COGNEX®

VisionPro 3D-Locate

Getting Started

1/31/2013

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VisionPro

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Wire Bonder

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Preface

The 3D–Locate API extends the capabilities of VisionPro by providing a .NET API you can use to create 3D applications.

Audience

This document is written for engineers who are familiar with VisionPro software and want to create 3D-Locate vision applications using the VisionPro 3D-Locate API.

Organization

This document lists the prerequisites to using the 3D-Locate features of VisionPro. In addition, this document describes the VisionPro 3D-Locate Starter Kit and the sample application included with VisionPro.

Conventions Used in This Guide

This document uses the following style conventions:

boldface	Indicates a specific component of the VisionPro 3D-Locate graphics user interface.
italic	Used for variables, arguments, file names, program names, book section names, and for emphasis.
`Courier`	Used for program output.
`bold courier`	Used in illustrations to show what you would type on a keyboard.
<*italic*>	When enclosed in brackets, used to indicate keyboard keys such as <Tab> or <Enter>.

Introduction

VisionPro supports a graphical as well as a .NET programming interface that provides functionality for**:**

- Acquiring and displaying images
- Analyzing images with 2D vision tools
- Linking your application to input/output lines or a TCP/IP connection to network hardware

Meanwhile, the 3D-Locate API adds functionality for:

- 3D calibration for a single camera, multiple cameras, and robot (hand-eye) systems.
- 3D triangulation based on found 2D features
- 3D Model generation
- Part Correspondence
- 3D pose estimation

Starter Kit

VisionPro supports an optional 3D-Locate Starter Kit with the hardware (cameras, camera lenses, GigE network adapter, cables, camera stand, calibration plate and sample part) needed to assemble a multi-camera 3D system, excluding a qualified PC. The VisionPro installation includes the source code for a sample application and project files that run with the Starter Kit hardware.

```
Be aware that the 3D-Locate Starter Kit sample application will not run
without an optional security bit not included in all VisionPro
installations. Contact your Cognex sales engineer about using the 3D-Locate
Starter Kit with the sample application.
```

Available Documentation

Choose **Start->Cognex->VisionPro->Documentation->English** for a list of available titles besides this document, including:

- VisionPro Online Documentation

  The online documentation for VisionPro includes a User's Guide, a Control Reference and a Programming Reference for creating VisionPro applications.

- *VisionPro 3D-Locate Developer's Guide*

  This developer's guide provides a comprehensive overview of the three-dimensional vision tools that take the information from two-dimensional images and generate information about objects in three-dimensional space.

- GigE Vision Cameras User's Guide

  The **Hardware** subdirectory of the **Documentation** directory contains a user's guide on configuring and using GigE Vision cameras.

In addition, you can view any of these titles before installing VisionPro by browsing the *\doc* directory of the VisionPro installation media.

PC Requirements

Refer to the *VisionPro Quick Reference* for a list of operating systems and compilers that VisionPro supports, as well as a list of minimum PC requirements.

Be aware, however, that most 3D-Locate applications are computationally intensive, and for these applications Cognex recommends a PC that uses:

- An Intel® Core™2 Quad processor or better
- A minimum of 3GB physical memory

In addition, your PC must have a PCI-Express slot available for a dual-port GigE network adapter included in the 3D-Locate Starter Kit.

Download the latest video driver for your video card to avoid any display issues with the images acquired from your GigE Vision cameras. Refer to the manufacturer's web site for details.

Deploying a VisionPro 3D Application

Cognex makes the following recommendations for deploying a VisionPro 3D application:

- Always enable the eBus Universal Pro Driver for your GigE Vision cameras.
- If the part you are inspecting is moving during inspection, use hardware triggered acquisition to ensure all cameras acquire images simultaneously.
- You can improve the cycle of your application by modifying all the tools in all the CogToolBlocks so that they do not generate any graphics.

Hardware Installation

The 3D-Locate Starter Kit includes the following components:

- Tripod
- Camera mounting plate, mounting screws, and Allen wrenches
- Dual-port GigE network adapter
- Cognex 10 mm calibration plate
- Two Basler 2.0 MP cameras (acA1600-20gm) and Power over Ethernet (PoE) injectors
- Two 9 mm camera lenses
- 4 Ethernet cables
- Two sample parts

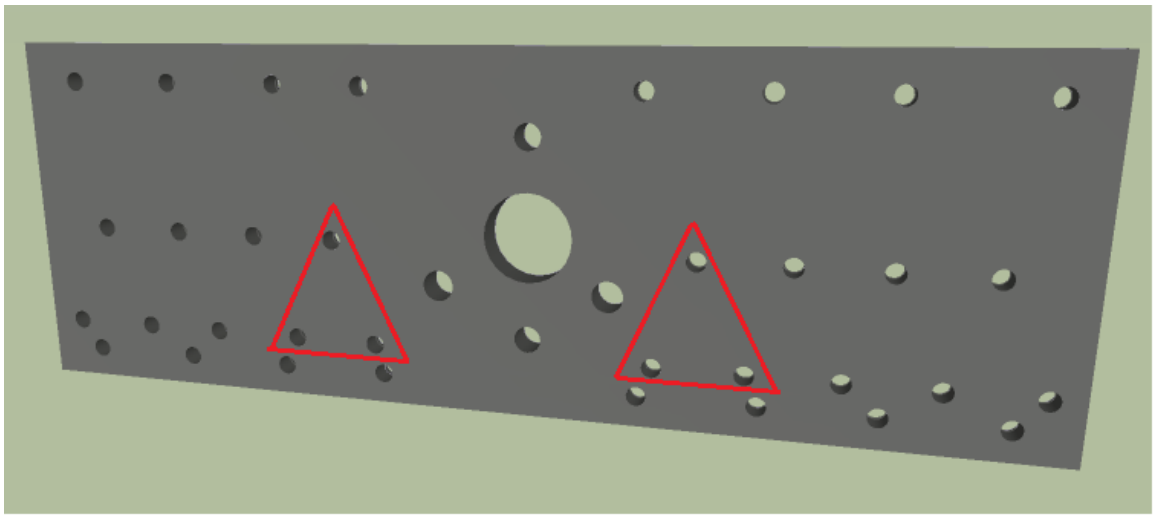
Installing the hardware is optional, as the sample application supports image acquisition from an image-database file of the same part included in the Starter Kit.

If you are using a PC, perform the following steps to install the hardware for the starter kit:

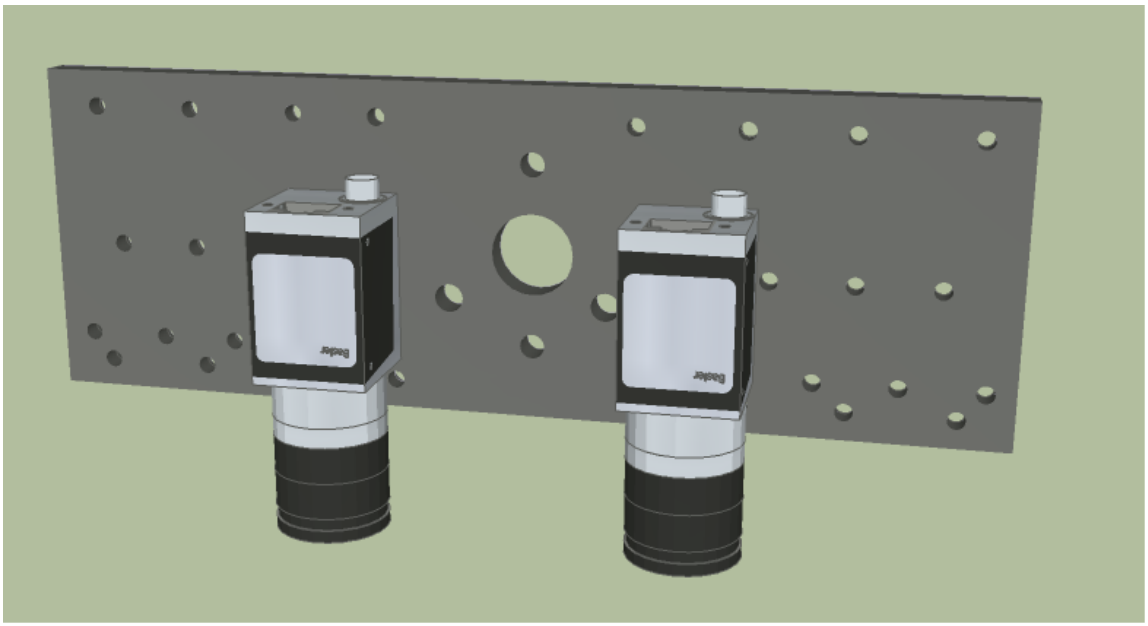
1. Turn off the PC and install the dual-port GigE network adapter.

   Refer to the User's Manual shipped with the network adapter for hardware installation instructions.

   If you are installing VisionPro on a laptop, use a Gigabit Ethernet ExpressCard to connect to a network switch, which will then connect to the cameras. The Starter Kit sample application supports a feature that allows you to use sequential acquisition with this type of setup.
2. Attach a 9 mm lens to each camera and tighten firmly.
3. Mount the two Basler Ace cameras on the camera mounting plate using six M3-5 screws and the holes highlighted in the following figure:



4. Insert the screws from the counter-bored side of the mounting plate to attach the cameras, and mount the cameras vertically, pointed down:

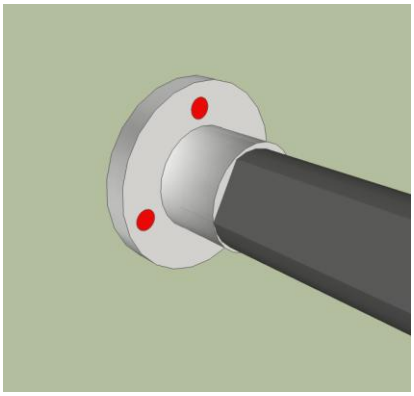


Adjust the vertical center column of the tripod so that it lies horizontal, as shown:

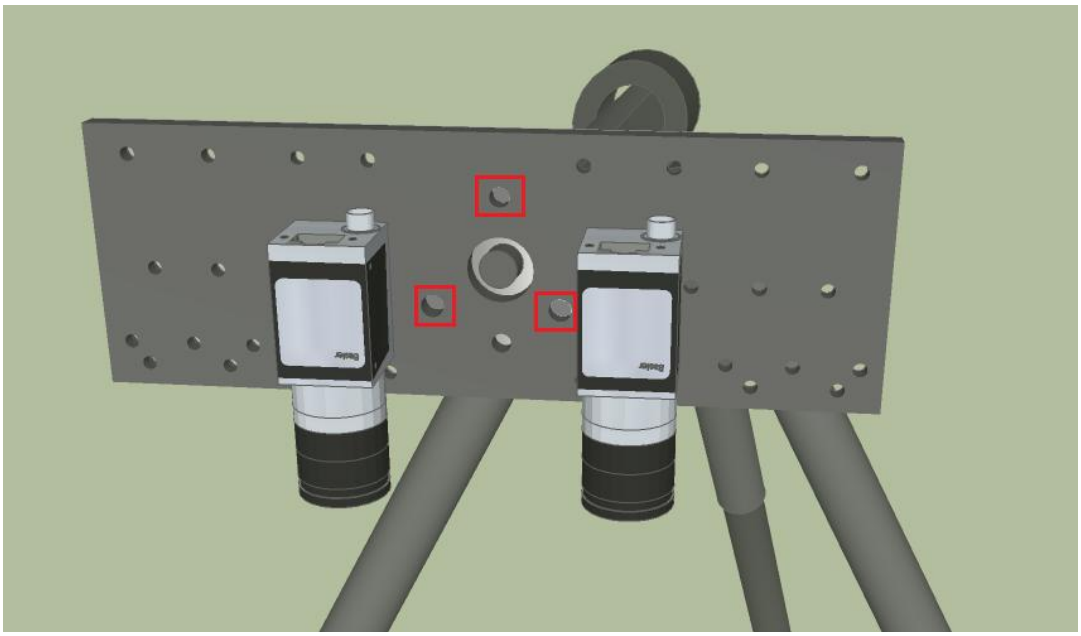
- Refer to the documentation for the tripod for instructions on how to position the legs of the tripod as well as adjust the height of the vertical center column.
- Do not raise the height of the tripod by extending the legs.
- Orient the center column so all the legs are clear of the intended field of view from the cameras and allow room to position the calibration plate to be used later.

5. Remove the three screws from the head of the vertical center column.

The screws can be accessed from the back of the head, as highlighted in the following figure:



6. Attach the mounting plate to the head of the vertical center column using three M6-12 screws using the locations highlighted in the following figure:



7. Connect the Basler cameras to their respective PoE (Power over Ethernet) injectors:
   - Connect one cable from the camera to the OUT port of the injector
   - Connect the other cable from the IN port of the injector to one port of the dual-port GigE network adapter.
8. Connect the PoE injectors to AC power.
9. Install any security key (dongle) supplied with your 3D-Locate Starter Kit.

   The security key contains the security bit necessary to use the 3D-Locate API.
10. Turn on the PC.
11. Install the manufacturer's drivers for the dual-port GigE network adapter. Refer to the manufacturer's web site for details.

The Starter Kit

VisionPro supports a 3D-Locate Starter Kit with the hardware needed to assemble and demonstrate a multi-camera 3D system. VisionPro also includes a Visual Studio solution containing a sample application that allows you to use the 3D system to accomplish the following tasks:

- Generate a 3D calibration for your GigE Vision cameras.
- Configure VisionPro CogToolBlocks to perform coarse location of your part under inspection.
- Configure the type of 2D features you want the application to locate.
- Generate a 3D Model of the part.
- Locate one or more part instances across multiple cameras.
- Use the 2D features to estimate the pose of the part.
- Display graphics indicating the pose of the part.

The section *Hardware Installation* on page 9 describes how to install and connect the hardware associated with the Starter Kit. You do not need to install the hardware to use the sample application, as the sample application included with VisionPro supports image acquisition from an image-database file.

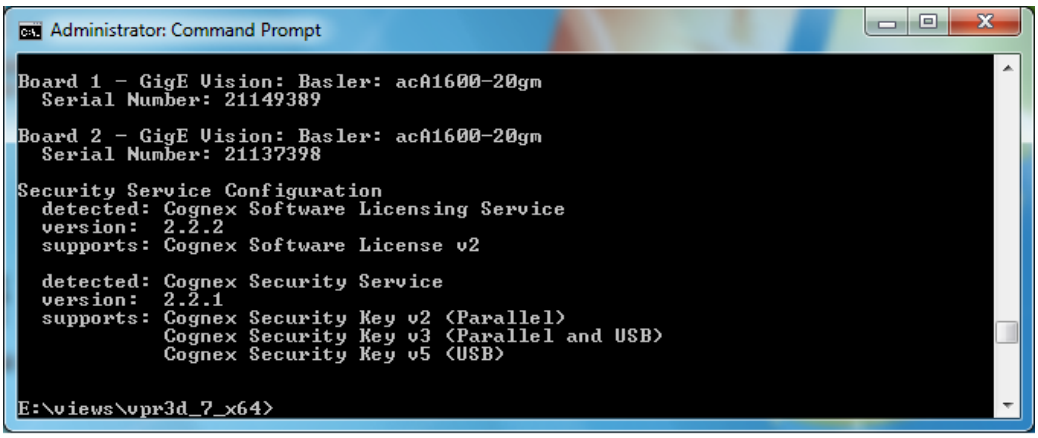
Configuring the GigE Vision Cameras

Perform the following steps to configure the GigE Vision cameras included in the Starter Kit:

1. Ensure the cameras are available by opening a command window and entering the following command:

```
cogtool --print
```

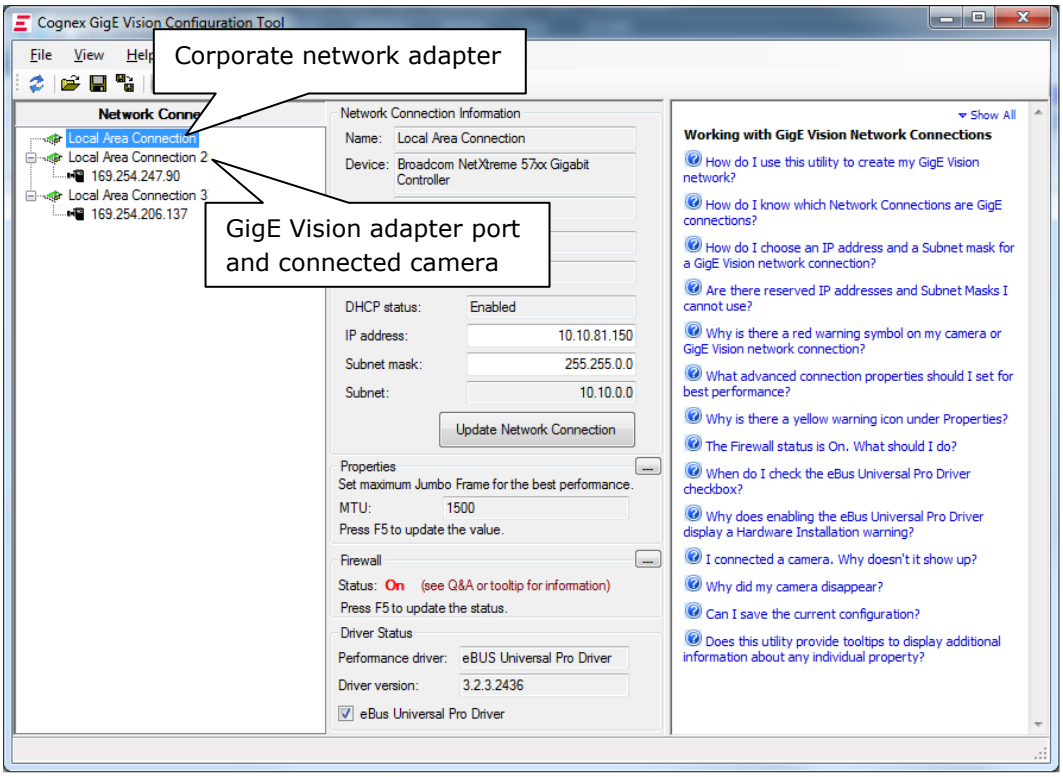
   The camera type and serial numbers should appear similar to what is shown in the following figure:



2. Close the command window.
3. Choose **Cognex->VisionPro->Utilities->GigE Vision Configuration Tool** to launch the GigE Vision Configuration Tool.

The GigE Vision Configuration Tool displays a **Local Area Connection** for any network adapter used by your corporate network and a **Local Area Connection** for each port on the GigE Vision network adapter (the adapter included in the Starter Kit supports two ports).

The tool associates each adapter port with its connected camera. For example, the following figure shows the **Local Area Connections** for a PC with one corporate network adapter and two GigE Vision ports:

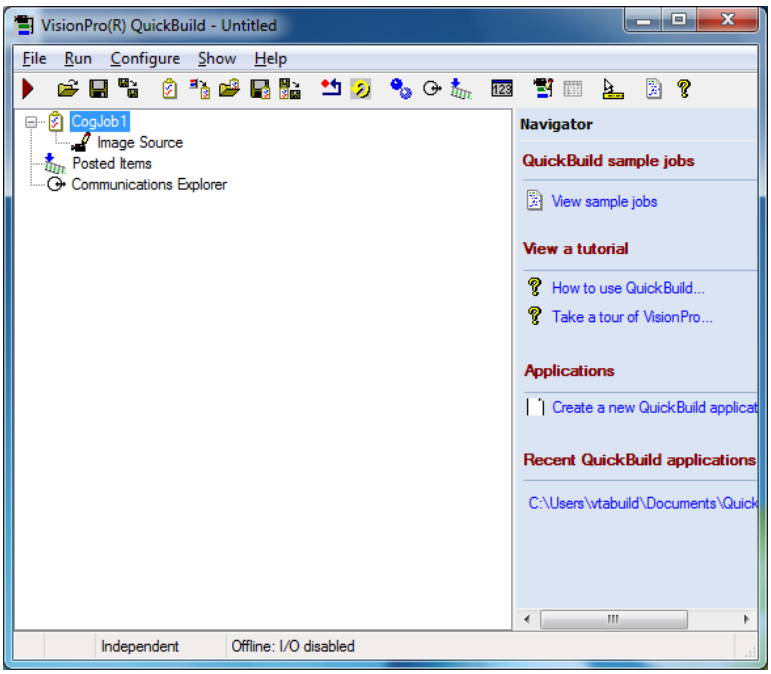


4. Set the IP addresses for the two network adapter ports and the two GigE Vision cameras.

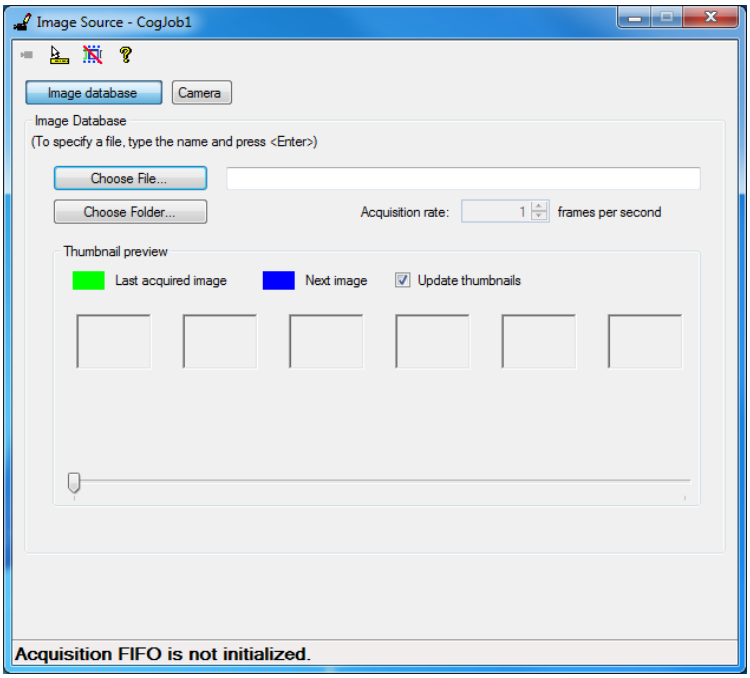
   Refer to the Q&A on the right side of the utility for help in setting the IP addresses. In addition, refer to the *GigE Vision Cameras User's Guide*, available from **Start->All Programs->Cognex->VisionPro->Documentation->Hardware Manuals**, for other steps that might be necessary for you to acquire images with the GigE Vision cameras. These steps can include:

   - Disabling the Windows firewall
   - Enabling jumbo frames
   - Disabling unused network clients

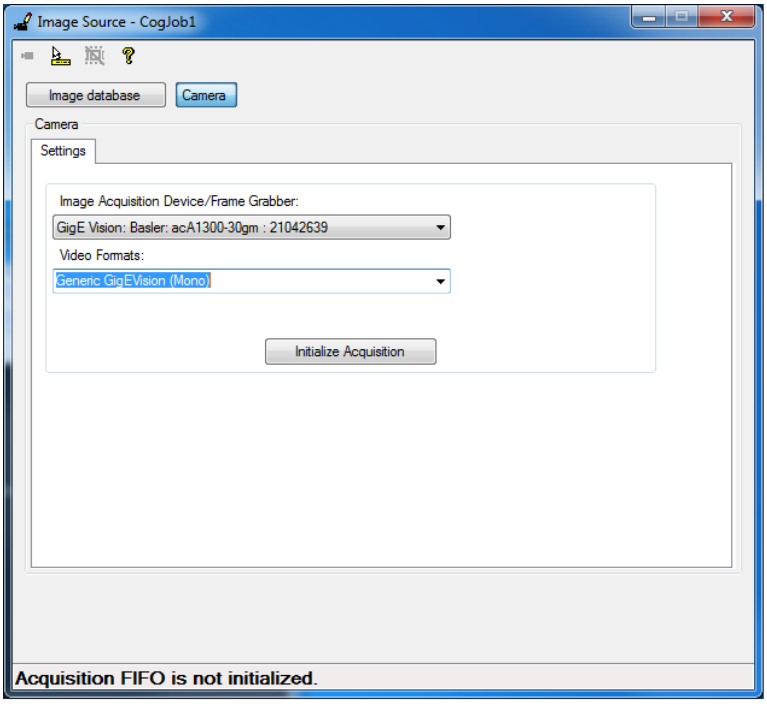
5. Exit the GigE Vision Configuration Tool once the IP addresses for the two GigE vision adapter ports and the two GigE Vision cameras are set.
6. Use VisionPro QuickBuild to verify that both GigE Vision cameras can acquire images:
   a. Choose **Start->All Programs->Cognex->VisionPro->VisionPro (R) QuickBuild** to launch VisionPro QuickBuild:



   b. Double-click the **Image Source** for **CogJob1**:



c. Click **Camera**, choose one of the connected GigE Vision cameras and select the **Generic GigE Vision (Mono)** format as shown:



d. Click **Initialize Acquisition**.

e. Click the Show Live Display icon along the top of the **Image Source** dialog box and verify that display shows live images from the GigE Vision camera.

You do not need to adjust camera hardware settings or acquisition settings at this time. Close the live display when you are satisfied that the camera is acquiring live images.

f. Select the other GigE Vision camera from the **Image Acquisition Device/Frame Grabber** list, and confirm that it can also acquire live images.

g. Close all open dialog boxes and quit QuickBuild.

You do not need to save the QuickBuild application.

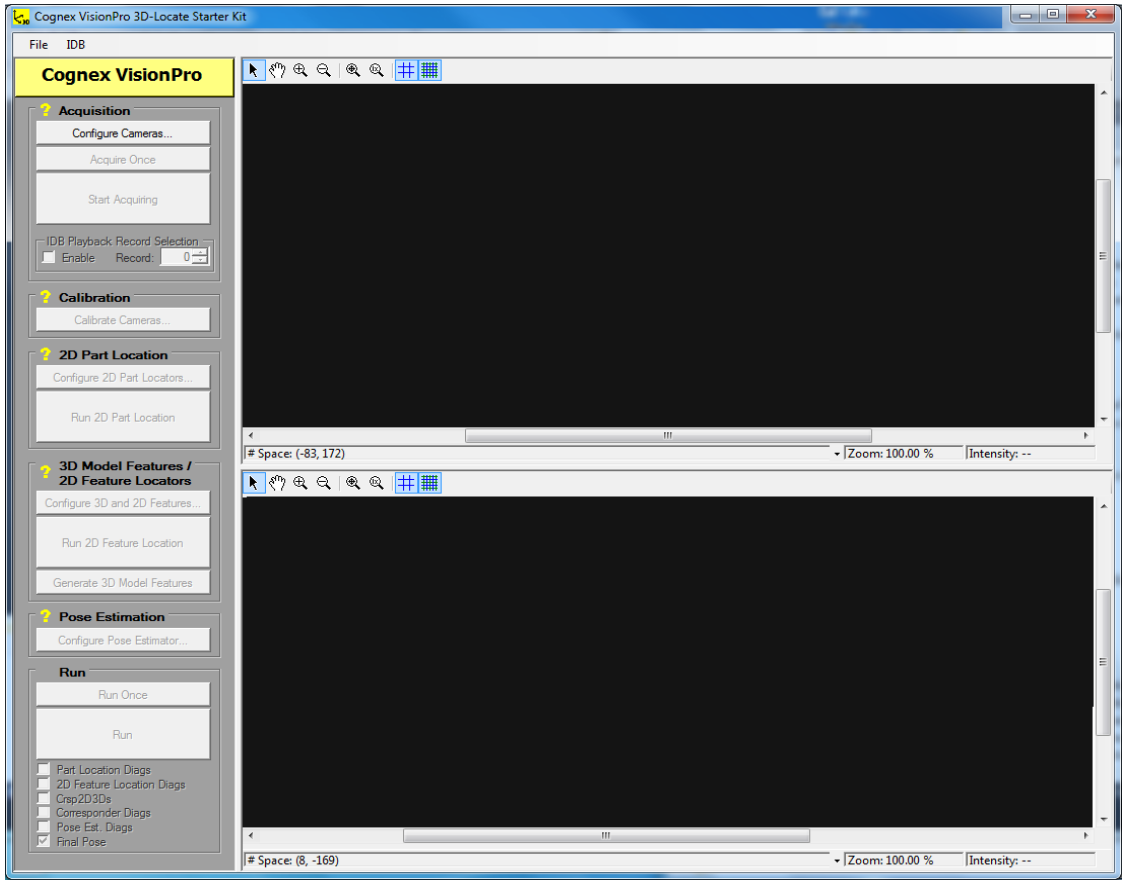
Launching the StarterKitApp

Perform the following steps to use the StarterKitApp:

1. Copy the StarterKit folder *%VPRO_ROOT%\samples3D\Applications\StarterKit* to a folder where you have write permission.
2. Launch Microsoft Visual Studio 2010.
3. Locate and open the solution *StarterKit.sln* installed in the directory *<yourDirectory>\StarterKit.*
4. Set the Startup project in the solution to *StarterKitGUI*, change to a release configuration and choose **Build->Build Solution** to build the project.
5. Press F5 to start the application.

The application automatically creates the subdirectories *\Parts*, *\Setup* and *\ToolBlock Templates* under *the %HOMEDRIVE%\VisionPro3DStarterKit* directory.

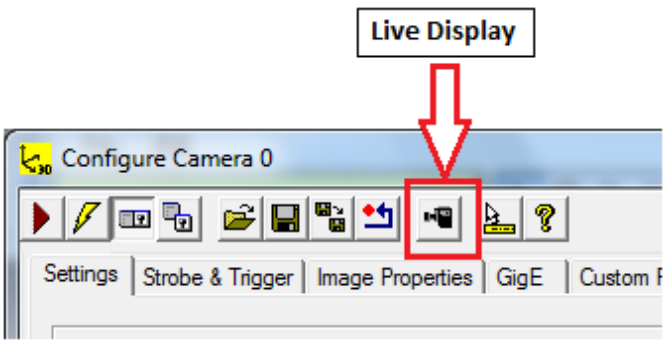
The application prompts you to configure the cameras and then launches as shown in the following figure:



Configuring the GigE Vision Cameras

The application uses two cameras, Camera 0 and Camera 1, to capture *ViewSets*, which are multiple images of the same scene acquired simultaneously. By default, each camera is preconfigured with the correct settings for one of the GigE Vision cameras. Perform the following steps to prepare both cameras for use:

1. Place a sample part in view of both cameras in a typical pose (position/orientation).
2. Click **Configure Cameras**, select **Camera 0**, and enable a live display:



3. Adjust the settings for **Exposure**, **Brightness** and **Contrast**, as well as the aperture and focus settings for the camera lens itself, until the display shows clear images with consistent brightness and good contrast between the block and the background.

   Close the **Configure Camera 0** dialog box when you are finished.

4. Click **Configure Cameras**, select **Camera 1**.

   Enable a live display and use settings similar to the parameters you used for **Camera 0** until the display shows similarly suitable images of the block.

5. If you installed VisionPro on a laptop and are using a network switch for your GigE Vision cameras, click **Configure Cameras** and enable **Use Sequential Acq**.

6. Click **Start Acquiring** to display live images from both cameras.

7. Make final adjustments to the aperture and focus settings on the cameras until both displays show clear images of the sample part against the background.

   Check the focus of the images as you move and rotate the sample part within the field of view.

8. Tighten the focus set screw and the aperture set screw when you are satisfied with the quality of the images the cameras acquire.

   Take care not to change the current settings for the camera as you tighten the screws.

9. Click **Stop Acquiring**.

Performing a Camera Calibration

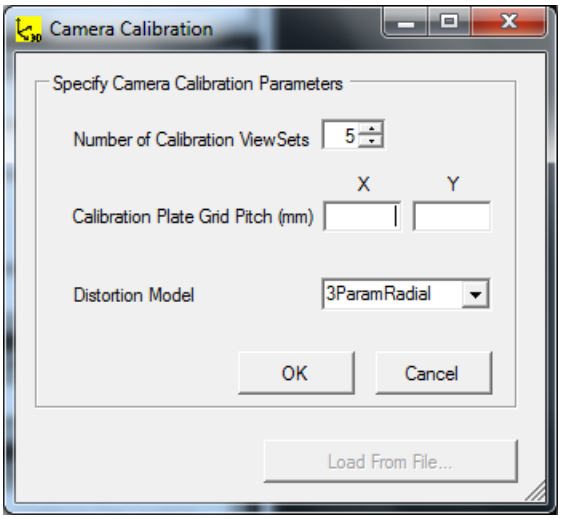
Three-dimensional calibration is a process that establishes a mathematical relationship between the 2D coordinate system associated with the pixels in an acquired image and a 3D coordinate system associated with the physical world in front of the camera.

For any three-dimensional vision environment, 3D calibration must be performed for each camera, whose configuration is defined by the physical location of the camera in addition to the optical system used to form an image on the image sensor. Once 3D calibration has been performed, the camera is *3D-calibrated* and has an associated *3D calibration object* of type **Cog3DCameraCalibration**.

To perform calibration, you must acquire a series of ViewSets of a Cognex calibration plate with the plate at different locations and orientations within your 3D environment. For more information about calibration, see the *VisionPro 3D-Locate Developer's Guide*, available through the **Start->Cognex->VisionPro->Documentation->English** menu.

Perform the calibration using the following steps:

1. Click **Calibrate Cameras** and select **Calibrate Cameras**:



   The minimum number of ViewSets you can use to calibrate your cameras is 5. This is acceptable for this sample application, but Cognex recommends you capture a total of 9 ViewSets for best results. See the *VisionPro 3D-Locate Developer's Guide* for details.

   The **3ParamRadial** type for the distortion model is appropriate for most camera lenses. Choose **SineTangentLaw** if you are using camera lenses with a wide-angle or fish-eye lens in which the distortion effects are severe, usually occurring for lenses with focal lengths such as 4 mm or shorter. This option can require more time for the 3D Calibration Wizard to generate a calibration object.

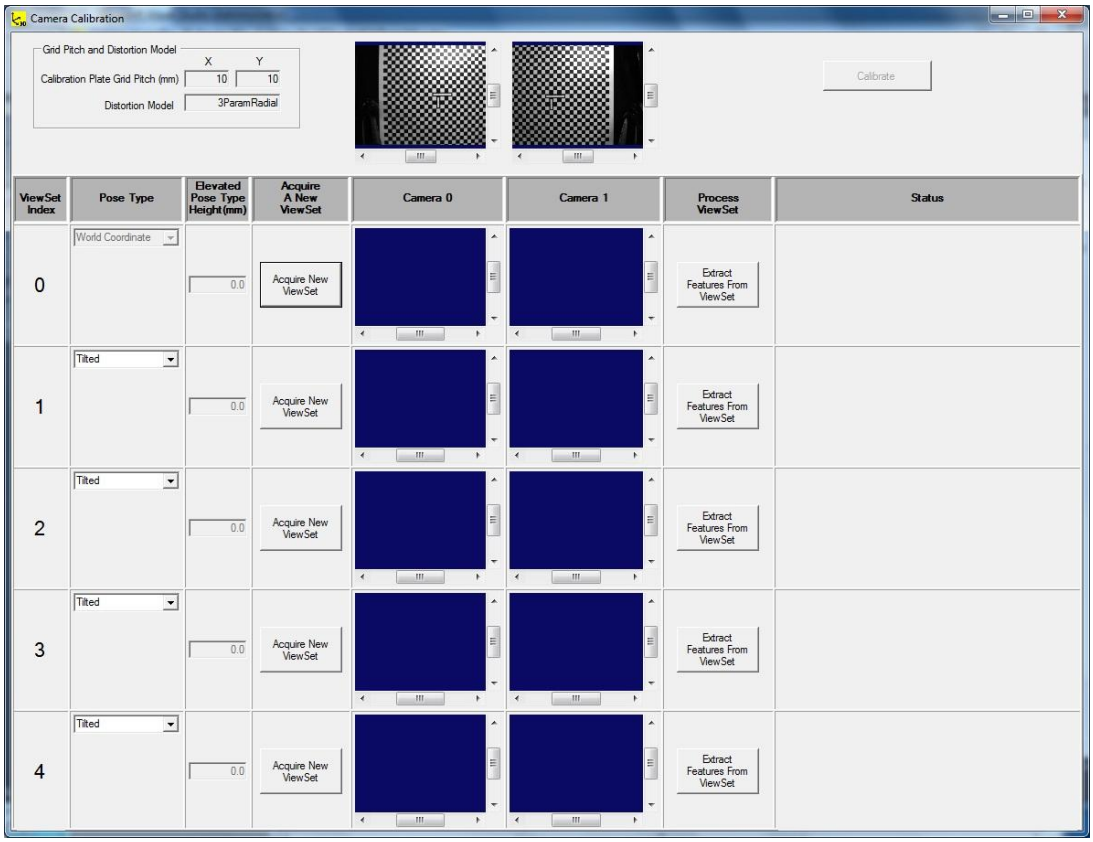
   Use the **Telecentric** option if you are using telecentric cameras, such as cameras with high-magnification lenses (such as microscope lenses) where lens distortion/perspective is usually miniscule. Telecentric cameras require a working environment where the calibration plate cannot undergo a change in translation or tilt. For calibration purposes, you must use appropriate hardware that allows the plate to undergo a change only within the Z axis.

2. Enter a grid pitch of **10** for both the **X** and **Y** axes and click **OK**.

   The Cognex calibration plate supplied with the Starter Kit contains a vertex at every 10 millimeters in the (X,Y) grid.

   If you are using a different calibration plate, then enter its Grid Pitch in millimeters. The StarterKitApp assumes all physical dimensions and coordinates are specified in millimeters.

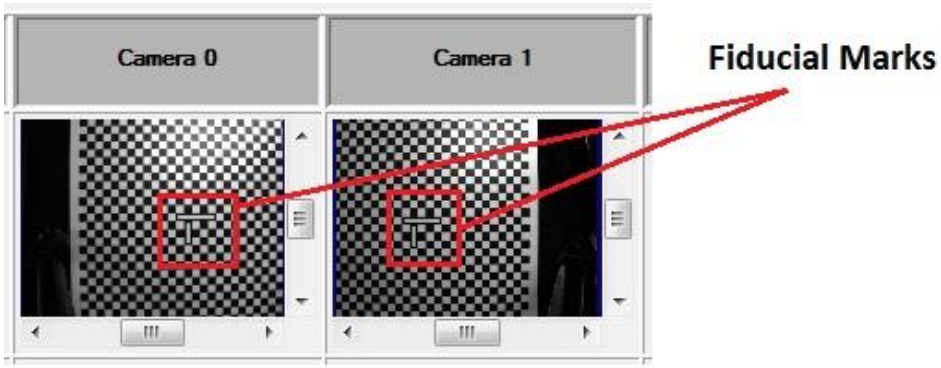
The StarterKitApp displays an interface for capturing the ViewSets you will need to generate the 3D calibration information:



The **Camera Calibration** dialog box displays a live image across the top and contains a row for each of the ViewSets it is configured to accept.

3. Position the calibration plate under the cameras, flat on your work surface, and click **Acquire New ViewSet** for **ViewSet Index 0**. The position of the calibration plate in ViewSet index 0 defines the World3D coordinate space. See the *VisionPro 3D-Locate Developer's Guide* for more information on coordinate spaces in VisionPro.

   Each image of the ViewSet must show the fiducial mark near the center of the calibration plate, as shown:



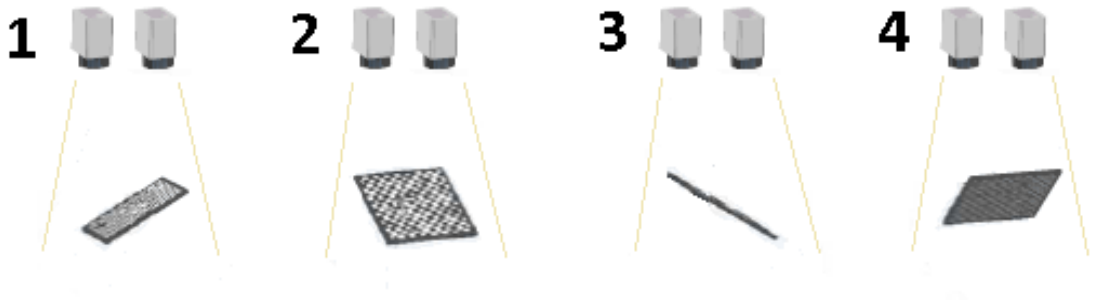
4. Click **Extract Features from ViewSet** on the row for **ViewSet Index 0**.

The calibration method will generate calibration data from this ViewSet and indicates a successful result with green graphics over the ViewSet and a **Status** of **Feature extraction done**:

If the calibration process does not generate a successful result, adjust the position of the calibration plate, acquire a new ViewSet, and try again.

5. Lift one side of the calibration plate and place an object under the edge so that the plate is raised by approximately 50 mm, and click **Acquire New ViewSet** for **ViewSet Index 1**.

   This captures a tilted ViewSet. The calibration process needs at least four tilted ViewSets, rotated about the optical axis of the cameras, to generate accurate calibration information. Refer to the following figure:



   The plate needs to be tilted at an angle greater than 15 degrees to the cameras' optical axes.

6. Click **Extract Features From ViewSet** on the row for **ViewSet Index 1**.

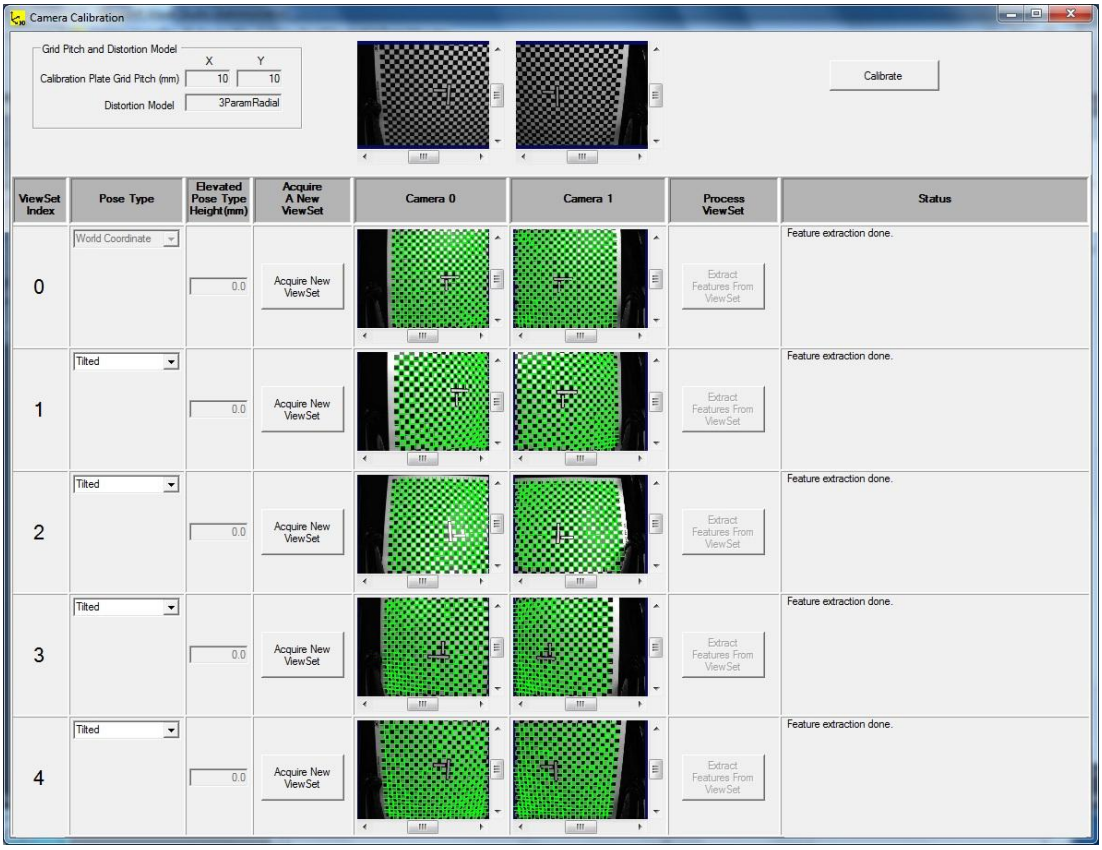
   If the feature extraction does not generate a successful result, adjust the position of the calibration plate, acquire a new ViewSet, and try again.

7. Rotate the calibration plate (along with whatever method you are using to tilt the plate) by 90 degrees (roughly), keeping the same edge lifted, and then capture and process a tilted ViewSet for **ViewSet Index 2**.

8. Rotate the tilted plate again by 90 degrees and then capture and process a ViewSet for **ViewSet Index 3**.

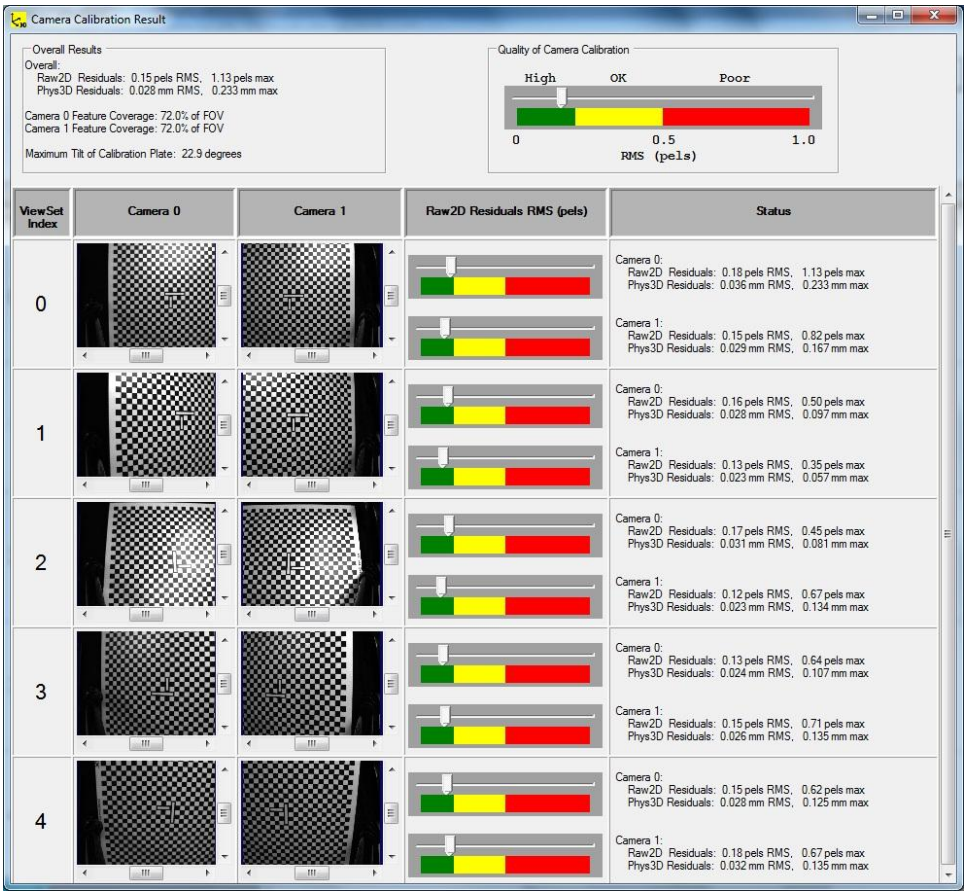
9. Rotate the tilted plate a final time by 90 degrees and capture the last tilted ViewSet for **ViewSet Index 4**.

With 5 ViewSets captured and processed by the StarterKitApp, the **Camera Calibration** dialog box should appear similar to the following figure:



10. Click **Calibrate** to generate the camera calibrations the StarterKitApp will use.

The calibration process can take a few minutes. Upon completion, it displays the results in a dialog box similar to the following:



11. Examine the quality of the calibration results.

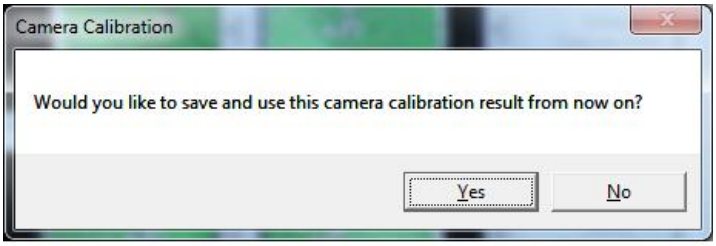
    A good calibration will have overall residuals less than or equal to 0.5 pels RMS. If the quality of the calibration is in the **Poor** range, you must recalibrate.

    - Try re-acquiring your ViewSets with the calibration plate tilted more or try capturing ViewSets where the calibration plate is completely in the field of view of one of the two cameras.
    - Replace any particular ViewSet where the residuals are greater than 0.5 pels RMS.
    - Check the focus and aperture settings of the cameras to ensure you are acquiring well-lit and well-focused images.
    - Ensure that each ViewSet includes the fiducial mark at the center.
    - Ensure there are 0 or only a small number of checkers in saturation (intensity value = 255).
    - See the *VisionPro 3D-Locate Developer's Guide* for more details on generating good camera calibrations.

    Re-calibrate until you receive calibration results in the **OK** range.

12. Close the **Camera Calibration Result** dialog box.

The Starter Kit prompts you to save this camera calibration result:

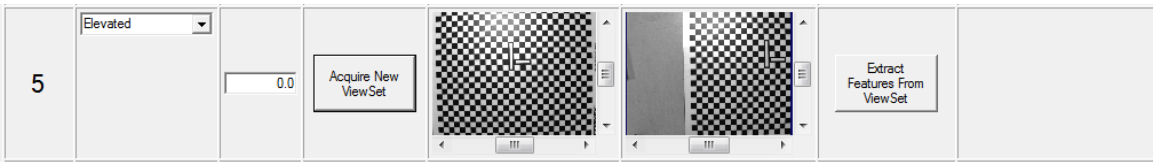


13. Click **Yes** to save and use this calibration result for your application.
14. Close the **Camera Calibration** dialog box and remove the calibration plate from the field of view.

Using Elevated Calibration Plate Poses

Although the StarterKitApp can produce a valid 3D calibration object with 5 ViewSets, Cognex recommends you use 9 ViewSets, 4 of which use elevated calibration plate poses. Elevated calibration plate poses are captured by changing the height of the calibration plate relative to the cameras by an accurate, known amount.

To capture elevated calibration plate poses in addition to the four tilted calibration plate poses, specify a greater **Number of Calibration ViewSets** when you click **Calibrate Cameras**, and then choose **Elevated** for the **Pose Type**, as shown:



For more information about elevated calibration plate poses, see the *VisionPro 3D-Locate Developer's Guide*, available through the **Start->Cognex->VisionPro->Documentation->English** menu.

Locating the Sample Part

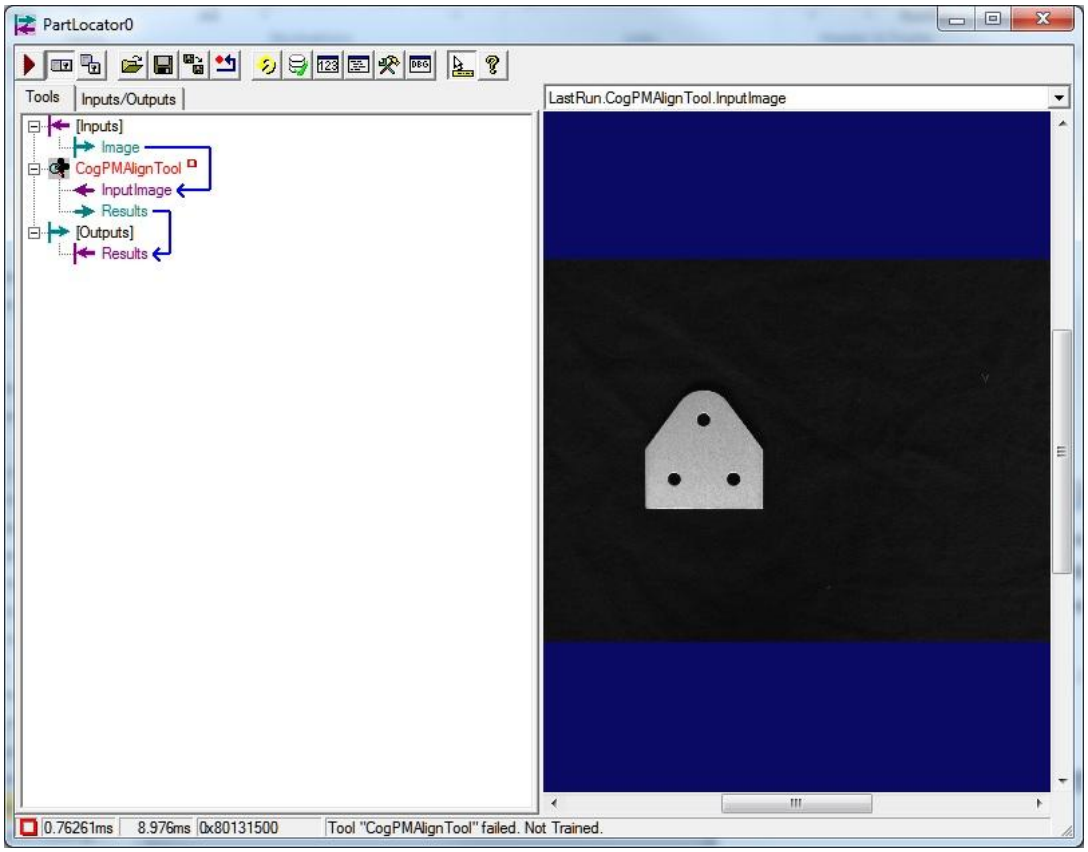
The next step is to configure the application to perform a coarse 2D location of a sample part provided with your Starter Kit. As you work with the sample part throughout the StarterKitApp, Cognex recommends the following:

- Provide lighting that evenly illuminates the part in both cameras with few specular reflections or harsh shadows.
- Provide a background that provides good contrast against the sample part. A black background works very well with the sample part.

Perform the following steps to configure the application to locate the sample part in each camera image:

1. Place a sample part in the field of view of both cameras.
2. Click **Configure 2D Part Locators** and select **Part Locator 0**.

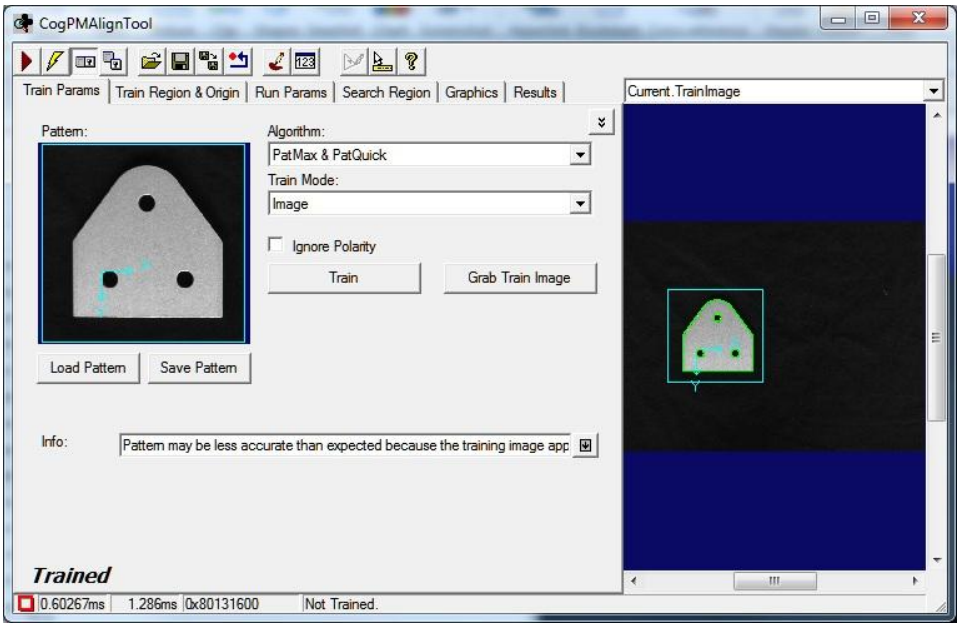
The application displays a CogToolBlock that contains the input image from Camera 0 and a CogPMAlign tool:



Refer to your VisionPro documentation for details on using a CogToolBlock.

3. Run the CogToolBlock once to pass the image from Camera 0 to the CogPMAlign tool.
4. Open the CogPMAlign edit control and train it to locate the sample part.

Refer to your VisionPro documentation for details on how to use a CogPMAlign tool edit control. The following shows a CogPMAlign tool configured to locate the part:



The **Train Params** tab has been pre-configured with an **Elasticity** of 10.

The **Run Params** tab has been pre-configured with the **Angle** degree of freedom for a range of -180 to +180 degrees and a **Scale** degree of freedom with a range of 0.9 to 1.1. In addition, it has been configured to locate up to two sample parts.

Note that a CogPMAlign tool can often handle more tilt of your part by setting the **Scale** degree of freedom to 1 and the **ScaleX** and **ScaleY** degrees of freedom to a range of 0.9 to 1.1.

5. Close the CogPMAlign tool edit control and the **partLocator0** CogToolBlock.
6. Click **Configure 2D Part Locators** again and select **Copy Part Locator 0 to Part Locator 1**.

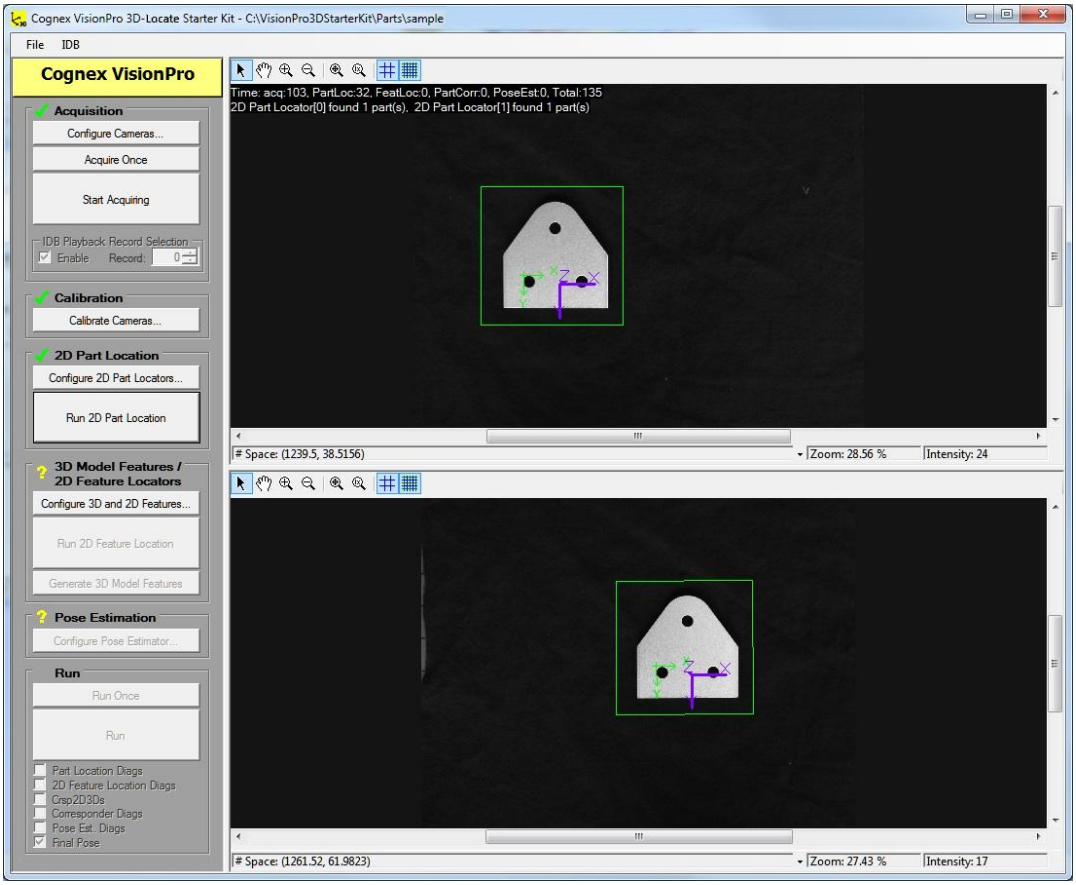
   This copies the CogToolBlock associated with Camera 0 to the CogToolBlock associated with Camera 1, which allows you to skip the necessary configuration steps that allow a CogPMAlign tool to locate the sample parts in images acquired from Camera 1.

   You can skip the configuration of this second CogPMAlign tool because the part images very similar to the way it images in Camera 0. If you ever have cameras that are angled inward so that the optical axes are not parallel, then you would need to completely configure the second CogPMAlign tool.
7. Click **Configure 2D Part Locators** and choose **Part Locator 1** and examine the CogToolBlock to confirm that it locates the sample part as expected.

   Close the CogToolBlock when you are finished.
8. Return to the main form of the StarterKitApp and click **Run 2D Part Location**.

   The application should acquire live images and locate the sample part as you move it around the field of view, indicating that it has found the part with the CogPMAlign tool,

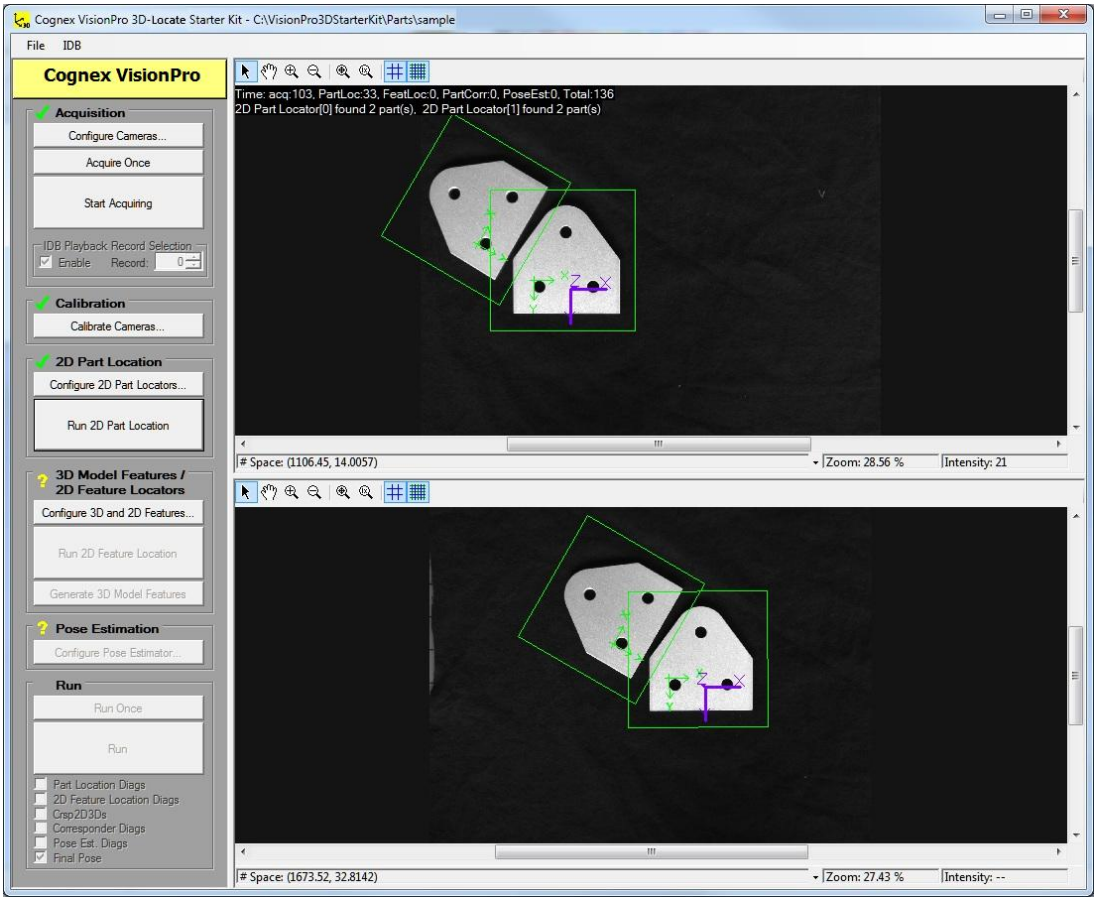
as shown in the following example:



Ensure that your 2D part location works robustly over the expected pose uncertainty range, which is the range of positions and rotations where the sample part can appear. The rotation uncertainty range in this application is 360 degrees about the Z-axis and roughly 15 degrees about the (X,Y) axes. The position uncertainty range in this application is the intersection of the field of views of the cameras.

9. Add a second sample part to the field of view.

   The application should consistently locate both parts over your pose uncertainty range as shown in the following example:



10. Click **Stop 2D Part Location** when you have finished testing the part location feature.
11. Choose **File->Save Part** and save your progress so far.

Saving and Loading Part Files

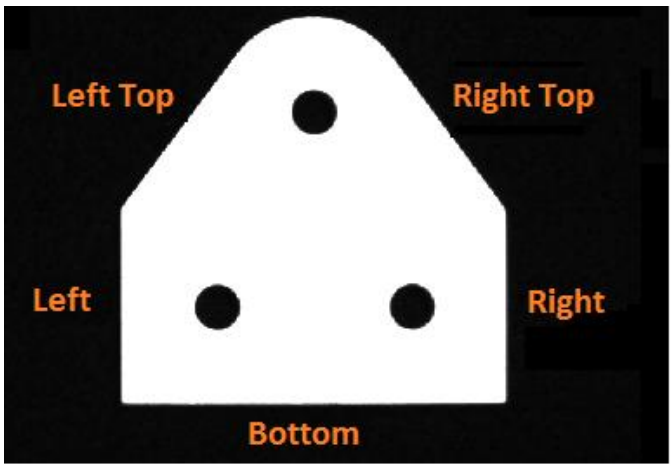
As you use the StarterKitApp you should choose **File->Save Part** to save your work. The StarterKitApp stores part files in the directory *%HOMEDRIVE%\VisionPro3DStarterKit\Parts*.

Choose **File->Load Part** to load an existing part file, or choose **File->New Part** to start a new part file.

Locating 2D Features for the 3D Model

Once the application can locate the sample part from each camera in 2D space, the next step is to decide on a set of 3D model features and configure the StarterKitApp to locate the corresponding 2D features on the part from each camera. See the *VisionPro 3D-Locate Developer's Guide* for more information on 3D model features and 3D models.

For our example, we will use the 5 edges (line segments) of the part as the 3D model.

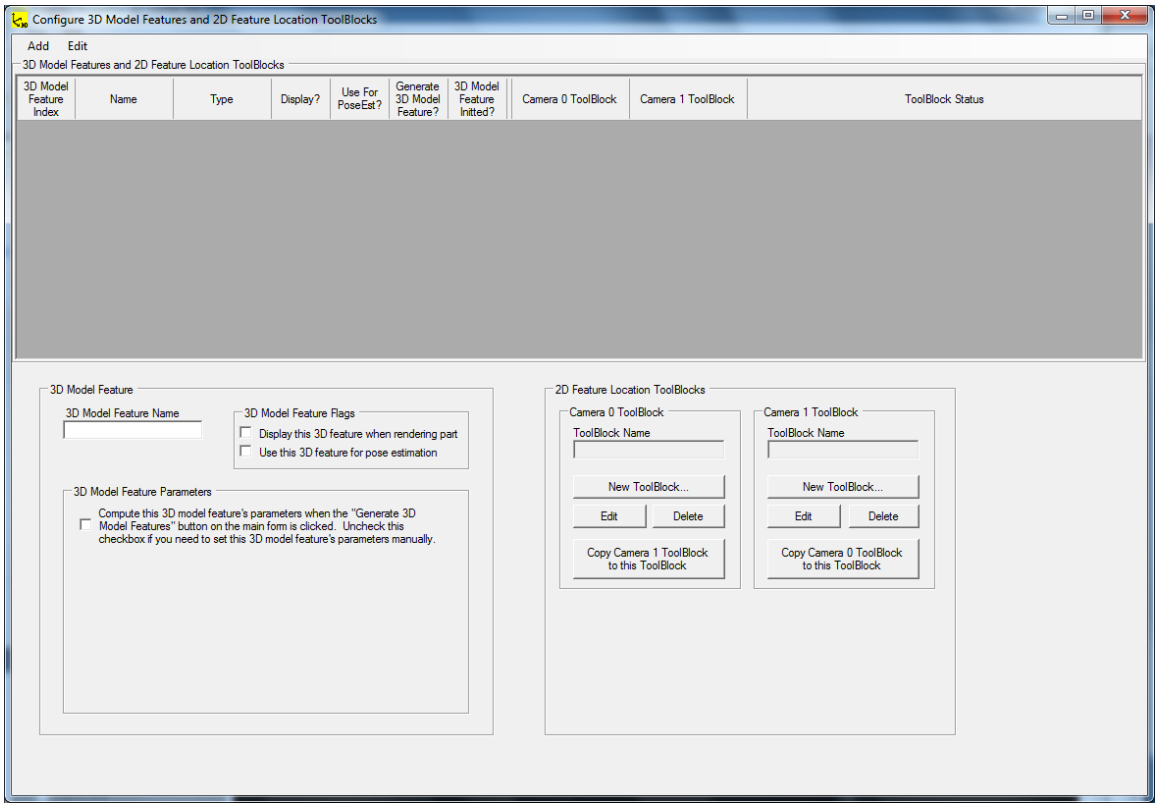


In general, adding more features to your 3D Model allows your application to perform more accurate 3D pose estimations, while also allowing situations where 3D pose estimations can still be performed even when one or more expected 2D features cannot be located in any particular ViewSet. Using more features, however, can increase the time necessary to perform the 3D pose estimation.

You should use at least five 3D features in your 3D model. Most applications require five or more for accuracy and for robust 3D pose estimations.

Place a single sample part in view of the cameras and click **Acquire Once** to capture a ViewSet of the part.

Click **Configure 3D and 2D Features** to specify the type of 3D model features in your 3D model as well as to configure the 2D feature locators.



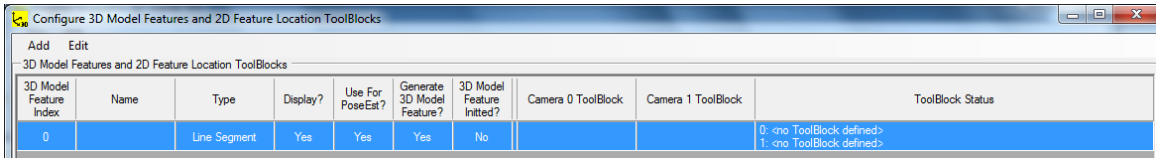
Locating the Bottom Edge of the Sample Part

Perform the following steps to specify the 3D model feature and to locate the 2D feature corresponding to the bottom of the sample part, as shown in a previous figure:

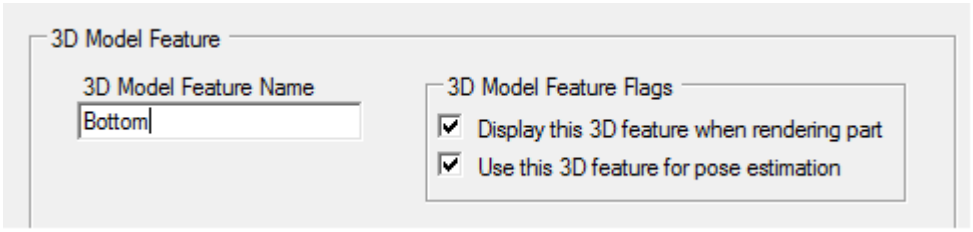
1. Choose **Add->3D LineSeg** from the top of the dialog box.

   The **Add** pull down menu includes options for 3D Point and 3D Circle, depending on your part.

   The dialog box displays a row of parameters whose values will vary based on parameters you set later:



2. Enter the string "Bottom" for the **3D Model Feature Name**:



Keep enabled both options for **3D Model Feature Flags**:

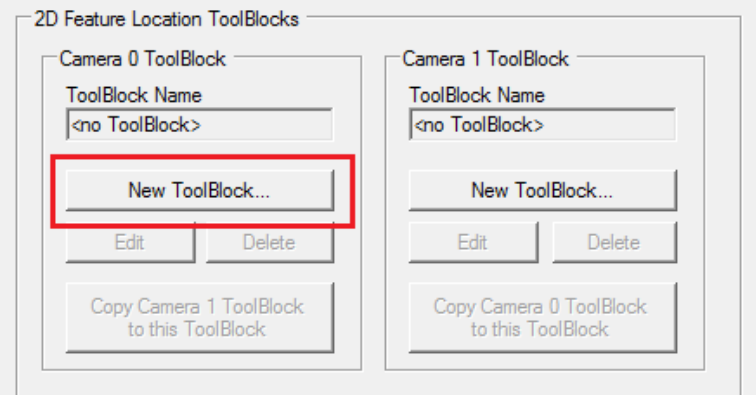
- **Display this 3D feature when rendering part**

  Display graphics representing this 3D feature whenever the part is rendered.

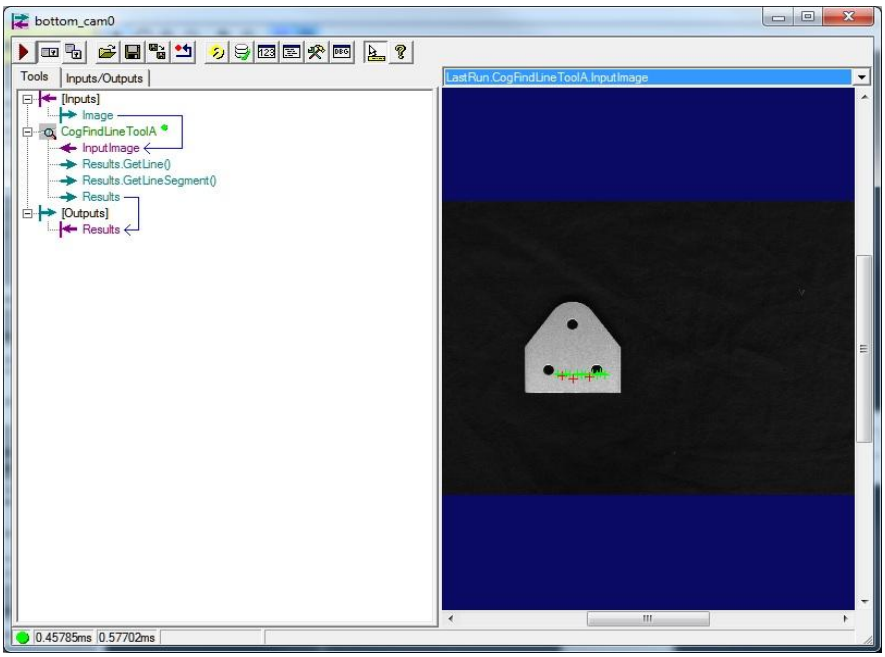
- **Use this 3D feature for pose estimation**

  As you develop your application you might create a large number of 3D Model features and then test which ones generate the most accurate 3D pose estimations. This option allows you to test 3D pose estimation with or without this 3D Model feature, rather than deleting it and re-creating it again later.

3. Under **2D Feature Location ToolBlocks**, click **New ToolBlock**:



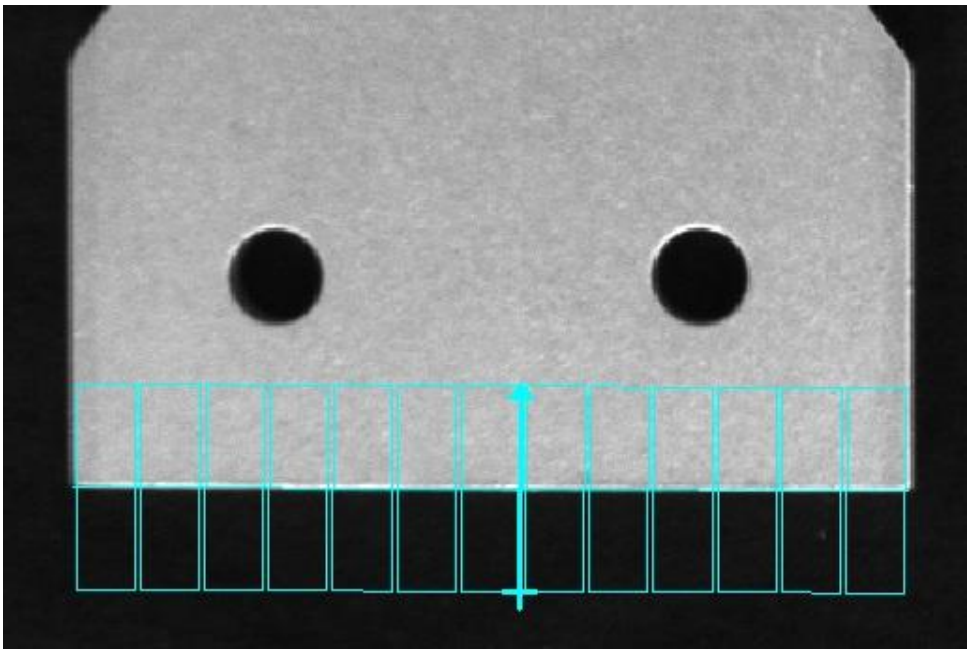
This opens a CogToolBlock configured with the input image passed to a CogFindLine tool:



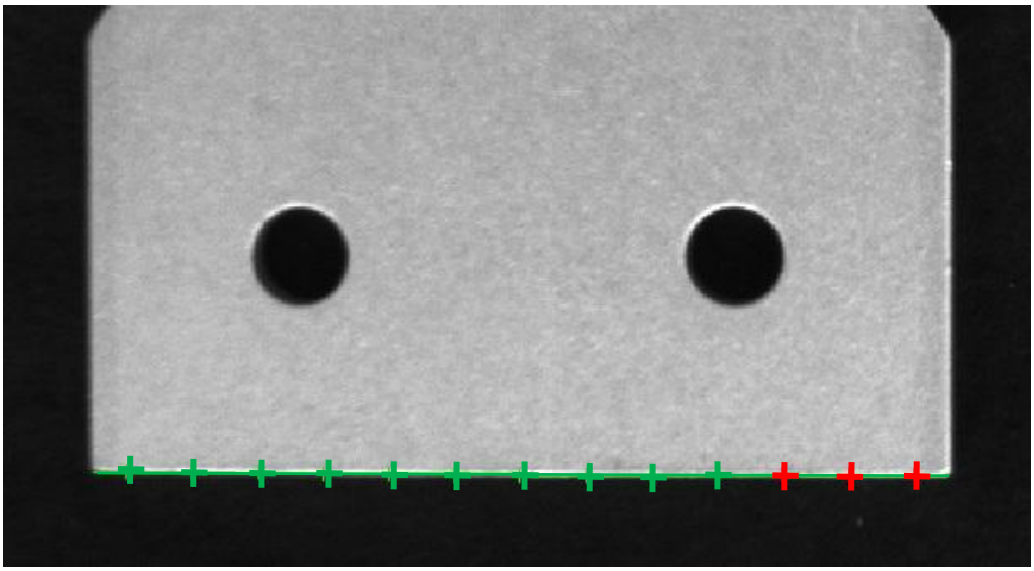
4. Open the CogFindLine tool edit control and configure it to locate the bottom of the sample part.

   Refer to your VisionPro online documentation for details on how to configure a CogFindLine tool through its edit control. When configuring the CogFindLine tool, the

endpoints of the expected line segment should be close to the actual endpoints of the sample part edge, as shown:



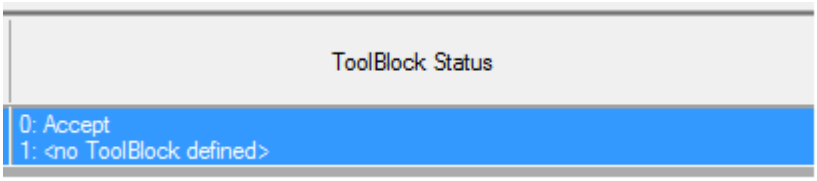
Run the CogFindLine tool to verify that it returns a line segment along the bottom of the sample part:



Adjust the parameters of the CogFindLine tool until the result tightly fits the edge of the sample part.

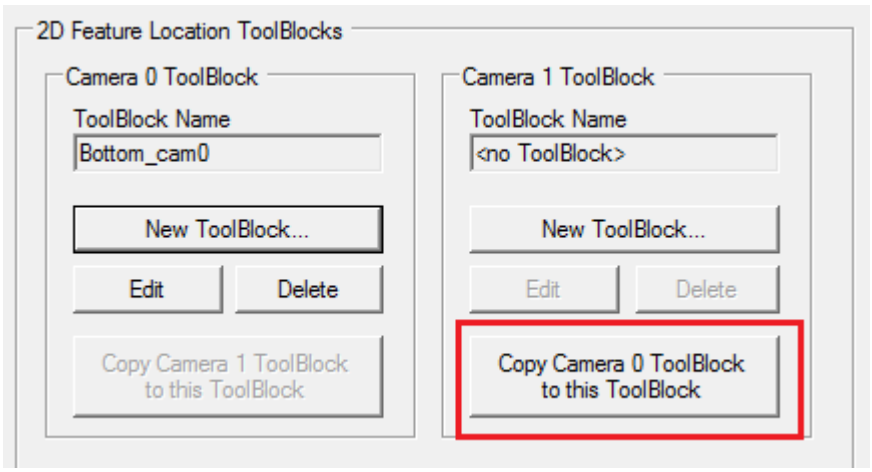
5. Close the CogFindLine tool edit control.
6. Close the CogToolBlock.

At this point Camera 0 has a CogToolBlock to locate the bottom of the sample part, as reflected in the **ToolBlock Status** of the dialog box:



The **Configure 3D Model Features and 2D Feature Location ToolBlocks** dialog box provides a quick way of copying the configured CogToolBlock for Camera 0 to Camera 1.

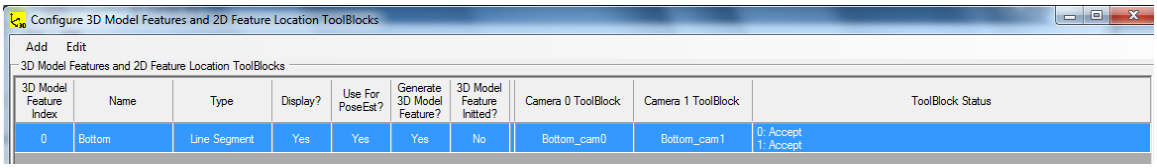
7. Under **2D Feature Location ToolBlocks**, click **Copy Camera 0 ToolBlock to this ToolBlock**:



This makes a copy of the CogToolBlock used to locate the edge feature in Camera 0 to Camera 1, allowing the same CogFindLine tool parameters to find the bottom of the sample part in the image from Camera 1. The copied CogToolBlock (CogToolBlock for Camera 1) will automatically appear in a CogToolBlock edit control.

8. Confirm that the CogToolBlock for Camera 1 finds the edge at the bottom of the sample part.
9. Close the CogToolBlock for Camera 1.

At this point, the dialog box reflects a complete 3D feature:



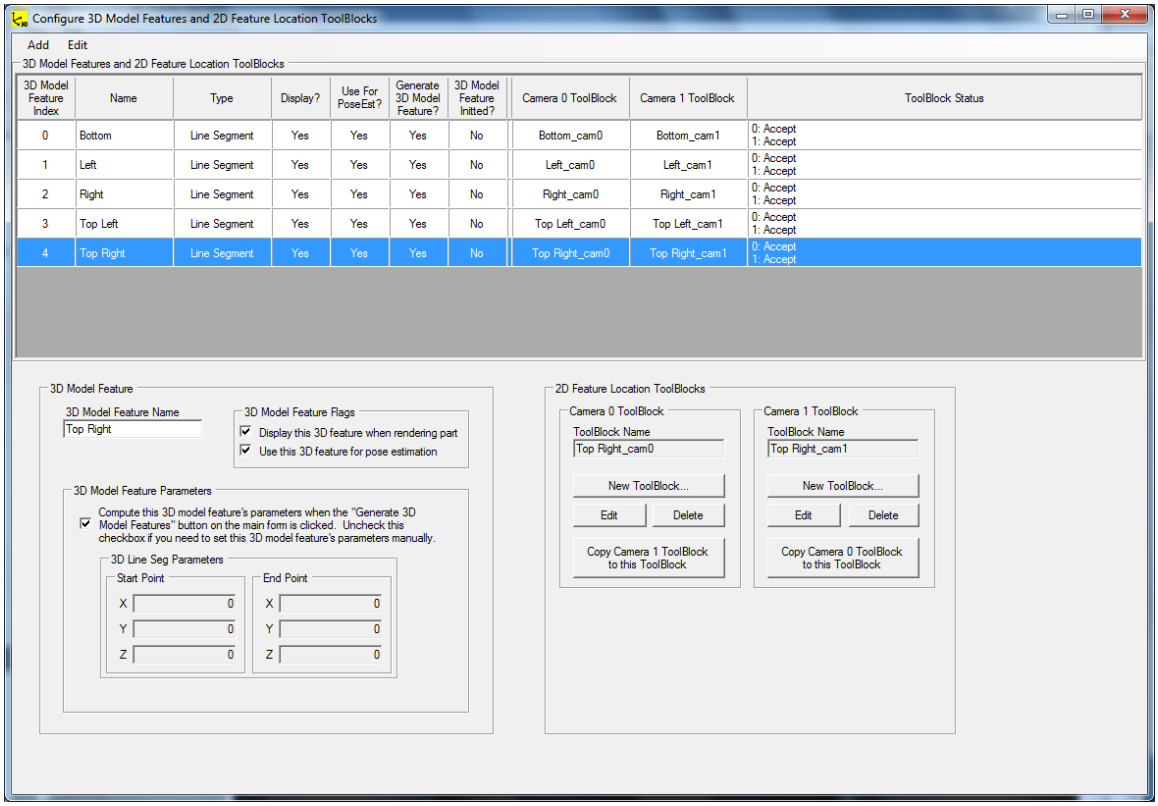
Before you can generate a 3D Model, you must add the other four 3D features corresponding to the remaining edges of the sample part.

Finding Remaining Edges

Use the same procedure outlined in the previous section (*Locating the Bottom Edge of the Sample Part* starting on page 29) to find the Left, Right, Top Left and Top Right edges of the sample part. In general, creating a new 3D feature involves:

- Adding a new entry for a 3D Point, 3D LineSeg, or 3D Circle using the **Add** menu.
- Giving the 3D feature a name using the **3D Model Feature Name** property
- Defining a CogToolBlock for Camera 0 to locate the 2D feature corresponding to the 3D feature you are adding
- Copying the settings of the CogToolBlock for Camera 0 to the CogToolBlock for Camera 1

The following figure shows the **Configure 3D Model Features and 2D Feature Location ToolBlocks** dialog box after all five 3D features have been configured for this sample part:

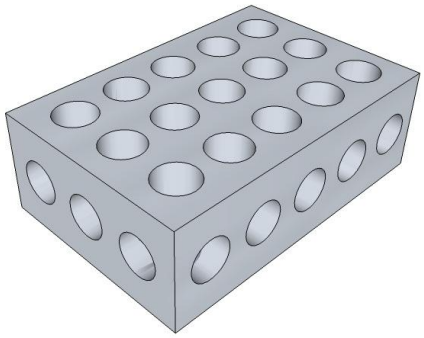


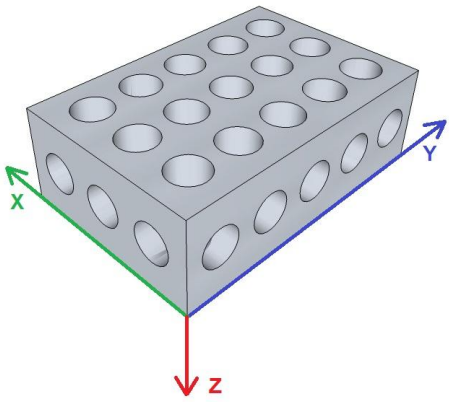
3D Model Feature Parameters

During 3D model feature generation, performed in the next step, the parameters (e.g. the 3D endpoints for a 3D lineSeg) for each 3D model feature are computed. You can disable the computation of the parameters for the currently selected 3D model feature by clearing the checkbox for **3D Model Feature Parameters.**

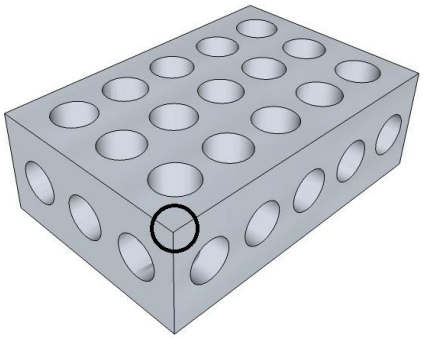
You should clear the checkbox for **3D Model Feature Parameters** if you want to manually enter the 3D model feature parameters in Model3D space. This can be suitable for parts where the parameters of 3D model features are known or easily measured.

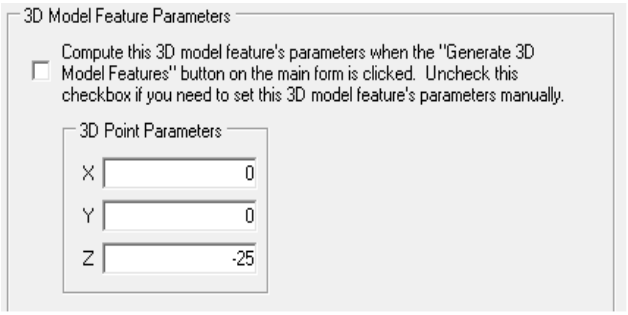
For example, the following figure shows a spacer block made to precise measurements, and the same spacer block resting at the origin of Model3D space:





If the spacer block is known to be 25 mm in height, 50 mm in width and 75 mm in length, you can enter the parameters of the 3D model features manually after clearing the checkbox for **3D Model Feature Parameters**. For example, you could create 3D Point features for the four corners along the top of the block and manually enter the Model3D coordinates for each point. The following figure highlights a point and the X, Y, Z coordinates for it:





3D Line Segments and 3D Circles can be manually configured in a similar manner.

Using 3D Points and 3D Circles

In addition to 3D LineSeg features, the **Configure 3D Model Features and 2D Feature Location ToolBlocks** dialog box allows you to also choose 3D Points and 3D Circles.

If you use 3D Circles, the associated CogToolBlock uses a CogFindCircle tool to locate the circular 2D feature.

If you use 3D Points, creating a new CogToolBlock allows you to choose between the following 2D feature locators to generate a point:

- **PMAlign**: A CogPMAlign tool. Note that the Search Region for this PMAlign tool should be sized about 50% larger than the PMAlign model and centered on the PMAlign model. (There is no need to search the entire image for the 2D feature being located by the PMAlign tool since the PMAlign tool runs in a fixtured space based on the 2D part location)
- **IntersectLineLine**: An intersection point found by running two CogFindLine tools and passing their results to a CogIntersectLineLine tool

- **Blank**: An empty CogToolBlock to define your own vision solution to locating a 2D point feature on the sample part. You must ensure the CogToolBlock has the following output terminals (just like the PMAlign CogToolBlock):
  - **Point0_X** (type must be Double)
  - **Point0_Y** (type must be Double)
  - **Valid** (type must be Boolean)

Locating the 2D Features

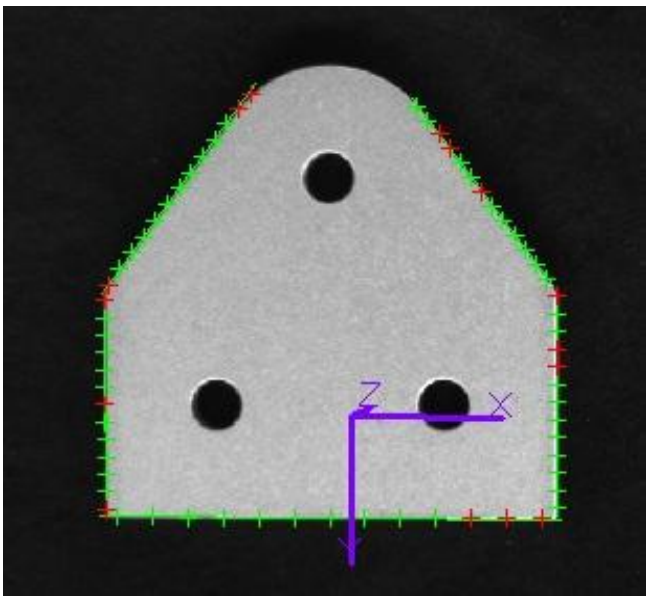
Confirm the application can reliably locate all the 2D features:

1. Close the **Configure 3D Model Features and 2D Feature Location ToolBlocks** dialog box and return to the main form of the StarterKitApp.
2. Click **Run 2D Feature Location**.

   The application begins acquiring ViewSets continually and running all the 2D feature locators.
3. Move the sample part in the field of view.

   The application should locate the sample part using the PMAlign tool configured in 2D Part Location, and then locate the desired 2D features on the part using the configured 2D feature locators.

   The following figure shows the display window for Camera 0 where the five line segments have been located on the sample part:



4. Try moving the sample part around the field of view and changing its angle with respect to the cameras.
5. Add a second sample part to the field of view and confirm that the application reliably locates both.
6. Click **Stop 2D Feature Location.** If you are satisfied that the StarterKitApp reliably locates the sample parts and their 2D features, go on to the next step. If you are not satisfied, then reconfigure your 3D model features and 2D feature locators.

7. Choose **File->Save Part** to save your progress.

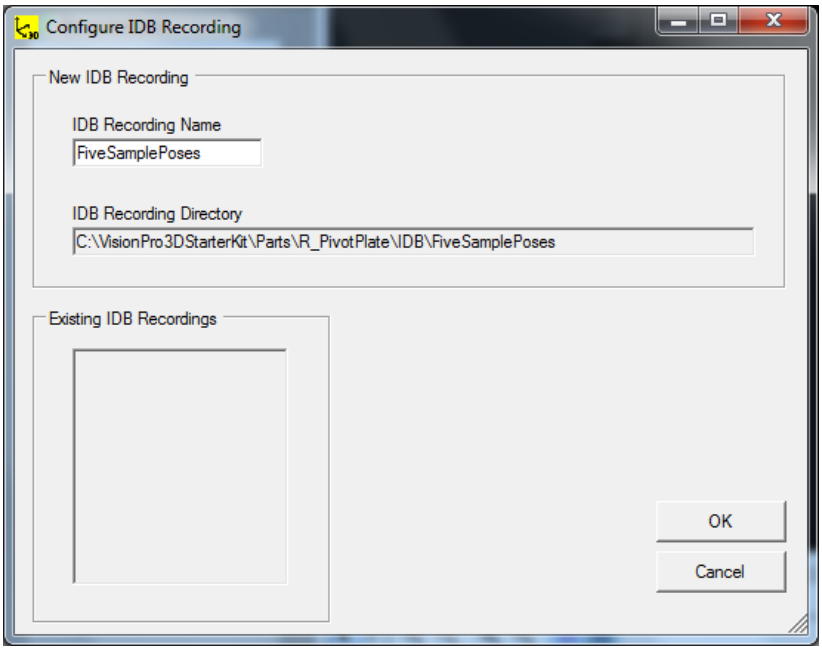
Creating the 3D Model

Click **Generate 3D Model Features** and select **Best Practices For 3D Model Feature Generation** to review a list of best practices recommended by Cognex for creating a 3D Model. The procedure outlined in this document uses those best practices, which includes generating an image-database of five ViewSets, each with a different Pose.

Creating an Image-Database for 3D Model Generation

Perform the following steps to create the image-database (IDB) file:

1. Choose **File->Save Part** to save the current part file.
2. Choose **IDB->Enable IDB Recording->Record User Specified ViewSets**.
3. Enter a name for the IDB recording and click **OK**:



4. Click **Start Acquiring**.
5. Place the sample part in the field of view with no rotation, near the origin of Phys3D space. The Phys3D space is indicated by the purple coordinate frame that appears when running the 2D feature locators.

   See the *VisionPro 3D-Locate Developer's Guide* for more information on the coordinate spaces generated by 3D calibration.
6. Choose **IDB->Record Currently Displayed ViewSet** to add Pose 0 to the IDB file.
7. Move the sample part to the upper-left corner of the field of view and rotate the part about 20 degrees about the Z axis as compared to the rotation in Pose 0. Then, choose **IDB->Record Currently Displayed ViewSet** to add Pose 1 to the IDB file.
8. Move the sample part to the upper-right corner of the field of view and rotate the part about 45 degrees about the Z axis as compared to the rotation in Pose 0. Then, choose **IDB->Record Currently Displayed ViewSet** to add Pose 2 to the IDB file.

9. Move the sample part to the lower-right corner of the field of view and rotate the part about ~67 degrees about the Z axis as compared to the rotation in Pose 0. Then, choose **IDB->Record Currently Displayed ViewSet** to add Pose 3 to the IDB file.
10. Move the sample part to the lower-left corner of the field of view and rotate the part about 90 degrees about the Z axis as compared to the rotation in Pose 0. Then, choose **IDB->Record Currently Displayed ViewSet** to add Pose 4 to the IDB file.
11. Choose **IDB->Disable IDB Recording** to stop recording ViewSets.

Verify that you have captured all five Poses by viewing the images in the IDB file:

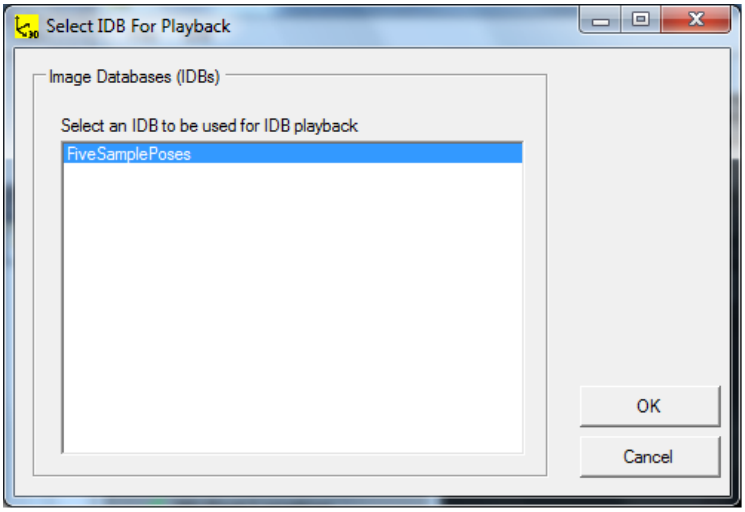
1. Choose **IDB->Enable IDB Playback** and select the IDB file you just created.
2. Click **Acquire Once** repeatedly to cycle through the images in the IDB file.
3. Choose **IDB->Disable IDB Playback** after you have confirmed that the IDB file contains the five Poses for 3D Model generation.

If you did not capture all five Poses, overwrite or capture a new IDB file using the procedure outlined previously.

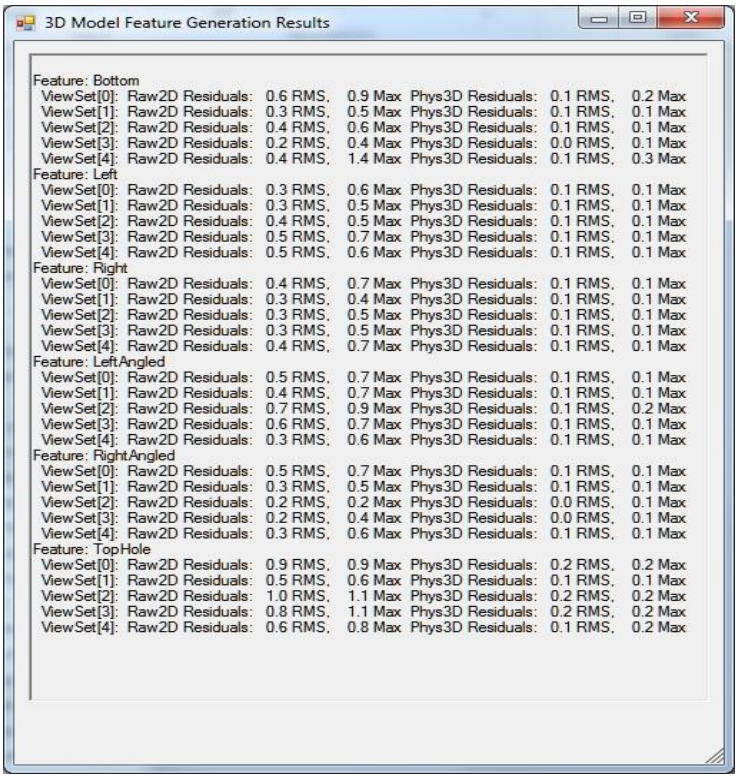
Running the 3D Model Feature Generator

Perform the following steps to create the 3D Model:

1. Click **Generate 3D Model Features** and choose **Generate 3D Model Features From IDB**.
2. Select the IDB file containing the five ViewSets and click **OK**:



The StarterKitApp generates a 3D Model using the ViewSets stored in the image database and displays a set of 3D Model Feature Generation Results, as shown:



3. Examine the results.

   In general, Raw2D residuals should be less than or equal to 1.5 pels RMS. If you have a feature or features with residuals greater than 1.5 pels RMS, it may be an indication that there is a problem with the feature's 2D part locator(s). Investigate this by enabling IDB playback of the image-database you created and running the 2D feature locators for each ViewSet where a high residual occurred.

4. Close the results display.

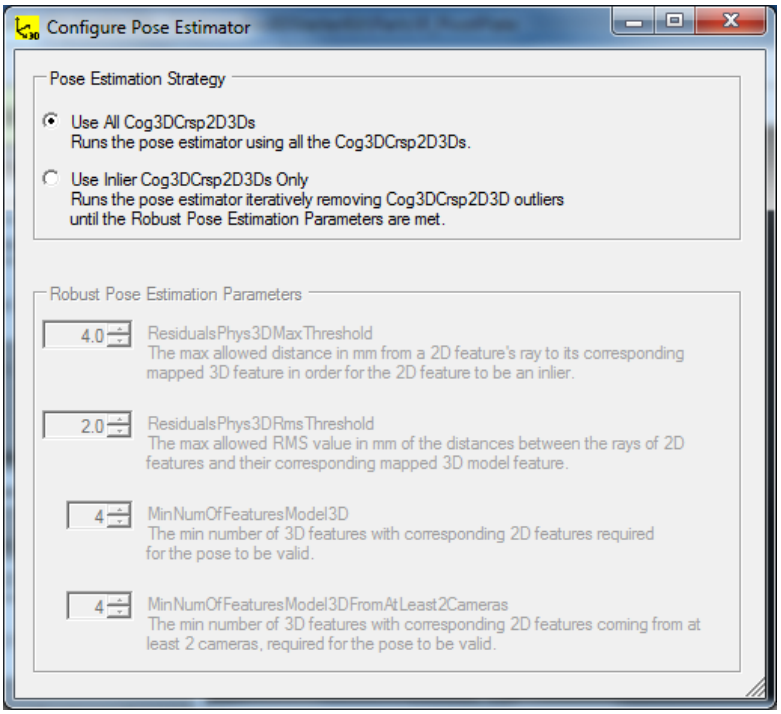
   The application prompts you to update the part file with this 3D Model.

5. Choose **File->Save Part** to save your progress.

Perform a 3D Pose Estimation

With the 3D Model generated, you can perform 3D pose estimation on any ViewSet after configuring the 3D pose estimator.

Click **Configure Pose Estimator** to choose a pose estimation strategy:



The StarterKitApp offers two pose estimation strategies:

- Use all the 2D to 3D feature correspondence Cog3DCrsp2D3D objects.

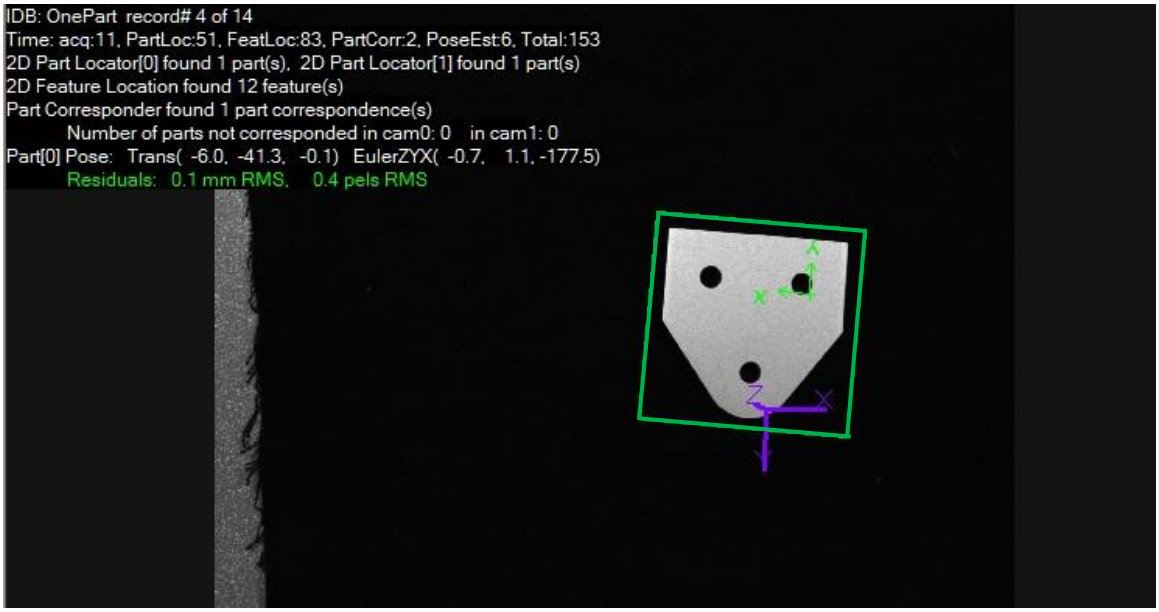
  The StarterKitApp creates a set of Cog3DCrsp2D3D objects based on the 2D feature locators you used to find the five edges of the sample part.

  See the *VisionPro 3D-Locate Developer's Guide* for a description of how your application must generate Cog3DCrsp2D3D objects.

- Use only the inlier Cog3DCrsp2D3D objects that meet a set of robust pose estimation criteria. This strategy removes the Cog3DCrsp2D3D objects that are considered to be outliers based on the **Robust Pose Estimation Parameters**.

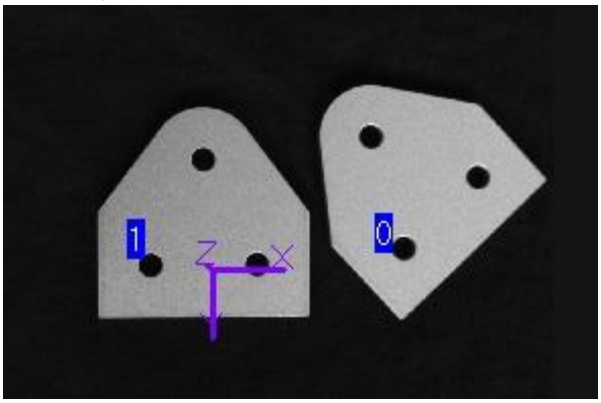
Select a strategy and close the dialog box. Click **Run** or **Run Once** to perform 3D pose estimation on the sample part currently in the field of view. The display window for Camera

0 includes 3D pose result information, as shown in the following example:



Test your completed configuration by moving your part around the field of view and tilting it. If you find a problem, record an image-database of the part in the problem pose. Then, starting with 2D part location, determine the source of the problem and correct.

Place a second sample part in the field of view and enable the **Corresponder Diags** option at the bottom of the interface. When you click **Run Once** or **Run**, the StarterKitApp performs a 3D pose for both parts and labels the individual sample parts across the ViewSet, as shown:



The StarterKitApp includes a set of options for graphics you can display over each sample part after 3D pose estimation:

- **Part Location Diags**: Display a graphic indicating where the sample part was found
- **2D Feature Location Diags**: Display graphics indicating all the found 2D features over each image.
- **Crsp2D3Ds**: Display graphics representing the 2D features in the Cog3DCrsp2D3D objects used for 3D pose estimation.
- **Corresponder Diags**: Display the part instance index over each part in the ViewSet.

- **Pose Est. Diags**: Display mapped model features using different colors: green for good matching features (inliers), red for outliers, and dark red for 3D features not being used for 3D pose estimation.
- **Final Pose**: Display the pose graphics for each part in each image. Green indicates parts with residuals less than 2.0 pels RMS. Yellow indicates parts with residuals between 2.0 and 5.0 pels RMS. Orange indicates parts with residuals greater than 5.0 pels RMS.

Loading a Complete Part File

Your VisionPro installation includes a complete part file for the sample part. To load and examine the file, perform the following steps:

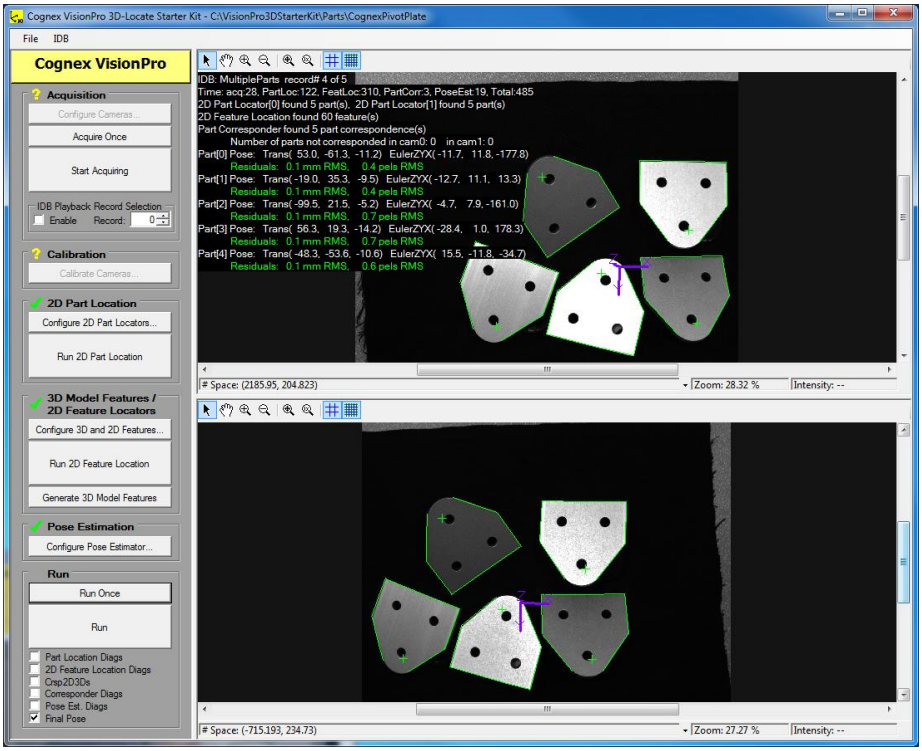
1. Launch the StarterKitApp.
2. Choose **File->Load Part**.
3. Choose **CognexPivotPlate** from the **Load Part** dialog box.

   The CognexPivotPlate part file includes three IDBs of the sample part:

   - 3DModelFeatureGeneration: Five ViewSets for creating a 3D Model
   - MultipleParts: ViewSets with multiple part instances in the field of view
   - OnePart: ViewSets with a single part instance in the field of view
4. Choose **IDB->Enable IDB Playback** and select an IDB file.

   With IDB playback, any ViewSet acquisition occurs from the IDB and not from any connected cameras.
5. Run the 3D Pose estimation on any IDB. The following figure shows the StarterKitApp using the images in the **MultipleParts** IDB, generating a 3D pose for each of the five

instances of the sample part:



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