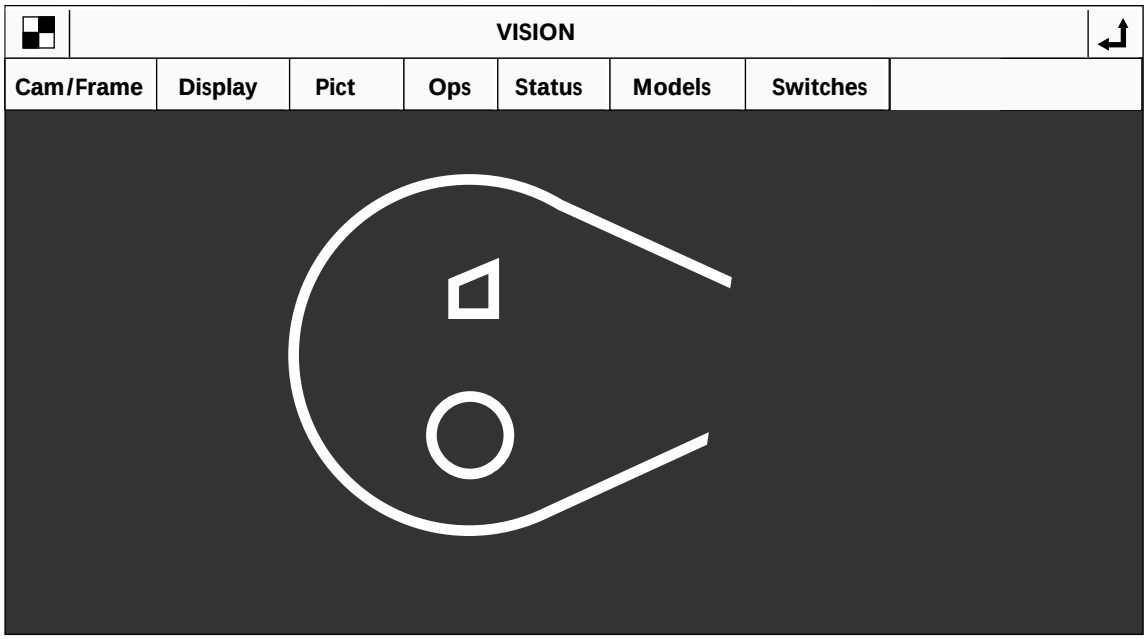



Figure 4-9. **Switch and Parameter Example 3**

If the small polygon in the object is not of interest to you, instruct the system to ignore it by changing the value of the minimum hole size the system will process within an object. (V.MIN.AREA will have to be raised to a value greater than V.MIN.HOLE.AREA.) "Switch and Parameter Example 4" shows the effects of changing these two parameters. Raising these two parameters further would cause the circular hole to be ignored.[1] (V.BINARY has been reenabled for this example.)

The settings for "Switch and Parameter Example 4" are:

| **Switches** | | | | | |
|---|---|---|---|---|---|
| ✔ | V.BINARY | ✔ | V.BOUNDARIES | ✔ | V.BACKLIGHT |
| **Parameters** | | | | | |
| 1 | V.FIRST.COL | 1 | V.FIRST.LINE | 640 | V.LAST.COL |
| 480 | V.LAST.LINE | 307,200 | V.MAX.AREA | 650 | V.MIN.AREA |
| 100 | V.OFFSET | 90 | V.GAIN | 625 | V.MIN.HOLE.AREA |
| 55 | V.THRESHOLD | 0 | V.2ND.THRESH | 20 | V.EDGE.STRENGTH |

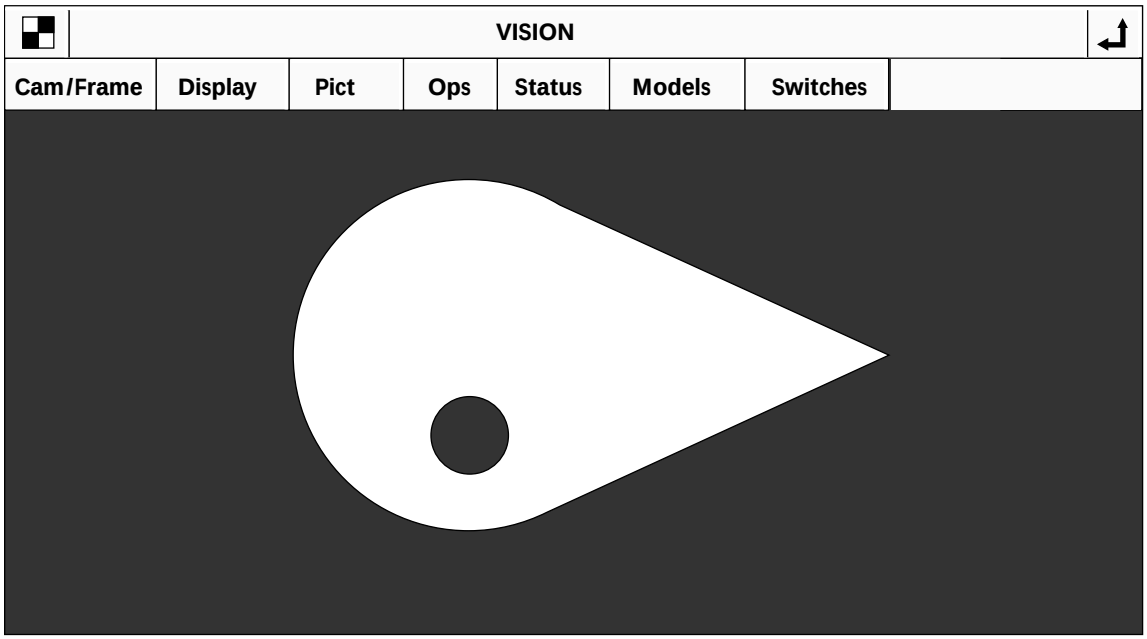



Figure 4-10. **Switch and Parameter Example 4**

[1] These two values could be raised high enough to cause the system to ignore the object completely.

The effects of changing V.THRESHOLD are shown in “Switch and Parameter Example 5”. We have lowered the threshold value to the point where the system does not see a sufficiently high intensity in the pixels at the tail end of the object to consider them part of the object. Therefore, they are considered background, and an image like the one in “Switch and Parameter Example 5” is produced. (Note that changing V.THRESHOLD for a binary image is similar to changing V.EDGE.STRENGTH for a gray-edge image — see “Switch and Parameter Example 3”.)

The settings for “Switch and Parameter Example 5” are:

| **Switches** | | | | | |
|---|---|---|---|---|---|
| ✔ | V.BINARY | ✔ | V.BOUNDARIES | ✔ | V.BACKLIGHT |
| **Parameters** | | | | | |
| 1 | V.FIRST.COL | 1 | V.FIRST.LINE | 640 | V.LAST.COL |
| 480 | V.LAST.LINE | 307,200 | V.MAX.AREA | 16 | V.MIN.AREA |
| 100 | V.OFFSET | 90 | V.GAIN | 8 | V.MIN.HOLE.AREA |
| 20 | V.THRESHOLD | 0 | V.2ND.THRESH | 20 | V.EDGE.STRENGTH |

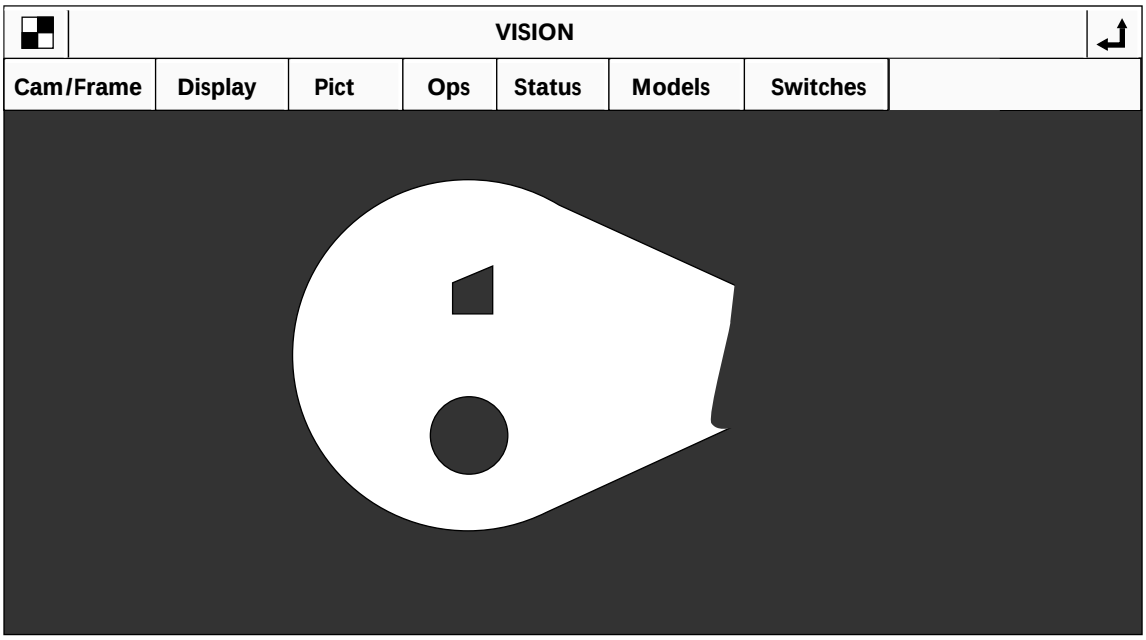



Figure 4-11. **Switch and Parameter Example 5**

You can limit the area of the field-of-view that is processed by changing the parameters that specify the starting and ending columns and rows of pixels to process. This is useful if you are interested in only a small area of the field-of-view, or if a portion of the field-of-view needs to be blocked off because it interferes with processing the area you are interested in. “Switch and Parameter Example 6” shows how to limit the processed area. Remember, line settings are measured from the bottom of the screen, and column settings are measured from the left side. These parameters apply only to the VPICTURE and VWINDOW instructions. The areas-of-interest defined for the various vision tools will over-ride any processing boundaries set with V.FIRST.COL, V.LAST.COL, etc.

The settings for Switch and Parameter Example 6 are:

| **Switches** | | | | | |
|---|---|---|---|---|---|
| ✔ | V.BINARY | ✔ | V.BOUNDARIES | ✔ | V.BACKLIGHT |
| **Parameters** | | | | | |
| 150 | V.FIRST.COL | 200 | V.FIRST.LINE | 360 | V.LAST.COL |
| 350 | V.LAST.LINE | 307,200 | V.MAX.AREA | 16 | V.MIN.AREA |
| 100 | V.OFFSET | 90 | V.GAIN | 8 | V.MIN.HOLE.AREA |
| 55 | V.THRESHOLD | 0 | V.2ND.THRESH | 20 | V.EDGE.STRENGTH |

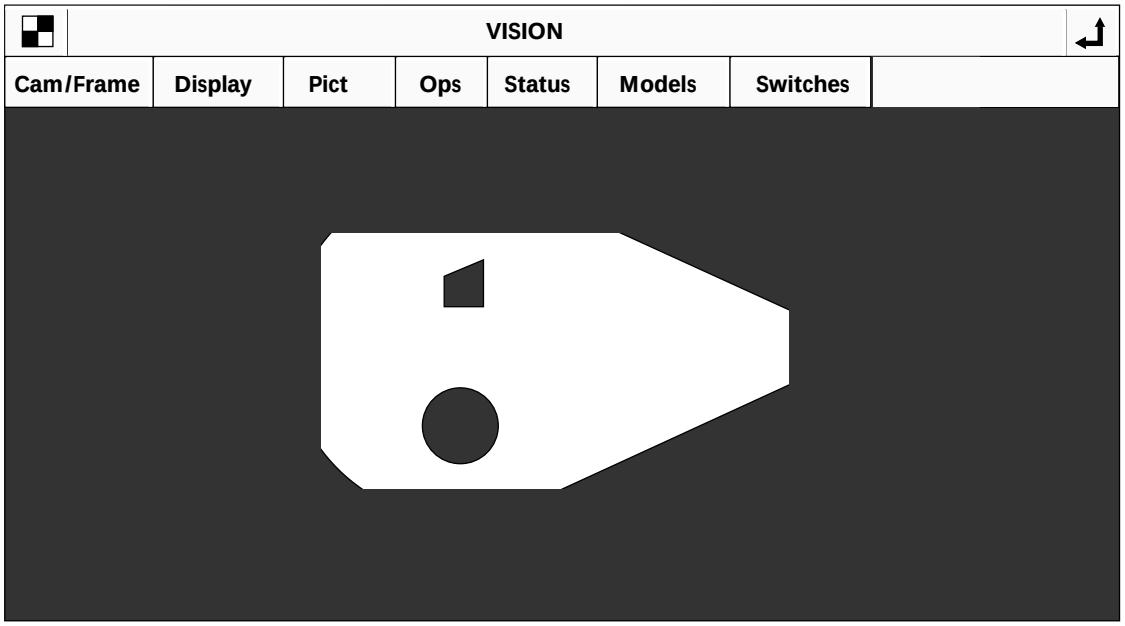



Figure 4-12. **Switch and Parameter Example 6**

"Switch and Parameter Example 7" shows the effect of disabling V.BACKLIGHT. What we have told the system is that we now have light objects on a dark background. This causes the system to consider areas of darkest intensity as background. In the image below, the processor considers the object to be the background and vice versa. (Remember, in VDISPLAY mode 3, the object is rendered as white and the background as black.) If your vision operation examines white labels on a black conveyor belt, you will disable this switch. You may also find that some inspections can be made more easily when the background/object intensities are reversed.

The settings for "Switch and Parameter Example 7" are:

| **Switches** | | | | | |
|---|---|---|---|---|---|
| ✔ | V.BINARY | ✔ | V.BOUNDARIES | | V.BACKLIGHT |
| **Parameters** | | | | | |
| 1 | V.FIRST.COL | 1 | V.FIRST.LINE | 640 | V.LAST.COL |
| 480 | V.LAST.LINE | 307,200 | V.MAX.AREA | 16 | V.MIN.AREA |
| 100 | V.OFFSET | 90 | V.GAIN | 8 | V.MIN.HOLE.AREA |
| 55 | V.THRESHOLD | 0 | V.2ND.THRESH | 20 | V.EDGE.STRENGTH |

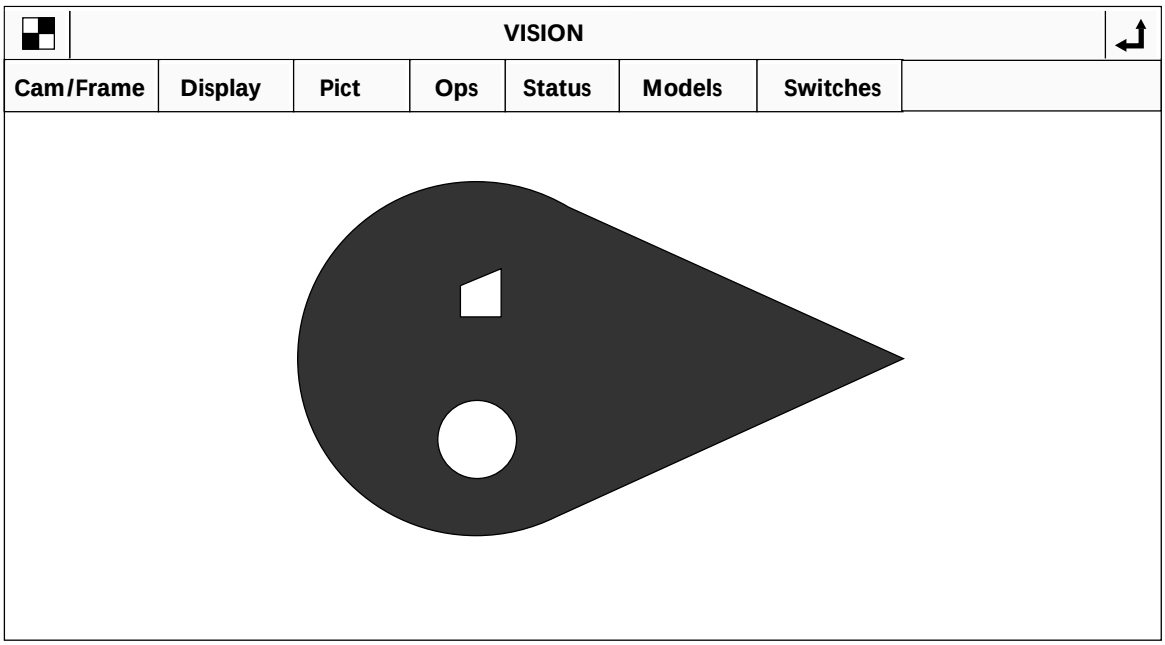



Figure 4-13. **Switch and Parameter Example 7**

# 5 Boundary Analysis

# 5.1 Introduction

Now that you know how to acquire and process an image, this chapter will show you how to get some useful information from that image. This chapter will cover the first information processing strategy that AdeptVision VME employs, boundary analysis (often called “blob analysis”).

Chapter 6 covers the second strategy, vision tools, and Chapter 7 covers the third information processing strategy, vision model processing.

When the system processes an image, it explores the boundaries of all the regions in the field-of-view and stores the information it gathers about each of those regions in a special vision queue. Two operations are required to retrieve boundary information. The first is VLOCATE which retrieves a region’s data from the vision queue. The second operation, VFEATURE, retrieves individual data items. In many cases this data will tell you all you need to know about an object; you will not have to use any other vision tools or model processing.

Before we look at VLOCATE and VFEATURE let’s examine the switches and parameters that influence their performance.

## Switches and Parameters Used During Boundary Analysis

In addition to the switches and parameters listed below, all the switches and parameters introduced in Chapter 4 affect VLOCATE and VFEATURE. For example, one piece of information available through VFEATURE is the number of holes in a region. If we set the parameter V.MIN.HOLE.AREA so that it was larger than the size of the two holes in our sample object (see Example 4 on page 50), then VFEATURE will report that there are 0 holes in the sample object.

The switches and parameters listed in Table 5-1 and Table 5-2 determine what data (and in some cases, the form of the data) the system gathers during boundary analysis of the regions within the processed image.

Table 5-1. **Boundary Analysis Switches**

| Switch | Effects |
|---|---|
| V.BOUNDARIES | Enables or disables boundary processing. If this switch is disabled, perimeter, edge, centroid, 2nd moment data, and hole data will not be gathered. Must be enabled for vision model processing. |
| V.SUBTRACT.HOLE | When this switch is enabled, the area of holes within an object will be subtracted from the area calculation. This switch affects the parameters V.MIN.AREA, V.MAX.AREA, and V.MIN.HOLE.AREA. |
| V.CENTROID | The centroid of an object is calculated if this switch is enabled. This switch increases processing time and should be disabled if the centroid information is not needed. (V.BOUNDARIES must be enabled.) |
| V.MIN.MAX.RADII | The perimeter points closest to and furthest from the centroid of an object are calculated when this switch is enabled. (V.BOUNDARIES and V.CENTROID must be enabled.) |

Table 5-1. **Boundary Analysis Switches** (Continued)

| Switch | Effects |
|---|---|
| V.2ND.MOMENT | The 2nd moments of inertia and best fit ellipse are calculated when this switch is enabled (V.CENTROID and V.BOUNDARIES must be enabled). V.SUBTRACT.HOLES is ignored. |
| V.PERIMETER | The perimeter of an object is calculated if this switch is enabled. |
| V.HOLES | If this switch is enabled, the statistics gathered for objects will also be gathered for the holes in the objects. |
| V.SHOW.EDGES | If this switch is enabled, the vision system will display the attempts at fitting primitive edges to an object. |
| V.SHOW.BOUNDS | If this switch is enabled, the vision system will display the results of attempting to fit lines and arcs during boundary analysis. This switch is useful during development as it allows you to see how the vision processor performs boundary analysis. |
| V.FIT.ARCS | Enabling this switch causes the system to attempt arc fitting during boundary analysis. If arcs are unimportant in your images, processing time will be improved by disabling this switch. |

Table 5-2. **Boundary Analysis Parameter**

| Parameter | Default | Range | | Effects |
|---|---|---|---|---|
| V.MAX.PIXEL.VAR | 1.5 | 0 | 8 | Sets the maximum pixel variation allowed when the system fits a line or an arc to a region boundary. |

## 5.2 Boundary Analysis Instructions

In order to make boundary analysis data available, you must:

- Enable the system switch V.BOUNDARIES (along with any other switches required for the data you are interested in).
- Acquire a processed image using VPICTURE. (You can also acquire an unpro cessed image and then use a VWINDOW instruction to process a limited area of the image. This procedure is described in section 6.6.)
- Remove a region's data from the vision queue and make it available to VFEATURE using the VLOCATE instruction.
- Use VFEATURE to return the particular information you are interested in.

We have already seen the syntax for VPICTURE and how to set system switches. This section will describe VLOCATE and VFEATURE, and describe the VQUEUE instruction that allows you to see the status of the vision queue.

## VLOCATE

When an image is processed, each region's data is stored in a queue. If V.HOLES is enabled, the data about the holes in each object is also stored in this queue. To use the data, you must remove it from the queue and make it available to VFEATURE. The VLOCATE program instruction performs this operation. The syntax for VLOCATE is:

```
VLOCATE (camera, mode, order) $var_name, trans_var
```

`camera` is replaced with the camera whose vision queue you wish to remove an object from. (There is a queue of data for **each** virtual camera.) The default is camera 0, which makes the contents of the queues of all virtual cameras available.

`mode` is replaced with:[1]

- 0 causing the system to attempt to remove a region's data from the queue (referred to as "locating a region"). 0 is the default.
- 4 causing the system to attempt to remove a hole's data from the vision queue. (V.HOLES must be enabled. Hole data is available only for holes in the most recently VLOCATEd region.)

`order` is replaced with:[1]

- 1 causing the system to remove objects from the queue starting with the largest object.
- 2 causing the system to remove objects from the queue starting with the smallest object.

`$var_name` To remove an unrecognized region (known as a "blob") from the queue, replace "`$var_name`" with **`"?"`**. To remove a hole's data (`mode` = 4) leave this parameter blank. (Until we cover prototype recognition in Chapter 7, all regions will be unrecognized and **`"?"`** will be used for "`$var_name`".)

`trans_var` Optional transformation variable to be assigned the location of the object.

### VLOCATE Examples

If a successful VPICTURE instruction has acquired and processed an image with at least one region in it, the instruction:

```
VLOCATE (1, 0) $name, trans_var
```

will locate any object in the queue and make its region data available through VFEATURE(). (If the object is recognized as a prototype, the prototype name will be returned.)

If the region located had at least one hole in it, the command:

---

[1] See the *AdeptVision Reference Guide* for details on default values for `mode` and `order`.

```
VLOCATE (1,4)
```

will locate the first hole in the most recently VLOCATEd region and make its region data available through VFEATURE(). For a hole to be located, V.HOLES must have been enabled when the image was processed.

## The DO Monitor Command

Most of the V+ operations covered in the rest of this manual are program instructions and do not have a monitor command format. Program instructions can be executed only from within a program and not directly from the system prompt. If you want to experiment with various program instructions without writing and executing a program, you can preface a program instruction with the monitor command DO and execute it from the system prompt. For example, to execute VLOCATE from the system prompt, enter the command:

```
DO VLOCATE (1,2) "?"
```

## VFEATURE

Once an image has been acquired and processed with a VPICTURE instruction, and a region or a hole in a region has been removed from the queue with a VLOCATE instruction, data on that object is available through use of the function VFEATURE.

### What is VFEATURE?

VFEATURE is not a monitor command or a program instruction. It is a system function that returns a value. As such, it can be used in most places you would use a variable. For example:

```
IF VFEATURE(10) > 975 THEN...
```

or

```
part_centerx = VFEATURE(42)
```

(A critical point to remember when using VFEATURE is that it is a function that returns a value and not an array of values. You cannot assign a value to a VFEATURE index. For example, the instruction VFEATURE(12) = 3.303 would produce an error.)

Table 5-3 lists the values available through VFEATURE as a result of boundary analysis. Additional data is available after prototype recognition; this is covered in Chapter 7. The complete VFEATURE table is printed in Appendix B.

Table 5-3. **VFEATURE Values and Interpretation**

| Index | Information | Unit | Switch/Parameter effects |
|---|---|---|---|
| 1 | Whether an object was found or not (true/false) | T/F | Returns – 1 for true or 0 for false. |
| 2 | Center X | mm | If V.CENTROID is enabled, the value is the centroid of the region. Otherwise, it is the center of the bounding box of the region. |
| 3 | Center Y | mm | |
| 4 | Center Z | mm | |
| 5 | Rotation about X | ° | |
| 6 | Rotation about Y | ° | |
| 7 | Rotation about Z | ° | |
| 10 | Area of object | pixels | If V.SUBTRACT.HOLES is enabled, the area of holes in the object is subtracted from this calculation. |
| 11-12 | ID numbers | # | See the description of VFEATURE in the *AdeptVision Reference Guide* for details on these two items. |
| 13 | Left limit of region's bounding box | mm | |
| 14 | Right limit of region's bounding box | mm | |
| 15 | Lower limit of region's bounding box | mm | |
| 16 | Upper limit of region's bounding box | mm | |
| 17 | Number of holes in the object | # | |
| 18 | Time spent acquiring, processing, and recognizing an object | secs | |
| 21 | When an object is located, all the holes within the object are given a reference number. This value is the reference number of the current hole. (Also holds true for "holes within holes.") | # | Holes can be located within a bounded region or within a hole in a bounded region. These values keep track of where you are in the locating sequence. Holes are number consecutively for each region. |
| 22 | Parent number of holes referenced in VFEATURE(21) | # | |
| 40 | Total area of all holes | pixels | V.HOLES must be enabled. |
| 41 | Outer perimeter of the object | mm | V.PERIMETER must be enabled. |

Table 5-3. **VFEATURE Values and Interpretation** (Continued)

| Index | Information | Unit | Switch/Parameter effects |
|---|---|---|---|
| 42 | Object centroid along X axis | mm | V.CENTROID must be enabled. |
| 43 | Object centroid along Y axis | mm | |
| 44 | The angle (relative to the vision coordinate system) of a line drawn to the closest point on the object perimeter from the centroid | ° | V.CENTROID and V.MIN.MAX.RADII must be enabled. |
| 45 | The angle to the furthest point on the object perimeter from the centroid | ° | |
| 46 | The shortest distance from an object's centroid to a point on its perimeter | mm | |
| 47 | The greatest distance from an object's centroid to a point on its perimeter | mm | V.CENTROID and V.MIN.MAX.RADII must be enabled. |
| 48 | The angle of the object's major axis (axis of least inertia) | ° | V.CENTROID and V.2ND.MOMENTS must be enabled. |
| 49 | Major radius of the ellipse [along the axis reported in VFEATURE(48)] | mm | |
| 50 | Major radius of the ellipse [perpendicular to the axis reported in V.FEATURE(48)] | mm | |

**Blob Allocation**

The number of blobs that can be stored in the various vision queues is dependent on vision memory. AdeptVision VME sets the maximum vision memory that can be used by the vision queues, as well as other objects that reside in vision memory. This default allocation can be changed to suit your particular application with the DEVICE instruction. Appendix F lists the default allocations and how to change them.

**VFEATURE Example**

Here is an example of boundary analysis using the values returned by VFEATURE. If we wanted to know the perimeter of our sample object, the number of holes in that object, and the center of the circular hole, the following program code would provide that information:

```
; Display the results of the next VPICTURE instruction in graphics mode

      cam.virt = 1

      VDISPLAY (cam.virt) 3

; Make sure hole information is gathered

      ENABLE V.HOLES [cam.virt]
      ENABLE V.BOUNDARIES [cam.virt]
      DISABLE V.DISJOINT [cam.virt]
      ENABLE V.CENTROID [cam.virt]

; Make sure perimeter information is gathered

      ENABLE V.PERIMETER

; Acquire and process an image

      VPICTURE (cam.virt) -1

; Remove any object from the queue for "cam.virt"

      VLOCATE (cam.virt) $name, trans_var

; Check for a successful VLOCATE (i.e., an object was found)

      IF VFEATURE(1) THEN

; Display the perimeter of the object and the number of holes

          TYPE "Object perimeter is: ", VFEATURE(41)
          TYPE "The number of holes in the object is: ", VFEATURE(17)

; Locate the largest hole in the object

          VLOCATE (cam.virt, 4, 1)

; Check for a successful VLOCATE

          IF VFEATURE(1) THEN

; Display the coordinates of the center hole

              TYPE "Center hole coordinates: ", VFEATURE(2), VFEATURE(3)
          END
      END
```

## VQUEUE

The monitor command VQUEUE shows the status of the vision queue. The syntax for VQUEUE is:

```
VQUEUE (cam.virt)
```

`cam.virt` is replaced with the camera number whose queue you wish to examine. The default is 0, indicating all cameras.

When you execute a VQUEUE command, you will see a display similar to:

| Name | Verify percent | Area | X | Y | RZ | Instance ID | Camera |
|---|---|---|---|---|---|---|---|
| ? | 0.0 | 177797 | 182.3 | 80.7 | 0.00 | 1 | 1 |
| ? | 0.0 | 2904 | 151.7 | 89.0 | 0.00 | 2 | 1 |
| aproto | 85.4 | 36855 | 159.1 | 85.9 | 8.70 | 3 | 1 |

Name — If a region has been recognized as a prototype, its name will appear in this column. Otherwise a "?" will appear indicating that information on an unidentified region ("blob") has been placed in the queue.

Verify percent — A measure of how confident prototype recognition is.

Area — Area of the region in raw pixels.

X, Y, RZ — Region transformation components (position and rotation in the vision coordinate system).

Instance ID — Order of processing for the different objects (an arbitrary but sometimes useful ID number).

Camera — Camera the image was acquired with.

To determine the number of items remaining in a queue from within a program, use the real-valued function VQUEUE(). The following code will remove objects from the vision queue for virtual camera 4 (if the 4 is omitted, the code will look through all queues):

```
WHILE VQUEUE(4) DO
     VLOCATE(4)

     ; code executed for each region

     TYPE "Number of objects left: ", VQUEUE(4)
END
```

# Vision Tools 6

This chapter covers the vision tools: rulers, finders, and windows.

# 6.1 Defining a Tool Area-of-Interest (AOI)

Vision tools operate within a specified area-of-interest. Since several different tools may be placed in the same area, AdeptVision VME allows you to predefine areas-of-interest. These areas-of-interest can then be used by multiple tools. Also, as we will see in Chapter 10, tools may be placed relative to reference frames generated by other tools. An area-of-interest definition allows you to easily reposition groups of tools based on new image data.

An AOI is a relative Cartesian reference that must be combined with an absolute origin point before it can be used. (The AOI also includes shape and orientation components.) The absolute origin to which an AOI is relative is a “virtual frame buffer”. When you combine an AOI with a virtual frame buffer you get an “image buffer region” that identifies the exact size, shape, orientation, and location for a vision tool.

## Frame Stores

A vision system has two physical frame stores. These physical frame stores are numbered 1 and 2. For the standard vision processor, the frame store size is 1024 x 512 pixels. Systems with the AdeptVision Enhanced VME Interface option have 1024 x 1024 frame stores. This frame size can be further divided into virtual frame buffers as described next. Any frame store area not used as a virtual frame buffer is used as a “scratch” area for tools such as Correlation Templates.

### Virtual Frame Buffers

The standard vision system can be divided into 2, 4, 12, or 16 virtual frame buffers. A system configured for 2 virtual frame buffers uses one 640 x 480 virtual frame buffer area in each physical frame store. A system configured for 4 frame stores uses two 512 x 480 virtual frame buffers in each physical frame store. A system configured for 12 frame stores uses six 360 x 240 virtual frame buffers in each physical frame store. And a system configured for 16 frame stores uses eight 256 x 240 virtual frame buffers in each physical frame store.

On systems with the AdeptVision Enhanced VME Interface option, the physical frame stores are twice as large so they may be divided into twice as many virtual frame buffers (four 640x 480 virtual frame buffers—two for each physical frame store, etc.).

The DEVICE instruction allocates virtual frame buffers. See “Examples” on page 195 for details. Figure 6-4 shows how physical frame stores are divided in the virtual frame buffers.

## Areas-of-Interest

Vision tools are placed within a virtual frame buffer based on a defined area-of-interest (AOI). AOIs are defined with the VDEF.AOI instruction and include a shape argument and several dimensional arguments. The syntax for VDEF.AOI is:

**`VDEF.AOI aoi = shape, dim1, dim2, dim3,`** `dim4, ang1, ang2`

| | |
|---|---|
| **`aoi`** | an integer that identifies the aoi being defined. This value must be a 4 to 6 digit integer. Counting from least significant to most significant (right to left), the fourth through sixth digits are used as the AOI number and the first through third digits are ignored. See “Defining an Image Buffer Region” on page 68 for details on how the first through third digits are used. |
| **`shape`** | defines the shape of the area-of-interest. The most common shapes are shown in Figures 6-2 and 6-2. See the *AdeptVision Reference Guide* for a complete description of the shapes. |
| **`dim1`** - `dim4` | define the size and location of the area-of-interest. |
| `ang1, ang2` | define the angular measurements of the area-of-interest |

Figure 6-2 shows the most common shapes for rectangular tools. Shape 1 is the normal shape for rectangular areas such as windows, line finders, point finders, etc. Shape 2 is the normal shape for rulers.[1] Figure 6-2 shows the most common shapes for arc-shaped tools. Shape 5 is the normal shape for arc finders, and shape 9 is the normal shape for circular inspection windows.

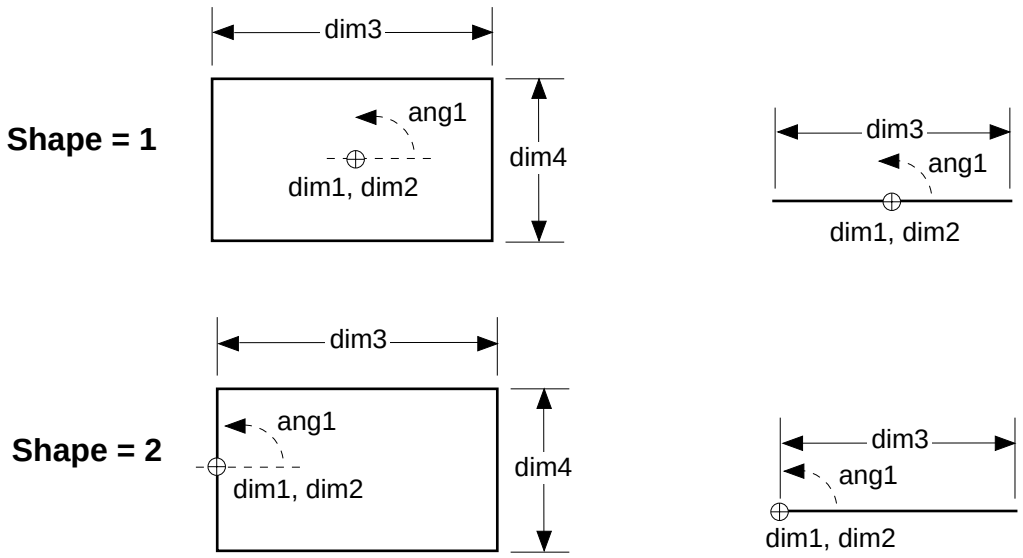



Figure 6-1. **Rectangular Area-of-Interest Shapes**

[1] The illustration shows a shape with a positive value for `dim3`. Negative values are allowed, in which case dim1 and dim2 will be on the opposite side of the rectangle.

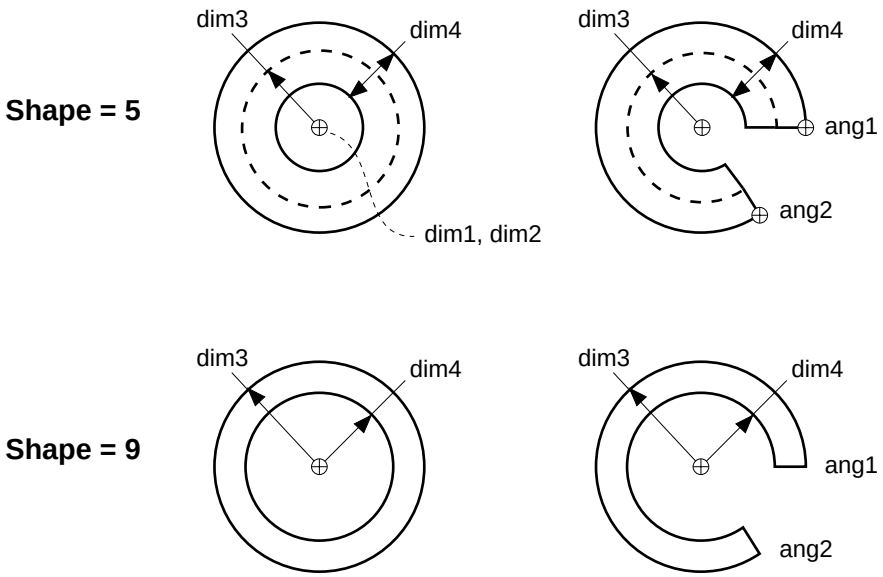



Figure 6-2. **Arc-Shaped Area-of-Interest Shapes**

**Defining an Image Buffer Region**

A image buffer region has the form:

AAAVVP

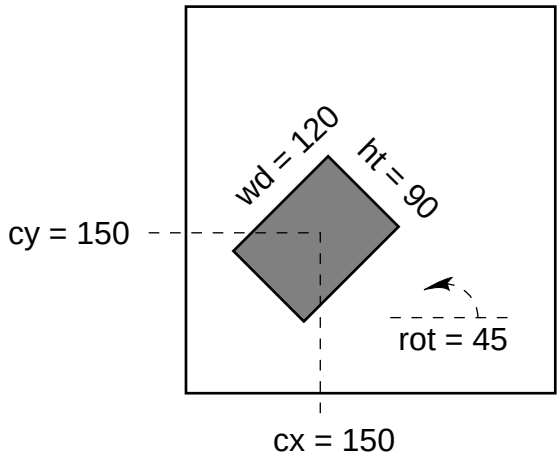
where “AAA” is the number of the area-of-interest (defined byVDEF.AOI), “VV” is the virtual frame buffer, and “P” is the number of the physical frame store. The combination of virtual frame store and a physical frame store creates a “virtual frame buffer”, which is the term most often used in Adept documentation.

If 000 is specified for the virtual frame buffer, the most recently acquired picture is used. Thus, a virtual frame buffer needs to be specified only when you want to place a tool in an image other than the one most recently acquired.

The next program example defines “aoi12”—a rectangular AOI that is centered at X = 150mm, Y = 150mm; is 90mm wide and 120mm high; and is rotated 45°.

```
shape = 1
cx = 150
cy = 150
wd = 120
ht = 90
rot = 45
aoi12 = 12000
VDEF.AOI aoi12 = shape, cx, cy, wd, ht, rot
```

Figure 6-3 shows the area-of-interest defined by the preceding code. The next program example defines an image buffer region that uses “aoi12”.




VDEF.AOI 12000 = 1, 150, 150, 120, 90, 45

Figure 6-3. **Sample Area-of-Interest**

In order to use this AOI with a virtual frame buffer other than the one an image was most recently acquired into, it must identify a virtual frame buffer. The following code combines virtual frame buffer 21 with “aoi12” to create the image buffer region “ibr_rect”:

```
phy.fr = 1
virt.fr = 20
ibr_rect = aoi12+virt.fr+phy.fr
```

“ibr_rect”, which now has the value 12021, can be used by any rectangular or line shaped tool that needs to be placed at the defined location in virtual frame buffer 21. The first example in Figure 6-4 shows the definition of “ibr_rect”. (The example assumes a mm/pixel ratio of 1.)

The second example in Figure 6-4 shows how an AOI definition can be combined with different virtual frame buffers to create different image buffer regions.

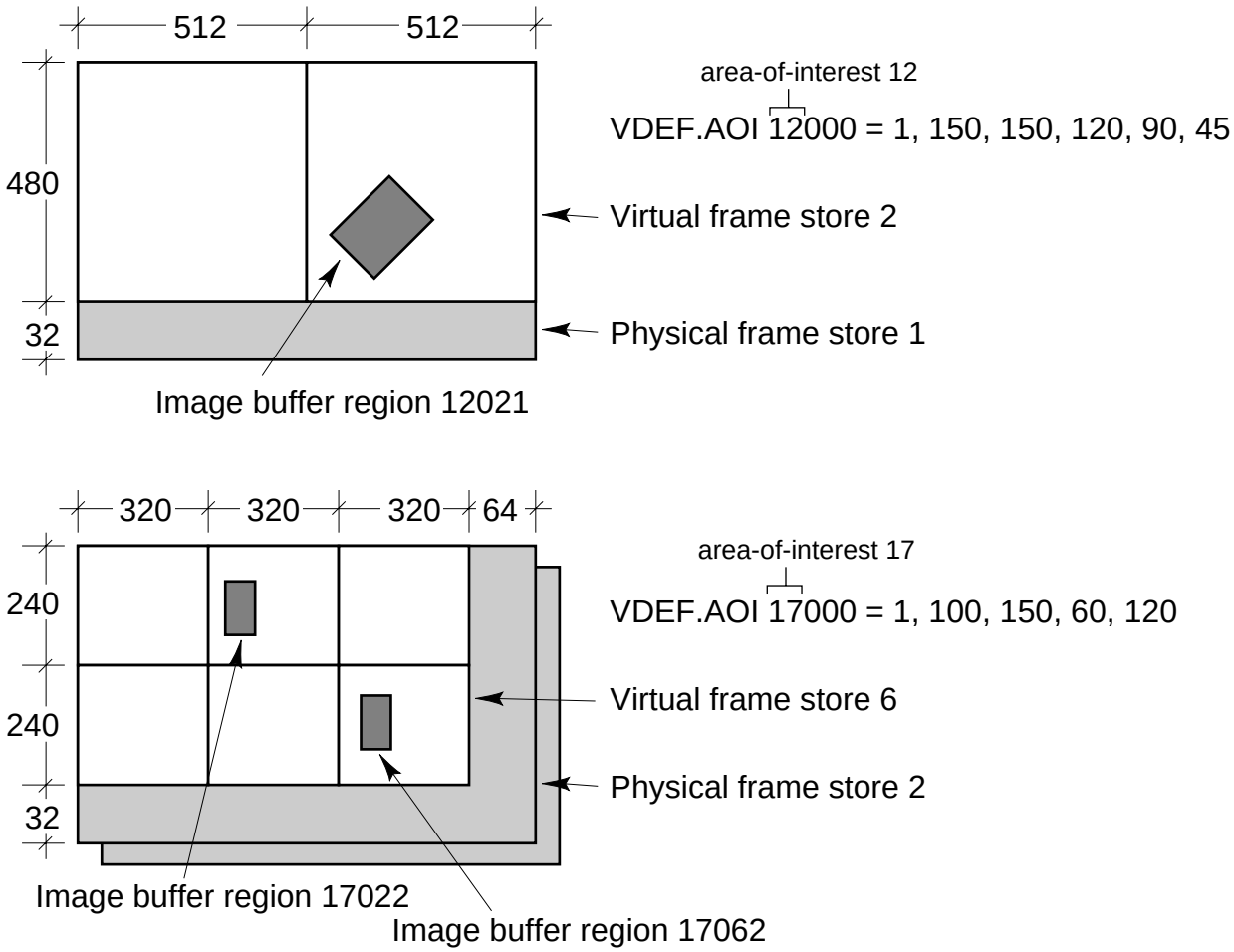



Figure 6-4. **Sample Image Buffer Regions**

## 6.2 Linear Rulers

Linear rulers are vision tools that detect edges found along the length of the ruler and return the distances from the start of the ruler. Linear rulers can operate on binary or grayscale data, regardless of the setting of V.BINARY.

The simplified syntax for a linear VRULERI is:

```
VRULERI (cam.virt, type) data[] = ibr
```

`cam.virt` is replaced with the number of a virtual camera. The value of V.EDGE.STRENGTH associated with this virtual camera will be used by some of the ruler types (see section 6.4 on page 77). The value of V.THRESHOLD is used with dynamic binary rulers. The default value is camera 1.

`type` is replaced with the type of ruler you want to place on the image. The default value is 0, indicating a run-length binary ruler. The different types of rulers are explained in section 6.4.

**`data[]`** is replaced with a variable name for the array into which you want the ruler data placed (see VRULERI array below).

**`ibr`** is replaced with the number of a defined image buffer region specifying a rectangular AOI (see section 6.1).

### VRULERI Array

When you have issued a VRULERI command, the edge transition data is placed in the array you specified. The element values are:

data[0] The number of edges found along the ruler.

data[1] For binary rulers, the color of the pixel the ruler started on. For grayscale rulers, whether or not the ruler was clipped by the field-of-view.

data[2] The distance from the starting point to the first transition.

data[3] The distance from the starting point to the second transition.

data[n] The distance from the starting point to the (n–1)th transition.

## Linear Ruler Example

This example code takes a picture of the sample object and reports how far it is from the round hole in the object to the left edge of the object, measured along the X axis. We start similarly to the VFEATURE example shown in Chapter 5:

```
;Display the results of the next VPICTURE in live mode
; with a graphics overlay.

      cam.virt = 1

      VDISPLAY (cam.virt) -1, 1

;Make sure hole information is gathered.

      ENABLE V.HOLES [cam.virt]
      ENABLE V.BOUNDARIES [cam.virt]
      DISABLE V.DISJOINT [cam.virt]

;Acquire and process an image.

      VPICTURE (cam.virt) -1

;Locate any object (i.e, remove the object from the queue).

      VLOCATE (cam.virt) $name

;Locate the round hole in the object

      VLOCATE (cam.virt, 4, 1)

;Place a 50mm fine-edge linear ruler that starts at the center of the circular
;þþhole--VFEATURE(2) & VFEATURE(3)--and is rotated 180 deg with respect to the X
;þþaxis. Place the ruler data in the array testdata[].

      VDEF.AOI 3000 = 2, VFEATURE(2), VFEATURE(3), 50, 0, 180
      VRULERI (cam.virt, 2) testdata[] = 3011      ;AOI 3, virt frame buffer 11

;Calculate the distance between the first and second transitions.

      dist_horz = testdata[3]-testdata[2]

;Display the result, dist_horz.

      TYPE "The distance is: ", dist_horz
```

Figure 6-5 illustrates the preceding code example.

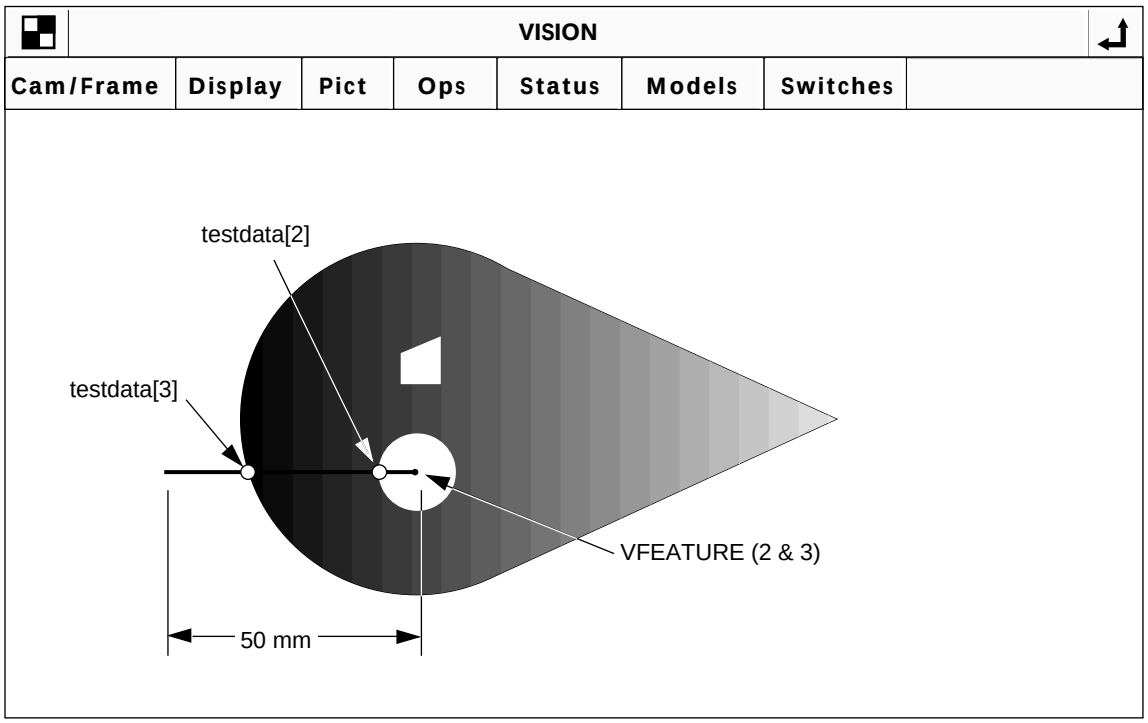



Figure 6-5. **Linear Ruler Example**

If (after executing the above code) you want to see all the values in the testdata array, issue this command:

```
LISTR[1] testdata[]
```

and the monitor window will display values similar to these:

```
testdata[0] = 2
testdata[1] = 1
testdata[2] = 5.15576
testdata[3] = 46.256
```

[1] LISTR is a monitor command that lists real variables resident in system memory.

## 6.3 Arc Rulers

In addition to linear rulers, AdeptVision VME allows you to place circular and arc shaped rulers. Arc rulers return the angular distance between edges found along an arc. These rulers are particularly useful for inspecting part features that are arranged radially around a part center. The syntax for an arc ruler is:

```
VRULERI(cam.virt, type) data[] = ibr
```

The parameters are the same as for a linear ruler, except the image buffer region must specify a circular AOI.

### Arc Ruler Example

Let's examine the face of a circular gauge to see if the graduation marks are properly spaced. The gauge we will examine is shown in Figure 6-6. We will assume that we know the ideal angular distance between the centers of any two graduation marks. We will also assume that the hole for the gauge dial is correctly placed.

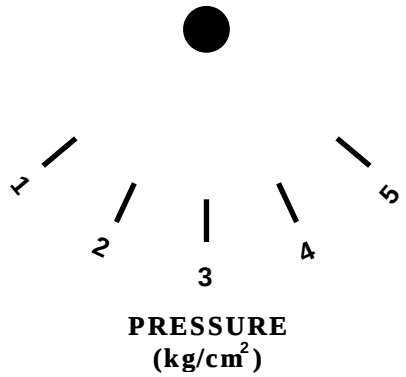



Figure 6-6. **Sample Gauge Face**

The code that would examine the gauge follows.

```
;Specify the pass-fail limits

      min_dist = 21
      max_dist = 23

;Display the results of the next VPICTURE in live mode
;with a graphics overlay.

      cam.virt = 1
      VDISPLAY (cam.virt) -1, 1

;Make sure hole information is gathered.

      ENABLE V.HOLES [cam.virt]
      ENABLE V.BOUNDARIES [cam.virt]
      DISABLE V.DISJOINT [cam.virt]
```

```
      ENABLE V.CENTROID [cam.virt]
;Set the minimum area parameters to filter "noise"

      PARAMETER V.MIN.AREA [cam.virt] = 60
      PARAMETER V.MIN.HOLE.AREA [cam.virt] = 50

;Acquire and process an image.

      VPICTURE (cam.virt) -1
      VWAIT

;Remove the largest object (the center hole) from the queue.

      VLOCATE (cam.virt, 2, 1) "?", gauge_center

;Check for successful VLOCATE

      IF NOT VFEATURE(1) THEN
          GOTO 100
      END

;Get the X/Y values of the gauge center

      centx = VFEATURE(2)
      centy = VFEATURE(3)

;Remove the topmost region from the queue.  This will be one of the
; graduation marks.

      VLOCATE (cam.virt, 2, 6) "?", mark_center

;Check for successful VLOCATE

      IF NOT VFEATURE(1) THEN
          GOTO 100
      END

;Use the function DISTANCE to calculate the distance from the center
; of the gauge to the center of a mark.

      arc_rad = DISTANCE(gauge_center,mark_center)

;Place an arc ruler

      VDEF.AOI 4000 = 7, centx, centy, arc_rad, 0, 170, 200
      VRULERI (cam.virt, 2) testdata[] = 4000

;Make sure the correct number of transitions were found

      IF testdata[0] <> 10 GOTO 100

;Print the inspection data

      FOR x = 3 TO 9 STEP 2
          act_dist = testdata[x+1]-testdata[x]
          pass = (act_dist > min_dist) AND (act_dist < max_dist)
          TYPE /S, "Distance from mark ", INT(x/2), " to mark "
```

```
        TYPE INT(x/2)+1, " is ", act_dist
        TYPE /S, "This inspection "
        IF pass THEN
           TYPE "passed."
        ELSE
           TYPE "failed."
        END
    END

100 TYPE "No object found, program stopped."
```

Figure 6-7 shows the ruler and transition points resulting from the preceding code.[1]

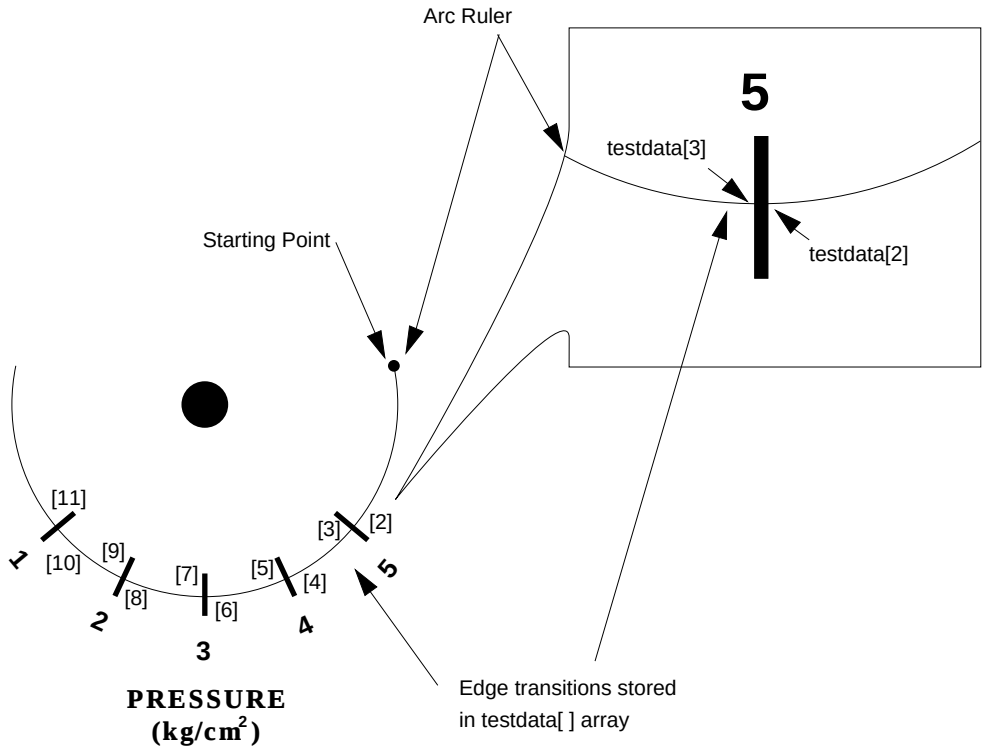



Figure 6-7. **Arc Ruler Example**

[1] This example could have been simplified by using the VRULERI parameter that specifies transitions in only one direction (light-to-dark or dark-to-light)—see the *AdeptVision Reference Guide*.

## 6.4 Ruler Types

VRULERI provided us with the first example of a vision operation that can be performed on an unprocessed image (quick frame grab). There are several different types of rulers, some of which work on a processed image and some of which work on the raw grayscale or binary image.

The argument "`type`" determines which type of ruler will be used.

### Standard Binary Rulers (*type* = 0)

This is the default ruler type (it is also referred to as the run-length binary ruler). It operates on processed image data (after VPICTURE in "*mode*" = –1, or within a VWINDOW processing window). The effects of most system parameters are taken into account by this type of ruler. (For example, if a ruler crosses a hole smaller than the size specified in V.MIN.HOLE.AREA, then it will not find the edges of the hole.) If V.BINARY is enabled, edges are found in a binary image. Otherwise, they are found in a binary edge image.

### Raw Binary Rulers (*type* = –1)

This ruler operates on unprocessed data in the binary frame store. Most of the system parameters will be ignored by this ruler. If V.BINARY is enabled, edges are found in a binary image. Otherwise, they are found in a binary edge image.

### Dynamic Binary Rulers (*type* = –2)

This ruler operates on data in the grayscale frame store. Edges are found based on the current value of V.THRESHOLD and V.2ND.THRESH (as opposed to the setting of these parameters when the image was acquired). As the ruler looks for edges in the grayscale frame store, the pixels it crosses are thresholded according to the current parameter setting (but the data in the frame stores is not changed). This ruler type allows you to specify different values for the threshold parameters for each ruler you place.

### Graylevel Rulers (*type* = 1)

This ruler operates on the grayscale frame store. It returns the graylevel value of each pixel the ruler crosses. The values are placed in the **`data[]`** array. The first value in the array is the number of pixels found.

### Fine Edge/Fine Pitch Rulers (*type* = 2/3)

These rulers operate on the grayscale frame store. They look for edges based on the setting of V.EDGE.STRENGTH. These rulers allow you to look for edges based on changes in intensity rather than binary thresholded values. Unlike other ruler types, these rulers find edges with subpixel accuracy. See the *AdeptVision Reference Guide* for more details.

Figure 6-8 shows a comparison of standard binary and raw binary rulers.

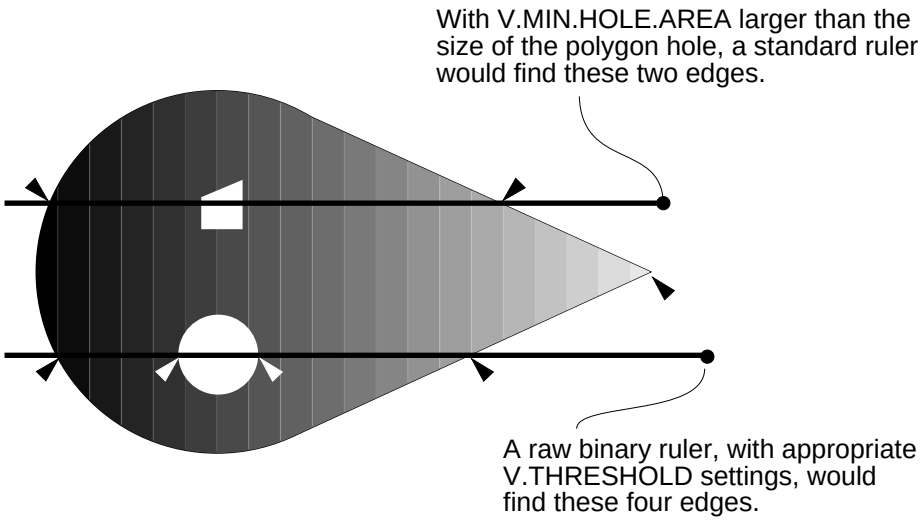



Figure 6-8. **Ruler Types**

**Ruler Speed and Accuracy**

The absolute speed and accuracy of rulers will depend on your particular application. In general:

- Ruler length and the number of transitions affect speed.
- Raw binary rulers are the fastest.
- Linear rulers are faster and more accurate than arc rulers.
- Linear rulers are faster and more accurate when they are nearly vertical or horizontal to the vision coordinate system.
- Fine edge rulers are the most accurate.

## 6.5 Finder Tools

The finder tools allow you to locate lines, points, and arcs within the field-of-view. The finder tools operate on raw grayscale data. This allows you to look for edges in an unpro
cessed image. In some cases the finder tools will tell you all you want to know about an image; in other cases you will perform further processing based on what you discovered with the finder tool.

In all the finder tools you will specify an area-of-interest within which to search for the line, point, or arc.

The behavior of all three finder tools is similar, so we will describe only the line finder, VFIND.LINE, in detail. The syntax for the other finder tools is described in the *AdeptVision Reference Guide*. The simplified syntax for VFIND.LINE is:

**VFIND.LINE (**cam.virt**) data[] = ibr**

| | |
|---|---|
| cam.virt | is replaced with a virtual camera number (the V.EDGE.STRENGTH parameter from this camera will be used by the line finder). The default value is 1. |
| **data** | is replaced with a variable name for the data array into which you want the results of the search placed. (The values placed in the array are described in "VFIND.LINE Array" below.) |
| **ibr** | is replaced with an image buffer region specifying a rectangular AOI (shape 1 is the most common shape). |

Figure 6-9 shows a sample VFIND.LINE area-of-interest.

## VFIND.LINE Array

The array values returned to the VFIND.LINE data array are:

| | |
|---|---|
| data[0] | TRUE if a line was fit, FALSE otherwise. |
| data[1] | TRUE if any part of the search window fell off the screen. |
| data[2] | X coordinate of a point on the line nearest to the search starting point. |
| data[3] | Y coordinate of a point on the line nearest to the search starting point. |
| data[4] | Angle of the fit line relative to the vision X axis (horizon). |
| data[5] | Percentage of the line's extent for which edge points were found. |
| data[6] | Maximum distance between the fit line and the most distant edge point used to compute the found line. The value is in pixels. |

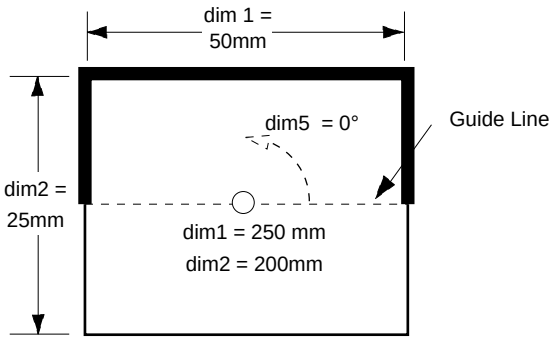



Figure 6-9. **Line Finder Search Area**

## Line Finder Tool Polarity

An important point to remember when using the line finder tool is that it locates dark-to-light transitions as viewed from the "dark side" of the tool. In Figure 6-9, the dark side is the side with the heavy line. When a finder tool is displayed in the vision window, the dark side is the dark blue half

of the tool search area. In order for the tool to find a line, a transition from dark-to-light must occur within the window as viewed from the dark blue side of the tool. If only light-to-dark transitions occur (as viewed from the dark blue side of the tool), a line will not be found. Figure 6-10 illustrates the polarity of a finder tool. In Example A, a dark-to-light transition occurs within the window, and the lower edge of the rectangle is found. In Example B, no dark-to-light transition takes place so an edge is not found (the light-to-dark edge is ignored). In order to find an edge with the tool in this position, the angle would have to be made 180° so the dark side of the tool would be in the rectangle. In Example C, the first dark-to-light transition is found, and the remaining transitions are ignored (the tool quits processing as soon as an edge is detected). In Example D, the first edge is a light-to-dark transition, so it is ignored and the second edge (a dark-to-light transition) is found.

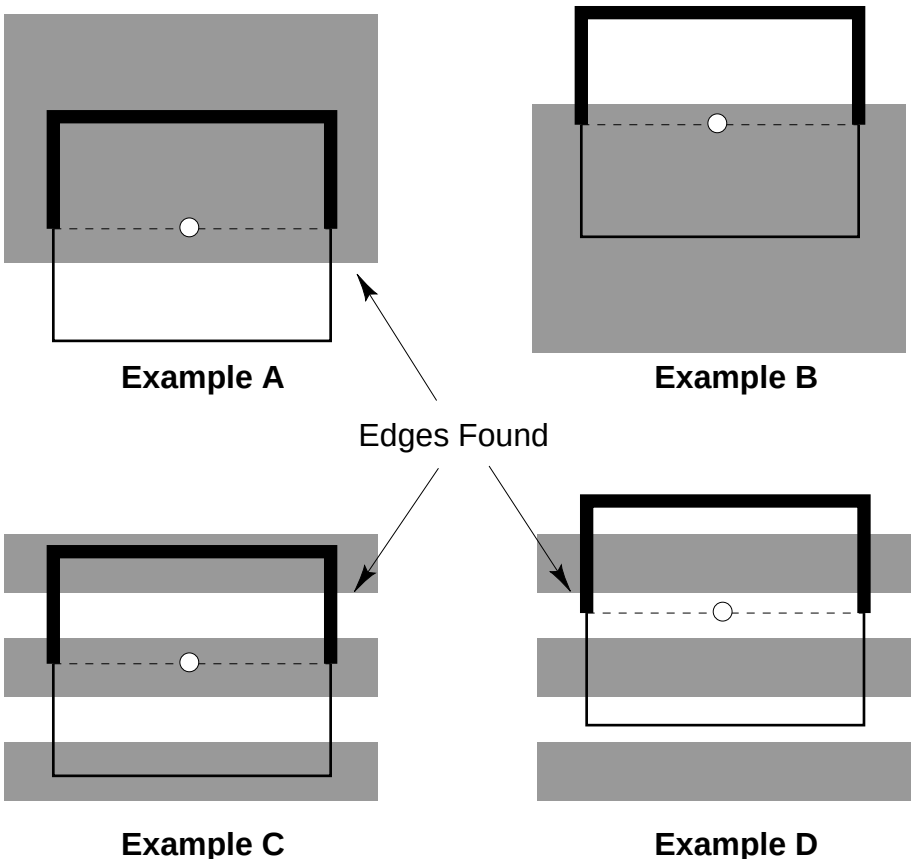



Figure 6-10. **Finder Tool Polarity**

## VFIND.LINE Example

This example locates the two straight edges of the sample object. Using the location and angle information returned in the data arrays from each finder tool and the V+ trig functions, the intersection of the straight edges can be calculated with high accuracy. This type of strategy is particularly useful on an object similar to our sample object, where the intensity changes at the intersection point are low enough that the system will have trouble recognizing exactly where the point is.

```
; Select a live grayscale image with a graphics overlay

      VDISPLAY -1, 1

; Acquire and process an image with camera 1

      VPICTURE (1)

; Place two line finders

      VDEF.AOI 2000 = 1, 80, 80, 30, 10, -205
      VDEF.AOI 3000 = 1, 80, 50, 30, 10, 25
      VFIND.LINE (1) data1[] = 2000
      VFIND.LINE (1) data2[] = 3000

; Pass the line finder data to a routine that calculates a line-to-line
; þþintersection (a sample routine is shown in the description of VFIND.LINE
; þþin the "AdeptVision Reference Guide" and a similar routine is shown in the
;   programming example in Chapter 8).

      x1 = data1[2]
      y1 = data1[3]
      ang1 = data1[4]
      x2 = data2[2]
      y2 = data2[3]
      ang2 = data2[4]

      IF data1[0] AND data2[0] THEN
          CALL line_line(x1, y1, ang1, x2, y2, ang2, x, y)
          TYPE "The lines intersect at x = ", x, " and y = ", y, "."
      ELSE
          TYPE "One of the line finders failed."
      END
```

Figure 6-11 shows the tool placement for the preceding example.

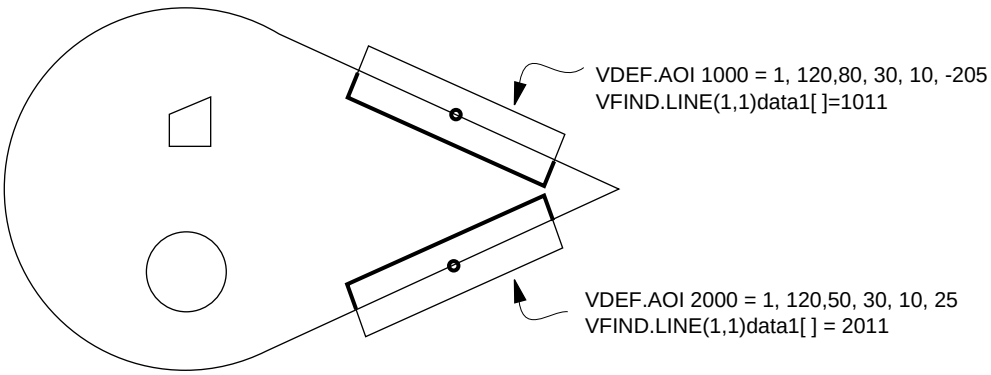



Figure 6-11. **Line Finder Example**

## 6.6 Processing Windows (VWINDOW)

In many cases, only a small section of the field-of-view will be of interest to you. You can reduce processing time by using the VWINDOW instruction to process only sections of the field-of-view that have critical features.

More than one processing window can be placed on an image and windows can overlap. Using multiple windows allows you to inspect different image areas using different combinations of switches and parameters.

Once you have placed a window, you can use VLOCATE, VFEATURE, and other vision tools just as you would if you were working with a fully processed field-of-view. The difference is that the results of these instructions will take into account only the portion of the image inside the window.

To use a processing window, you first acquire an unprocessed image by executing a VPICTURE instruction in mode 2 (quick frame grab). You then issue a VWINDOW instruction to process the area you are interested in.

After a VWINDOW instruction, boundary analysis is performed on the area inside the window. VLOCATE and VFEATURE can now be used to obtain data about the regions within the area of interest window. Vision tools that operate on processed image data can also be used.

The simplified syntax for a rectangular processing window is:

**VWINDOW (**cam.virt**) ibr**

| | |
|---|---|
| `cam.virt` | is replaced with a virtual camera whose switch and parameter settings will be used during processing by the window tool. |
| **`ibr`** | is replaced with the an image buffer region specifying a rectangular AOI. Shapes 1 and 4 are the normal shapes for a processing window. |

## VWINDOW Example

For this inspection we'll use the point found by the two VFIND.LINE instructions in our previous example (Figure 6-11). Using this point (x,y) we'll place an area of interest window that just encompasses the sample object.

```
w.width = 90
w.height = 60
VDEF.AOI 5000 = 1, x-w.width/2, y, w.width, w.height

VWINDOW (cam.virt) 5011
```

The above instruction results in the window illustrated in Figure 6-12. (In this case, for maximum speed in locating the x, y position, you would use type #–1 line finders.)

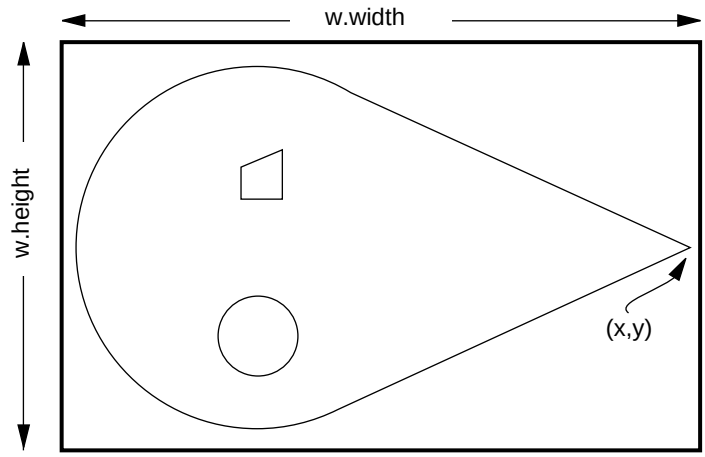



Figure 6-12. **VWINDOW Example**

## 6.7 Vision Tools: Inspection Windows (VWINDOWI)

VWINDOWI returns graylevel or binary data about the portion of an image inside the inspection window. The number of nonzero pixels, average graylevel, standard deviation of the graylevels, object and background pixel counts, and number of edge points in the window are calculated with this instruction.

VWINDOWB returns basic information about the binary image. See the *AdeptVision Reference Guide* for details on these instructions.

## 6.8 Vision Tool Data Arrays

All the vision tools return data to the array you specify in the instruction line. A potential problem arises with these arrays when your application is cycling through multiple inspections and placing the data in the same array during each iteration of the cycle. The entire array is not overwritten during each cycle. Only the currently generated values are overwritten.

For example, suppose you were inspecting parts with linear rulers and you expected to find six edges in each part. If a defective part containing only four edges was inspected, the fifth and sixth array cells would still hold the distance to the fifth and sixth edges left over from the previous inspection. To detect this problem, check the array element that indicates how many edges were detected before processing the ruler.

## 6.9 Windows, Windows, Windows

Documentation for AdeptVision VME uses the term “windows” in several contexts, which can lead to confusion. These are the different windows AdeptVision VME uses:

**Window** used by itself refers to the windows that are open on the display screen. These are the windows you can open and close, perform operations in, and view the results of vision operations in.

An **inspection window** results from issuing a VWINDOWI instruction. The information available from this type of window is what is returned in the data array specified when the instruction was issued.

A **processing window** is the window resulting from issuing a VWINDOW or VWINDOWB instruction. A VWINDOW instruction makes VFEATURE details available. Vision models can be processed within this type of window, and rulers can be placed inside these windows. A VWINDOW instruction by itself returns no data. A VWINDOWB instruction makes basic binary image data available through a specified array.

# 7 Vision Model Processing

# 7.1 Introduction

Vision model processing has two major steps, training and recognition.

The first step, training, involves creating an idealized “vision model” of the object you want to recognize. After this model has been created, it can be stored in a disk file and called into vision memory when needed.

The second step, recognition, involves placing the vision models in memory, presenting actual objects to the camera, and instructing the vision system to see if any of those objects match the models stored in vision memory.

AdeptVision VME has three types of vision model processing: prototypes, optical character recognition (OCR), and correlation.

## Why Use Prototype Recognition?

The most common use for prototype recognition is identifying objects that enter the field of view in a random fashion. A typical application would be a manufacturing operation where several different objects are produced and then placed in random order and orientation on a conveyor for inspection or acquisition by a robot. You would use prototype recognition to identify each object and then take appropriate action based on which object was identified. Prototyping is also the only way to separate objects that are touching or overlapping and thus form a single region. It is also the only way to recognize multiple disjoint regions that comprise a single object. Some things to remember when using prototypes are:

- Prototype recognition is processing-intensive. If you have only a few simple objects, you might be able to recognize them more efficiently with other vision tools.
- All vision tools can be applied to recognized objects, and VFEATURE data is available for recognized objects.
- Prototype recognition enables you to recognize objects that are touching or slightly overlapping, or are formed from disjoint regions.
- When you train a prototype, it will have its own frame of reference which can be used to place other inspection tools or as part of the vision transformation for guided vision. (This procedure will be described in the next chapter.)

## Why Use Correlation?

Correlation is similar to prototyping, but the training and recognition process is simpler. In correlation, a “template” is created from a region of pixels in a processed image. This template is then compared to a section of the field-of-view to see if the pixel pattern is repeated in that section. Correlation is used when you want to know how well objects in the field-of-view match a template of an ideal part. Correlation is “normalized” so that additive or multiplicative changes in lighting do not affect the correlation results. Unlike prototype matching, correlation matches must have the same orientation as the template.

### Why Use OCR?

Optical character recognition has two primary uses: text recognition and text verification. Text recognition identifies characters from a trained font. Text verification verifies that a string of expected characters was in fact found in the field-of-view (verifying date and lot codes, for example).

## 7.2 Training Prototypes

Prototype training is the process of creating prototype models of objects that you want the system to be able to recognize. During prototype training you will:

- Present multiple instances of an object to the system for training. The system will average the data from these instances to create the vision model that it will use for recognition.
- Name the prototype and specify the following parameters that will be used during prototype recognition:

  The effort level the system should apply when attempting recognition.

  The percent of the object boundary that must agree with the prototype before recognition will be considered successful.

  Constraints on the object's position and orientation that must be met for successful recognition.

### Creating Prototypes

The steps to create a prototype are:

1. Set the switches and parameters to the settings that provide the best possible image. Data provided by boundary analysis will be used to create the prototype model.
2. Make sure the correct calibration data is loaded for the cameras you will be using. **Changing camera settings or calibration after you train a prototype will invalidate the prototype.**
3. Select:

   **Models ➡** Train

   If no other prototypes are in vision memory, you will be prompted for a prototype name. If other prototypes are loaded, you will be given the option to train additional instances of loaded prototypes or to create a new prototype.
4. If the "Select the prototype..." pop-up window is presented, click on "<new prototype>".
5. In the "Type new name" pop-up window, enter a prototype name (using normal V+ variable naming conventions), and click on **Ok**. (This name is for an individual prototype, not the disk file for storing the prototypes. Multiple prototypes can be stored in a single file. See "VSTORE" on page 104.)
6. A screen listing the 32 virtual cameras will be presented. Click on the numbers of the virtual cameras you want to be able to recognize this prototype (the cameras must be cal-

ibrated). Click on **Done** when you have finished selecting virtual cameras. Cameras can be added or deleted during subsequent training sessions.

7. Place the object you want to train in the field of view and click on the **Ok** button in the training window.

8. Edit the prototype. (Editing is detailed in the next section.)

9. When you have completed editing of the prototype example, select:

   **Done** ➡ Use example.

10. The training window will display the default verify percentage (75%). Click on the percentage to change it. Click on **Ok** to accept the percentage displayed in the dialogue box.[1]

11. The training window will display the available effort levels. The suggested effort level will be highlighted. Click on **Ok** to accept the suggested effort level.

12. Select:

    **New example** ➡ New Example

    and follow steps 5 through 7 to train at least five additional examples of the prototype. Orient the part differently during each training session. After training each additional example, the program will prompt you to:

    a. Select a corner in the new example.

    b. Select the corresponding corner in the existing prototype. Click on **Done** when you have selected the two corners.

    c. The system will attempt to fit the new example to the existing prototype. If the match is successful, a blue outline will be overlaid on the existing prototype. If the outline and the prototype match, click on **Yes**. If the match is unsuccessful, you will have to select different features (or additional features) to match, or abandon the example.

13. When you have finished training examples, select:

    **Done** ➡ Done

14. The prototype model now exists only in vision memory. It must be stored to disk so it can be retrieved for future use. Activate the monitor window and store the prototype using the VSTORE command.

## Editing Prototypes

If you are not in the prototype training window, select:

**Models** ➡ Train

[1] Verify percent and effort level are prototype parameters that will have meaning only when you begin using prototypes. These two prototype parameters, along with the other prototype and system parameters, are discussed later in this chapter.

and click on the prototype you want to edit.

Select:

**New Example ➡** New Example

Place an example of the prototype in the field of view and click on the **Ok** button in the training window. A graphic representation of the prototype example will be presented, showing arcs in purple, lines in yellow, and corners as white dots. During prototype editing, you will edit the boundaries fit by the system so they match your object as closely and simply as possible. The most common editing tasks you will perform are:

- Removing extra corners
- Turning arcs into lines
- Deleting features that are unimportant or are part of the background

Figure 7-1 shows the prototype training window and its functional groups of features. The process of editing a prototype using the training window is described below.

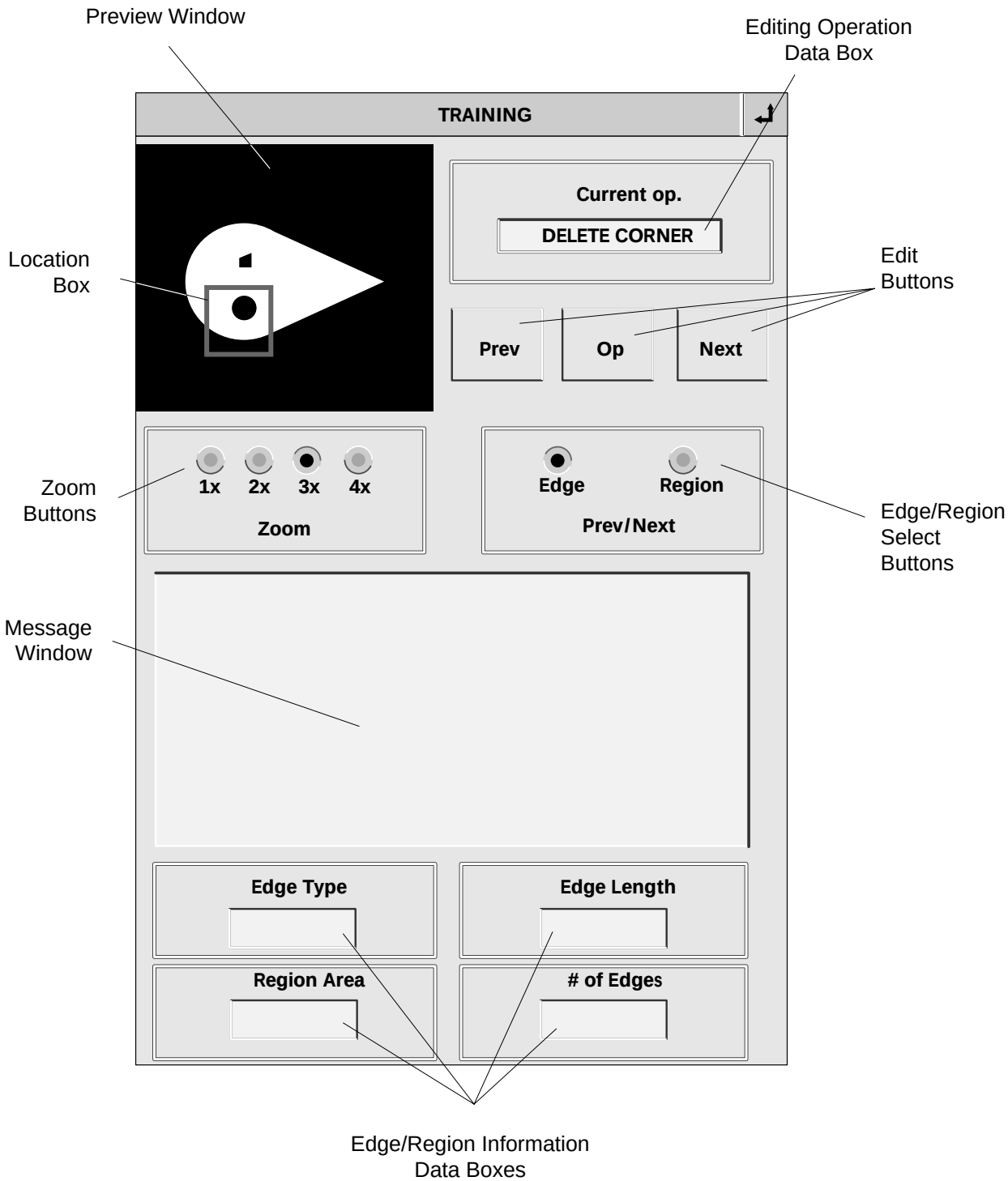



Figure 7-1**. Prototype Editing Operations**

## Preview Window

This window shows a reduced view of the vision window. When ◉ **1x** is selected, the preview window and the vision window show the same extent of view. When ◉ **2x** (or greater) is selected, the objects in the vision window will be magnified, and a location box will appear in the preview window showing the area of the vision window you are working on. You can move to a different area of the vision window by clicking on this location box and dragging it to a new area.

## Zoom Buttons

These buttons allow you to work with different levels of magnification of the prototype object. The area you have zoomed to is shown in the Preview Box.

## Message Window

This box will display information and error messages during the prototype training process.

## Edit Buttons

There are two methods of editing a prototype: clicking on the object's features with the pointing device and using the Edit Buttons. The main difference between the two methods is that data reported in the Edge/Region Information Windows is available only when using the Edit Buttons. The editing operation that will be performed (using either method) is selected from the **Operation** menu in the vision window. The current operation is shown in the Editing Operation data box.

When you edit with the pointing device, the current operation will be performed on the line, arc, or corner nearest the pointer click.

When you edit with the Edit Buttons:

> The first time you click on **Prev** or **Next**, an "X" will appear on one of the lines or arcs of the prototype. If you click on **Op**, the operation indicated by the Editing Operation Window will be performed.
>
> If the Edge button is selected, the next time you click on **Prev** or **Next**, the "X" will move to the previous or next line or arc in the region. Clicking on **Op** will perform the current operation.
>
> If the Region button is selected, the next time you click on **Prev** or **Next**, the "X" will move to the previous or next region in the vision window. Clicking on **Op** will perform the current operation.

## Editing Operation Data Box

This data box shows the editing operation that will be performed using the Edit Buttons, or by clicking on the prototype. The edit operation is selected from the **Operation** menu in the prototype window. The editing tasks are:

| | |
|---|---|
| Delete Corner | Delete the corner nearest to a mouse click, or the next corner in sequence when **Op** is clicked. |
| Restore Corner | Restore a corner deleted with a delete corner operation. |

| | |
|---|---|
| Arc <=> Line | Convert a line to an arc, or an arc to a line. |
| Delete Region | Delete the region nearest to the mouse click, or the region currently selected with the Edit Buttons. (Can be performed only on the first prototype example.) |
| Delete Edge | Delete the edge currently selected with the Edit Buttons or the edge nearest the mouse click. (Can be performed only on the first prototype example.) |
| Create Corner | Place a corner at the mouse click or, when **Op** is clicked, on the currently selected line or arc. (Can be performed only on the first prototype example.) |

## Edge/Region Data Boxes

When you are editing using the Edit Buttons, these data boxes show:

- Edge type (line or arc)
- Region area in pixels
- Edge length (distance in pixels from one corner to the next)
- Number of edges in the region (holes are not included in this count)

This data will not be displayed if you are using the mouse to edit the prototype.

## Edge/Region Radio Buttons

These buttons work in conjunction with the Edit Buttons. When ◉ **Edge** is selected, pressing **Prev** or **Next** will select the previous or next edge in a region.

When ◉ **Region** is selected, pressing **Prev** or **Next** will select the previous or next region within the field-of-view.

## Prototype Training Hints

After you have completed prototype training, you can still train additional examples of a part or change the prototype parameters (described later in this chapter). If you make any changes to an existing prototype, you must **store the changes** using the VSTORE command (if you use the same file name, the existing disk file must be renamed or deleted).

When you train the first example, make the prototype as simple as possible. When you train additional examples, do as little editing as possible.

## SubPrototypes

A region within a prototype can be designated as a subprototype. Sub-rototypes allow you to more accurately determine the position and “goodness of fit” of a prototype based on the region selected as a subprototype. See the description of VDEF.SUBPROTO in the *AdeptVision Reference Guide*.

## Prototype Parameters

In addition to the parameters described above, each prototype has several prototype parameters associated with it. System parameters are associated with a virtual camera and will be in effect for any prototype recognized by that virtual camera. Prototype parameters are associated with a trained prototype and will be in effect for that given prototype, regardless of the virtual camera that acquired the image.

## Setting Prototype Parameters

To change parameters for a given prototype (prototype parameters are described below):

1. Load the prototype into vision memory using the VLOAD command.
2. Activate the vision window and select:

   **Models** ➡ Train
3. Select the parameter you wish to set from the **Prototype Parameter** menu. A dialogue box will be displayed that will allow you to change the parameter value. Repeat for as many parameters as you want to change.
4. After you have made all changes, select the monitor window and store the prototype to disk using the VSTORE command.

**Verify Percent**

This parameter sets the percentage of total boundary length (including holes) that must be common to both the prototype model and the current region before recognition will be successful. This parameter can be used in conjunction with the system parameter V.MAX.VER.DIST to control:

- objects incorrectly recognized as matching a prototype, and
- objects matching a prototype that are not recognized.

**Effort Level**

Effort level affects recognition accuracy and processing speed. Recognizing prototypes with few distinguishing features as well as recognizing prototypes among multiple overlapping objects will require higher effort levels and more processing time.

**Min/Max Area**

Changing the minimum area setting allows you to ignore noncritical features of an object.

Changing the maximum area setting allows you to isolate an area within a large object, or ignore large, noncritical areas within the field-of-view.

**Limit Position**

These parameters allow you to constrain the location and rotation variance an object can have from the prototype model and still be recognized.

**Edge Weights**

In some cases, accuracy of prototype recognition can be improved by weighting an object's edges. Important features of an object can be given a high weight and unimportant features can be given a

low weight. Edge weights work in conjunction with verify percent to determine how closely an object must match the prototype model for successful recognition.

**Assign Cameras**

Any cameras you will be using to attempt recognition of a given prototype must be assigned to that prototype.

## 7.3 Using Prototypes

In the previous section we learned how to create prototype objects. This section will show you how to use those prototypes.

### Recognizing a Prototype

In order for the system to recognize a prototype, the following steps need to be taken:

1. The prototype must be loaded into vision memory (using the VLOAD command).
2. The camera calibration that was in effect when the prototype was trained must be loaded.
3. The system switches V.BOUNDARIES and V.RECOGNITION must be enabled.

After an image containing prototype objects has been acquired, the individual prototypes can be removed from the vision queue using the VLOCATE instruction. The syntax for VLOCATEing a prototype is:

```
VLOCATE (cam.virt, 2) "proto_name", proto_loc
```

| | |
|---|---|
| `cam.virt` | is the virtual camera whose queue holds objects recognized as matching the specified prototype. Default = 1. |
| **`2`** | indicates that a particular object is to be removed from the vision queue. |
| **`proto_name`** | is the prototype you are looking for (must have been loaded to vision memory). |
| `proto_loc` | receives a transformation that defines the object's location in the field-of-view. |

Once an object has been recognized and removed from the queue you will be able to retrieve all the VFEATURE data available for blobs (unrecognized regions), as well as data available only from recognized prototypes. See Appendix B for additional VFEATURE data.

In some cases, recognizing an object will be the only inspection you need to make. In other cases, you may want to use rulers and other vision tools to make a more thorough inspection of the object. Chapter 10 describes the use of prototype-relative inspections. This inspection strategy allows you to place vision tools on the prototype regardless of its location and orientation in the field-of-view.

### Prototype-Relative Inspection

You can use DEF.TRANS, VFEATURE(2), VFEATURE(3), and VFEATURE(7) to establish a reference frame for all vision tools.

### Prototype-Relative Part Acquisition

If the objects you are acquiring:

- are similar and cannot be identified by blob recognition or by using a combination of finder and ruler tools,
- do not have a strong elliptical character, or have features that define the object's rotation,
- are touching or overlapping, or are formed by disjoint regions,

then prototyping may be the best way to define a reference frame for the objects.

Prototypes have their own reference frame based on the orientation of the part the first time it was trained. When a prototype is recognized (VLOCATE operation), a reference frame based on the recognized object is returned. The following code will move to a recognized prototype (assuming the robot is a four-axis SCARA—see Chapter 9 and the *Advanced Camera Calibration Program User's Guide* for more information on guided vision operations):

```
     cam.virt = 1
     ENABLE V.RECOGNITION [cam.virt];enable prototype recognition

; Acquire a processed image and locate the prototype.

     VPICTURE (cam.virt) -1
     VLOCATE (cam.virt, 2)"sample_object", proto.loc

; Use the prototype object location to acquire the recognized prototype

     HERE #cur.loc
     DECOMPOSE jt[1] = #cur.loc
     SET link2 = HERE:INVERSE(TOOL):RZ(–jt[3]):TRANS(,,jt[4])
     SET obj.loc = link2:to.cam:proto.loc:grip.trans
     MOVE obj.loc
```

# 7.4 Performing Correlation Matches

A correlation template is simply an array of graylevel values recorded from the pixels in a specified area of the field-of-view. When a correlation match is attempted, this array of graylevel values is compared with the graylevel values in a given search area. The template and the search area can be any size as long as the search area is larger than the template. Larger templates and search areas will increase processing time for a template match.

Since changes in ambient lighting will alter the graylevel values recorded, template correlation is "normalized" to account for changes in lighting from when the template was created to when a correlation match is attempted. Lighting changes that uniformly affect the field-of-view will not affect template matching.

## Creating a Correlation Template

A correlation template is created with the program instruction:

**VTRAIN.MODEL (**cam.virt**) $tmpl_nn, , ibr**

| | |
|---|---|
| cam.virt | is the virtual camera to use. |
| **$tmpl_nn** | is the name of the correlation template. Correlation template names begin with "tmpl_" and end with a number between 1 and 50. Multiple templates can be stored in a single disk file. |
| **ibr** | is a defined image buffer region (see section 6.1). |

Once a correlation template has been created, it can be stored, loaded, and compared with new camera images. The VCORRELATE program instruction searches for a template match in an image. See description of VCORRELATE in the *AdeptVision Reference Guide* for details on hierarchical and binary correlation. These options speed up correlation searches.

## Matching a Correlation Template

An area of the field-of-view is compared to a defined correlation template with the program instruction:

**VCORRELATE (**cam.virt**) data[] = tmp.num, ibr**

| | |
|---|---|
| cam.virt | is the number of the virtual camera to use. |
| **data[]** | is an array name to receive the results of the correlation operation:<br>data[0] receives the correlation value of the best match found (1 is perfect correlation).<br>data[1] receives the x value of the area matching the template.<br>data[2] receives the y value of the area matching the template. |
| **tmp.num** | is the number of a loaded correlation template. |
| **ibr** | is a defined image buffer region (see section 6.1). |

# 7.5 Performing Optical Character Recognition

This section describes the optical character recognition capacities (OCR) of AdeptVision VME.

## Training an OCR Font

Before characters can be recognized or verified, a sample of the font containing all characters that might be encountered must be trained. As with all vision model processes, before models can be built or recognized, the camera must be installed, adjusted, and calibrated. The system parameters should be set to acquire the best image possible.

Before a font can be trained it must be defined with the program instruction:

**VDEF.FONT (**op**) font.num, $chars, height**, black?

| | |
|---|---|
| op | determines what action the instruction will initiate:<br>0 define a new or replace an existing font (default)<br>1 modify an existing font |
| **font.num** | number of the font to be defined (or altered). |
| **$chars** | list of characters in the font. |
| **height** | typical height of the largest character (must be between 6 and 63 pixels). |
| black? | boolean indicating whether the font is dark characters on a light background or light characters on a dark background. The default is TRUE (dark characters on a light background). |

Fonts are trained with the program instruction:

**VTRAIN.MODEL (**cam.virt**) $font, $font.chars, ibr**

| | |
|---|---|
| cam.virt | virtual camera whose switches and parameters will be used when training the font. |
| **$font** | a defined font in the form “font_nn”. |
| **$font.chars** | the characters in the font sample, entered in the order they occur in the sample. |
| **ibr** | a defined image buffer region (see section 6.1). |

Train the font 5 - 15 times, using samples that represent the range of examples the system might encounter.

> **NOTE:** Fonts are trained based on the binary image. Therefore, a constant, optimized image must be used during training and recognition to obtain accurate, consistent OCR results.

## Font Planning

After fonts have been defined and trained, but before sample characters can be recognized, the vision system must plan a recognition strategy. Planning will take place the first time recognition is attempted on an unplanned font, or when planning is specifically requested. Since font planning can take a few minutes, we recommend you plan fonts before using them in an application. The instruction to plan a font is:

```
VTRAIN.MODEL(cam.virt, 1) $font
```

As fonts are planned, each character planned is shown in the upper left corner of the vision window. When planning is complete, a matrix showing the font characters vs. the found characters is displayed. A red square at the intersection of a font character and a sample character indicates a well defined and trained character.

After a font is trained, a matrix showing the relative similarities among the characters in the font is displayed. The rows of the matrix are marked with the characters in the font as are the columns. The color of the intersecting cell indicates how similar the character in the row is to the character in the column. Red indicates very high similarity, and the corner-to-corner diagonal cells should be red. Orange and yellow indicate strong similarity and indicate one character may get interpreted as the other. Greens indicate a moderate similarity—characters such as E and F or O and Q may regularly show this similarity. As long as lighting remains consistent and the characters are clearly printed, these characters will be correctly identified. Gray indicates little similarity—these characters are unlikely to be confused with each other. Figure 7-2 shows a sample matrix. All the characters show very high similarity with themselves. The F and E show a strong similarity that may cause confusion. The M and N show a moderate similarity which should not be confusing as long as conditions remain consistent.

If characters show an unacceptable similarity:

- Train additional instances of the font
- Improve the lighting conditions
- Optimize the image
- Train a new sample of the font

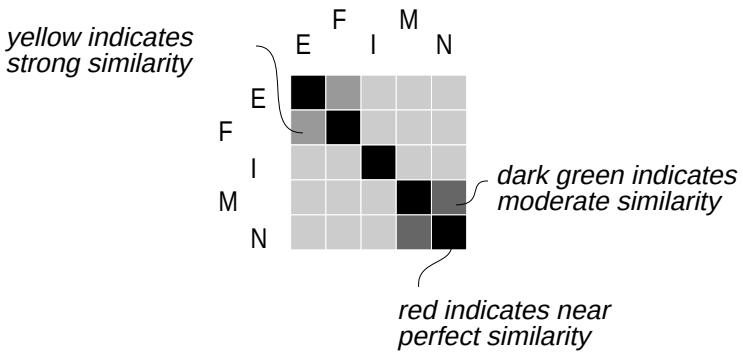



Figure 7-2**. Font Similarity Matrix**

## Character Recognition

The VOCR instruction performs font recognition or verification. The syntax is:

**VOCR (**cam.virt, op**) data[]**, = **font_num,** $expected**, ibr**

| | |
|---|---|
| cam.virt | virtual camera number (default is 1) |
| op | 0 = text verification (default)<br>3 = text recognition |
| **data[]** | text verification or recognition data.<br>For op = 0:<br><br>data[0] = number of character regions found and analyzed<br>data[1] = average score of "$expected" characters verified<br>data[2] = minimum score of "$expected" characters verified<br><br>For op = 3:<br><br>data[0] = number of character regions found and analyzed<br>data[1] = average score of two most likely values per region<br>data[2] = minimum score of two most likely values per region<br>data[3] & data[4] not used<br>data[5] = ASCII value of character most likely to match region<br>data[6] = score of most likely character<br>data[7] = ASCII value of character 2nd most likely to match region<br>data[8] = score of 2nd most likely character<br>data[9] - data[12] repeats data[5] - data[8] for the second analyzed region, data[13] - data[16] for the third analyzed region, etc. |
| **font_num** | number of a trained and loaded font |
| $expected | expected text for op = 0 |
| **ibr** | number of a defined image buffer region (see section 6.1) |

**OCR Examples**

The following code will output the characters found in the area defined by cx, cy, dx, and dy (font 1 must be trained and loaded).

```
     VPICTURE (cam.virt)
     VWAIT
     VDEF.AOI 3000 = 1, cx, dx, cy, dy
     VOCR (cam.virt,3) data[],= 1, 3000

;The first array value is the number of characters found

     found = data[0]

;The ASCII values of the found characters are stored in every fourth array cell
;starting at 5

     index.inc = 4

;Output the characters

     FOR x = 5 TO (found*index.inc)+4 STEP index.inc
          type $CHR(data[x]), " ", /S
     END
     TYPE
```

The following code will output the average verification score of characters from the string $ver.string found in the area defined by cx, cy, dx, and dy:

```
     VPICTURE (cam.virt)
     VWAIT
     VOCR(cam.virt,0) data[],= 1, $ver.string, 3000
     TYPE "The average verification score is: ", data[1]
```

The VOCR instruction has several different options and returns extensive data on recognition and verification processes. See the description of VOCR in the *AdeptVision Reference Guide.*

## 7.6 Prototype Model Switches and Parameters

The following tables list the switches and parameters that affect the prototype model process.

Table 7-1. **Prototype Model Switches**

| Switch | Default | Effects |
|---|---|---|
| V.RECOGNITION | ✔ | Disabling this switch will cause the system to behave as if no prototypes have been defined. Must be enabled to perform prototype recognition. (Not required for OCR or correlation.) |
| V.DISJOINT | | A single object may appear to the vision system to be two separate objects (e.g., a dark object with a white line down the middle would look like two objects). If you are attempting prototype recognition on this type of object, this switch will have to be enabled or the object will not be recognized. Disable this switch when you are not doing prototype analysis. When doing region analysis, this switch must be disabled for hole data to be gathered. |
| V.TOUCHING | | If the objects you are attempting to recognize are touching each other, the system will see them as one object and fail to recognize multiple touching objects. If you need to recognize touching objects, enable this switch. This switch increases processing time for object recognition. See the *AdeptVision Reference Guide* for details on how V.TOUCHING, V.DISJOINT, and V.OVERLAPPING interact. |
| V.OVERLAPPING | | Enabling V.OVERLAPPING will improve recognition of objects that are overlapping. This switch increases processing time for object recognition and should be disabled if objects do not overlap. (V.TOUCHING is assumed to be enabled whenever this switch is enabled.) |
| V.SHOW.BOUNDS | | If this switch is enabled, the vision system will display the results of attempting to fit lines and arcs during prototype recognition. This switch is useful during development because it allows you to see what the vision processor is going through during object recognition. V.RECOGNITION must be enabled. |
| V.SHOW.RECOG | ✔ | If this switch is enabled and an object is recognized, the silhouette of the recognized prototype will be overlaid on the object. The “SHOW” switches are time consuming and are generally turned off in the production environment. |
| V.SHOW.VERIFY | | Enabling this switch will cause the system to display all attempts the system makes during prototype recognition. This switch is useful during development when you attempt to create prototypes that produce the most accurate results in the least amount of time. It should be disabled during normal operations. |

Table 7-2. **Prototype Model Parameters**

| Parameter | Default | Range | Effects |
|---|---|---|---|
| V.BORDER.DIST | 0 | 0<br>100 | Allows you to disable prototype recognition processing on objects that are not entirely within the field of view. |
| V.MAX.TIME | 5 | 1<br>999 | Sets the maximum time the vision system will spend trying to recognize a prototype. |
| V.MAX.VER.DIST | 3 | 1<br>16 | Sets the pixel variance allowed for successful fitting of image boundaries to the prototype model. |
| V.LAST.VER.DIST | 0 | 0<br>16 | Sets the pixel variance allowed for successful fitting of image boundaries to the prototype model when a successfully recognized prototype is reverified. When this switch is set to 0, the additional verification process is defeated. |

## 7.7 Loading and Storing Vision Models

The vision processor board has its own memory that is separate from system processor memory. Trained vision models reside in this memory area. VSTORE stores a vision model (or group of similar models) to a disk file. VLOAD loads a vision model or group of models (stored with the VSTORE command) from a disk file to vision memory.

### VSTORE

VSTORE works the same way as STORE except it will store vision models from the vision processor memory to a disk file.[1] The syntax for VSTORE is:

```
VSTORE drive: file_spec = model_1,...,model_n
```

To store prototypes “goodpart”, “badpart”, and “okpart” to the file PARTSCMP.PTS on the B: drive, enter the command:

```
VSTORE B:partscmp.pts = badpart, goodpart, okpart
```

To store correlation templates “tmpl_1” and “tmpl_2” to the file TPLATES.VS on the default drive, enter the command:

```
VSTORE tplates = tmpl_1, tmpl_2
```

All correlation template names must have the form “tmpl_nn”.

To store font “font_3” to the file FONTS.VS on the A: drive, enter the command:

```
VSTORE fonts = font_3
```

All font names must have the form “font_nn”.

Only one type of vision model can be stored in a file. The instruction:

```
VSTORE models = a.proto, font_4, tmpl_5
```

will result in an error.

Remember, after training, vision models reside only in vision memory. They must be explicitly stored to a disk file or they will be lost when the controller is turned off.

If the filespec does not contain a file extension, the default extension “.VS” is added when storing vision models.

[1] VSTORE is also a program instruction.

## VLOAD

In order to use vision models, you must load them to vision memory (rather than the system memory). VLOAD loads files from a disk file to vision memory; its syntax is similar to LOAD.[1]

**`VLOAD`** `drive:` **`file_spec`**

To load the disk file of vision models "VMODELS.VS" from the C: drive into vision system processor memory, issue the command:

```
VLOAD C:vmodels
```

".VS" is automatically added if an extension is not specified.

## Displaying Vision Models

Vision models in vision memory can be displayed and listed from the **Models** menu. To display a graphic representation of a vision model:

1. Select Show prototype, Show font or Show template from the **Models** menu.
2. A pop-up window will appear showing the names of all the selected vision models currently in vision memory. Click on the model you want to see, and the model will be displayed in the vision window. (Vision models must be loaded with the VLOAD command before they can be displayed.)

To see an alphabetic listing of all the prototypes currently in vision memory, select List prototypes, List fonts, or List templates from the **Models** menu. A dialogue box will appear listing all appropriate models in vision memory.

## Deleting Vision Models

To delete a model from vision memory:

1. Select Delete prototype, Delete font, or Delete template from the **Models** menu.
2. Click on the model to be deleted from vision memory.
3. The system will prompt you to verify the deletion. Click on **Yes** to delete the prototype. Click on **No** to abandon the operation.

The command/instruction:

```
VDELETE model_name
```

will also delete models from vision memory.

This operation removes a model from vision memory, not from the disk file it is stored on. To permanently delete a vision model, the disk file must be deleted with the FDELETE command.

---

[1] VLOAD is also a program instruction.

## Renaming Vision Models

To rename a vision model:

1. Select Rename prototypes, Rename fonts, or Rename templates from the **Models** menu.
2. A list of appropriate models in vision memory will be presented. Click on the model to be renamed.
3. Type the new name in the dialogue box presented. Click on **Ok** to change the name. Click on **Prev** to abandon the change.

The monitor command:

```
VRENAME new_name = old_name
```

will also rename a vision model. Renaming a model in vision memory does not change the name in the disk file the model is stored in. To permanently change a vision model's name, the disk file must be deleted with the FDELETE command and the models (if any) must be stored with the VSTORE instruction.

# 8 Programming AdeptVision VME

# 8.1 Introduction

This chapter details the development of an AdeptVision VME program. The program includes vision instructions that were presented in the last two chapters as well as other V+ program instructions. As you go through this example, remember that we are not attempting to present the most efficient vision inspection application. We are attempting to present examples of vision instructions in a simple, straightforward context.

This chapter assumes that you are familiar with basic V+ programming. All the commands presented in this example are detailed in the *V+ Language Reference Guide* or the *AdeptVision Reference Guide.*

This chapter develops a basic inspection application. Chapter 9 develops a robot guidance vision application.

# 8.2 Application Development Strategy

We recommend that vision inspection applications be developed in the following sequence:

1. Install the controller and any other equipment you will be using to deliver or remove parts.
2. Select a lighting strategy and install the lighting equipment (see Appendix D). Make the lighting environment as consistent as possible.
3. Determine the lens requirements (see Appendix C). Install the cameras and lenses.
4. Optimize the camera image (select a live grayscale image):

   Focus the lens.

   Set the f-stop (aperture) for maximum contrast.

   Set V.THRESHOLD (select a live binary image). The command VAUTOTHR will provide suggested threshold levels.
5. Calibrate the cameras (see “Camera Calibration” on page 28).
6. Determine the part location strategy. If parts will always be in the same location, inspection tools can be placed relative to the vision coordinate system. If the parts will be presented to the camera in varying locations, inspection tools will have to be placed using a “part-relative” strategy. The program in this chapter uses finder tools and boundary analysis data to determine tool locations. Additional part-relative strategies are discussed in Chapter 10.
7. Determine which vision tools to use to make inspections.
8. Write the application code.
9. Debug the application.
10. Fine-tune the application.

## 8.3 Inspection Vision Example Program

The program detailed in this chapter will inspect the sample object that we have worked with in the last several chapters. Here are the major steps the program will perform (see the flow chart in Figure 8-1):

1. A digital output signal will be sent to a conveyor belt. The belt will bring the object into the field-of-view. When the object is in place, a digital input signal will be sent to the system indicating the part is ready. When the part is in place, the digital output signal to the belt will be turned off.
2. The first step after the part is in place will be to take a picture.
3. When the objects are placed on the conveyor belt, the tail will be facing forward. The object's location and rotation can vary, but must be within limits set by the placement of two line finders we will use to locate the object. If the object is positioned outside the allowed area, it will be sent back. If it is located, its centroid and rotation will be determined.
4. Based on the object's location and orientation, we will process the image area that just encompasses the object.
5. We will now make five inspections:
    a. Check that the center of the circular and polygon-shaped holes are correctly spaced from the object center (within ±0.5mm).
    b. Check the diameter of the circular hole. It should be 10mm (±1mm).
    c. Check the angle of the slanted side of the polygon. It should be 25° (±2°).
    d. Check the arc on the top of the object. Its center should be centered between the polygon and circular holes.
    e. The surface of the object should have a constant gradation from the front to the back. If this gradation exceeds a certain value, the part will be rejected.
6. If any inspection fails, a program will be called to remove the bad part and the conveyor will bring in a new part and begin again. If the object passes all inspections, the conveyor will move a new part into position and carry the inspected part out of the field of view.

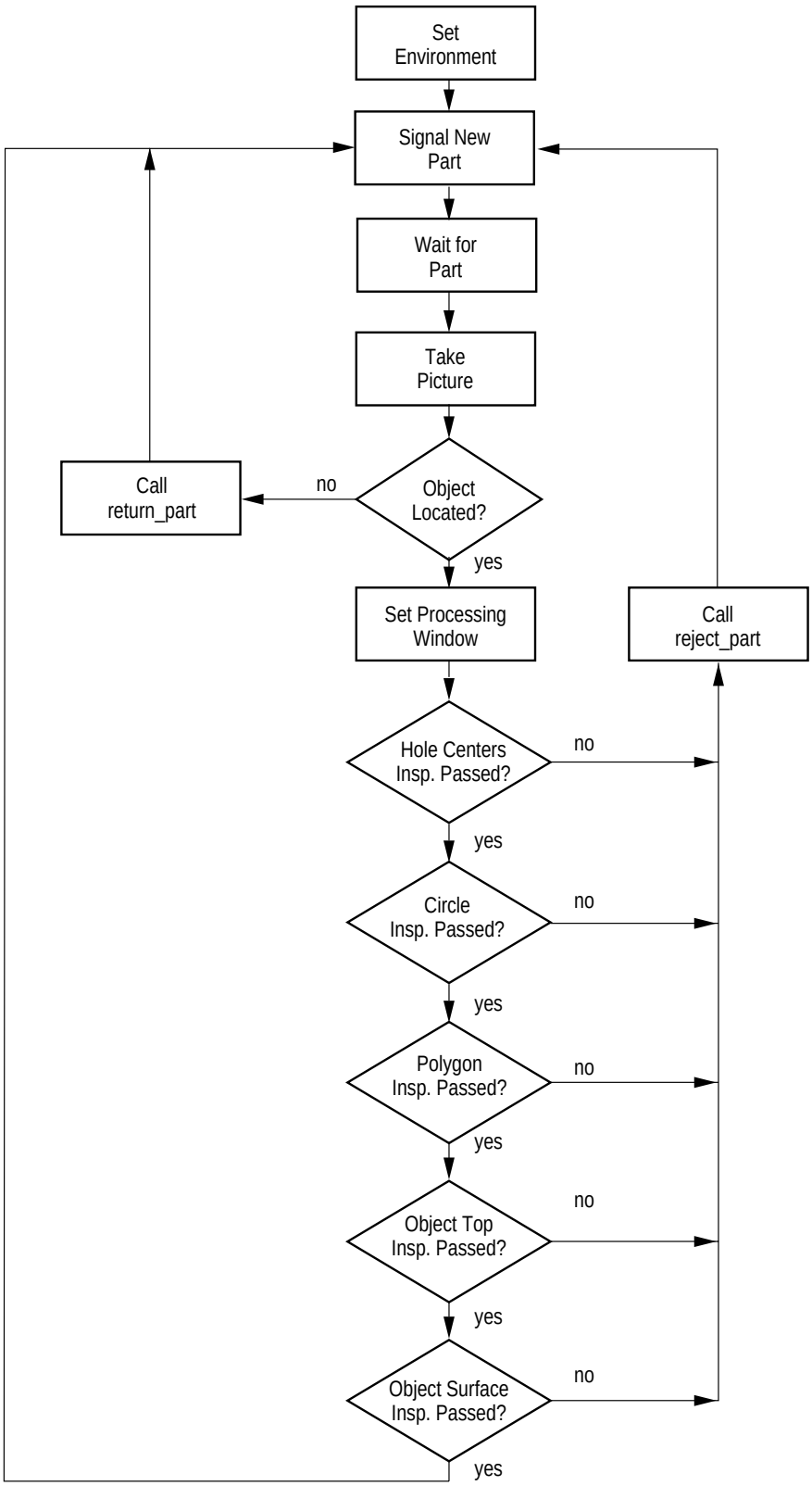



Figure 8-1. **Application Flow Chart**

## 8.4 Developing the Program Code

### Program Header and Variables Declarations

All programs should begin with a header that gives the program abstract, creation date, side effects, input and output parameters, and any modifications that have been made. The header should be similar to this:

```
.PROGRAM inspect.part(re_init)
;
; ABSTRACT:  Inspect the sample object for defects in the round and
;       ÞÞpolygon shaped holes, the arc at the front of the object, and the
;         surface gradation.
;
; INPUT PARM:   re_init    determine whether to call the system initialization
;        ÞÞ                routine. 1 = re-initialize, 0 = no initialization
;
; OUTPUT PARM: None
;
; SIDE EFFECTS: The global variables 'num_parts' and 'avg_time'
;       will be updated.
;
```

The next section of your program should contain the variable declarations. The V+ language allows you to declare variables dynamically, but these variables will be global to all programs. To guarantee you do not inadvertently use the same variable name used globally by another program, you should declare all variables used exclusively within your program to be automatic variables.

```
; Declare local variables
;
      AUTO obj_width                      ;object width
      AUTO cent_circlex, cent_circley     ;x, y center of circular object
      AUTO obj_centx, obj_centy           ;x, y center of the object
      AUTO arc_centx, arc_centy           ;x, y center of object arc
      AUTO gvalue                         ;acceptable graylevel variance
      AUTO grulerx, grulery               ;starting point of g-level ruler
      AUTO good_part                      ;boolean indicating status of part
      AUTO di.part_ready                  ;digital sig indicating part is ready
      AUTO cycle_time                     ;average inspection cycle time
      AUTO do.belt                        ;digital sig for conveyor belt
      AUTO poly_angle, circ_diam          ;correct part dimensions
      AUTO poly_dist, poly_act            ;               "
      AUTO rnd_dist, rnd_act              ;               "
      AUTO win_ibr, rul_ibr, lfdr_ibr     ;define image buffer regions
      AUTO afdr_ibr, grul_ibr
      AUTO last, $msg[19], $err
      AUTO i, lun

; Initialize known values

      obj_length = 0
      obj_centx = 85              ;object center X (within 12mm)
      obj_centy = 60              ;object center Y (within 12mm)
      obj_width = 82              ;object width
```

```
obj_hgt = 50                ;object height
gvalue = 10                 ;acceptable graylevel variance
poly_angle = 25             ;correct angle of polygon edge
poly_dist = 19              ;correct dist from object center
rnd_dist = 17               ;           "
do.belt = 31                ;digital signal for conveyor belt
di.part_ready = 1032        ;digital signal for part ready
good_part = TRUE            ;assume the part is good
circ_diam = 10              ;correct diameter of circular hole
cam = 1                     ;virtual camera used for inspections
```

**Set the Camera Environment**

An important principle to remember when programming AdeptVision VME is that when any program makes changes to the switches and parameters associated with a given camera, those changes are in effect for any further pictures taken by that camera, regardless of the program using the camera. This means that all critical switches and parameters should be explicitly set at the beginning of each program. Otherwise, changes made by other programs running during the same session as your program may unexpectedly change critical switch/parameter settings, and cause your program to behave erratically.

Disabling switches that aren't needed for your program will improve processing time by reducing the amount of data the system has to gather about each image.

```
; Set switches and parameters

      ENABLE V.HOLES[cam]               ;hole information is needed
      ENABLE V.BINARY[cam]              ;processing to be in binary mode
      ENABLE V.BOUNDARIES[cam]          ;region analysis will be done
      ENABLE V.BACKLIGHT[cam]           ;dark objects on a light background
      DISABLE V.PERIMETER[cam]          ;data not needed
      DISABLE V.DISJOINT[cam]           ;must be disabled to get hole data
      DISABLE V.RECOGNITION[cam]        ;no prototype recognition
      DISABLE V.TOUCHING[cam]           ;we have only one part
      DISABLE V.OVERLAPPING[cam]        ;
      DISABLE V.2ND.MOMENTS[cam]        ;data not needed
      DISABLE V.STROBE[cam]             ;strobes are not being used
      DISABLE V.MIN.MAX.RADII[cam]      ;data not needed
      PARAMETER V.MIN.AREA[cam] = 101   ;filter small areas
      PARAMETER V.MIN.HOLE.AREA[cam] = 100  ;        "
```

When we execute the main program, we send in an indication of whether to reinitialize the camera and cycle time variables. CALL the initialization program if the boolean is true (this routine is on page 130).

```
; If necessary, initialize the cycle time variables and load camera calibration
      IF re_init THEN
          CALL init.program(cam)
      END
; Set the display mode to a graphics mode so we can see the processed image
      VDISPLAY (cam) 3
```

**Acquire an Image and Start Processing**

We are now ready to start the application, and as with so many things in life, the first thing we do is wait. In this case we are waiting for the object to come into position in the field-of-view. Digital output signal 31 controls conveyor belt movement. Digital input signal 1032 has been configured to sense when the object is in position. As soon as signal 1032 is detected, signal 31 should be turned off, the system should begin timing the inspection operations, and the program should resume execution. (See *Adept MV Controller User's Guide* for details on installing digital I/O.)

```
; Start conveyor belt

      SIGNAL do.belt

; Wait for part ready signal (sig 1032) before beginning processing

      WAIT SIG(di.part_ready)
      SIGNAL -do.belt       ;shut off conveyor belt
      TIMER 1 = 0           ;start timing operation
```

After the part-in-place signal has been received, we are ready to take a picture. Since we will be reducing the processed area, we want to acquire an unprocessed image.

```
; Acquire an unprocessed image with camera 1

      VPICTURE (cam) 2
```

**Locate the Object and Begin Inspections**

We now have an unprocessed image and are ready to check the location of the object. The program “line.line()” makes this inspection. This program returns the coordinates of the object tail, the object rotation, and a boolean indicating the object was found. See “Subroutine - line.line” on page 128 for details.

```
; Locate sample object, calculate the tail point and object's rotation

      CALL line.line(tailx, taily, obj.rot, good_part)
```

The subroutine “return_part” takes the required steps when a part is rejected. Since the reject routine could have many options, it is left as a dummy call for you to complete.

```
; Call return program and get next part if point is not found

      IF NOT good_part THEN
          TYPE "The object was not found or was incorrectly positioned."
          CALL return_part()
      END ; if
```

We now know that the part is in place. We also know the location of the object tail and the rotation of the object. We will use this data plus the dimensions of the object to set an area-of-interest window. The VWINDOW instruction will define the image area to be processed and then process that area (see Figure 8-2).

```
;Use the coordinates of the object tail to set a processing window

       IF good_part THEN
           win_ibr = 3000                    ;AOI 3
           VDEF.AOI win_ibr = 1, tailx-obj_width/2, taily, obj_width+5,
obj_hgt+15, obj.rot
           VWINDOW (cam) win_ibr
```

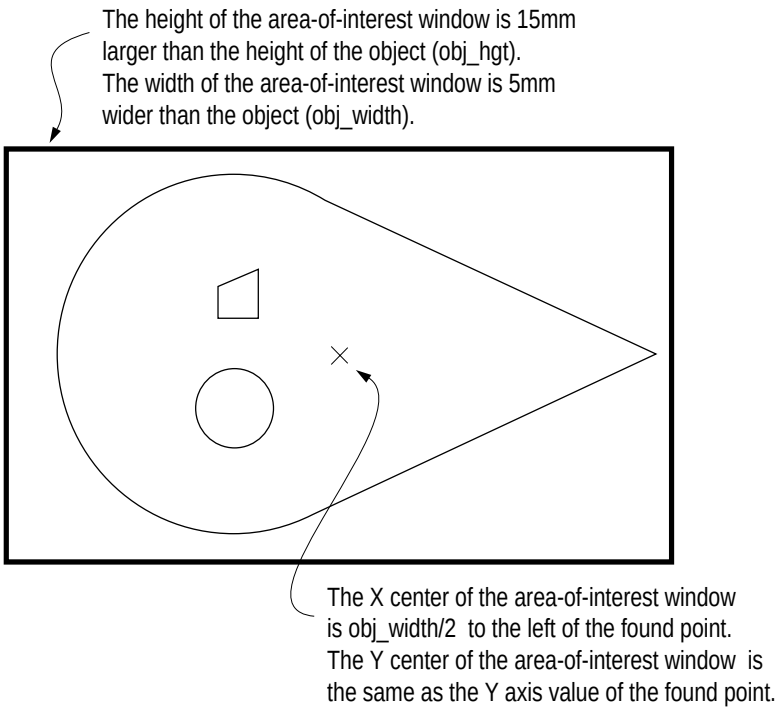



Figure 8-2. **Executing the VWINDOW Instruction**

We now have an object in the vision queue, and we are ready to do inspections on that object.

The first thing we will do is VLOCATE the object and check to be sure it has two holes. If it does not, we reject the part. If the part is to be rejected, we call the program “reject_part” which will activate the necessary machinery to remove the part and signal the conveyor belt to bring in the next part.

```
; Remove the object from the vision queue and make its characteristics
;   available to the VFEATURE function.

           VLOCATE (cam, 2) "?", obj.loc

; Check to see if a part was successfully located.

           IF NOT VFEATURE(1) THEN
```

```
            TYPE "A hole was not located."
            CALL reject_part()
            good_part = FALSE
        END
    END ; if good_part

; Check that there are two holes in the part

    IF good_part THEN
        IF VFEATURE(17) <> 2 THEN
            TYPE "The part has an incorrect number of holes."
            CALL reject_part()
            good_part = FALSE
        END
    END ; if good_part
```

The next inspection involves checking the distance from the centers of the circular and polygon holes to the center of the object. The part will be rejected if these values differ by more than 0.5 millimeters from their ideal values.

```
; Remove the holes from the queue and check their centroids.
;   Remove the largest hole (the circle) from the queue.

    IF good_part THEN
        VLOCATE (cam, 4, 1) , rnd.loc

; Save the circle's centroid X and Y values

        cent_circlex = VFEATURE(2)
        cent_circley = VFEATURE(3)

; The next hole removed will be the polygon

        VLOCATE (cam, 4) , poly.loc

; Calculate the distance

        rnd_act = DISTANCE(obj.loc,rnd.loc)
        poly_act = DISTANCE(obj.loc,poly.loc)

; Compare the distances and reject part if they are not within .5mm of correct.

        IF ABS(rnd_act-rnd_dist) > 0.5 THEN
            TYPE "The round hole is out of alignment."
            CALL reject_part()
            good_part = FALSE
        END ; if ABS

        IF ABS(poly_act-poly_dist) > 0.5 THEN
            TYPE "The polygon hole is out of alignment."
            CALL reject_part()
            good_part = FALSE
        END ; if ABS

    END ; if good_part
```

If the part passes this inspection, we turn to the circular hole to see if its diameter agrees with the correct value to within 1mm. We will use a linear ruler to perform this inspection.

```
; Place a ruler that starts at the center of the circular hole and
;   goes past its edge.

      IF good_part THEN
          rul_ibr = 4000                  ;AOI 4
          VDEF.AOI rul_ibr = 2, cent_circlex, cent_circley, 10, 0
          VRULERI (cam, 0, 1) circ_hole[] = rul_ibr

; Check the value of the first transition (which will be the radius)
;   against the required value.

          IF circ_hole[0] == 0 THEN
             TYPE "The radius of the circular hole could not be determined."
          ELSE
             IF ABS((2*circ_hole[2])-circ_diam) > 1 THEN
                 TYPE "The circular hole is not the correct size."
                 CALL reject_part()
                 good_part = FALSE
             END            ; if ABS
          END    ; þif circ_hole[0]
      END ; if good_part
```

We are now ready to inspect the polygon to see if the angle of the slanted face equals 25° (±2°). We will use a VFIND.LINE tool to make this inspection. The center coordinates of the polygon are still available through VFEATURE so we can center a VFIND.LINE tool on these coordinates.

```
; Place a VFIND.LINE tool at the center of the polygon, and have it
;   look in the negative Y direction for an edge. Search from dark
;   to light (object to background).

      IF good_part THEN
          lfdr_ibr = 501100               ;AOI 5
          VDEF.AOI lfdr_ibr = 1, VFEATURE(2), VFEATURE(3), 10, 10, obj.rot
          VFIND.LINE (cam, 0) poly_hole[] = lfdr_ibr

; Compare the actual value with the acceptable value

          IF ABS(poly_hole[4]-poly_angle) > 2 THEN
             TYPE "The poly shaped hole is incorrectly oriented."
             CALL reject_part()
             good_part = FALSE
          END; if ABS
      END ; if good_part
```

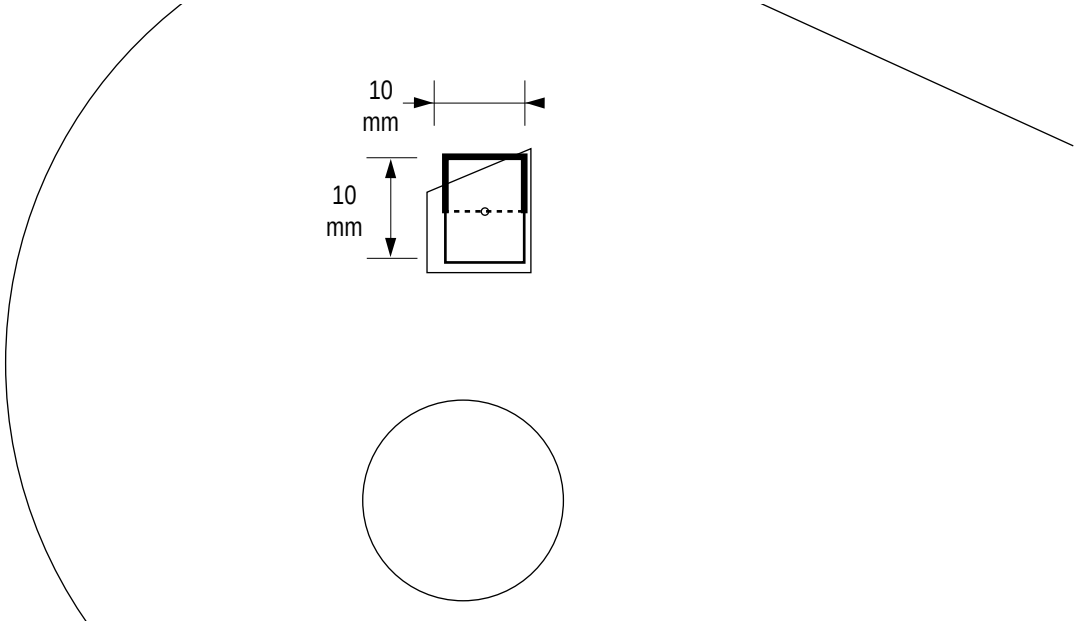



Figure 8-3. **Executing a VFIND.LINE Instruction**

The time has come to inspect the location of the arc on the front of the object with respect to the center line of the two holes. We will use the X,Y values of the object center to place the arc finder. If the actual center of the object arc does not coincide with the midpoint between the two holes (±1mm), the part will be rejected. We will use the VFIND.ARC tool to see if the arc center is centered between the two holes in the object.

```
       IF good_part THEN

; Calculate the X,Y center point for the arc finder

           x = DX(obj.loc)
           y = DY(obj.loc)

;Use the locations of the two holes to calculate the midpoint

           arc.centx = (DX(rnd.loc)+DX(poly.loc))/2
           arc.centy = (DY(rnd.loc)+DY(poly.loc))/2

; Place an arc finder centered around the two holes and look from
;   dark to light for an arc.

           afdr_ibr = 6000                  ;AOI 6
           VDEF.AOI afdr_ibr = 5, x, y, obj_hgt/2, obj_hgt/2+5, 90+obj.rot,
270+obj.rot
           VFIND.ARC (cam) arc_data[] = afdr_ibr

; Check to see if an arc was found

           IF NOT arc_data[0] THEN
```

```
            TYPE "The outer radius was not located."
            CALL reject_part()
            good_part = FALSE
         END ; if not
      END ; if good_part

; Calculate the center variance

      IF good_part THEN
         IF ((ABS(arc_data[2]-arc_centx) > 100) OR (ABS(arc_data[3]-arc_centy)
> 1)) THEN
            TYPE "The outer radius is not correctly aligned with the two
holes."
            CALL reject_part()
            good_part = FALSE
         END ; if ABS
      END ; if good_part
```

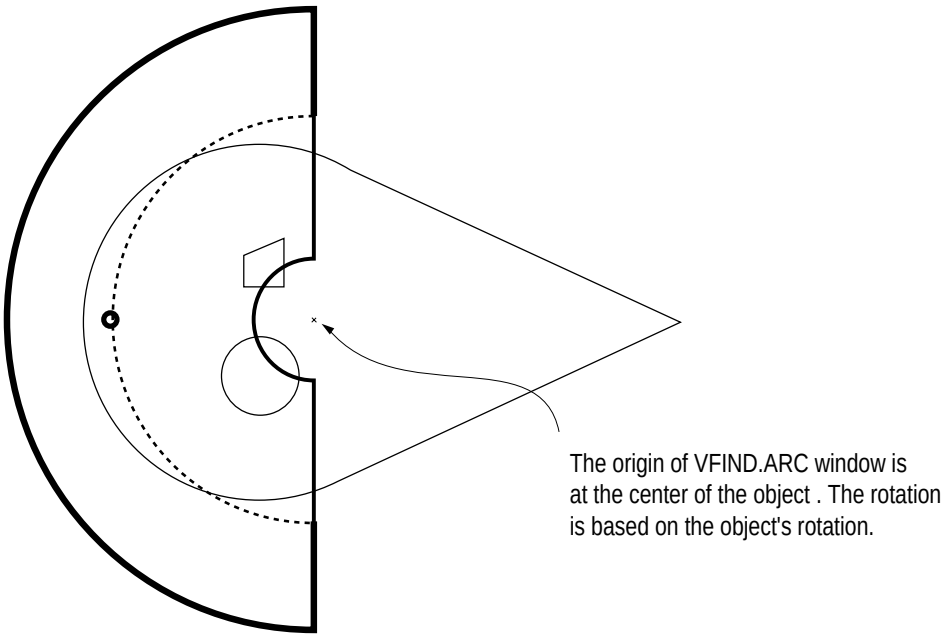



Figure 8-4. **Executing a VFIND.ARC Instruction**

We have at last come to the final inspection: looking at the surface gradation of the part to see that there is a constant gradation from light to dark across the part. We will use a grayscale ruler to perform this operation. A graylevel ruler differs from a regular ruler in that it returns the graylevel intensities for each pixel along the ruler rather than the transitions found along the ruler.

From the data array returned by the previous VFIND.ARC instruction, we know the center and radius of the object arc. We also know the width of the object. With this information we can place a ruler along the X axis and make sure it stays within the object.

```
; Place a graylevel ruler along the width of the object, starting at
;   object tail and ending 5mm from the edge of the object.

       IF good_part THEN
           grul_ibr = 7000                  ;AOI 7
           VDEF.AOI grul_ibr = 1, tailx-5, taily, obj_width-10, 180+obj.rot
           VRULERI (1, 1) gray_data[] = grul_ibr

; Calculate the graylevel changes every 25 pixels and compare them
;   with the acceptable value (gvalue).

           FOR i = 2 TO (gray_data[0]-25) STEP 25
              good_part = ABS(gray_data[i]-gray_data[i+25]/gvalue) > 0.9
              good_part = good_part AND (ABS((gray_data[i]-gray_data[i+25])/
gvalue < 1.1))
              IF NOT good_part THEN
                  CALL reject_part()
                  TYPE "Graylevel ruler failed."
                  GOTO 90                          ;exit on failure
              END
           END            ; for i = 2
       END ;þþþif good_part
```

**Output the Results**

If the part has gotten to this stage, it has passed all its inspections and is ready to be moved on down the line. We now read the cycle timer to see how long the cycle took and update the global variables that keep track of cycle time. Then we ship the part to the next station.

```
; Read the timer

    90 cycle_time = TIMER(1)

; Calculate the total time.

       total_time = cycle_time+(avg_time*num_parts)
       IF good_part THEN
           num_parts = num_parts+1
       END
       IF num_parts == 0 THEN
           avg_time = 0
       ELSE
           avg_time = total_time/num_parts
       END
```

Once we have gathered the data, we will output this information as text to the vision window. $V^+$ provides several “G” commands to control output to graphics windows. The GTYPE instruction is used in the subroutine write.vwin to do this. Write.vwin is introduced in the next code segment, and the code for the complete subroutine is shown at the end of this chapter. The other “G” commands are covered in the *$V^+$ Language Reference Guide*.

```
; Output the data to the vision window.

      $msg[0] = "Average Processing Time: "
      $msg[1] = $ENCODE(avg_time)
      $msg[2] = "Number of units passed: "
      $msg[3] = $ENCODE(num_parts)

; Get the mm/pixel ratio and divide the screen into 20 lines

      VGETCAL (cam) cal[]
      hgt = cal[16]*480     ;Screen height in millimeters
      inc = hgt/20

; Start at the first line and indent text one line

      x = inc
      y = inc

      FOR i = 3 TO 0 STEP -1

; Write text results to vision window

          CALL write.vwin(cam, x, y, $msg[i], $err)
          y = y+inc
          IF $err <> "" THEN
             TYPE $err             ;Output error message
             EXIT
          END
      END
```

Before we look at the next object, let's set V.THRESHOLD if it hasn't been set recently. We'll use timer 2 to decide when to change thresholds. In this case we will reset the threshold every half hour (1,800 seconds).

```
; Read timer 2 to see how long it has been since the threshold was set.
;   If it exceeds 30 minutes, set V.THRESHOLD and restart timer 2.

      ttime = TIMER(2)
      IF ttime > 1800 THEN
          VWAIT                          ;make sure the processor is idle
          VAUTOTHR tarray[]
          IF tarray[0] THEN
             PARAMETER V.THRESHOLD = tarray[1]
          END; if
          TIMER 2 = 0
      END ; if

.END
```

One program cycle is now complete. The number of cycles executed can be controlled several ways. A WHILE loop around the entire program could watch for operator input of a digital input signal. A FOR loop with an operator input index could control an absolute number of cycles. Or, as

is the case in this program, the program is executed with a –1 argument indicating the program should loop until it is aborted.

## Further Programming Considerations

The program presented here is not very robust and could be modified to make it much more "crash proof." For example, inspections can be done to eliminate the requirement that the part enter the field of view within 12mm of the desired location. In Chapter 10 we will describe the use of frames and prototype-relative processing that will allow you to inspect objects in any orientation.

The data arrays that are returned by the finder and ruler tools provide information with which to make much more rigid inspections of the part. You will also find that the assumptions made about a particular feature being in the expected place may not be warranted. Whenever a VLOCATE is done, check VFEATURE(1) to see if the locate was successful.

Also bear in mind that during each successive cycle, only the array values generated during the current cycle will overwrite the values generated during the last cycle. So if you expect four transitions from a ruler, and only three are generated, the array location that would normally hold the fourth value will not be blank but will hold the fourth value from the previous cycle.

This program provides no opportunity for operator intervention when errors are generated. You will want your programs to be much more fault tolerant. The simplest method is to place an IF...THEN clause around conditions that indicate errors and prompt for operator attention. In a more complicated vein, the program could communicate with other cell devices or computers in an attempt to nonfatally resolve errors.

As you build a more robust program, you will likely find that each inspection should be broken down into its own subroutine. This will make the program more readable and maintainable.

## 8.5 The Complete Inspection Vision Program

### The Main Program - inspect.part

```
.PROGRAM inspect.part(re_init)
;
; ABSTRACT:  Inspect the sample object for defects in the round and
;       þþpolygon shaped holes, the arc at the front of the object, and the
;      surface gradation.
;
; INPUT PARM:   re_init    determine whether to call the system initialization
;        þþ                routine. 1 = re-initialize, 0 = no initialization
;
; OUTPUT PARM: None
;
; SIDE EFFECTS: The global variables 'num_parts' and 'avg_time'
;       will be updated.
;
; Declare local variables
;
      AUTO obj_width               ;object width
      AUTO cent_circlex, cent_circley;x, y center of circular object
      AUTO obj_centx, obj_centy    ;x, y center of the object
      AUTO arc_centx, arc_centy    ;x, y center of object arc
      AUTO gvalue                  ;acceptable graylevel variance
      AUTO good_part               ;boolean indicating status of part
      AUTO di.part_ready           ;digital sig indicating part is ready
      AUTO cycle_time              ;average inspection cycle time
      AUTO do.belt                 ;digital sig for conveyor belt
      AUTO poly_angle, circ_diam   ;correct part dimensions
      AUTO poly_dist, poly_act     ;              "
      AUTO rnd_dist, rnd_act       ;              "
      AUTO win_ibr, rul_ibr, lfdr_ibr;define areas-of-interest
      AUTO afdr_ibr, grul_ibr
      AUTO last, $msg[19], $err
      AUTO i, lun

; Initialize known values

      obj_length = 0
      obj_centx = 85               ;object center X (within 12mm)
      obj_centy = 60               ;object center Y (within 12mm)
      obj_width = 82               ;object width
      obj_hgt = 50                 ;object height
      gvalue = 10                  ;acceptable graylevel variance
      poly_angle = 25              ;correct angle of polygon edge
      poly_dist = 19               ;correct dist from object center
      rnd_dist = 17                ;            "
      do.belt = 31                 ;digital signal for conveyor belt
      di.part_ready = 1032         ;digital signal for part ready
      good_part = TRUE             ;assume the part is good
      circ_diam = 10               ;correct diameter of circular hole
      cam = 1                      ;virtual camera used for inspections

; Set switches and parameters
```

```
       ENABLE V.HOLES[cam]          ;hole information is needed
       ENABLE V.BINARY[cam]         ;processing to be in binary mode
       ENABLE V.BOUNDARIES[cam]     ;region analysis will be done
       ENABLE V.BACKLIGHT[cam]      ;dark objects on a light background
       DISABLE V.PERIMETER[cam]     ;data not needed
       DISABLE V.DISJOINT[cam]      ;must be disabled to get hole data
       DISABLE V.RECOGNITION[cam]   ;no prototype recognition
       DISABLE V.TOUCHING[cam]      ;we have only one part
       DISABLE V.OVERLAPPING[cam]   ;
       DISABLE V.2ND.MOMENTS[cam]   ;data not needed
       DISABLE V.STROBE[cam]        ;strobes are not being used
       DISABLE V.MIN.MAX.RADII[cam] ;data not needed
       PARAMETER V.MIN.AREA[cam] = 101      ;filter small areas
       PARAMETER V.MIN.HOLE.AREA[cam] = 100  ;         "

; If necessary, initialize the cycle time variables and load camera calibration

       IF re_init THEN
           CALL init.program(cam)
       END
; Set the display mode to a graphics mode so we can see the processed image.

       VDISPLAY (cam) 3

; Start conveyor belt

       SIGNAL do.belt

; Wait for part ready signal (sig 1032) before beginning processing

       WAIT SIG(di.part_ready)
       SIGNAL -do.belt       ;shut off conveyor belt
       TIMER 1 = 0           ;start timing operation

; Acquire an unprocessed image with camera 1

       VPICTURE (cam) 2

; Locate sample object, calculate the tail point and object's rotation

       CALL line.line(tailx, taily, obj.rot, good_part)

; Call return program and get next part if point is not found

       IF NOT good_part THEN
           TYPE "The object was not found or was incorrectly positioned."
           CALL return_part()
       END ; if


;Use the coordinates of the object tail to set a processing window

       IF good_part THEN
           win_ibr = 3000                   ;AOI 3
           VDEF.AOI win_ibr = 1, tailx-obj_width/2, taily, obj_width+5,
obj_hgt+15, obj.rot
```

```
           VWINDOW (cam) win_ibr


; Remove the object from the vision queue and make its characteristics
;   available to the VFEATURE function.

           VLOCATE (cam, 2) "?", obj.loc

; Check to see if a part was successfully located.

           IF NOT VFEATURE(1) THEN
              TYPE "A hole was not located."
              CALL reject_part()
              good_part = FALSE
           END
       END ; if good_part

; Check that there are two holes in the part

       IF good_part THEN
           IF VFEATURE(17) <> 2 THEN
              TYPE "The part has an incorrect number of holes."
              CALL reject_part()
              good_part = FALSE
           END
       END ; if good_part

; Remove the holes from the queue and check their centroids.
;   Remove the largest hole (the circle) from the queue.

       IF good_part THEN
           VLOCATE (cam, 4, 1) , rnd.loc

; Save the circle's centroid X and Y values

           cent_circlex = VFEATURE(2)
           cent_circley = VFEATURE(3)

; The next hole removed will be the polygon

           VLOCATE (cam, 4) , poly.loc

; Calculate the distance

           rnd_act = DISTANCE(obj.loc,rnd.loc)
           poly_act = DISTANCE(obj.loc,poly.loc)

; Compare the distances and reject part if they are not within .5mm of correct.

           IF ABS(rnd_act-rnd_dist) > 0.5 THEN
              TYPE "The round hole is out of alignment."
              CALL reject_part()
              good_part = FALSE
           END ; if ABS

           IF ABS(poly_act-poly_dist) > 0.5 THEN
              TYPE "The polygon hole is out of alignment."
```

```
            CALL reject_part()
            good_part = FALSE
         END; if ABS

      END ; if good_part

; Place a ruler that starts at the center of the circular hole and
;   goes past its edge.

      IF good_part THEN
         rul_ibr = 4000                  ;AOI 4
         VDEF.AOI rul_ibr = 2, cent_circlex, cent_circley, 10, 0
         VRULERI (cam, 0, 1) circ_hole[] = rul_ibr

; Check the value of the first transition (which will be the radius)
;   against the required value.

         IF circ_hole[0] == 0 THEN
            TYPE "The radius of the circular hole could not be determined."
         ELSE
            IF ABS((2*circ_hole[2])-circ_diam) > 1 THEN
               TYPE "The circular hole is not the correct size."
               CALL reject_part()
               good_part = FALSE
            END           ; if ABS
         END    ; þif circ_hole[0]
      END ; if good_part

; Place a VFIND.LINE tool at the center of the polygon, and have it
;   look in the negative Y direction for an edge. Search from dark
;   to light (object to background).

      IF good_part THEN
         lfdr_ibr = 5000                 ;AOI 5
         VDEF.AOI lfdr_ibr = 1, VFEATURE(2), VFEATURE(3), 10, 10, obj.rot
         VFIND.LINE (cam, 0) poly_hole[] = lfdr_ibr

; Compare the actual value with the acceptable value

         IF ABS(poly_hole[4]-poly_angle) > 2 THEN
            TYPE "The poly shaped hole is incorrectly oriented."
            CALL reject_part()
            good_part = FALSE
         END; if ABS
      END ; if good_part

      IF good_part THEN

; Calculate the X,Y center point for the arc finder

         x = DX(obj.loc)
         y = DY(obj.loc)

;Use the locations of the two holes to calculate the mid-point

         arc.centx = (DX(rnd.loc)+DX(poly.loc))/2
         arc.centy = (DY(rnd.loc)+DY(poly.loc))/2
```

```
; Place an arc finder centered around the two holes and look from
;   dark to light for an arc.

          afdr_ibr = 6000                 ;AOI 6
          VDEF.AOI afdr_ibr = 5, x, y, obj_hgt/2, obj_hgt/2+5, 90+obj.rot,
270+obj. rot
          VFIND.ARC (cam) arc_data[] = afdr_ibr

; Check to see if an arc was found

          IF NOT arc_data[0] THEN
             TYPE "The outer radius was not located."
             CALL reject_part()
             good_part = FALSE
          END ; if not
      END ; if good_part

; Calculate the center variance

      IF good_part THEN
          IF ((ABS(arc_data[2]-arc_centx) > 100) OR (ABS(arc_data[3]-arc_centy)
> 1)) THEN
             TYPE "The outer radius is not correctly aligned with the two
holes."
             CALL reject_part()
             good_part = FALSE
          END ; if ABS
      END ; if good_part

; Place a graylevel ruler along the width of the object, starting at
;   object tail and ending 5mm from the edge of the object.

      IF good_part THEN
          grul_ibr = 7000                 ;AOI 7
          VDEF.AOI grul_ibr = 1, tailx-5, taily, obj_width-10, 180+obj.rot
          VRULERI (1, 1) gray_data[] = grul_ibr

; Calculate the graylevel changes every 25 pixels and compare them
;   with the acceptable value (gvalue).

          FOR i = 2 TO (gray_data[0]-25) STEP 25
             good_part = ABS(gray_data[i]-gray_data[i+25]/gvalue) > 0.9
             good_part = good_part AND (ABS((gray_data[i]-gray_data[i+25])/
gvalue < 1.1))
             IF NOT good_part THEN
                 CALL reject_part()
                 TYPE "Graylevel ruler failed."
                 GOTO 90    ;exit on failure
             END
          END            ; for i = 2
      END ;þþþif good_part

; Read the timer

    90 cycle_time = TIMER(1)
```

```
; Calculate the total time.

      total_time = cycle_time+(avg_time*num_parts)
      IF good_part THEN
          num_parts = num_parts+1
      END
      IF num_parts == 0 THEN
          avg_time = 0
      ELSE
          avg_time = total_time/num_parts
      END

; Output the data to the vision window.

      $msg[0] = "Average Processing Time: "
      $msg[1] = $ENCODE(avg_time)
      $msg[2] = "Number of units passed: "
      $msg[3] = $ENCODE(num_parts)

; Get the mm/pixel ratio and divide the screen into 20 lines

      VGETCAL (cam) cal[]
      hgt = cal[16]*480     ;Screen height in millimeters
      inc = hgt/20

; Start at the first line and indent text one line

      x = inc
      y = inc

      FOR i = 3 TO 0 STEP -1
          CALL write.vwin(cam, x, y, $msg[i], $err)
          y = y + inc

          IF $err <> "" THEN
             TYPE $err             ;Output error message
             EXIT
          END
      END

; Read timer 2 to see how long it has been since the threshold was set.
;   If it exceeds 30 minutes, set V.THRESHOLD and restart timer 2.

      ttime = TIMER(2)
      IF ttime > 1800 THEN
          VWAIT                            ;make sure the processor is idle
          VAUTOTHR tarray[]
          IF tarray[0] THEN
             PARAMETER V.THRESHOLD = tarray[1]
          END; if
          TIMER 2 = 0
      END ; if

.END
```

### Subroutine - line.line

```
.PROGRAM line.line(x, y, tool.ang, status)

;
; ABSTRACT: This program uses data from two line finder tools to calculate
;       the intersection of two lines, and the angle of a line bisecting
;       the intersection point (used to place other tools). The current frame
;       store must have a valid image.
;
; INPUT PARM: None
;
; OUTPUT PARMS:  x - x coordinate of the intersection point
;       y - y coordinate of the intersection point
;       tool.ang - angle of a line bisecting the intersection point
;       status - success of operation
;
; SIDE EFFECTS: None
;
      LOCAL ang.t, xt, yt, dxt, dyt        ;top line data
      LOCAL ang.b, xb, yb, dxb, dyb        ;bottom line data
      LOCAL obj.ang                        ;angle between sides of the object
      LOCAL aoi1, aoi2

      status = TRUE                        ;assume lines are found

; Place the two line finders

      aoi1 = 1001
      aoi2 = 2001
      VDEF.AOI aoi1 = 1, 110, 80, 40, 30, 150
      VDEF.AOI aoi2 = 1, 110, 50, 40, 30, 30
      VFIND.LINE (1) top[] = aoi1
      VFIND.LINE (1) bottom[] = aoi2

; Check to see if both lines were found

      IF NOT (top[0] AND bottom[0]) THEN
          status = FALSE                   ;return failure in status
          GOTO 100
      END

; Extract the line finder data

      ang.t = top[4]
      ang.b = bottom[4]
      dxt = COS(ang.t)
      dyt = SIN(ang.t)
      dxb = COS(ang.b)
      dyb = SIN(ang.b)
      xt = top[2]
      yt = top[3]
      xb = bottom[2]
      yb = bottom[3]

; Calculate the rotation of the object
```

```
        obj.ang = ang.b+180-ang.t
        tool.ang = ang.b-(obj.ang/2)

; Calculate the intersection point

        numerator = (yb-yt)*dxb-(xb-xt)*dyb

        IF ABS(dxt) > ABS(dyt) THEN
            fract = dyt/dxt
            f = numerator/(fract*dxb-dyb)
            x = xt+f
            y = yt+fract*f
        ELSE
            fract = dxt/dyt
            f = numerator/(dxb-fract*dyb)
            y = yt+f
            x = xt+fract*f
        END

    100 ;Exit on failure

.END
```

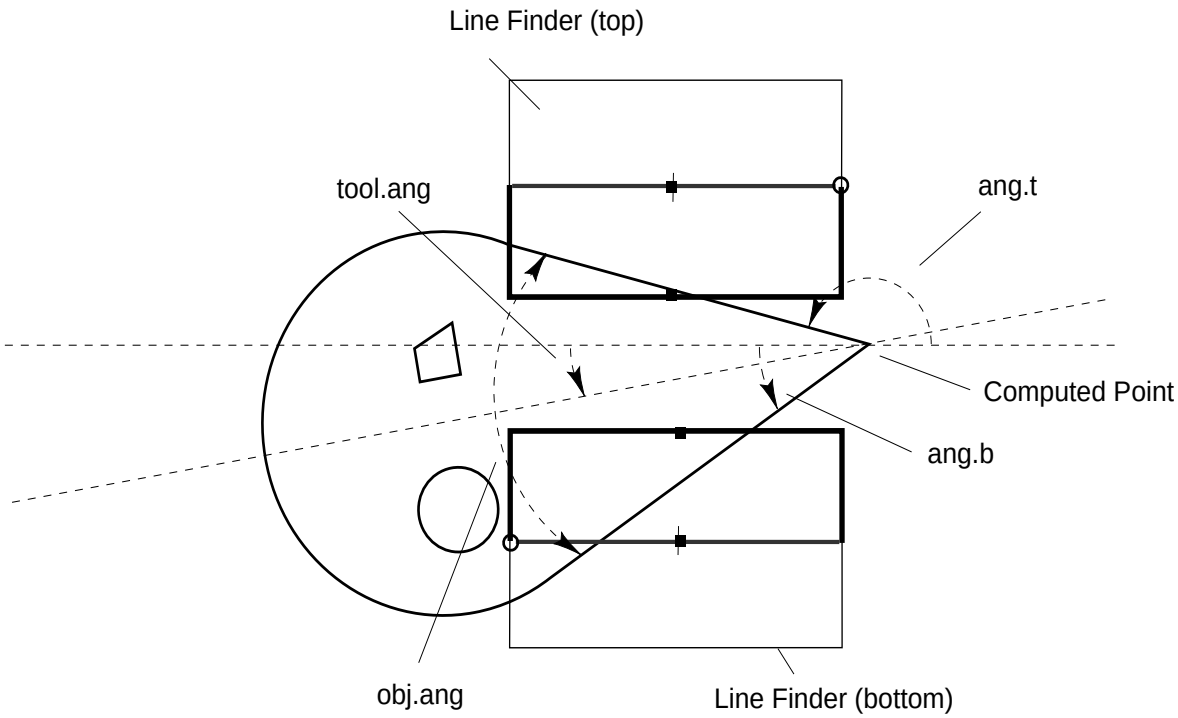



Figure 8-5**. Calculating the Object Tail Location**

### Subroutine - init.program

```
.PROGRAM init.program(cam)


; ABSTRACT:   This program initializes the cycle time statistics and camera
;              environment.
;
; INPUT PARMS:    cam        virtual camera being used
;
; OUTPUT PARMS:   None
;
;GLOBAL VARS:   to.cam, thresholds[], cam.cal[], $err
;
; SIDE EFFECTS: If the global variables avg_time, total_time, and num_parts
;       are not defined, they are set to 0
;

       num_parts = 0
       avg_time = 0
       total_time = 0

; Load calibration data.  load.area is supplied on the utility disk in the
; file LOADAREA.V2.  See the "Instructions for Adept Utility Programs" for
; details on the calling sequence.

       CALL load.area("area87.dat", cam, thresholds[], TRUE, to.cam, cam.cal[],
$err)

; Reset the timer used to determine when to recalculate V.THRESHOLD

       TIMER (2) = 0

; Set the binary threshold

       VAUTOTHR thresholds[]
       IF thresholds[0] THEN
           PARAMETER V.THRESHOLD = thresholds[0]
       ELSE
           TYPE "A threshold could not be computed. Check the lens aperture
setting."
       END

.END
```

### Subroutine - write.vwin

```
.PROGRAM write.vwin(cam, x, y, $text, $err)

; ABSTRACT: This program demonstrates how to use the millimeter scaling mode of
;      GTRANS to label an object in the vision window.
;
; INPUT PARM: cam     virtual camera number (REAL variable)
;                     x, y    location of text on vision screen (REAL variable)
;                     $text          text containing (STRING variable)
;
; OUTPUT PARM: $err   string containing error messages

       AUTO vlun

       $err = ""      ;Assume no error

; Attach and open the vision window

       ATTACH (vlun, 4) "GRAPHICS"
       IF (IOSTAT(vlun) < 0) OR (vlun == -1) GOTO 100

       FOPEN (vlun) "Vision";Open the vision window
       IF IOSTAT(vlun) < 0 GOTO 100

; Select display mode, color, and graphics mode

       VDISPLAY (cam) 1, 1   ;Display grayscale frame and graphics

       GCOLOR(vlun) 1        ;Select the color black
       GTRANS (vlun, 1)      ;Select millimeter scaling

; Output the text to the screen at the desired location

       GTYPE(vlun) x, y, $text, 3

; Detach from the logical unit (frees up the communications path)

       DETACH (vlun)

; Check for errors

100    IF (IOSTAT(vlun) < 0) THEN
           $err = $ERROR(IOSTAT(vlun))
       END
       IF vlun == -1 THEN
           $err = "All logical units are in use."
           PAUSE
       END


.END
```

# 9 Guidance Vision

## 9.1 Introduction

Before a camera can be used for inspection or guidance vision, the camera must be calibrated and the calibration data must be transferred to the vision system. Cameras are normally calibrated using the advanced camera calibration utility. See the *Advanced Camera Calibration Program User's Guide* for details. Once you have calibrated a camera and stored the calibration data to a disk, the calibration data can be loaded from disk using the LOADAREA utility program (on the Adept Utility Disk #1). See the sample program on page 130 for an example. (Camera calibration data must be reloaded each time the controller is turned off or system memory is zeroed. See "Loading Vision Calibration Data" on page 31.)

One element of the camera-to-robot calibration relates the vision coordinate frame (see Figure 9-1) to the world coordinate system of the robot. The vision system returns X and Y coordinates and RZ rotation defining the location and orientation of an object with respect to the vision coordinate system. This information is combined into a transformation value that represents an object's location in world coordinates. This section describes how to use the two most common camera mountings: fixed-mount camera and cameras mounted on the second link of several common robot types. Additional camera mountings are described in the camera calibration user's guide.

## 9.2 Using a Fixed-Mount Camera

A fixed-mount camera is any camera that acquires images at a fixed location in the robot workspace.

The following code will locate a "blob" and then move the robot to the blob's location:

```
.PROGRAM pickup.part.fix (); pickup part with fixed camera

; ABSTRACT: The following sample program is used to:
;    1) Move to a  location outside the camera field of view
;    2) Locate a single part using blob recognition
;    3) Acquire the part with a single pneumatic gripper (vacuum or mechanical)
;    4) Raise the part 50 mm
;
; COMMENTS: In order for this program to run, a location called "pic.loc" must
;    already exist. When the robot is at pic.loc, the part must be in the
;    camera's field of view and not obstructed by the robot.

     LOCAL obj.loc, part.loc, vis.loc, $ret

     MOVE pic.loc              ; Move to picture taking location
     BREAK                     ; Stop robot

     VPICTURE (1)  -1          ; Take picture with camera 1

     VLOCATE(1, 0) $name, vis.loc    ; Find single object in field of view
                                     ; with Blob recognition
     SET obj.loc = to.cam[1]:vis.loc:RZ(VFEATURE(48)); Determine the location
                                                     ; and orientation of the
                                                     ; part in world coordinates
; Transformation to.cam[1] is generated by the Advanced Camera Calibration
;    Utility Program and loaded by the utility LOADAREA.V2 on the Adept Utility
;    Disk

     IF NOT DEFINED (grip.trans) THEN
; If it is necessary to reteach the "grip.trans" transformation, the existing
;    "grip.trans" transformation must be deleted at the system prompt by typing
;    DELETEL GRIP.TRANS before executing this program.
```

```
        DETACH(0)                ; Detach robot so pendant can be used

        TYPE " Using the pendant, place the gripper on the part to pick it up"
        TYPE " Once the robot is in position, Hit COMP/PWR on the pendant"
        PROMPT " and hit return on the keyboard ", $ret

        HERE obj.loc:grip.trans
        ATTACH(0)                ; Reattach robot

    END

    SET part.loc = obj.loc:grip.trans    ;Complete transformation to pickup
                                         ;part.  part.loc should have pitch of
                                         ;180. Check by typing LISTL part.loc

    APPRO part.loc, 50         ; Approach part by 50 mm
    BREAK                      ; Stop robot

    MOVE part.loc              ; Move to part
    BREAK
    CLOSEI                     ; Close gripper or turn on vacuum

    DEPART 50                  ; Move part up 50 mm
    BREAK
.END
```

The location variables in the preceding code are calculated as follows:

to.cam [1] — is the camera calibration transformation for virtual camera 1.

vis.loc — is the vision location returned by the VLOCATE instruction.[1] The transformation returned by boundary analysis has a rotation the same as the vision coordinate frame. The axis of least inertia (returned by VFEATURE(48)) is used to calculate the location orientation.

grip.trans — is the grip transformation for the part. Since the vision system can calculate location data only in a two-dimensional plane, an additional transformation must be defined to account for the Z component of the final world location (and possibly the gripper rotation necessary for grasping a part).

**CAUTION:** A new grip transformation should be defined whenever new calibration data is computed. Failure to use a valid grip transformation could cause the robot to run into the part or the work surface when moving to a location determined from a vision image.

part.loc — is the compound transformation based on the vision location (vis.loc), the camera calibration transformation (to.cam), and the grip transformation. This transformation represents the part location in world coordinates.

Figure 9-1 shows the components of the vision transformation, “to.cam”, “vis.loc”, and “grip.trans”.

[1] The vision location (vis.loc) can be created by any vision operation(s) that return information that can be used to calculate a transformation representing the location of an object within the vision coordinate system. The remainder of this chapter and the next chapter describe vision operations that return location data.

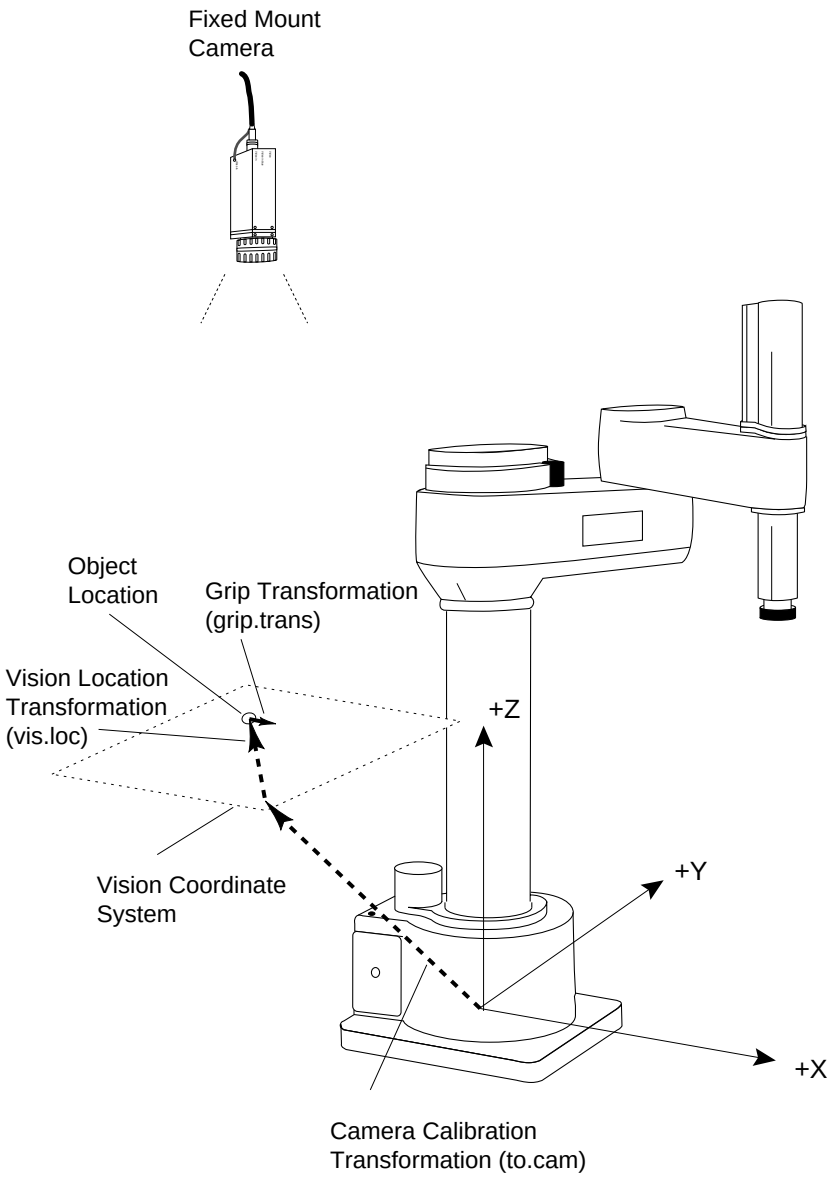



Figure 9-1. **Fixed-Mount Camera (Vision Location)**

Figure 9-2 shows all the components of the vision transformation, plus the resulting compound transformation, “part.loc”.

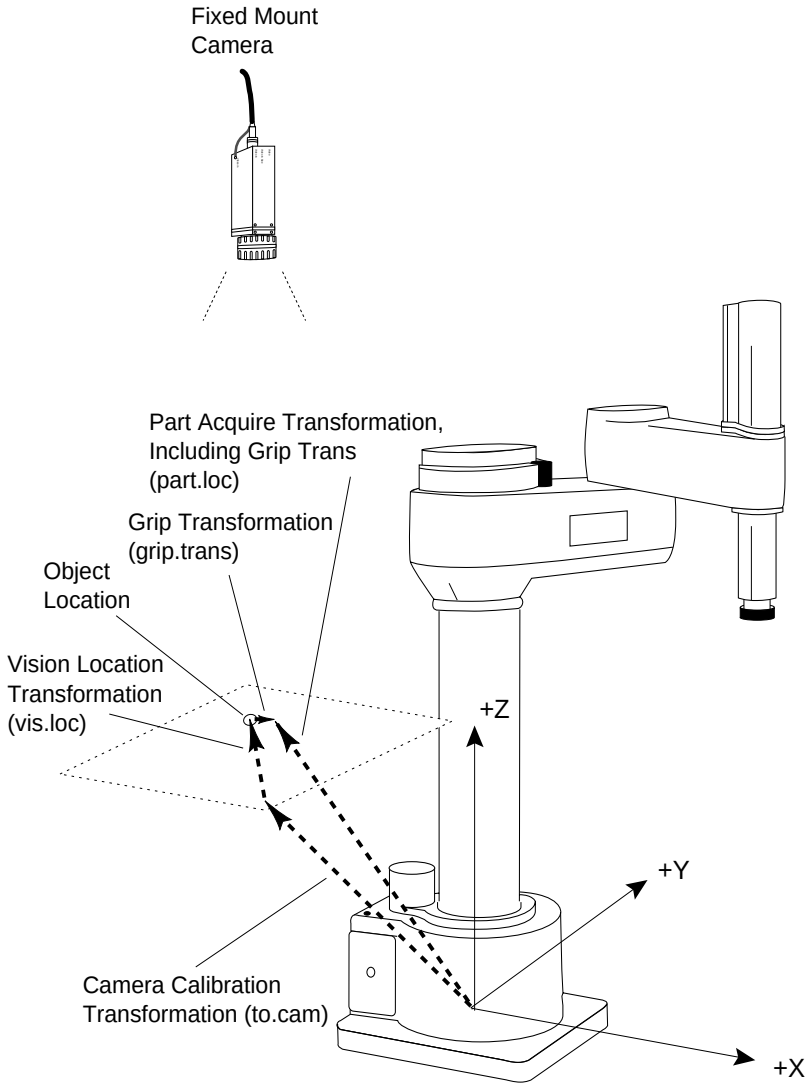



Figure 9-2. **Fixed-Mount Camera Vision Transformation**

## 9.3 4-Axis SCARA Robot with Camera on Link #2

The instructions in this section will work for a camera mounted on SCARA, XY, XYZ, or XYZ-Theta type robots. The strategies shown in this section can be extended to define a guided vision application with the camera mounted on any axis of a motion device.

When you use a robot-mounted camera, the camera calibration transformation defines the location of the vision coordinate frame relative to the robot link on which the camera is mounted. In order to use location information from the vision system, you must know the relationship between the link holding the camera and the robot world coordinate system.

For a camera mounted on the robot, we conceptually break down the robot into a series of “links” connected by “joints”. Each link can be considered as having its own coordinate system. For example, the world coordinate system is the same as the coordinate system of the base of the robot (link #0). For Adept SCARA robots, the origin of the world coordinate system is on the joint-1 axis at the level of the robot base.

The “outer” link of an Adept SCARA robot is link #2. (Figure 9-3 shows the “link2” coordinate frame.) We define the coordinate system for link #2 as follows:

- The origin is fixed relative to the outer link, at the center of the quill, at the height of the quill flange when joint 3 is at its zero position.
- The Z axis points down.
- The X axis points away from joint #2, as if it is an extension of the outer link.

The following program shows how to locate and acquire a part with a camera mounted on link #2.

```
.PROGRAM pickup.part.lk2(); pickup part with link 2 camera

; ABSTRACT: The following sample program is used to:
;     1) Move to a  picture taking location
;     2) Locate a single part using blob recognition
;     3) Acquire the part with a single pneumatic gripper (vacuum or mechanical)
;     4) Raise the part 50 mm
;
; COMMENTS: In order for this program to run, a location called "pic.loc" must
;     already exist. When the robot is at pic.loc, the part must be in the
;     camera's field of view.

     LOCAL jt[], link2, obj.loc, part.loc, vis.loc, $ret

     MOVE pic.loc          ; Move to picture taking location
     BREAK                 ; Stop robot

     DELAY 0.1             ; Let camera settle for 0.1 seconds
     BREAK

     HERE #pic.loc         ; Create a precision point at pic.loc

     VPICTURE (1)  -1      ; Take picture with camera 1

     VLOCATE(1, 0) $name, vis.loc    ; Find single object in field of view
                                     ; with Blob recognition

     DECOMPOSE jt[1]=#pic.loc   ; Obtain joints values at #pic.loc for
                                ; use in building part location transformation

     SET link2=HERE:RZ(-jt[4]):TRANS(,,-jt[3])  ; Develop first part of object
                                                ; transformation
     SET obj.loc = link2:to.cam[1]:vis.loc:RZ(VFEATURE(48)) ; Develop world
                                                           ; location of object
```

```
     ; Transformation to.cam[1] is generated by the Advanced Camera Calibration
     ; Utility Program and loaded by the utility LOADAREA.V2 on the Adept
Utility
     ; Disk

     IF NOT DEFINED (grip.trans) THEN

     ; If it is necessary to reteach the "grip.trans" transformation, the
     ; existing "grip.trans" transformation must be deleted at the system prompt
     ; by typing DELETEL GRIP.TRANS before executing this program.

          DETACH(0)       ; Detach robot so pendant can be used

          TYPE " Using the pendant, place the gripper on the part to pick it up"
          TYPE " Once the robot is in position, Hit COMP/PWR on the pendant"
          PROMPT " and Hit return on the Keyboard", $ret

          HERE obj.loc:grip.trans
          ATTACH(0)       ; Reattach robot

     END

     SET part.loc = obj.loc:grip.trans; Complete transformation to pickup
                                      ; part. part.loc should have pitch of 180.
                                      ; Check by typing LISTL part.loc

     APPRO part.loc, 50   ; Approach part by 50 mm
     BREAK                ; Stop robot

     MOVE part.loc        ; Move to part
     BREAK
     CLOSEI               ; Close gripper or turn on vacuum
     DEPART 50            ; Move part up 50 mm
     BREAK
.END
```

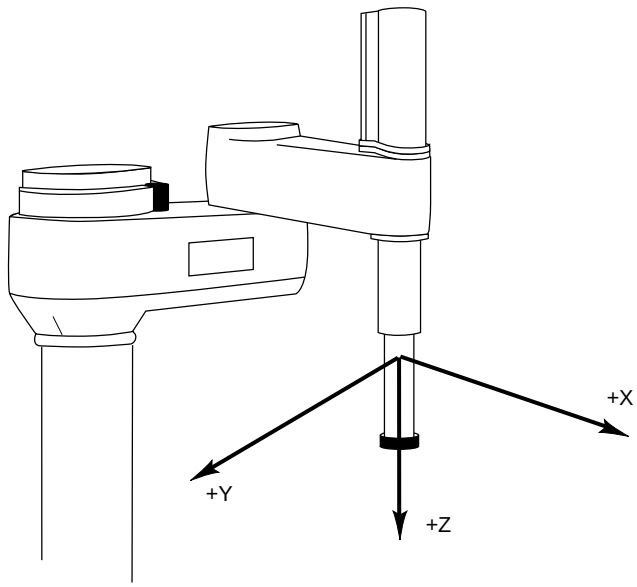



Figure 9-3. **Link2 Coordinate Frame**

Figure 9-4 shows the link transformation, “link2”, that was calculated by the preceding program instructions. The program instruction HERE creates a transformation in world coordinates that represents the current tool tip. RZ(–jt[4]) removes any rotation of joint4 from the resulting transformation. TRANS(,,–jt[3]) removes any quill extension from the transformation. Note: the preceding program and Figure 9-4 assume that a NULL TOOL is invoked. If a NULL TOOL is not used, then the link transformation (last code line on page 138) should be changed to:

```
SET link2 = HERE:INVERSE(TOOL):RZ(-jt[4]):TRANS(,,-jt[3])
```

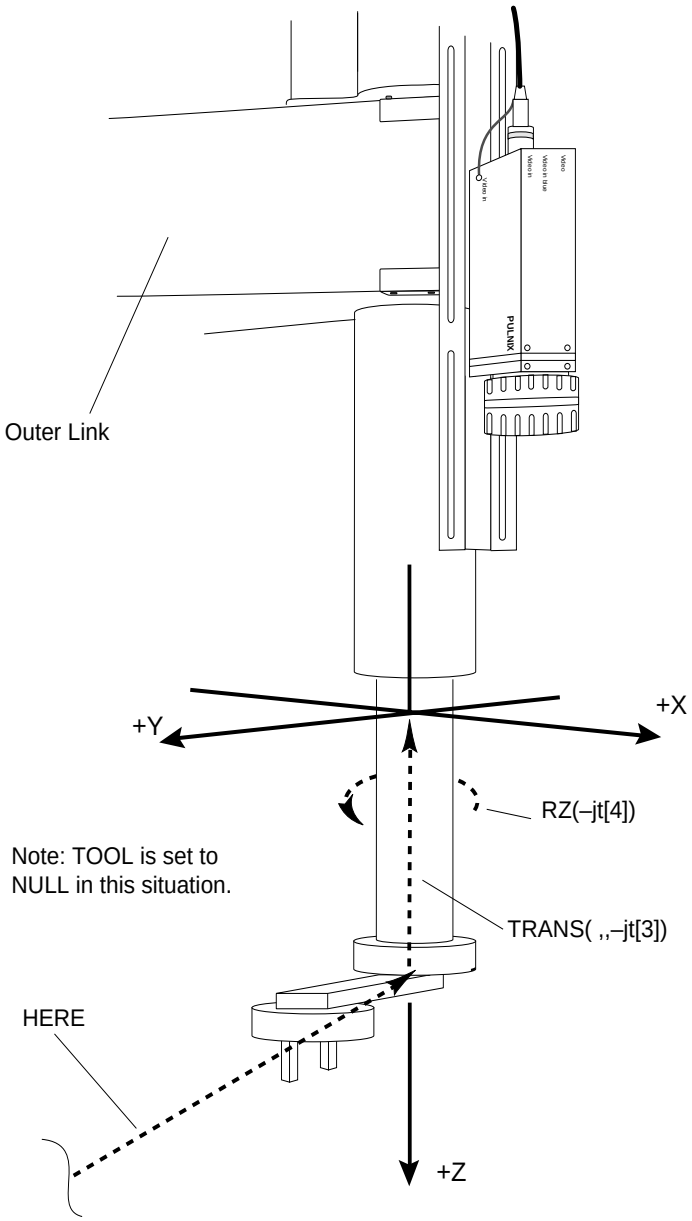



Figure 9-4. **Calculating the “Link2” Transformation**

Since the camera calibration transformation was created based on the link2 coordinate frame, anytime you use the camera calibration transformation ("to.cam" in this example), it must be applied to the link2 coordinate frame.

Note that the value of "link2" must be computed from the robot's location when the vision image is acquired. Thus, the instructions above will have to be executed each time a picture is taken at a new location.

Figure 9-5 shows how the remaining components of the location are calculated. "link2" was calculated as shown in Figure 9-4. "to.cam [1]" (created during camera calibration) is added to create a transformation relating the vision coordinate system to the world coordinate system. "vis.loc" (returned by a vision operation—blob recognition in this case) is added to create a transformation that represents the location of the found part in the XY plane of the vision coordinate system. RZ(VFEATURE(48)) is added to give the orientation of the part. "grip.trans" is added to create a transformation that offsets and/or rotates the gripper if the found object is to be acquired at a location offset or rotated from the location returned by the vision operation.

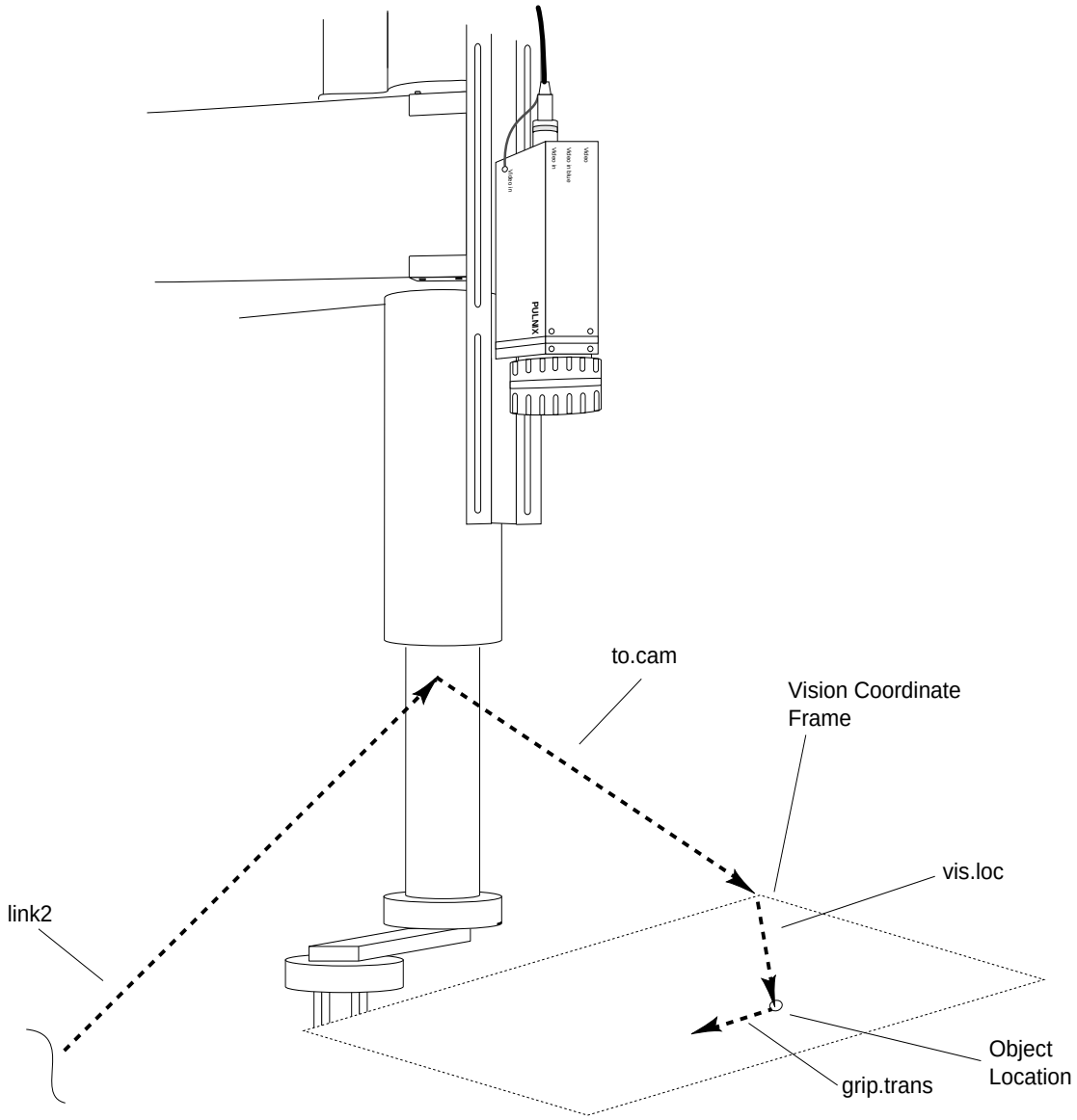



Figure 9-5. **Components of the Vision Location**

Figure 9-6 summarizes the transformations used when calculating the final part acquire location.

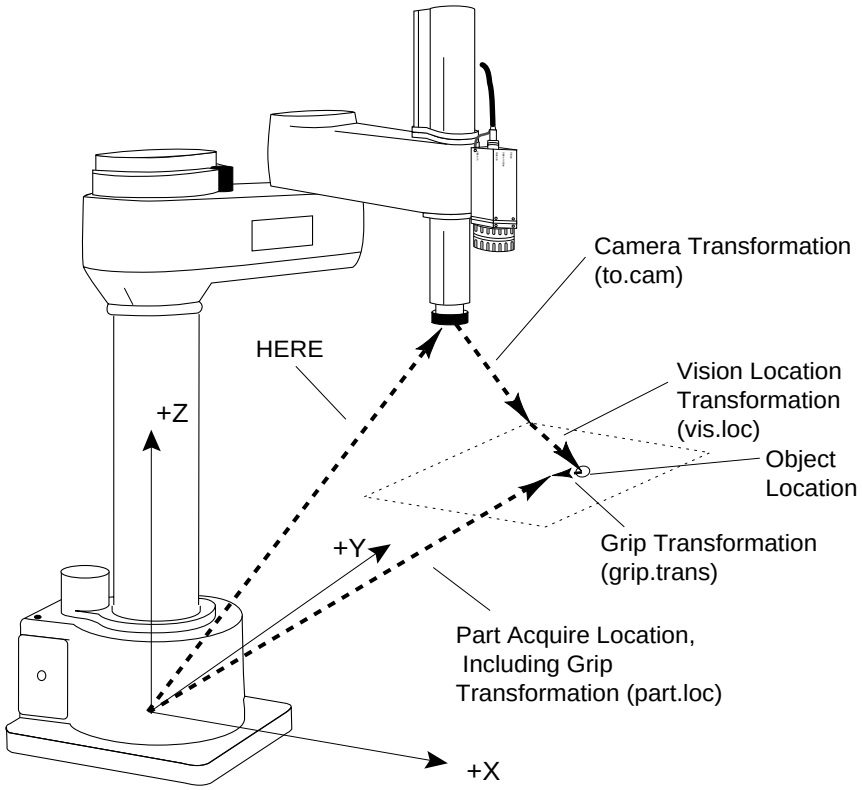



Figure 9-6. **Final Part Acquire Location**

## 9.4 5-Axis SCARA Robot with Camera on Link #2

If a fifth axis is attached to an Adept SCARA Robot (AdeptOne and AdeptThree) we now have another joint that must be accounted for when we calculate the "link2" coordinate frame. When a fifth axis is mounted on the robot, the kinematic model automatically sets the null tool from the normal position at the end of joint three (the tool flange) to the pivot point of the fifth axis. However, the fifth axis has an additional offset from the pivot point to the new tool flange that needs to be nulled in the "link2" transformation. The dimension of this offset is 50mm. Starting at the end of the robot the procedure is as follows: Find the current location of the end effector "HERE", null any tool transformation currently in effect "INVERSE(TOOL)", null the offset along the negative tool Z axis "TRANS(,,-50)", null the rotation of the fifth axis (rotation about the local Y axis) "RY(-jt[5])", null the rotation of joint 4 (rotation about the local Z axis) "RZ(-jt[4])", null the height of joint 3 "TRANS(,,-jt[3])". Use the "link2" transformation below when working with a fifth axis and the camera mounted on link #2.

```
SET link2 = HERE:INVERSE(TOOL):TRANS(,,-50):RY(-jt[5]):RZ(-jt[4]):TRANS(,,-jt[3])
```

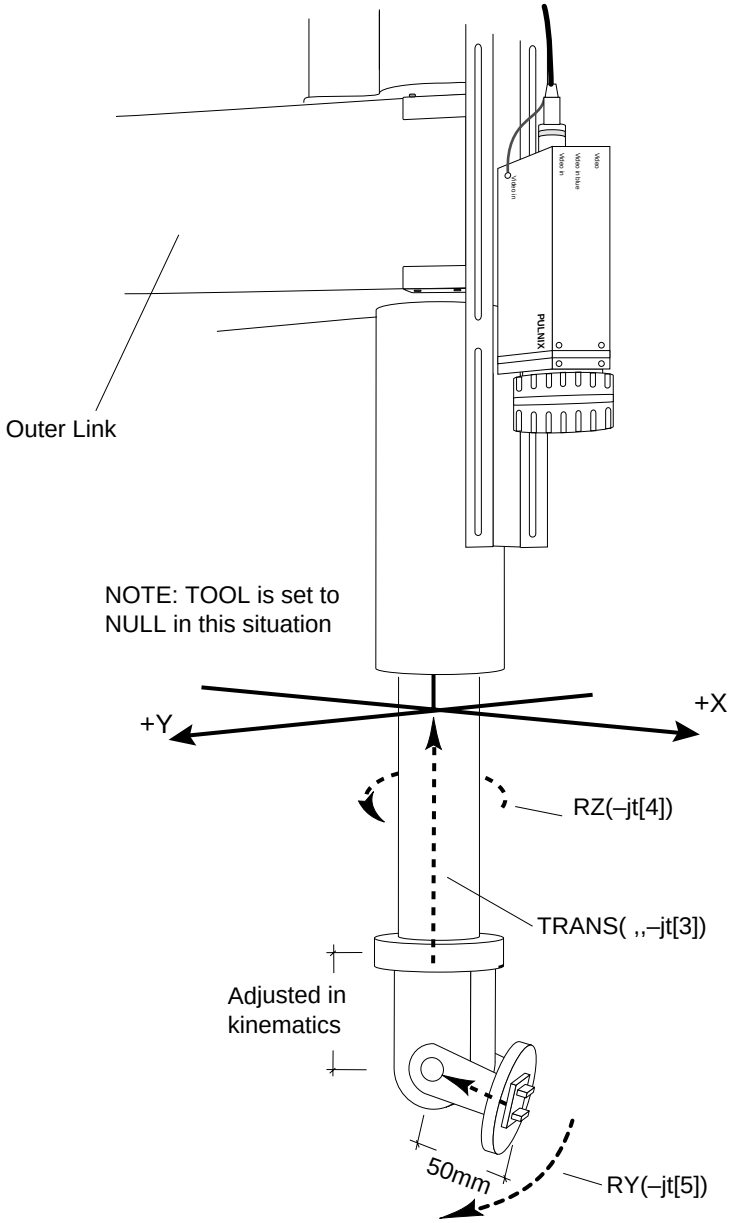



Figure 9-7. **Five-Axis Vision Transformation**

## 9.5 Guidance Vision Program

This section details the development of an AdeptVision VME guidance vision program. The program includes vision instructions that were presented in previous chapters as well as other V+ program instructions. As you go through this example, remember that we are not attempting to present the most efficient guidance vision application. We are attempting to present examples of vision instructions in a simple, straightforward context.

This example assumes that you are familiar with basic V+ programming. All the commands presented in this example are detailed in the *V+ Language Reference Guide* or the *AdeptVision Reference Guide.*

The program listed below will pick up round parts from one conveyor belt and palletize them to pallets on another conveyor belt. The parts will be randomly located on the conveyor belt. An arm-mounted camera will be used to locate the parts and guide the robot to pick them up. Both conveyor belts are "indexing" belts and will be started and stopped using digital I/O signals.

After each part is picked up, it will be presented to a fixed-mount upward-looking camera for inspection. If the part passes inspection, it will be palletized. Otherwise, it will be taken to a scrap bin.

The conveyor belt carrying the pallets holds the pallets rigidly in parallel with the robot X axis so no X axis correction is necessary. The pallets are also rotationally rigid so no rotation correction is necessary. There is some variance in the absolute Y location. This variance is calculated using a fixed-mount downward-looking camera. Figure 9-8 shows the physical setup for this workcell.

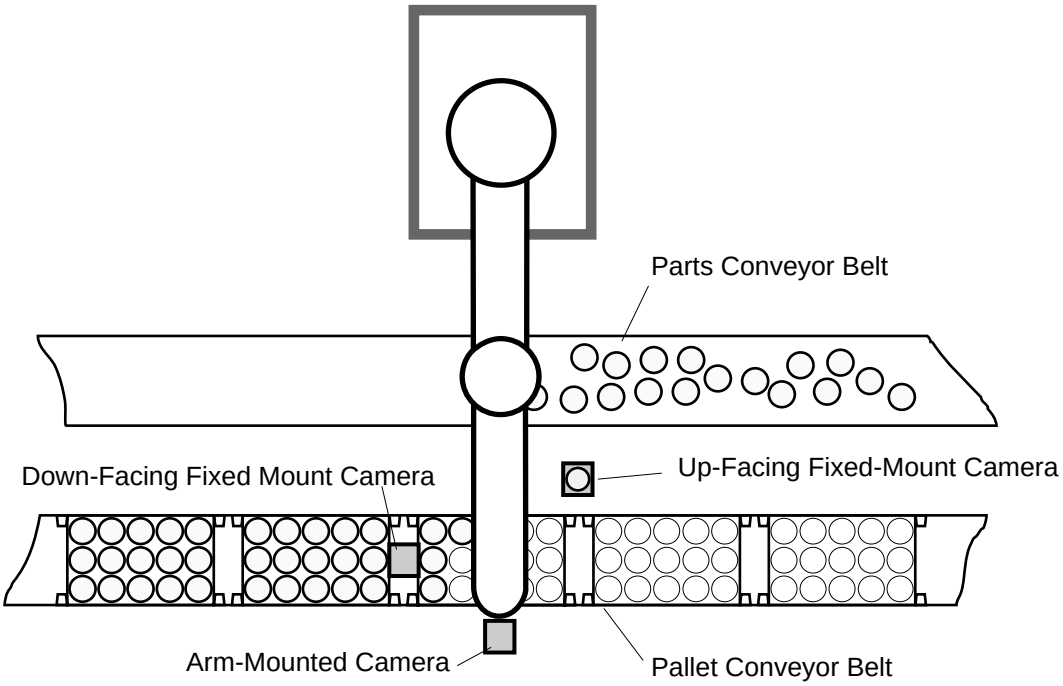



Figure 9-8. **Example Program Setup**

## The Sample Program

```
.PROGRAM guided.vis.examp()

; ABSTRACT: This program implements a robot workcell that:
;   1) Allows teaching of workcell locations if necessary,
;   2) Visually locates parts brought into the workcell on an
;      indexing conveyor,
;   3) Picks up the parts and presents them to a camera for inspection,
;   4) Discards the part if it fails, or palletizes it if it passes.
;   The program will also load camera calibration files that have
;   been previously stored on the default disk.
;
; INPUT PARMS:  None
;
; OUTPUT PARMS: None
;
; SIDE EFFECTS: The following global variables are set:
;   pallet.loc - location of row 1, col 1 on the pallet
;   pallet.frame - reference frame for the pallet
;   inspect.loc - location robot presents part to up-mounted camera
;   pic.loc - location robot takes picture of incoming part
;   scrap.loc - location robot takes rejected parts
;   arm.cam - number of the arm-mounted camera (locates parts)
;   up.cam - number of the upward-looking camera (inspects parts)
;   dwn.cam - number of the downward-looking camera (locates pallets)
;   di.oper - input signal controlling main processing loop
;   di.part.ready - input signal indicating a part is ready
;   di.pallet.ready - input signal indicating a pallet is ready
;   do.pal.belt - output signal driving the pallet conveyor
;   do.part.belt - output signal driving the parts conveyor
;

    AUTO row, col, max.rows, max.cols, row.dist, col.dist
    AUTO passed, num.parts
    AUTO $ans
    AUTO gripz
    AUTO i

; Initialize variables

    arm.cam = 1
    dwn.cam = 2
    up.cam = 3
    di.oper = 1001
    di.part.ready = 1002
    di.pallet.ready = 1003
    do.pal.belt = 5
    do.part.belt = 6

    passed = FALSE  ;Assume the part failed inspection
    row = 1
    col = 1
    max.rows = 3    ;The pallet is 3x5
    max.cols = 5
    row.dist = 50   ;Spacing of pallet locations
    col.dist = 50
```

```
    ENABLE UPPER

; Check to see if camera cal data is loaded - load if necessary

    IF NOT DEFINED(to.cam[1]) THEN
        CALL load.cam.cal()
    END

; Should the operator create new robot locations?

    DO
        PROMPT "Do you want to teach new robot locations? ", $ans
    UNTIL ($ans == "y") OR ($ans == "n")

    IF $ans == "y" THEN

; Get the first pallet

        SIGNAL do.pal.belt
        TYPE "Waiting for pallet."
        WAIT SIG(di.pallet.ready)
        SIGNAL -do.pal.belt

; Teach the robot locations

        CALL teach.pallet(max.rows, max.cols, pal.offset, gripz)

    ELSE

; Bring in a new pallet and update the pallet location

        CALL new.pallet(pal.offset, pal.correction)
        SET cur.frame = SHIFT(pallet.frame BY ,pal.correction)

    END


; Start up the workcell

    TYPE /C1
    PROMPT "Turn on the RUN switch and press ENTER when ready to begin.", $ans
    WAIT SIG(di.oper)

    WHILE SIG(di.oper) DO

; Move to the picture taking location and settle the robot

        MOVE pic.loc
        DELAY 0.2
        BREAK

; Bring parts into the workcell

        SIGNAL do.part.belt
        TYPE "Waiting on a part."
        WAIT SIG(di.part.ready)
        SIGNAL -do.part.belt
```

```
;Create the variables for determining the link2 coordinate frame

        HERE #pic.loc
        DECOMPOSE jt[1] = #pic.loc
        VPICTURE (arm.cam) -1, 0

; Make sure vision processor is idle, then determine how many parts are seen

        VWAIT
        num.parts = VQUEUE(arm.cam,"?")

; Locate the parts and palletize them

        FOR i = 1 TO num.parts
            VLOCATE (arm.cam, 2) "?", vis.loc

; Calculate the object location in world coordinates

            SET link2 = pic.loc:RZ(-jt[4]):TRANS(,,-jt[3])
            SET part.loc = link2:to.cam[1]:vis.loc:TRANS(,,gripz,,180)

; Pick up the part

            APPRO part.loc, 50
            OPENI
            SPEED 20
            MOVE part.loc
            CLOSEI
            BREAK
            DEPART 50

; Inspect the part

            CALL inspect.part(passed)

; If the part passed, palletize it...

            IF passed THEN
                row.offset = row.dist*(row-1)
                col.offset = col.dist*(col-1)
                SET place.loc =
cur.frame:TRANS(row.offset,col.offset):pallet.loc
                APPRO place.loc, 50
                SPEED 20
                MOVE place.loc
                OPENI
                DEPART 50

; Check the row and column count, increment or reset as necessary

                IF row < max.rows THEN
                    row = row+1
                ELSE
                    row = 1
                    IF col < max.cols THEN
                        col = col+1
                    ELSE        ;Bring in a new pallet
```

```
                        row = 1
                        col = 1
                        CALL new.pallet(pal.offset, pal.correction)
                        SET cur.frame = SHIFT(pallet.frame BY ,pal.correction)
                    END ;if row
                END ;if col

; If the part failed, move it to the scrap location.

            ELSE
                APPROS scrap.loc, 50
                MOVE scrap.loc
                OPENI
                DEPART 50
            END ;if passed

;Get ready to take a new picture

            MOVE pic.loc

        END ;for i = 1

    END ;WHILE SIG(di.oper)

.END
```

```
.PROGRAM inspect.part(passed)

; ABSTRACT: This program uses an upward-looking camera to inspect a
;   round part presented to the camera by a robot. An arc finder is used
;   to check the radius of the part. The global variable up.cam identifies
;   virtual camera being used.
;
; INPUT PARMS:  None
;
; OUTPUT PARMS: passed   indicates whether or not the part passed
;
; SIDE EFFECTS: None

    LOCAL x, y, r.tool, r.search, up.limit, low.limit

    x = 100
    y = 100
    r.tool = 25
    r.search = 75
    up.limit = 24
    low.limit = 26

; Move the part inspection location

    MOVE inspect.loc
    DELAY 0.5
    BREAK

; Acquire an image and place the arc finder

    VPICTURE (up.cam) 2
    VDEF.AOI 3000 = 5, x, y, r.tool, r.search, 0, 0
    VFIND.ARC (up.cam, 5) data[] = 3000

; If an arc is found and the radius is within the limits, the part passes

    passed = DATA[0]
    IF passed THEN
        passed = (data[4] > low.limit) AND (data[4] < up.limit)
    END

.END
```

```
.PROGRAM load.cam.cal()

; ABSTRACT:  This program loads the camera calibration data for three
;   cameras. The calibration files must have been created and stored
;   on the default disk. Global variables arm.cam, dwn.cam, and up.cam
;   must have been previously defined.
;
; INPUT PARM:  None
;
; OUTPUT PARM: None
;
; SIDE EFFECTS: The array elements to.cam[1] - to.cam[3] are updated and three
;   virtual cameras are readied for use.
;
    LOCAL $arm.cal, $dwn.cal, $up.cal
    LOCAL $arm.dat, $dwn.dat, $up.dat

; Get the calibration data file numbers

    TYPE /C24, /U20
    PROMPT "What is the calibration number for the arm-mounted camera? ",
$arm.dat
    PROMPT "What is the calibration number for the down-mounted camera? ",
$dwn.dat
    PROMPT "What is the calibration number for the up-mounted camera? ", $up.dat

    $arm.cal = "area"+$arm.dat+".dat"
    $dwn.cal = "area"+$dwn.dat+".dat"
    $up.cam = "area"+$up.dat+".dat"

; Load the calibration files. See the "Instructions for Adept Utility Programs"
; for details on 'load.area'.

    CALL load.area($arm.cal, arm.cam, VAL($arm.dat), TRUE, to.cam[1], arm.cam.
cal[], $error)
    CALL load.area($dwn.cal, dwn.cam, VAL($dwn.dat), TRUE, to.cam[2], dwn.cam.
cal[], $error)
    CALL load.area($up.cal, up.cam, VAL($up.dat), TRUE, to.cam[3], up.cam.cal[],
$error)

.END
```

```
.PROGRAM new.pallet(orig.offset, correction)

; ABSTRACT: This program monitors the proper digital I/O to bring a new
;   pallet into the workcell. When a pallet is in place, a line finder
;   calculates the new pallet correction factor.
;
; INPUT PARM: orig.offset   the offset that was calculated when the pallet
;             reference frame was originally taught.
;
; OUTPUT PARM: correction   the difference between the location of the
;             original pallet and the current pallet.

; Bring the pallet into the workcell

    SIGNAL do.pal.belt
    TYPE "Waiting for pallet."
    WAIT SIG(di.pallet.ready)
    SIGNAL -do.pal.belt

; Locate the edge of the current pallet and calculate the difference
; between it and the original pallet.

    VDISPLAY (dwn.cam) -1, 1
    VPICTURE (dwn.cam) 2
    VDEF.AOI 2000 = 1, 100, 150, 50, 25, 180
    VFIND.LINE (dwn.cam) data[] = 2000

    correction = data[3]-orig.offset

.END
```

```
.PROGRAM teach.pallet(rows, cols, pal.offset, gripz)

; ABSTRACT: This program teaches all the locations required by the
;   palletizing workcell. It creates a reference frame for the pallet and
;   calculates the Z offset for parts being acquired based on arm-mounted
;   camera data.
;
; INPUT PARMS: rows    number of rows in the pallet
;   cols    number of columns in the pallet
;
; OUTPUT PARMS: pal.offset    offset from the vertical edge of the field-
;                             of-view to the edge of a pallet.
;   gripz   the Z value for the grip transformation used to acquire
;             parts based on arm-mounted camera data.

; SIDE EFFECTS: The following global locations are updated:
;   pallet.loc - reference frame for the pallet
;   pic.loc - picture taking location for acquiring a part
;   inspect.loc - picture taking location for part inspection
;   scrap.loc - part reject location
;   pallet.frame - reference frame for the pallet

    AUTO fr.origin, fr.posx, fr.posy ;pallet frame locations
    AUTO $ans
    AUTO jt[], data[]

; Get the three locations required to establish a pallet reference frame.

    DETACH ()
    TYPE /C24, /U20, "Create the pallet reference frame."
    TYPE "Place the robot at the row 1, col 1 location on the pallet."
    PROMPT "Press ENTER when ready. ", $ans
    HERE fr.origin

    TYPE /C2, "Place the robot on the row 1, col ", rows," location."
    PROMPT "Press ENTER when ready. ", $ans
    HERE fr.posx

    TYPE /C2, "Place the robot in the row ", rows, " col ", cols," location."
    PROMPT "Press ENTER when ready. ", $ans
    HERE fr.posy

; Create the pallet frame

    SET pallet.frame = FRAME(fr.origin,fr.posx,fr.posy,fr.origin)

; Return to the frame origin and create the row1, col1 pallet location (relative
; to 'pallet.frame').

    TYPE "Enable 'COMP' mode.";Make sure comp mode is selected
    PROMPT "The robot will return to the frame origin. Press ENTER.", $ans
    ATTACH ()
    SPEED 20 ALWAYS         ;Slow down while in teach routine
    DEPART 50
    APPRO fr.origin, 50
    MOVE fr.origin
    BREAK
```

```
    HERE pallet.frame:pallet.loc
    DEPART 50
    SPEED 100
    DETACH ()

; Create the part acquire picture taking location

    TYPE /C2, "Establish the part acquire picture taking location."
    VPICTURE (arm.cam) 2
    VDISPLAY -1, 1
    TYPE "Place the robot at the picture taking location."
    PROMPT "Press ENTER when ready. ", $ans
    HERE pic.loc

; Create the part inspect picture taking location

    TYPE /C2, "Establish the part inspect picture taking location."
    VPICTURE (up.cam) 2
    VDISPLAY -1, 1
    TYPE "Place the robot at the picture taking location."
    PROMPT "Press ENTER when ready. ", $ans
    HERE inspect.loc

; Create the part reject location

    TYPE /C2, "Establish the part reject location."
    TYPE "Place the robot at the reject location."
    PROMPT "Press ENTER when ready. ", $ans
    HERE scrap.loc

; Calculate the Z offset for the grip transformation
; (A NULL TOOL is assumed, and no grip offset from the center of the part is
; needed.)

    TYPE /C2, "Establish the nominal part pickup location."
    TYPE "Place a sample part in the field of view and grip it with the robot."
    PROMPT "Press ENTER when ready.", $ans

; The grip trans will be added to the transformation composed of the link2
; coordinate frame and the camera calibration location.

    HERE #part.nom
    DECOMPOSE jt[1] = #part.nom
    SET link2 = HERE:RZ(-jt[4]):TRANS(,,-jt[3])
    HERE link2:to.cam[1]:part.loc
    ATTACH ()

;Extract the Z offset for the part

    gripz = DZ(part.loc)

;Determine the nominal offset of the pallet

    VPICTURE (dwn.cam)
    VDEF.AOI 6000 = 1, 100, 150, 50, 25, 180
    VFIND.LINE (2) data[] = 6000
    pal.offset = data[3]
.END
```

## 9.6 Further Programming Considerations

### Error Handling

In the interest of presenting clear examples, several necessary steps have been left out of this program. The most basic missing steps are error handling and data validation. The data arrays returned by the various vision tools include a boolean value that tells you whether the tool found anything. This value should be checked before attempting to access any of the other data array values. This is particularly important during multiple iterations of the program. When a tool instruction is processed, the previously created array values are not deleted; they are overwritten with any new values generated. This means that if a tool fails, the only array value overwritten will be the one indicating that the tool failed. The other array values will contain the values from the previous iteration of the tool.

Location values should be checked to see if they can be reached by the motion device. It is possible to create a transformation that the motion device cannot reach. The INRANGE function can be used to check a location prior to issuing the move instruction to that location.

During the teaching phase of the program, the operator should have been given the opportunity to verify the locations. For critical locations, teaching the location several times and then averaging the components of each instance may be in order.

All I/O instructions should be checked with the IOSTAT function to make sure they were successful. Since I/O failures are not fatal, if your program does not detect and deal with them, the program will continue on as if the I/O were successful.

### Generalizing the Program

The above program has several constraints that could be alleviated to make it more versatile. The first restriction is on the shape of the parts. The program assumes they are radially symmetrical so the robot gripper can pick them up in any orientation. If the parts are not radially symmetrical, the grip transformation would need to take into account any offset or rotation. The part pick up location would also need to have the rotational component calculated. One method of finding this orientation is with the major ellipse axis data available through VFEATURE. If the part has been prototyped, the prototype reference frame can be used to calculate the part rotation.

The pallet is allowed to move only parallel to the robot Y axis. This restriction could be removed by putting unique fiducial marks on the pallet and then using the vision system to calculate the pallet's orientation.

This example uses an "indexing" conveyor—the conveyor moves parts into position and then stops until the assembly or palletizing operation is complete. The *V+ Language User's Guide* provides details on setting up and calibrating a moving conveyor.

The inspection of the part was extremely simple. A realistic inspection would require additional tools and possibly presenting the part to the camera in different orientations.

# Advanced Operations 10

# 10.1 Performing High-Speed Inspections

### What is "High Speed?"

The definition of high speed will vary considerably from application to application. Generally, an operation that inspects parts on the order of several per second is considered a high-speed operation. The physical limit of AdeptVision VME is one picture every 16 milliseconds. The actual rates you will be able to achieve depend on how complicated your inspections are, the level of operator feedback required, and the accuracy of positioning of the inspected parts.

You will achieve the highest inspection rates when you follow these guidelines:

1. Always acquire an unprocessed image (VPICTURE mode 2).
2. If you are displaying the image, display a frozen image. If you are displaying graphics, use the special mode described in the section below, "Using VDISPLAY With Different Frame Stores."
3. Enable V.BINARY so the edge operator is not performed at every picture.
4. Use both of AdeptVision VME's frame stores to inspect alternating parts (the two frame stores are described next).
5. Have the system gather the minimum data required to successfully inspect the part.
6. Use vision tools, such as raw binary or fine-edge rulers, that operate on unpro cessed image data whenever possible.
7. Rulers are faster when they are rotated exactly 0°, 45°, 90°, 135°, 180° etc.
8. If an inspection needs to be performed on processed image data, perform the inspection within as small an inspection window as practical.
9. Make the inspection tools as small as practical.
10. VWINDOW, VWINDOWB, and VWINDOWI tools that are oriented orthogonally are much faster than rotated windows.
11. When using tools that return a variable number of elements to an array (such as VRULERI), limit the number of array elements the tool looks for.
12. On tools that allow you to set the effort level, set the lowest level possible that still achieves effective inspections.
13. Fixture the part as accurately as possible so processing time does not have to be expended looking for the part.
14. Organize the sequence of inspections so the most likely sources of failure are checked first. Terminate inspections as soon as a failure is detected.
15. A strobing device or a shuttered camera with a 1/1,000 shutter speed will be required for high-speed inspections.
16. Image processing and acquisition is faster with field acquires than with full frame acquires.

17. Make the object size only as large as necessary in the field of view so that required resolution is achieved.

18. Use low resolution virtual frame buffers whenever possible.

## Using the Two Frame Store Areas

AdeptVision VME provides you with two frame store areas into which you can store two different images. Each frame store area has two image buffers; raw grayscale data is stored in one buffer and binary data is stored in the other. Using the two frame stores, you can acquire an image in one area while you are processing the image in the other area. This operation is referred to as "ping-ponging" (see Figure 10-1).

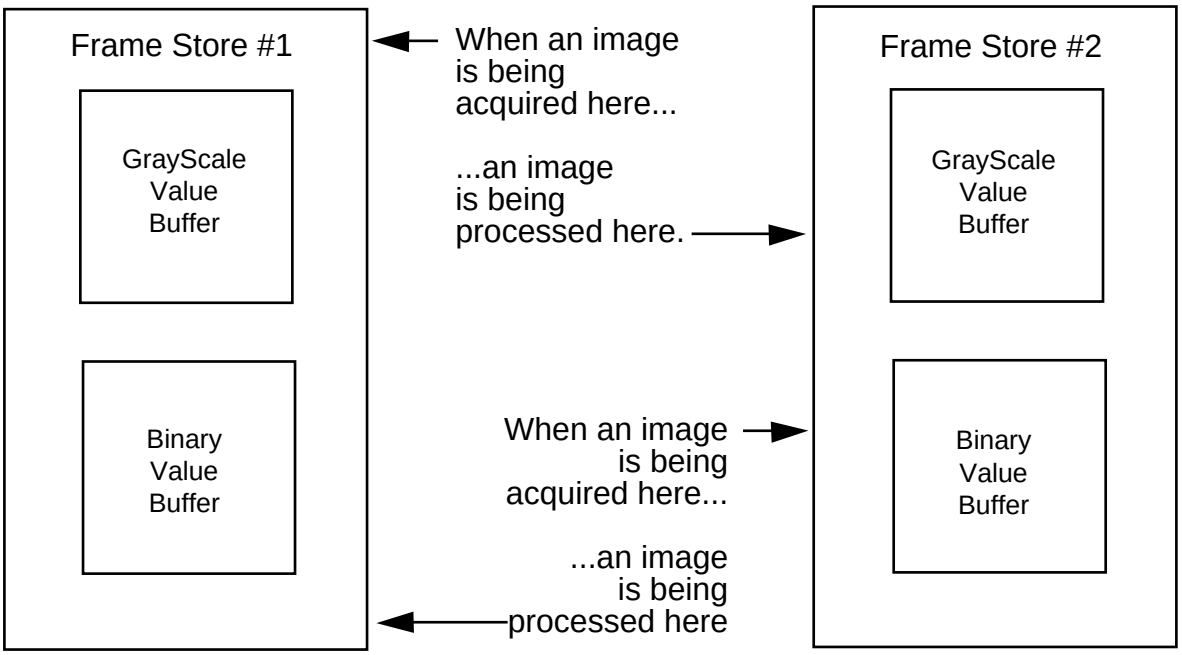



Figure 10-1. **Ping-Pong Frame Grabbing**

## Using VPICTURE With Different Frame Stores

In order to use both frame store areas, we will need to examine more of the VPICTURE syntax for a high-speed inspection:

```
VPICTURE(cam.virt, FALSE, acq_ibr, pro_ibr) 2
```

**`cam.virt`** is the virtual camera number to be used.

**`acq_ibr`** is the image buffer region into which the current picture will be acquired.

**`pro_ibr`** is the image buffer region that subsequent processing is to take place on. The definitions of **`acq_ibr`** and **`pro_ibr`** must specify different physical frame stores.

## Using VDISPLAY With Different Frame Stores

The VDISPLAY instruction has a special mode to be used when both frame stores are being used in a ping-pong fashion and you want to see system- or user-generated graphics. The problem with using a graphics overlay in ping-pong frame grabbing is that before the graphics can be adequately displayed, the system is acquiring another image and overwriting the existing graphics. Using the special mode (5) allows you to instruct one frame area to not display an image, thus allowing the other frame store exclusive access to the monitor. The next section shows how this special mode would be used in a high-speed application.

## Sample Code for a High-Speed Inspection

Let's write the code shell for high-speed inspection of parts on a moving belt. An operator-generated input signal (1030) will control program execution. The program will signal belt motion with digital output signal 34. When the part is in place, a proximity switch will return digital input signal 1032.

```
; Declare local variables

      AUTO first.frm, second.frm, cam1, cam2, vfb1, vfb2, aoi
      AUTO do.belt, di.part_ready, di.begin

; Initialize variables

      cam1 = 1
      cam2 = 2
      vfb1 = 11                    ;default area-of-interest, frame store 1
      vfb2 = 12                    ;default area-of-interest, frame store 2
      aoi = 10000                  ;area-of-interest 10
      do.belt = 34
      di.part_ready = 1032
      di.run = 1030

; Define the AOIs

      VDEF.AOI aoi = 1, 20, 20, 10, 5
      first.frm = aoi+vfb1                ;virtual frame buffer 11
      second.frm = aoi+vfb2               ;virtual frame buffer 12

; Set switches and parameters

      ENABLE V.BINARY
      ENABLE V.STROBE

; Set display mode to a grayscale frame store with graphics overlay
;   and display only the image from camera 2

      VDISPLAY (cam1) 5
      VDISPLAY (cam2) 1, 1

; Wait for the ready signal and start the belt

      WAIT SIG(di.run)
      SIGNAL do.belt
```

```
; Wait for the first part to be ready and then acquire
;   the first image in a wait mode so we insure an image is present
;   when we begin processing during the second image acquisition

      DO
      UNTIL SIG(di.part_ready)
      VPICTURE (cam2, TRUE, second.frm, first.frm) 2

; Begin the ping-pong routine

      DO

; Start a busy loop waiting for part to be ready

          DO
          UNTIL SIG(di.part_ready)


; Acquire an image with camera 1 and select frame store 2 for processing

          VPICTURE (cam1, 0, first.frm, second.frm) 2

; Inspect the part

          VWINDOWB d2[] = second.frm
          ; Deal with results

; Wait for the next part

          DO
          UNTIL SIG(di.part_ready)

; Acquire an image with camera 2 and select frame store 1 for processing

          VPICTURE (cam2, 0, second.frm, first.frm) 2

; Inspect the part

          VWINDOWB d1[] = first.frm
          ; Deal with results

      UNTIL NOT SIG(di.run)

; Inspect the final part

      VWINDOWB d2[] = second.frm
      ; Deal with results
```

---

The actual time required for ping-pong inspection will be determined by the frame store requiring the longest processing time. If your inspection operations take 75 milliseconds and acquisition takes 33 milliseconds, processing on the newly acquired image will have to wait 42 milliseconds while processing finishes on the other image.

### The High-Speed Trigger

In the above example, image acquisition is started when the part-present sensor signals that a part is ready. There is a small potential delay due to the way digital signals are monitored in V+. Digital signals are read once every major CPU cycle. Thus, a slight delay may be encountered before the system actually registers the digital signal. To overcome this delay, a digital signal can be configured as an "external" trigger. When the state of an external trigger changes, a system interrupt is generated and the signal is registered immediately (within .02 ms).

Before you can use an external trigger, you must run the controller configuration utility CONFIG_C to specify the digital signal to monitor as an external trigger. See the *Instructions for Adept Utility Programs* and the description of V.IO.WAIT in the *AdeptVision Reference Guide*.

When you use a high-speed trigger, image acquisition becomes dependent on the state of the vision switch V.IO.WAIT. If V.IO.WAIT[cam] is set to 1, image acquisition by camera "cam" will wait until the state of the external trigger transitions before acquiring an image (the specific digital signal used for the external trigger does not have to be specified).

## 10.2 Performing Frame-Relative Inspections

In many applications, the object's being presented to the camera may be in random orientation. Frame-relative inspections allow you to orient inspection tools with respect to the object's actual orientation. In frame relative inspections, a reference frame is generated based on an object's location in the field-of-view, and vision tools are placed relative to this reference frame rather than the vision reference frame. If you are inspecting a line of similar objects, or objects that are easily distinguished with vision tools, you would use finder and ruler tools or boundary analysis data to create the relative frame. If you are inspecting a line of multiple object types that need prototype identification before they are inspected, you would use prototype-relative inspection.

The programming example in Chapter 8 presented a simple example of using line finders to place frame-relative inspection tools. The main disadvantage of the strategy in the example program is that the object's location and rotation must be constrained. A more sophisticated strategy that removes this constraint is to create a reference frame for the object and then place inspection tools relative to the new reference frame. The following examples create reference frames based on an object's location, and then place inspection tools based on that reference frame.

### Blob-Relative Inspection

When a blob is located, it will have a reference frame with the same orientation as the vision reference frame. The starting point of this reference frame is the centroid of the blob (see the V.CENTROID switch for additional details). If the blob has a strong elliptical character, you can identify the change in orientation based on the VFEATURE() data generated by a VLOCATE operation. Using the VFEATURE() data and the origin of the blob reference frame, you can create a reference frame unique to each found blob. Is that perfectly clear? Let's examine some sample code that places a blob-relative ruler:

```
; Initialize the ruler location variables. These variables represent the
;   location of the ruler relative to the centroid and rotation of the blob.

      ruler_ang = 45       ;Angle of the ruler, relative to object's orientation
```

```
       xoffset = -8         ;x offset of the ruler start point
       yoffset = 0          ;y offset of the ruler start point
       length = 50          ;Length of the ruler
       cam = 1

; Enable gathering of centroid, perimeter, and min/max radii data

       ENABLE V.BOUNDARIES
       ENABLE V.CENTROID
       ENABLE V.PERIMETER
       ENABLE V.MIN.MAX.RADII

;Get the object's location variable with a VLOCATE instruction

       VPICTURE (cam)
       VWAIT
       VLOCATE (cam, 2) "?", obj_loc


; Calculate the object rotation based on the angle of a line from the blob center
;   to the furthest point on the blob. The major ellipse axis is not used
;   because the positive direction of the X axis is not known without further
;   calculations.

       obj_rotation = VFEATURE(45)

; Rotate the reference frame by 'obj_rotation' and offset it by tool location
;   offsets.

       SET tool_loc = obj_loc:RZ(obj_rotation):TRANS(xoffset,yoffset)

; Using the orientation and starting point of the blob, place the frame
;   relative ruler

       VDEF.AOI 2000 = 2, DX(tool_loc), DY(tool_loc), length, 0,
ruler_ang+obj_rotation
       VRULERI (cam) ruler_data[] = 2000
```

---

Figure 10-2 shows how the reference frame for the preceding code was calculated.

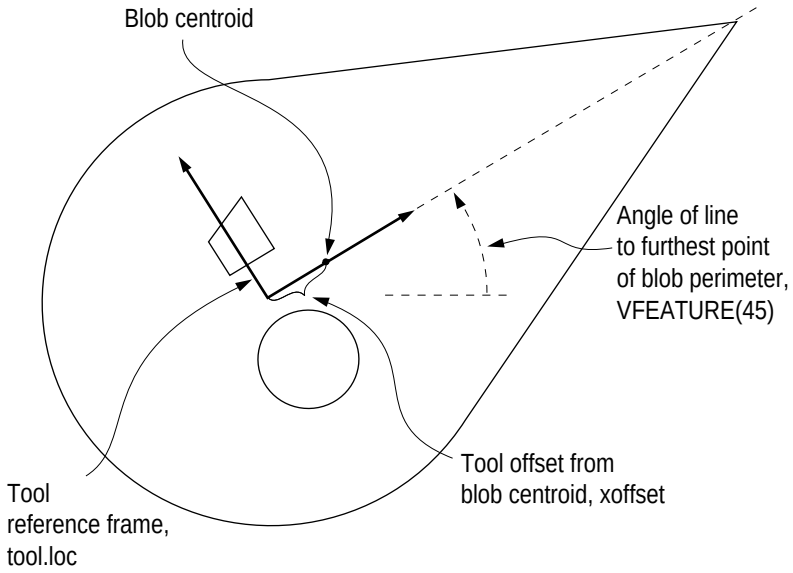



Figure 10-2. **Blob-Relative Inspection**

## Prototype-Relative Inspection

If the objects you are inspecting:

- Are similar and cannot be identified by blob recognition or by using a combination of finder and ruler tools,
- Do not have a strong elliptical character, or have features that define the object's rotation,
- Are touching or overlapping,

then prototyping may be the best way to define a reference frame for the object.

Prototypes have their own reference frame based on the orientation of the part the first time it was trained. When a prototype is recognized (VLOCATE operation) a reference frame based on the recognized object is returned. The following code will place a prototype-relative ruler.

```
; Identify the offset and rotation of the tool relative to the prototype
;    reference frame.

     xoffset = -5         ;ruler x offset from proto reference frame
     yoffset = 30         ;ruler y             "
     ruler_ang = 320      ;ruler angle
     length = 50          ;ruler length (relative to proto ref frame)
     cam = 1

     ENABLE V.RECOGNITION ;enable prototype recognition
     ENABLE V.CENTROID

; Acquire a processed image and locate the prototype.

     VPICTURE (cam)
     VLOCATE (cam, 2)"sample_object", proto.loc

; Create tool location variables based on the prototype reference frame.
;    The X and Y values of the origin of the prototype reference frame are
```

```
;    returned in VFEATURE(2) and VFEATURE(3).

     tool.x = VFEATURE(2)+xoffset
     tool.y = VFEATURE(3)+yoffset

; The rotation of the object relative to the prototype frame of
;    reference is contained in VFEATURE(7).Create a variable for this angle.

     obj_ang = VFEATURE(7)
     tool_ang = obj_ang+ruler_ang

; Issue a VRULERI instruction that uses the X and Y values from
;    the location variable for the center of the ruler, and adds
;    the object rotation to the angle of the ruler.

     VDEF.AOI 2000 = 1, tool.x, tool.y, length, tool_ang
     VRULERI (cam) data[] = 2000
```

Blob and prototype recognition is relatively processing-intensive and may be too slow for high-speed inspections. The location and position data returned from vision tools operating in binary mode or grayscale on an unprocessed image may provide you with a less processing-intensive way of creating object-relative reference frames.

## 10.3 Frame-Relative Inspections Using VDEF.TRANS

The VDEF.TRANS instruction will offset and rotate a defined AOI. The following code shows the use of the VDEF.TRANS function for part relative tool placement in inspection vision. In this example, the radius of the hole in a part is inspected.

```
; Declare local variables

     AUTO shape, xoffset, yoffset, outer.r, inner.r, cam, circ_ibr
     AUTO $name, data[10]

     shape = 9       ; donut shaped AOI
     xoffset = -50   ; x-offset for center of arcfinder relative to part
     yoffset = -75   ; y-offset for center of arcfinder relative to part
     outer.r = 45    ; outer radius
     inner.r = 15    ; inner radius
     cam = 1
     circ_ibr = 2000

; Set switches and a parameters

     ENABLE V.BOUNDARIES
     ENABLE V.CENTROID
     ENABLE V.MIN.MAX.RADII

; Define AOIs

     VDEF.AOI circ_ibr = shape, xoffset, yoffset, outer.r, inner.r

; Locate the object using blob finding

     VPICTURE (cam)
     VWAIT
     VLOCATE (cam) $name
```

```
; Define a vision transformation with centroid and angle of max radius.
     VDEF.TRANS VFEATURE(42), VFEATURE(43), VFEATURE(45)
; Using the defined AOI which will now be part relative, use an arc finder
;    placed over the hole to extract the hole data
     VFIND.ARC (cam) data[] = circ_ibr
; Type result for radius
     TYPE "Hole Radius = ", data[4]
; Zero the vision transformation
     VDEF.TRANS
     VDISPLAY (cam) 0, 1
```

---

## 10.4 Using a Vision-Guided Tracking Conveyor

An upstream, fixed-mount mounted camera can be used to locate parts on a moving conveyor belt. The following basic steps must be taken to use vision with a moving conveyor:

- The conveyor must be mounted and calibrated to the robot (see the *V+ Language User's Guide*).
- The camera must be mounted upstream of the robot with a field-of-view that will encompass all the belt width that might have parts.
- The camera must be calibrated using the "object on moving belt..." option in the Advanced Camera Calibration program (see the *Advanced Camera Calibration Program User's Guide*).
- See the *V+ Language User's Guide* for details on defining belt-relative locations.
- The part location must be taught dynamically with a program that:
  1. Prompts for a part to be placed upstream of the camera
  2. Starts the calibrated conveyor moving
  3. When the part enters the field-of-view, either stops the conveyor and allows the user to take a picture or relies on a digital signal to trigger the picture taking
  4. Moves the conveyor until the part is in the robot workspaces
  5. Stops the conveyor and prompts the user to manually grip the part (without moving it)
  6. Records the location relative to the belt location and the camera transformation

# Switches and Parameters A

## Setting Vision Switches

```
ENABLE switch[cam.virt],...,switch[cam.virt]
DISABLE switch[cam.virt],...,switch[cam.virt]
```

| | |
|---|---|
| `switch` | is replaced with any of the switches listed in Table A-1. |
| `cam.virt` | is replaced with the number of the camera you want to set the switch for. The default value is **all** cameras. If you are using multiple cameras with different switch settings, make sure you include a camera number with each SWITCH command. |

## Viewing Switch Settings

To see the settings for all switches (for the virtual cameras specified by the system parameter DISPLAY.CAMERA), issue the command:

```
SWITCH
```

## Setting Vision Parameters

```
PARAMETER parameter_name[cam.virt] = value
```

| | |
|---|---|
| **`parameter_name`** | is replaced with the name of the parameter you want to set. |
| `cam.virt` | is replaced with the camera number you want to set the parameter for. The default is **all** cameras. If you are using multiple cameras with different parameter settings, make sure you include a camera number with each PARAMETER command. |
| **`value`** | is replaced with the new value you want the parameter to have. |

## Viewing Parameters

To output the parameter list to the screen, issue the command:

```
PARAMETER
```

## List of Switches

This table lists all the switches available to AdeptVision VME and a brief description of what they do. Complete information on each switch is available in the *AdeptVision Reference Guide*.

Table A-1. **Vision Switches**

| Switch | De-fault | Effects |
|---|---|---|
| V.2ND.MOMENTS | | The 2nd moments of inertia and best-fit ellipse are calculated when this switch is enabled (along with V.CENTROID and V.BOUNDARIES). The data is reported in VFEATURE(48-50). (V.SUBTRACT.HOLES is ignored.) |
| V.BACKLIGHT | ✔ | The system has no way of differentiating between background and object unless you tell it which one is dark and which one is light. This switch tells the system which intensity is background and which intensity is object. If the switch is set incorrectly, the system will process the background rather than the object. Disable the switch for a dark background and enable it for a light background. (Binary processing only.) |
| V.BINARY | ✔ | If disabled, it will affect the operation of VPICTURE modes –1, 1, and 2 in the following ways:<br>For VPICTURE modes 2 and 1, it will start a VEDGE operation immediately following the completed acquisition into the virtual frame buffer.<br>For VPICTURE mode –1, a VEDGE operation is performed prior to processing of the image. In this case, the VPICTURE instruction will not complete until after the first stage of processing (the computation of run-lengths) is complete. Therefore, the run-lengths are computed on the binary edge image which is the result of VEDGE (see Appendix B in the *AdeptVision Reference Guide* for details on how vision run-lengths are generated).<br>In each case above, the choice of edge operation to be performed (cross-gradient or Sobel) is determined by the value of the system parameter V.EDGE.TYPE. And the edge strength threshold is given by the V.EDGE.STRENGTH system parameter. |
| V.BOUNDARIES | ✔ | Enables or disables boundary processing. If this switch is disabled, perimeter, edge, centroid, 2nd moments, and hole data will not be gathered. Must be enabled for vision model processing. |
| V.CENTROID | | The centroid of an object is calculated if this switch is enabled. This information is then available in VFEATURE(42-43). This switch increases processing time and should be disabled if the centroid information is not needed. (V.BOUNDARIES must be enabled.) |

Table A-1. **Vision Switches** (Continued)

| Switch | De-fault | Effects |
|---|---|---|
| V.DISJOINT | ✔ | A single object may appear to the vision system to be two separate objects. (E.g., a dark object with a white line down the middle would look like two objects.) If you are attempting prototype recognition on this type of part, this switch will have to be enabled or the part will not be recognized. Disable this switch when you are not doing prototype analysis. When doing region analysis, this switch must be disabled for hole data to be gathered. |
| V.DRY.RUN | | Allows you to see the placement of vision tools without having the tools actually perform any processing. Useful during development when you are trying to position your tools. A graphics display mode must be selected. |
| V.EDGE.INFO | | Enabling this switch causes the system to gather statistics about edges. These statistics will be available through the instruction VEDGE.INFO. |
| V.FIT.ARCS | ✔ | Enabling this switch causes the system to not attempt to fit arcs during boundary analysis. If arcs are unimportant in your application, processing time will be improved by disabling this switch. |
| V.HOLES | | If this switch is enabled, the statistics gathered for objects will also be gathered for the holes in the objects. The total number of holes in a region is available in VFEATURE(40). After an individual hole has been VLOCATEd, all its features are available through VFEATURE. |
| V.MIN.MAX.RADII | | The points closest to and furthest from the centroid of an object are calculated when this switch is enabled. The data is available in VFEATURE(44-47). (V.BOUNDARIES and V.CENTROID must be enabled.) |
| V.OVERLAPPING | | Enabling V.OVERLAPPING will improve recognition of parts that are overlapping. This switch increases processing time for part recognition and should be disabled if objects do not overlap. (V.TOUCHING is assumed to be enabled whenever this switch is enabled.) |
| V.PERIMETER | | The perimeter of an object is available in VFEATURE(41) if this switch is enabled. |
| V.RECOGNITION | ✔ | Disabling this switch will cause the system to behave as if no prototypes have been defined. Must be enabled to perform prototype recognition. |

Table A-1. **Vision Switches** (Continued)

| Switch | De-fault | Effects |
|---|---|---|
| V.SHOW.BOUNDS | | If this switch is enabled, the vision system will display the results of fitting lines and arcs during boundary analysis. This switch is useful during development as it allows you to see how the vision processor performs boundary analysis. (All the "SHOW" switches require a graphics display mode or overlay.) |
| V.SHOW.EDGES | | If this switch is enabled, the vision system will display the primitive edges fit to an object's boundary. |
| V.SHOW.GRIP | ✔ | If robot gripper positions have been defined for a prototype, enabling this switch causes the system to show the effects of clear-grip tests. |
| V.SHOW.RECOG | ✔ | If this switch is enabled and a part is recognized, the silhouette of the prototype model will be overlaid on the part. |
| V.SHOW.VERIFY | | Enabling this switch will cause the system to display all attempts the system makes during prototype recognition. This switch is useful during development when you attempt to create prototypes that produce the most accurate results in the least amount of time. It should be disabled during normal operations. |
| V.STROBE | | Whenever a VPICTURE instruction is issued and this switch is enabled, a strobe signal is sent to the strobe port of the camera taking the picture. |
| V.SUBTRACT.HOLE | | When this switch is enabled, the area of holes within an object will be subtracted from the area calculation (reported in VQUEUE and VFEATURE(10). (See Appendix B for VFEATURE information.) This switch affects the performance of V.MIN.AREA, V.MAX.AREA, and V.MIN.HOLE.AREA. |
| V.TOUCHING | | If the objects you are attempting to recognize are touching each other, the system will see them as one object and may fail to recognize multiple touching objects. If objects in the field of view touch, and you need to recognize all of them, enable this switch. This switch may increase processing time for part recognition. See the *AdeptVision Reference Guide* for details on how V.TOUCHING, V.DISJOINT, and V.OVERLAPPING interact. |
| VISION | ✔ | Disabling this switch will cause the system to behave as if the vision option is not installed. |

## List of Parameters

This table lists all the parameters available to AdeptVision VME and a brief description of what they do. Complete information on each parameter is available in the *AdeptVision Reference Guide.*

Table A-2. **Vision Parameters**

| Parameter | De-fault | Range | Effects |
|---|---|---|---|
| DISPLAY.CAMERA | 4 | 1<br>32 | Sets the number of camera values that will be displayed when a PARAMETER or SWITCH command is issued. |
| V.2ND.THRESH | 0 | 0<br>127 | Used with V.THRESHOLD to establish a range of intensities that the system will see as black or white. With V.THRESHOLD at 50 and 2ND.THRESHOLD at 70, all pixels between 50 and 70 would be seen as dark. |
| V.BORDER.DIST | 0* | 0<br>100 | Allows you to disable prototype recognition processing on objects that are not entirely within the field-of-view. |
| V.EDGE.STRENGTH | 20 | 0<br>127 | Sets the threshold at which the system recognizes an edge in grayscale processing. If the variation in pixel intensity in a local area exceeds this parameter, an edge is recognized. |
| V.EDGE.TYPE | 1 | 1<br>2 | A cross-gradient edge detector is used when this parameter is set to 1 and a Sobel edge detector is used when it is set to 2. |
| V.FIRST.COL | 1* | 1<br>640 | Sets the first column that will be processed by a VPICTURE or VWINDOW instruction. Used to speed processing time by ignoring unwanted areas of the left side of the field of view. Must be less than V.LAST.COL. |
| V.FIRST.LINE | 1* | 1<br>480 | Sets the first line that will be processed by a VPICTURE or VWINDOW instruction. Used to speed processing time by ignoring unwanted areas at the bottom of the field of view. Must be less than V.LAST.LINE. |
| V.GAIN | 128 | 1<br>256 | AdeptVision VME recognizes 128 degrees of intensity. V.GAIN works with V.OFFSET to maximize the use of these 128 values. |
| V.IO.WAIT | 0 | 0<br>1 | When this parameter is set to 1, image acquisition will wait until the digital input channel configured as an external trigger transitions. |
| V.LAST.COL | 640* | 1<br>640 | Sets the last column that will be processed. Everything to the right of this column will remain unprocessed. Must be greater than or equal to V.FIRST.COL. |
| V.LAST.LINE | 480* | 1<br>480 | Sets the last line that will be processed. Everything above this line will remain unprocessed. Must be less than or equal to V.FIRST.LINE. |

* Measurements are in pixels

Table A-2. **Vision Parameters** (Continued)

| Parameter | De-fault | Range | Effects |
|---|---|---|---|
| V.LAST.VER.DIST | 0* | 0<br>16 | Sets the degree of accuracy for boundary-to-prototype model fitting required when a successfully recognized prototype is reverified. When this switch is set to 0, the additional verification process is defeated. |
| V.MAX.AREA | 307,200 * | 1<br>1,048,576 | Sets a value for the largest object the system will attempt to process. Useful if a large object is in the same field of view as the object you are interested in. The setting V.SUBTRACT.HOLES affects this parameter. Must be greater than or equal to V.MIN.AREA. |
| V.MAX.PIXEL.VAR | 1.5* | 0<br>8 | Sets the maximum pixel variation allowed when the system fits a line or an arc to a region. When set to 0, lines and arcs are not fit to the boundary, saving time when only centroids, perimeters, etc., are needed. |
| V.MAX.TIME | 5 | 1<br>999 | Sets the maximum time the vision system will spend trying to recognize a region. |
| V.MAX.VER.DIST | 3* | 1<br>16 | Sets the degree of accuracy of boundary-to-prototype model fitting required for a successful prototype recognition. |
| V.MIN.AREA | 16* | 1<br>1,048,576 | Sets a value for the smallest object the system will attempt to process. Useful for ignoring small objects you are not interested in and for filtering noise. The setting of V.SUBTRACT.HOLES is considered when comparing area values. Must be greater than or equal to V.MIN.HOLE.AREA and less than or equal to V.MAX.AREA. |
| V.MIN.HOLE.AREA | 8* | 1<br>1,048,576 | Sets a value for the smallest hole in an object that the system will process. The setting of V.SUBTRACT.HOLES is considered when comparing area values. Must be smaller than or equal to V.MIN.AREA. |
| V.OFFSET | 255 | 0<br>255 | AdeptVision VME recognizes 128 degrees of intensity. V.GAIN works with V.OFFSET to maximize the use of these 128 values. |
| V.THRESHOLD | 63 | 0<br>127 | Sets the intensity at which the system sees a pixel as either black or white. |

* Measurements are in pixels

# VFEATURE( ) Values B

## Viewing VFEATURE( ) Values

VFEATURE( ) is not a monitor command or a program instruction. It is a system function that returns a value. As such, it can be used in most places you would use a variable. For example:

```
IF VFEATURE(10) > 975 THEN...
```

or

```
part_centerx = VFEATURE(42)
```

(A critical point to remember when using VFEATURE is that it is a function that returns a value and not an array of values. You cannot assign a value to a VFEATURE() index. For example, the instruction:

```
VFEATURE(12) = 3.303
```

would not be accepted by the $V^+$ system.)

## Establishing VFEATURE( ) Values

VFEATURE() values are established as the result of a successful VLOCATE or VSHOW instruction. You cannot directly view or set these values. Before attempting any access to a VFEATURE() value, your program should contain an instruction to check the success of the last VLOCATE or VSHOW instruction. Here is an example:

```
IF VFEATURE(1) THEN
        ;{strategy when object found}
ELSE
        ;{strategy when no object found}
END
```

Table B-1. **VFEATURE( ) Values and Interpretation**

| Index | Information | Unit | Switch/Parameter Effects |
|---|---|---|---|
| 1 | Whether the last VLOCATE instruction was successful or not | T/F | As long as a VLOCATE operation successfully removes objects from the vision queue or a VSHOW operation successfully displays a prototype, this value will be returned as true (–1) and information about that object will be available through VFEATURE access. |
| 2 | Center X | mm | After a VLOCATE:<br>With V.CENTROID enabled, the location components are the centroid of the region.<br>With V.CENTROID disabled, the location components are the center of the bounding box of the region.<br>The reference frame is relative to the vision reference frame.<br>After a VSHOW:<br>The location components are the prototype's centroid.<br>The reference frame values are the prototype's reference frame. |
| 3 | Center Y | | |
| 4 | Center Z | | |
| 5 | Rotation about X | ° | |
| 6 | Rotation about Y | | |
| 7 | Rotation about Z | | |
| 8 | Encoder offset | See the *V+ Language User's Guide* | |
| 9 | Percentage of boundary that matched during prototype recognition (will be 0 for unrecognized regions) | % | After VLOCATE:<br>% of prototype verified.<br>After VSHOW:<br>recognition % specified during training. |
| 10 | Area of object | raw pixels | If V.SUBTRACT.HOLES is enabled, the area of holes in the object is subtracted from this calculation. |
| 11 | ID numbers | # | V.DISJOINT, V.TOUCHING, and V.OVERLAPPING will influence the number of objects processed. |
| 12 | | | |
| 13 | Left limit of region bounding box | mm | After VLOCATE:<br>Bounding box is relative to vision reference frame.<br>After VSHOW:<br>Bounding box is relative to prototype reference frame. |
| 14 | Right limit of region bounding box | | |
| 15 | Lower limit of region bounding box | | |
| 16 | Upper limit of region bounding box | | |
| 17 | Number of holes in the region | # | V.HOLES must be enabled. |

Table B-1. **VFEATURE( ) Values and Interpretation** (Continued)

| Index | Information | Unit | Switch/Parameter Effects |
|---|---|---|---|
| 18 | Time | secs | Time spent acquiring, processing, and recognizing an object.<br>Time for first region includes all time from V.PICTURE (or VWINDOW) until placing in queue. For remaining regions, time is from when one region is placed in the queue until the next object is queued. |
| 19 | Not currently used | | |
| 20 | First clear grip | | Returns number of first clear grip if grips have been defined with V.DEF.GRIP. |
| 21 | When an object is located, all the holes within the object are given a reference number. This value is the reference number of the current hole. (Also holds true for “holes within holes.”) | # | Holes can be located within a bounded region or within a hole in a bounded region. These values keep track of where you are in the locating sequence. Holes are numbered consecutively for each region. |
| 22 | Parent number of holes referenced in VFEATURE(21) | # | |
| 23 | Number of the virtual camera that located this object | # | |
| 24 | Effort level assigned during training for prototype recognition, 1 to 4 | | Prototype must have been recognized. After VSHOW only. |
| 25 | Color of prototype when trained; 0 = black, 1 = white | | |
| 26 | Number of samples taught during prototype training | # | |
| 27 | Number of bounds in the prototype or region | # | In prototypes, holes are included. In regions, they are not. |
| 28 | Maximum area assigned to a prototype during training | pixels | After VSHOW only. |
| 29 | Minimum area assigned to a prototype during training | | |
| 30<br>31 | Indicates the virtual cameras associated with the prototype | bit field | Bit field indicating the virtual cameras associated with a prototype.<br>After VSHOW only. |
| 32<br>33 | Indicates the range of edge numbers for a prototype | # | After VSHOW only. |

Table B-1. **VFEATURE( ) Values and Interpretation** (Continued)

| Index | Information | Unit | Switch/Parameter Effects |
|---|---|---|---|
| 34 | x constraint of prototype | mm | After VSHOW only.<br>(Prototype parameters defined during prototype training) |
| 35 | y constraint of prototype | | |
| 36 | angular constraint of proto | | |
| 37-39 | Not currently used | | |
| 40 | Total area of all holes | pixels | Calculation is influenced by V.MIN.HOLE.AREA. |
| 41 | Outer perimeter of the object | mm | V.PERIMETER must be enabled. |
| 42 | Object centroid along X axis | mm | V.CENTROID must be enabled.<br>V.SUBTRACT.HOLES is ignored. |
| 43 | Object centroid along Y axis | | |
| 44 | The angle (relative to the object's centroid) of a line drawn to the closest point on the object perimeter | ° | V.CENTROID and V.MIN.MAX.RADII must be enabled. |
| 48 | The direction of the object's major axis. The ellipse is centered at the region's centroid (axis of least inertia). This is the major axis of the best-fit ellipse. | ° | V.CENTROID and V.2ND.MOMENTS must be enabled. |
| 49 | Major radius of the ellipse defined in VFEATURE(48) | mm | |
| 50 | Minor radius of the ellipse defined in V.FEATURE(48) | | |

# Lens Selection C

The following formulas are useful for selecting a camera lens. The optimum lens focal length depends on the desired measurement resolution, the width or height of the camera field-of-view, and the distance from the work surface to the camera.

Figure C-1 shows how an image is produced on the imaging element of the camera. A relationship exists between the camera-to-object distance, the size of the field-of-view, and the lens focal length. The size of the camera imaging element determines a scaling factor to be applied to this relationship. The relationship is given in the following formula.

**Formula for Focal Length**

$$f = S(C \div H)$$

where:

$f$ = lens focal length in millimeters

$S$ = camera scale factor (see Table C-1)

$C$ = camera height (distance from front of lens to work surface)

$H$ = height of camera field-of-view (same units as $C$)

Figure C-2 illustrates these relationships and the meaning of the camera scale factor. In the two examples in this illustration, the field-of-view width and the camera-to-object distance remain constant while two cameras with different size imaging surfaces are used. In order to keep the image within the imaging surface on both cameras, different focal length lenses must be used. By applying the correct camera scale factor for each camera (based on the imaging surface size), the correct lens focal length can be determined.

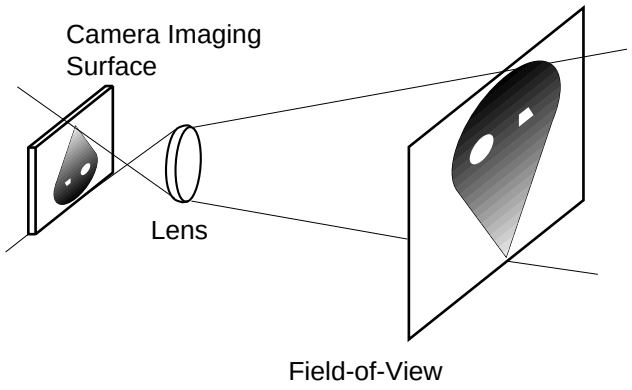



Figure C-1. **Camera Imaging**

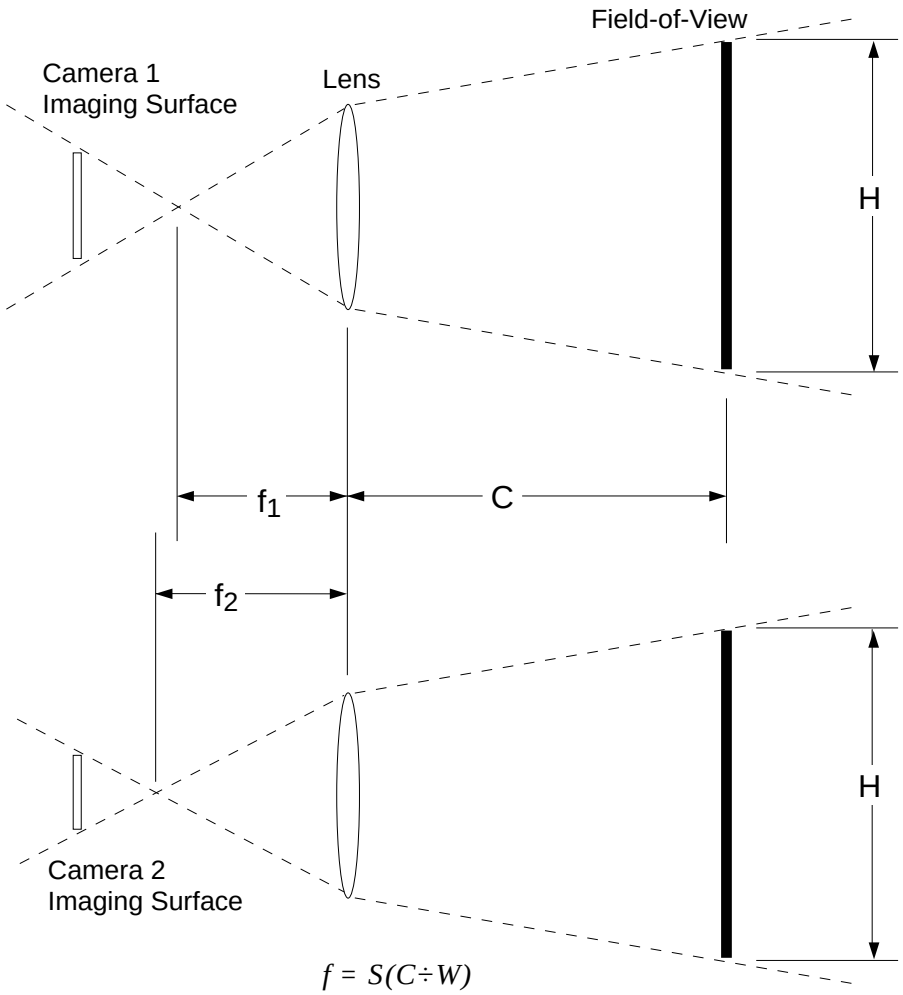



Figure C-2. **Camera Scale Factor**

The following formula shows the relationship between resolution and image size for AdeptVision systems.

**Formula for Resolution**

$$r = (H \div 480)$$

where:

$r$ = resolution (height of one pixel)

$H$ = height of field-of-view (same units as $r$ )

Table C-1. **Camera Scale Factors**

| Camera | Scale Factor |
|---|---|
| Panasonic GP-CD 40 | 4.8 |
| Panasonic GP-MF 702 | 6.6 |
| Sony XC-77 | 6.6 |

When choosing the size of the field-of-view, there is always a trade-off between image size and image resolution. When the image is large, more objects or features can be captured in each picture, which reduces the number of pictures required for the application. However, image resolution is reduced as the image size is increased, and resolution is the key to accurately locating and measuring image features. On the other hand, processing time increases as larger areas of the image are processed.

The following steps will help you decide on a lens and camera-to-object distance:

1. Determine the minimum required resolution (smallest feature that must be resolved accurately). We recommend that a factor of 5 to 10 be applied to this minimum resolution to guarantee consistent results.[1]
2. Based on the required resolution, determine the maximum field-of-view size. If the maximum available field-of-view is too small to view the entire object you are inspecting, you will have to:
    a. Use more than one camera to make the inspection.
    b. Move different areas of the part into the field-of-view and make multiple inspections.
    c. Accept a lower minimum resolution.
3. Using the upper and lower limits of the camera-to-object distances, determine the range of possible lenses.

[1] This factor is sometimes referred to as the Part Tolerance Measurement Ratio (PTMR).

For example, suppose you are using a medium-resolution camera. Your measurement accuracy needs to be within 0.1 mm, and the camera can be mounted 60 to 100 mm away from the object.

1. Using 1/4 pixel accuracy, apply a factor of 10 to the desired resolution and calculate the available field-of-view height:

$$r = (0.1 \div 10)(4)(480) = 9.2$$

2. Calculate the lens focal length at the minimum distance:

$$f = 4.8(60 \div 19.2) = 15$$

3. Calculate the lens focal length at the maximum distance:

$$f = 4.8(100 \div 19.2) = 25$$

4. Your application will achieve the desired resolution using lenses with focal lengths between 15 and 25 mm. If a 16 mm lens is selected, the proper viewing distance is:

$$16 = 4.8(C \div 19.2)$$

$$C = (16 \div 4.8)19.2 = 64$$

**NOTE:** The effective focal length of a given lens can be lengthened by adding extension tubes. However, extension tubes may introduce image distortion.

These calculations do not take into account any error introduced by manufacturing inaccuracies in the camera. In general, higher resolution cameras are better constructed and should be used when resolution tolerances are tight.

# Lighting Considerations D

## D.1 Types of Lighting

Table D-1. **Types of Lighting**

| Type | Advantages | Disadvantages |
|---|---|---|
| Incandescent | Inexpensive, can be cycled | Short life (for AC lamps), heat, inconsistent lumen output as wattage degrades |
| Fluorescent | Efficient, cool, large areas, low cost | Can not be cycled, flickers, not high intensity, large in size |
| Tungsten-Halogen | High output, compact | Heat |
| Strobes | High power, freezes motion | Expensive, lumen output may not be repeatable, must be synchronized with camera, potential health hazards |
| Lasers | Bright points and lines | Federally regulated, speckles, fragile, potential eye hazards |
| Laser diodes | Bright points and lines, small, can be easily pulsed, rugged | Federally regulated, requires collection optics, potential eye hazards |

## D.2 Lighting Strategies

Light is reflected from a surface at the opposite angle it struck the surface. By making use of this principle, lighting strategies make use of the various properties of light sources and reflective materials to maximize important image detail, minimize unimportant details, and eliminate noise.

### Diffuse

Diffuse lighting illuminates a surface with light that strikes the surface from as many different angles as possible, thus minimizing shadows, reflections, and the need for critically placed light sources.

Fluorescent lighting is the most diffuse of the lighting types listed in Table D-1. Diffuser plates and reflecting panels produce a more diffuse light. True diffuse lighting requires a parabolic shaped reflector.

Applications with high-contrast, complicated objects, spherical objects, highly reflective objects, or objects that require multiple inspections of interior features are candidates for diffuse lighting.

### Back

In backlighting, the light source (usually a diffuse source) is placed below the object to be inspected.

Backlighting will effectively light objects whose silhouettes are the critical feature. This is particularly effective if the objects are highly reflective or have highly variable surfaces.

### Directional

Incandescent floods, ring lights, and fiber lights mounted above or to the side of an object provide directional lighting.

This lighting is the simplest to install, but effective vision operations depend on this type of light source remaining constant. If the light source dims, the object will appear different to the camera. If the angle changes, shadows may be added that will be interpreted as features of the object.

This type of lighting will be most effective with simple objects or objects where specific, highly identifiable features are being inspected. Highly reflective surfaces or objects with variable surface brightness will be difficult to inspect with this type of lighting.

### Structured

In structured lighting, a highly collimated light source is applied to the object. The angle of the light is coincident with camera axis. Ring lights and lasers are sources of collimated light.

This type of lighting allows the vision system to perceive three-dimensional features, such as depth changes in the surface plane or holes in the object. Reflective surfaces are not amenable to structured lighting.

### Strobe

Strobe lighting is required in high-speed applications (multiple images per second) or when the speed of moving objects exceeds one pixel every 17 milliseconds.

Strobes cast harsh shadows.

## D.3 Filtering and Special Effects

In many cases specific lighting problems can be solved by placing an optical filter on the camera lens. The two most common filters used for black and white cameras are polarizing filters and color filters.

## Polarizing Filters

Reflected light is highly polarized (the light waves have a predominate orientation about the wave axis). A polarizing filter can be adjusted so that light waves with a predominate orientation are filtered. If reflected glare from an object is a problem, a polarizing filter may minimize the problem. A polarizing filter will reduce the overall scene brightness so more intense lighting sources will be needed with this type of filter.

By adjusting the orientation of polarizing filters on both the light source and lens, you can significantly reduce ambient light and reduce shiny (specular) reflections.

## Color Filters

Color filters allow you to reduce or eliminate different colors of light that reach the camera. Color filters may enable the system to ignore annoying object features that are a given color, or ignore non-significant differences in an object that develop due to differences in the colors of the feature.

Color filtration is difficult and should be attempted only when other avenues have been exhausted.

# Vision Window Menu E

**Cam/frame**

| | |
|---|---|
| ✔**Frame #11** | Select the frame store for the next image acquire. |
| **" #12** | |
| ✔ **Camera #1** | Select the camera to use for the next image acquire. This option selects a physical/ virtual camera pair. You cannot select different physical/virtual camera pairs using this menu option. |
| **" #2** | |
| **" #3** | |
| **" #4** | |

**Dis-play**

| | | |
|---|---|---|
| ✔ **Live grayscale:** | **-1,0** | Display the live video input from the selected camera. |
| **Live binary:** | **0,0** | Display the live thresholded image from the selected camera. |
| **Grayscale frame:** | **1,0** | Display the image in the selected grayscale frame store. |
| **Binary frame:** | **2,0** | Display the image in the selected binary frame store. |
| **Graphics only:** | **3** | Display a processed image and any tool or user graphics. |
| **Static graphics:** | **4** | Don’t erase graphics with each picture operation. |
| | | |
| ✔ **Graphics overlay:** | ***,1** | Display tool and user graphics over live video or frame image. |
| **Static overlay:** | ***,2** | Overlay graphics; don’t erase with each picture operation. |

**Pict**

| | |
|---|---|
| **Acquire:** **2** | Acquire an unprocessed image (quick frame grab). |
| **Process:** **0** | Process image in frame store selected from **Cam/frame** menu. |
| **Acquire & process: -1** | Acquire & process an image (frame selected from **Cam/frame** menu). |

**Ops**

| | |
|---|---|
| **Histogram** | Display histogram showing frequency of each graylevel value. |
| **Auto-threshold** | Generate recommended values for V.THRESHOLD. |
| **Copy frame 11 to 12** | Copy image data between the two frame stores. |
| **Convolve 3x3 average: 1** | Perform a convolve operation on the selected frame store. See the description of VCONVOLVE in the *AdeptVision Reference Guide* for details on image convolutions. |
| **" 5x5 average: 7** | |
| **" user def.: 17** | |
| **Subtract grayscale, 11 -12** | Subtract the grayscale or binary values in physical frame store 1 from the physical frame store 2. See the description of VSUBTRACT for details on image subtraction. |
| **" binary, "** | |
| **Add grayscale, 11+12** | Add the grayscale or binary values in physical frame store 1 to the physical frame store 2. See the description of VADD for details on image addition. |
| **" binary, "** | |
| **Average grayscale, "** | Average graylevels in the two frame stores. |
| **Binary threshold** | Show edges found based on the value of V.THRESHOLD. |
| **Gray. edges, gradient** | Show edges found based on the value of V.EDGE.STRENGTH using either the standard gradient operator or the Sobel operator. See the description of V.EDGE.TYPE. |
| **" " Sobel** | |
| **Morph. erode: 1** | Perform a morphological operation on the selected image. See the description of VMORPH in the *AdeptVision Reference Guide* for details on morphological operations. |
| **" dilate: 2** | |
| **" user def.: 9** | |

**Status**

| | |
|---|---|
| **Status** | Display the status of the vision system. |
| **Abort processing** | Abort any active vision processing (prototype planning, for example). |

**Models**

| | |
|---|---|
| **Train prototype** | Initiate training of a new or existing prototype model. |
| **List prototypes** | List all prototypes currently in vision memory. |
| **Show prototype** | Display a prototype model. |
| **Rename prototype** | Rename a prototype model (not a file of prototypes). |
| **Delete prototype** | Delete a prototype of vision memory (not from disk). |
| | |
| **List fonts** | List all fonts currently in vision memory.* |
| **Show font** | Display a loaded font. |
| **Rename font** | Rename a font (not a file of fonts). |
| **Delete font** | Delete a font from vision memory (not from disk). |
| | |
| **List templates** | List correlation templates in vision memory.* |
| **Show template** | Display a template currently in vision memory |
| **Rename template** | Rename a template (not a file of templates). |
| **Delete template** | Delete a template from vision memory (not from disk). |

*See the description of VLOAD for details on loading vision models to vision memory.

The **Switches** menu shows all the vision switches. A "✔" next to the switch indicates the switch is enabled for the selected camera (selected under the **Cam/frame** menu).

| Switch-es | |
|---|---|
| ✔ **BINARY** | Select binary or edge processing. |
| ✔ **BOUNDARIES** | Enable/disable boundary analysis. |
| ✔ **FIT.ARCS** | Enable/disable arc fitting during boundary analysis. |
| ✔ **RECOGNITION** | Enable/disable prototype recognition. |
| ✔ **BACKLIGHT** | Select light background or dark background. |
| ✔ **DISJOINT** | Enable/disable prototype recognition of disjoint regions. |
| **TOUCHING** | Enable/disable prototype recognition of touching objects. |
| **OVERLAPPING** | Enable/disable prototype recognition of overlapping objects. |
| **SUB-TRACT.HOLE** | Subtract hole area(s) for calculated region areas. |
| **STROBE** | Enable/disable sending of strobe signal at image acquisition. |
| **CENTROID** | Enable/disable calculation of centroid data. |
| **2ND.MOMENTS** | Enable/disable calculation of 2nd moment data. |
| **PERIMETER** | Enable/disable calculation of region perimeters. |
| **MIN.MAX.RADII** | Enable/disable calculation of region min. and max. radii. |
| **HOLES** | Enable/disable calculation of VFEATURE() data on holes. |
| **EDGE.INFO** | Enable/disable calculation of edge data (see VEDGE.INFO). |
| **SHOW.BOUNDS** | Show boundaries calculated during boundary analysis. |
| **SHOW.EDGES** | Show edges calculated when an image is processed. |
| ✔ **SHOW.GRIP** | Show the effects of clear grip tests (see VDEFGRIP). |
| ✔ **SHOW.RECOG** | Show prototype silhouettes on top of recognized prototypes. |
| ✔ **SHOW.VERIFY** | Show all attempts at prototype recognition. |

# Using DEVICE With Vision F

The V+ DEVICE instruction can be used to:

- Reconfigure frame store sizes and memory allocations
- Read/modify camera interface registers.[1]
- Read/modify camera model parameters.[1]
- Read/modify vision constants.[1]

**CAUTION:** When DEVICE is used to change frame store sizes or memory allocations, all models (prototypes, templates, fonts), AOI definitions, and VTRANS transformations are deleted and vision is re-enabled.

## F.1 The DEVICE Instruction With Vision

The format for using DEVICE with the vision system is:

```
DEVICE(type, unit, status, command, arg, value) input[], output[]
```

| | |
|---|---|
| **type** | Must be 4 (to select vision). |
| **unit** | Set to 0. |
| status | Real variable that will be assigned an error code by the vision system. 1 = success, any other value = failure (use $ERROR to display error text). |
| **command** | 1 = read/modify frame store sizes and memory allocations<br>2 = read/modify camera interface registers[1]<br>3 = read/modify camera model parameters[1]<br>4 = read/modify vision constants[1] |
| **arg** | 0 = reset to defaults<br>1 = read current values<br>2 = write the values from "input[]" |
| cam.virt | Selects the virtual camera affected when "**command**" is 2.<br>Selects the camera model number affected when "**command**" is 3.<br>Ignored when "**command**" is 1 or 4. |

[1]For Adept-internal use only.

`input[]` Array of data values when "**`arg`**" is 2. This should not be specified when "**`arg`**" is 0 or 1.

`output[]` Array of data that is filled by the vision system when "arg" is 1.

The "`input[]`" and "`output[]`" arrays always have the same format. So, if settings are read ("**`arg`**" = 1), then they can later be written ("**`arg`**" = 2) using the same array.

When "**`command`**" = 1, the "`input[]`" and "`output[]`" arrays have the format shown in Table F-1:

Table F-1. **DEVICE Input/Output Format**

| Index | Contents |
|---|---|
| 0 | The number of elements that follow: 9 |
| 1 | Number of the virtual frame store size in the range 1 to 4:<br>1=> 256x240<br>2=> 320x240<br>3=> 512x480<br>4=> 640x480<br>5=> reserved<br>6=> 1024x1024 (Enhanced Vision Interface only) |
| 2 | Blobs allocation in Kb |
| 3 | Object data structures allocation in Kb |
| 4 | Run lengths allocation in Kb |
| 5 | Bounds-in-box allocation in Kb |
| 6 | Unmatched bounds allocation in Kb |
| 7 | Allocation of AOIs in Kb |
| 8 | Allocation of VTRANS in Kb |
| 9 | Allocation of user LUTs in Kb |

Elements 2 through 7 are memory allocations in units of kilobytes. These values should be in the range specified in Table F-2. If a value outside the range is specified, the closest in-range value is used. If a given value is 0, then the default allocation is used. By doubling the allocation size, the number of items would double. A few of the default allocations differ depending on the image size. Table F-2 applies to a 512x480 image setup.

Table F-2**. Vision Memory Allocation**

| | Allowed Range in Kb | Default Kb | ItemSize | Approx. # items | Bytes Used |
|---|---|---|---|---|---|
| Blobs alloc: | 4 to 32 | 28 | 32 | 875 | 28000 |
| Objects alloc: | 4 to 800 | 77 | 116 | 663 | 76908 |

Table F-2**. Vision Memory Allocation** (Continued)

| | Allowed Range in Kb | Default Kb | ItemSize | Approx. # items | Bytes Used |
|---|---|---|---|---|---|
| Run-lengths alloc: | 4 to 126 | 125 | 4 | 31250 | 125000 |
| Bnds-in-box alloc: | 1 to 40 | 4 | 56 | 71 | 3976 |
| Unmatched alloc: | 2 to 56 | 30 | 12 | 2500 | 30000 |
| AOIs alloc: | 1 to 100 | 6 | 28 | 214 | 5992 |
| VTRANS alloc: | 1 to 100 | 1 | 48 | 20 | 960 |
| User LUT alloc: | 1 to 33 | 1 | 258 | 3 | 774 |

**NOTE:** If the total of the above allocations does not leave at least 190Kb of free space, an error is returned.

**Examples**

The following code will change the number of virtual frame stores to six 320 x 240 frame stores (twelve 320 x 240 frame stores with the Enhanced Vision Interface). Make sure all vision models have been saved before running this code:

```
; Get the current configuration

        DEVICE(4, 0, error, 1, 1), vis_config[]
        IF error <> 1 GOTO 100

; Alter element 1 of the output array

        vis_config[1] = 2

; Write the new configuration

        DEVICE(4, 0, error, 1, 2) vis_config[]
        IF error <> 1 GOTO 100

100 ; Handle errors
```

The following code will change the space allocated for blobs to 24Kb and the allocation for object data structures to 500Kb. Make sure all vision models have been saved before running this code:

```
; Get the current configuration

        DEVICE(4, 0, error, 1, 1), vis_config[]
        IF error <> 1 GOTO 100

; Alter elements 2 and 3 of the output array

        vis_config[2] = 24
        vis_config[3] = 500

; Write the new configuration
```

```
        DEVICE(4, 0, error, 1, 2) vis_config[]
        IF error <> 1 GOTO 100

100 ; Handle errors
```

(left blank for future additions)

(left blank for future additions)

(left blank for future additions)

# Third-Party Suppliers G

## G.1 Third-Party Suppliers (U.S.)

Table G-1. **Fiber Optic Lighting Suppliers**

| Manufacturer | Product Line |
|---|---|
| Dolan-Jenner Industries, Inc.<br>P.O. Box 1020<br>Blueberry Hill Industrial Park<br>Woburn, MA 10801<br>Phone: (617) 935-7444 Fax: (617) 938-7219 | Fiber-Lite illuminators; annular, single-head, and dual-head fiber optic cables. |
| Fostec, Inc.<br>273 Genesee St.<br>Auburn, NY 13021<br>Phone: (315) 255-2791 Fax: (315) 255-2695 | Optical fiber bundles (medium quality, good price) |
| General Fiber Optics, Inc.<br>98 Commercial Road<br>Cedar Grove, NJ 07009<br>Phone: (201) 239-3400 Fax: (201) 239-4278 | Fiber optic arrays, flexible image guides, illumination bundles, fiber optic cables |
| Lumitex, Inc.<br>11941 Abbey Road, Bldg. H<br>Cleveland, OH 44133-9908<br>Phone: (216) 237-5483 Fax: (216) 237-5743 | Woven, fiber optic light pads (provide cool, diffuse light from a thin pad).<br>Available in custom sizes. |
| Moritex Corp.<br>6440 Lusk Blvd.<br>San Diego, CA 92121<br>Phone: (619) 453-7905 Fax: (619) 453-7907 | DC Fiberlight, fiber bundles |
| Volpi Manufacturing USA<br>26 Aurelius Ave.<br>Auburn, NY 13021<br>Phone: (315) 255-1737 Fax: (315) 255-1202 | Fiber optic light sources and cables in various shapes including single and dual head, annular and linear |

Table G-2**. Lighting Suppliers**

| Manufacturer | Product Line |
|---|---|
| Aristo Grid Lamp Products, Inc.<br>65 Harbor Road P.O. Box 769<br>Port Washington, NY 14445<br>Phone: (516) 484-6141 Fax: (516) 484-6992 | Mic-O-Lite ring lights |
| Cool-Lux Lighting Industries, Inc.<br>5723 Auckland Ave.<br>N. Hollywood, CA 91602-2207<br>Phone: (818) 761-8181 Fax: (818) 761-3202 | Mini-Cool lights |
| E. G. & G. Electro Optics<br>35 Congress Street<br>Salem, MA 01970<br>Phone: (508) 745-3200 Fax: (508) 745-0894 | Strobe lights |
| Honeywell Microswitch / Visitronic<br>11 West Spring St., Freeport, IL 61032<br>Phone: (815) 235-6600 Fax: (815) 235-5574 | Industrial light sources that provide direct, diffused, collimated, patterned, or fiber optic illumination. NEMA-12 lighting, halogen DC lamps. |
| Magnatek (formerly Triad)<br>1124 East Franklin St.<br>Huntington, IN 46750<br>Phone: (219) 356-7100 Fax: (219) 356-3148 | High frequency electronic ballasts for fluorescent lights |
| Stocker & Yale, Inc.<br>Route 128 & Brimbal Ave. P.O. Box 494<br>Beverly, MA 01915<br>Phone: (508) 927-3940 Fax: (508) 927-8756 | Lite Mite ring lights |
| Vision Engineering Laboratories, Inc.<br>1360 72nd St. North<br>Largo, FL 34647<br>Phone: (813) 545-0018 Fax: (813) 545-0525 | Standard and custom strobe lights, power supplies and systems for machine vision |
| Lasiris, Inc.<br>3549 Ashby<br>Saint-Laurent<br>Quebeck, Canada H3R 2K3<br>Phone: (514) 335-1005 Fax: (514) 335-4576 | Laser based structured light generators. Single line (1-33 lines), concentric, and special patterns are available |

Table G-3**. Camera Equipment Suppliers**

| Manufacturer | Product Line |
|---|---|
| Bogen<br>565 East Crescent Ave., P.O. Box 506<br>Ramsey, NJ 07446<br>Phone: (201) 818-9500 Fax: (201) 818-9177 | "Magic Arms"–flexible fixturing for cameras, lighting, parts, etc.<br>"Copy stands"–Camera mounting stand with vertical stage. |
| Desoutter, Inc.<br>11845 Brookfield Ave.<br>Livonia, MI 48150<br>Phone: (313) 522-7010 Fax: (313) 522-1466 | Mechanical columns, clamps, and other machine vision mounting hardware |
| R.K. Industries<br>7330 Executive Way<br>Frederick, Maryland 21701<br>Phone: (301) 696-9400 Fax: (301) 696-9494 | Phoenix Mechano modular mounting systems, steel and aluminum, round and square tube and clamp systems |
| Worksmart Systems, Inc.<br>33 Ship Avenue<br>Medford, MA 02155<br>Phone: (617) 396-0650 Fax: (617) 391-9150 | Modular mounting systems for cameras, monitors, terminals, etc., aluminum tubing and clamps |
| Intercon 1, Inc.<br>Box 1C<br>Merrifield, MN 56465<br>Phone: (800) 237-9676 Fax: (218) 765-3900 | Standard and custom camera cables, junction boxes |

Table G-4**. Frame Splitter Suppliers**

| Manufacturer | Product Line |
|---|---|
| American Sound<br>1800 Russel St.<br>Covington, KY 41014<br>Phone: (606) 261-9024 Fax: Same as phone | Frame splitter combines two camera inputs into one for higher speed–part number AD1470A |

Table G-5**. Camera Suppliers**

| Manufacturer | Product Line |
|---|---|
| Sony Corporation of America<br>10833 Valley View Street<br>P.O. Box 6016<br>Cypress, California 90630-0016<br>Phone: (714) 220-9100 Fax: (714) 229-4298 | Sony XC-77RR (shuttered) cameras–compatible with AdeptVision AGS EMUX. |

Table G-6. **Filter and Optics Suppliers**

| Manufacturer | Product Line |
|---|---|
| Aerotech World Headquarters<br>101 Zeta Drive, Pittsburgh, PA 15238<br>Phone: (412) 963-7459 Fax: (412) 963-7470 | Electro-optical components; mirrors, lasers, positioning stages |
| Ealing Electro-Optics<br>22 Pleasant St., South Natick, MA 01760<br>Phone: (800) 343-4912 Fax: (508) 429-7893 | Electro-optical components; optical benches, prisms, filters, light sources, lasers, lenses, mirrors |
| Edmund Scientific<br>101 E. Glouster Pike<br>Barrington, NJ 08007<br>Phone: (609) 573-6260 Fax: (609) 573-6295 | Scientific and optical supplies; prisms, lenses, optical bench hardware |
| Melles Griot<br>1170 Kettering St., Irvine, CA 92714<br>Phone: (800) 835-2626 Fax: (714) 261-7589 | Filters, lasers, prisms, optics, positioning devices, optical benches, polarizers |
| Newport Corp.<br>18235 Mt. Baldy Circle<br>Fountain Valley, CA 92728<br>Phone: (714) 965-5406 Fax: (714) 963-2016 | Electro-optical components for machine vision, filters, lasers, structured lighting, optical benches |
| Spirotone, Inc.<br>P.O. Box 8051, Pittsburgh, PA 15216-8051<br>Phone: (412) 571-3770 Fax: (412) 571-3777 | Photographic supplies, lenses, filters, polarizing sheets, lighting |
| Tiffin Manufacturing<br>90 Oser Ave.<br>Hauppauge, NY 11788-3886<br>Phone: (516) 273-2500 Fax: (516) 273-2557 | Filters, lenses |

Table G-7. **Lens Suppliers**

| Manufacturer | Product Line |
|---|---|
| Chugai International Corp.<br>20695 S. Western Ave., 116<br>Torrance, CA 90501<br>Phone: (213) 618-8615 Fax: (213) 618-9963 | C-mount lenses, extension tubes, range finders, 35mm format lenses |
| D. O. Industries, Inc.<br>317 E. Chestnut St.<br>E. Rochester, NY 14445<br>Phone: (716) 385-4920 Fax: (716) 359-4999 | Flat field enlarger lenses, custom lenses, optical systems. Zoom 6000, Dyotar, and Fujinon high quality C-mount lenses. |

Table G-7**. Lens Suppliers** (Continued)

| **Manufacturer** | **Product Line** |
|---|---|
| ESCO Products, Inc.<br>171 Oak Ridge Road<br>Oak Ridge, New Jersey 07438<br>Phone: (201) 697-3700 Fax: (201) 697-3011 | Custom-made lenses, prisms, filters, beamsplitters, and machining services |
| Infinity Photo-Optical Company<br>706 Mohawk Drive, Suite 15<br>Boulder, CO 80303-2648<br>Phone: (303) 499-6262 Fax: (303) 499-1099 | InfiniProbe microscope<br>K2, long distance microscope<br>CFM, continuous focus microscope<br>HDF, high depth of field macro system |
| Nikon, Inc. Instrument Group<br>623 Stewart Ave<br>Garden City, NY 11530<br>Phone: (516) 547-4200 Fax: (516) 547-0299 | Precision 35mm format lenses |
| R.O.I. Industries<br>15192 Triton Lane,<br>Huntington Beach, CA 92649<br>Phone: (714) 895-1880 Fax: (714) 373-1170 | OVP, optical video probe<br>VDZ, video direct zoom<br>Right angle probes |
| Schneider Corp.<br>400 Crossroads Park Drive<br>Woodbury, NY 11797<br>Phone: (516) 496-8500<br>(800) 645-7239<br>Fax: (516) 496-8524 | High-quality C-mount lenses with very low distortion |
| Toyo Optics<br>580 W. Lambert Rd., Suite H<br>Brea, CA 92621<br>Phone: (714) 529-4688 Fax: (714) 529-5766 | Cosmicar C-mount lenses, extension tubes, and accessories |

## G.2 Third-party Suppliers (Europe)

Table G-8. **Mounting Hardware Suppliers**

| Manufacturer | Product Line |
|---|---|
| Lino Manfrotto & Co.<br>Zona Industriale di Campese<br>36061 Bassano del Grappa, Italy<br>Phone: 424-808043 Fax: 424-808402 | "Magic Arms" - flexible fixturing for cameras, lighting, parts, etc. |
| Phoenix Mechano Ltd.<br>Unit 2, Pasadena Close<br>Pump Lane Trading Estate<br>Hayes, Middlesex UB3 3NQ, England<br>Phone: 01-848-1937 Fax: 01-5737-114<br><br>Rose + Krieger<br>Flurweg 1, Postfach 1265<br>4952 Porta Westfalica, Germany<br>Phone: 0571/50406-0 Fax: 0571/504068-9 | Modular mounting systems, steel and aluminum, round and square tube and clamp systems. |

Table G-9. **Lighting Suppliers**

| Manufacturer | Product Line |
|---|---|
| R.Y.F. Optical Instruments<br>Markt Tassig<br>Markt Platz 7<br>CH-2540 Grenchen, Switzerland | Lite Mite ring lights |
| Volpi AG<br>Wiesenstrasse 33<br>CH-8952 Schlieren, Switzerland<br>Phone: 01/730-9761 Fax: 01/730-9044 | Fiber optic illuminators in various shapes including ring and linear |

Table G-10. **Lens Suppliers**

| **Manufacturer** | **Product Line** |
|---|---|
| Chugai Boyeki (Deutschland) GmbH<br>Willstätter Strasse 1<br>D-4000 Düsseldorf 11, Germany<br>Phone: 0211-596370<br><br>Chugai Boyeki (U.K.), Ltd.<br>Computar House<br>6 Garrick Industrial Centre<br>Garrick Road, London NW 9 6AQ, England<br>Phone: 01-202-3434 Fax: 01-202-3387<br><br>Chugai Boyeki (U.K.), Ltd.–Milano Branch<br>Via Carolina Romani 1/11<br>20091 Bresso (MI), Italy<br>Phone: 02-66300941 Fax: 02-66300808 | C-mount lenses, extension tubes, range finders, 35mm format lenses |
| Joseph Schneider Optische Werke Kreuznach GmbH<br>Ringstrasse 132<br>6550-D Bad Kreuznach, Germany<br>Phone: 671-601287 Fax: 671-601109 | High-quality C-mount lenses with very low distortion |

Table G-11. **Filter and Optics Suppliers**

| **Manufacturer** | **Product Line** |
|---|---|
| Aerotech Gmbh<br>Neumeyerstr 90<br>D-8500 Nürnberg 10<br>Germany<br>Phone: (911)521031 Fax: (911) 521235<br><br>Aerotech Ltd. (Aerotech)<br>3 Jupiter House<br>Calleva Park, Aldermaston<br>Berkshire RG74QW, United Kingdom<br>Phone: (07356)77274 Fax: (07356) 5022 | Electro-optical components; filters, mirrors, positioning stages. |
| A.R.I.E.S. (Aerotech)<br>44 Bis Blvd., Felix Faure<br>92320 Chatillon, France<br>Phone: (1) 46-57-41-71<br>Fax: (1) 46-56-69-39 | Electro-optical components; filters, mirrors, positioning stages. |

Table G-11. **Filter and Optics Suppliers** (Continued)

| Manufacturer | Product Line |
|---|---|
| Ealing Electro-Optics plc<br>Greycaine Road<br>Watford WD2 4PW, England<br>Phone: (0923) 242261 | Electro-optical components; light benches, prisms, filters, light sources, mirrors |
| Fotonica S.A. (Aerotech)<br>Pinat, 6-BIS<br>L-28006, Madrid, Spain<br>Phone: (1) 2627763 Fax: (1) 2627762 | Electro-optical components; filters, mirrors, positioning stages. |
| Melles Griot, Ltd.–England<br>1 Frederick St. Aldershot<br>Hampshire GU11 1LQ, England<br>Phone: (0252) 334411 Fax: (0252) 334410<br><br>Melles Griot–France<br>10 Rue Ampere, P.A.B.A. Nord<br>78180 Montigny-le-Bretonneux, France<br>Phone: (1) 34 60 5252 Fax: (1) 30 45 4890<br><br>Melles Griot–Germany<br>Postfach 130181<br>D-6100 Darmstadt, Germany<br>Phone: (06151) 86331 Fax: (06151) 82352<br><br>Melles Griot–Netherlands<br>Edisionstraat 98<br>6900 AG Zevenaar, Netherlands<br>Phone: (08360) 33041 Fax: (08360) 28187 | Mirrors, prisms, filters, polarizers, lasers, optical benches, component holders, positioning devices |
| Medilas AG (Aerotech)<br>Lerzenstrasse 11<br>CH-8953 Dietikon, Switzerland<br>Phone: (1) 7411111 Fax: (1) 7414505 | Electro-optical components; filters, mirrors, positioning stages. |

Table G-11. **Filter and Optics Suppliers** (Continued)

| **Manufacturer** | **Product Line** |
|---|---|
| Newport GmbH – Germany<br>Bleichstrasse 26<br>D-6100 Darmstadt, Germany<br>Phone: 06151/26116 Fax: 06151/22639<br><br>Newport, Ltd. – England<br>Pembroke House<br>Thompsons Close<br>Harpenden, Herts, AL5 4ES, England<br>Phone: 0582 / 769995 Fax: 0582 / 762655<br><br>Newport Instruments AG – Switzerland<br>Giessenstrasse 15<br>CH-8952 Schlieren, Switzerland<br>Phone: 01-740-2283 Fax: 01-740-2503 | Electro-optical components for machine vision, filters, lasers, structured lighting, optical benches |
| Oriel Scientific, Ltd. – England<br>1 Mole Business Park<br>Leatherhead, Surrey England KT22 7AU<br>Phone: (0372)378822<br><br>Oriel SARL<br>Les Ulis, France<br>Phone: (1) 69.07.20.20 Fax: (1) 69.07.23.57 | Lenses, filters, polarizers, mirrors, prisms, beam splitters, fiber optics |
| OT-LAS S.R.L. (Aerotech)<br>Via Po, 7a<br>I-50013 Campi Bisenzio<br>Firenze, Italy<br>Phone: (55)892475 Fax: (55) 893291 | Electro-optical components; filters, mirrors, positioning stages. |

# G.3 Third-Party Suppliers (Asia-Pacific)

Table G-12. **Lighting, Filter, and Optics Suppliers**

| Manufacturer | Product Line |
|---|---|
| Barnin Enterprises Co., Ltd. (Oriel Scientific, Ltd.)<br>P.O. Box 87-594<br>Taipei, Taiwan (R.O.C.)<br>Phone: 02-760-5513 Fax: 02-763-1231 | Lenses, filters, polarizers, mirrors, prisms, beam splitters, fiber optics |
| Dolan-Jenner Europe BV<br>Bas Straat 4<br>5402AG Uden, Netherlands<br>Phone: 04-132-639-30 | Fiber optic light sources and cables |
| E.G.&G. Ireland, Ltd.<br>Electro-Optics Division<br>Bay D3/4<br>Shannon Industrial Estate<br>County Clare, Ireland<br>Phone: 353-61-62577 Fax: 353-61-62390 | Strobe lights |
| Harvin Agencies (Oriel Scientific, Ltd.)<br>6-3 1090/B/4<br>Raj Bhavan Road<br>Soma Jiguda<br>Hyderabad-500 482 AP, India<br>Phone: 36858 | Lenses, filters, polarizers, mirrors, prisms, beam splitters, fiber optics |
| Ing. Volker Hippe<br>auf der Platte 32<br>D-6000 Frankfurt/Main 50, Germany<br>Phone: 069-545470 | Line stripe projectors |
| Keehwa Enterprise Corp. (Oriel Scientific, Ltd.)<br>Ha Nam Bldg., Suite 906<br>44-27 Yedeudo-Dong<br>Yeoung Dung Po-Ku (Oriel Scientific, Ltd.)<br>Seoul, Korea<br>Phone: 783-7396 Fax: (02) 784-3935 | Lenses, filters, polarizers, mirrors, prisms, beam splitters, fiber optics |

Table G-12. **Lighting, Filter, and Optics Suppliers** (Continued)

| Manufacturer | Product Line |
|---|---|
| Leonix Corp. (Oriel Scientific, Ltd.)<br>Mutsumi Building<br>4-5-21 Kohjimachi<br>Chiyoda-Ku<br>Tokyo 102, Japan<br>Phone: 03-239-3090 Fax: 03-239-3191 | Lenses, filters, polarizers, mirrors, prisms, beam splitters, fiber optics |
| Melles Griot−Japan<br>Towa Bldg. 3F, 2-16-3 Shibuya<br>Shibuya-ku, Tokyo, Japan<br>Phone: (03) 407-3613 Fax: (03) 486-0923<br><br>Melles Griot−Taiwan<br>#2, Industrial E. Road III<br>Science-Based Industrial Park<br>Hsinchu, Taiwan, R.O.C.<br>Phone: (35) 775-111 Fax: (35) 776-182<br><br>Melles Griot−Singapore<br>105 Sims Avenue<br>#03-12 Chancerlodge Complex<br>Singapore 1438<br>Phone: 743-5884 Fax: 743-4524<br><br>Melles Griot−Hong Kong<br>3/F, Room 6<br>Hilton Center, Tower A<br>Shatin, Hong Kong<br>Phone: (852) 691-4921 Fax: (852) 603-0285 | Mirrors, prisms, filters, polarizers, lasers, optical benches, component holders, positioning devices |
| Marubun Corporation (Newport Corp.)<br>8-1 Nihombashi Odemmacho<br>Chuo-Ku, Tokyo, 103 Japan<br>Phone: 03-648-8115 Fax: 03-648-9398 | Electro-optical components for machine vision, filters, lasers, structured lighting, optical benches |
| Moritex Corp.<br>Fiber Optics Department<br>Sakuragoaka-cho, 8-9 Shibuya-ku<br>Meisei Bldg., Tokyo 150, Japan<br>Phone: 03-476-1021 Fax: 03-476-1698 | DC Fiber light, fiber optic cables |
| Quentron Optics Pty. Ltd. (Oriel Scientific, Ltd.)<br>Laser Court, 75A Angas St.<br>Adelaide 5001, South Australia<br>Phone: (08) 223-6224 Fax: (08) 223-5289 | Lenses, filters, polarizers, mirrors, prisms, beam splitters, fiber optics |
| Spectra Physics Pty., Ltd. (Newport Corp.)<br>2-4 Jesmond Road<br>Croydon, Victoria, Australia<br>Phone: 03-723-6600 Fax: 03-725-4822 | Electro-optical components for machine vision, filters, lasers, structured lighting, optical benches |

Table G-12. **Lighting, Filter, and Optics Suppliers** (Continued)

| Manufacturer | Product Line |
|---|---|
| Superbin Co., Ltd. (Newport Corp.)<br>5F-3, 792, Tun Hua South Road<br>P.O. Box 59555<br>Taipei, Taiwan 106<br>Phone: 02-733-3920 Fax: 02-732-5443 | Electro-optical components for machine vision, filters, lasers, structured lighting, optical benches |
| Teltec Semiconductor Pacific, Ltd. (Oriel Scientific, Ltd.)<br>Room 604, Che San Bldg.<br>10 Pottinger St.<br>Central Hong Kong<br>Phone: (5) 214213 Fax: (5) 8106090 | Lenses, filters, polarizers, mirrors, prisms, beam splitters, fiber optics |
| Wooyang Trading Co. (Newport Corp.)<br>C.P.O. Box 8200<br>Room No. 201 Keum-Sam Building<br>17-1 Yoido-dong Deung Po-Ku<br>Seoul, Korea<br>Phone: 02-783-6722 Fax: 02-785-6271 | Electro-optical components for machine vision, filters, lasers, structured lighting, optical benches |

# Index IX

# Adept User's Manual Comment Form

We have provided this form to allow you to make comments about this manual, to point out any mistakes you may find, or to offer suggestions about information you want to see added to the manual. We review and revise user's manuals on a regular basis, and any comments or feedback you send us will be given serious consideration. Thank you for your input.

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