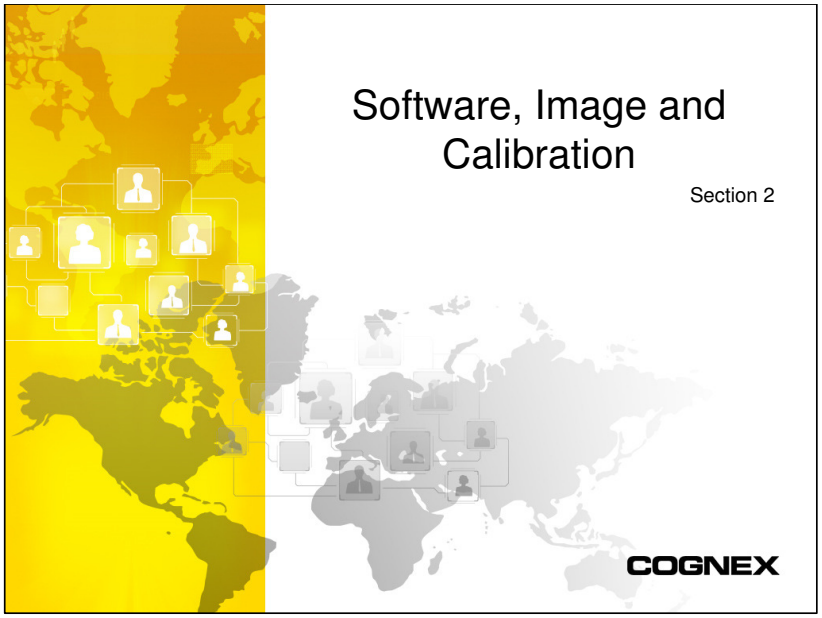
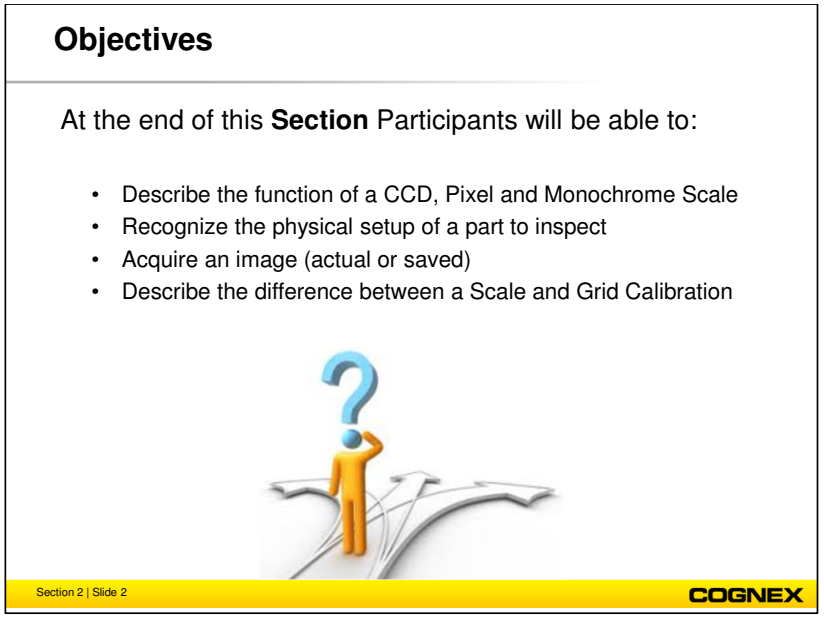


The second section of the In-Sight EasyBuilder Standard training will focus on **Software, Image and Calibration**.



At the end of this section, Participants will be able to:

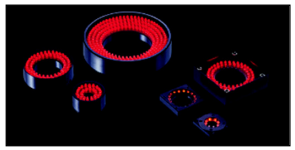
- Describe the function of a CCD, Pixel and Monochrome Scale
- Recognize the physical setup of a part to inspect
- Capture an image to the camera (actual and saved)
- Describe the difference between a Scale and Grid Calibration

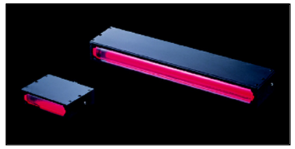
Working with Images

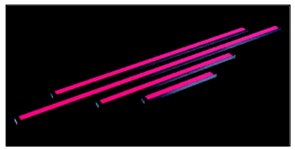
Section 2 | Slide 3 COGNEX

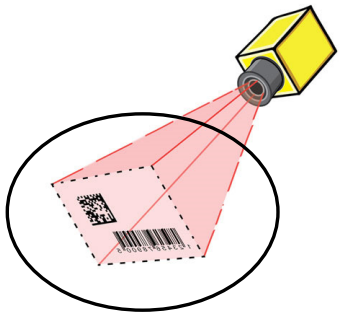
In this section we will cover how to work with images.

Lighting, FOV, and Lens









Section 2 | Slide 4 COGNEX

In a later section on **Lighting and Optics**, we will take an in-depth look at lighting and optics and how they affect the quality of the image.

Field of View is the image area of an object under inspection. This is the portion of the object that fills the camera's sensor. Field of View is critical for choosing the correct optical components to use in an imaging application. Since resolution is dependent of field view, determining field of view affects what one is trying to analyze or measure.

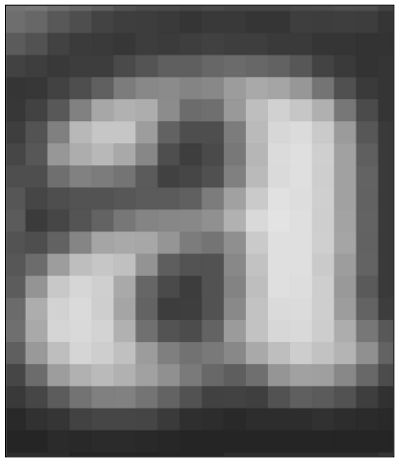
The camera's aperture setting controls the are over which light can pass through your camera lens. It is specified in terms of an f-stop value. The area of the opening *increases* as the f-stop *decrease*, and vice versa. The camera's aperture setting is what determines the depth of field. So, a wide opening will give a shallow depth of field, and a narrow opening will give a wide depth of field.

A **Fixed Aperture** will function independently of the lens focal length. The barrel of the lens does not extend or retract when the focal length changes. The fixed aperture prevents accidental changes in the size of the aperture or slowly shifting aperture values through vibrations effectively.

An **Adjustable Aperture** can be adjusted to vary the amount of light appearing at the focal plane of the imager.

The **Focus** is an important aspect in many applications involving machine vision. The degree of focus in an image is a factor in determining image quality. For example, a focused image may contain some details not present in an unfocused image of the same part.

Image Acquisition



Section 2 | Slide 5 COGNEX

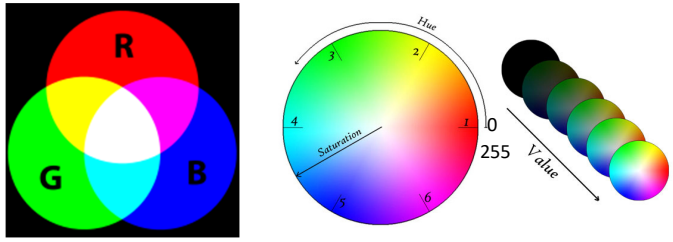
The **Charge Coupled Device** (CCD) is an integrated circuit etched onto a silicon surface forming light sensitive elements called pixels. This is also called the image sensor. The CCD converts light into an analog voltage, the camera then converts the analog voltage into a digital value.

The image is divided into grid of square picture elements called *pixels*. Each *pixel* consists of a location within the image (X/Y coordinates) and a light intensity value or values.

Pixels

Monochrome Cameras

Color Cameras



Section 2 | Slide 6 COGNEX

The Light intensity in a Monochrome Camera is represented as a greyscale value from 0 to 255, with 0 representing black and 255 representing white.

In a Color Camera each color is composed of three separate color components. Each component of a pixel is converted to a value from 0 to 255.

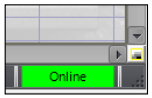
These components may be represented as combinations of:

- Red, Green, and Blue (RGB)
  - Red = 255, 0, 0
  - Green = 0, 255, 0
  - Blue = 0, 0, 255
- Hue, Saturation, and Intensity (HSI).
  - Red = 0, 255, 85
  - Green = 85, 255, 85
  - Blue = 170, 255, 85

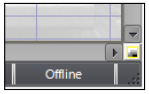
NOTE: *In-Sight Color vision systems report the color components of the pixel.*

Online vs. Offline

Online means that all In-Sight Input and Output signals are enabled.



Offline means that most In-Sight Input and Output signals are disabled.



Section 2 | Slide 7 COGNEX

Online means that all In-Sight Input and Output signals (discrete, serial, network, and non-manual triggers) are enabled.

When **Online**:
You can do this:
- Acquisition triggers
- Serial I/O
- Discrete I/O
- Network I/O

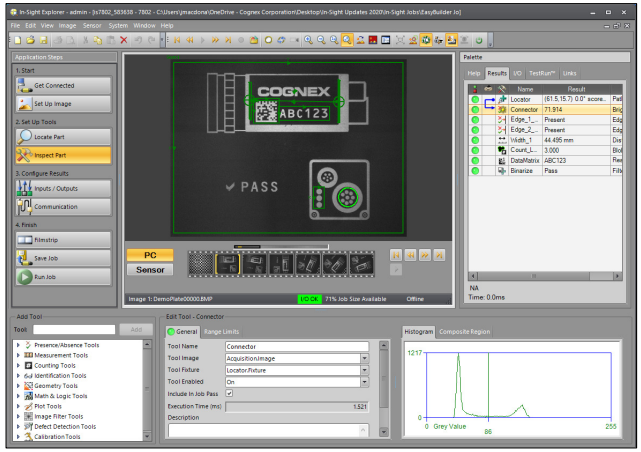
But not this:
- Edit spreadsheet
- Open Property Sheets

Offline means that most In-Sight Input and Output signals are disabled.

When **Offline**:
You can do this:
- Edit spreadsheet
- Open Property Sheets

But not this:
- Acquisition triggers
- Serial I/O
- Discrete I/O
- Network I/O

What is In-Sight Explorer?



Section 2 | Slide 8 COGNEX

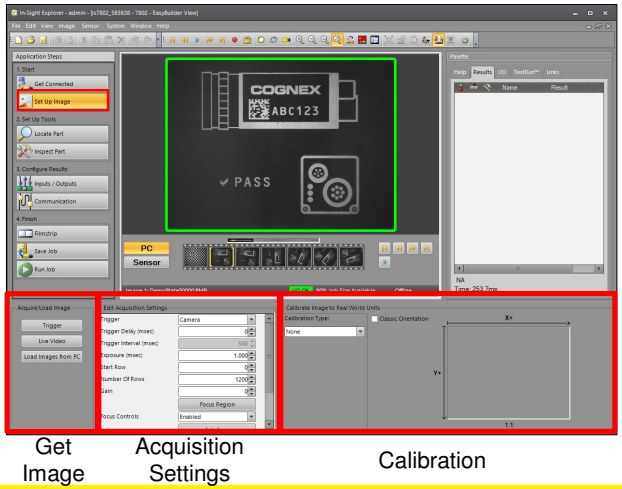
In-Sight Explorer provides a powerful and completely integrated vision system configuration, management and operator interface, all within a single software package. In-Sight Explorer includes two development environments to program and manage In-Sight vision systems: EasyBuilder and Spreadsheet.

- Application that manages multiple networked In-Sights
- Log onto any In-Sight system on network
- Create and modify jobs on any In-Sight
- View and manage multiple jobs simultaneously

In-Sight Explorer automatically detects any In-Sight vision systems on your subnet and displays them. Vision systems with a camera icon represent actual In-Sight vision systems (for example, the In-Sight 5100) while the computer icon represent In-Sight emulators running on networked PCs. The name of the emulator is the computer's name under Microsoft Windows. To make sure the list is current, select **View→ Refresh** or press **<F5>.**

You can view more than one camera in In-Sight Explorer by going to the Windows menu and selecting one of the **Tile** options. This will display all the cameras to which you are connected.

1. Start – Set Up Image

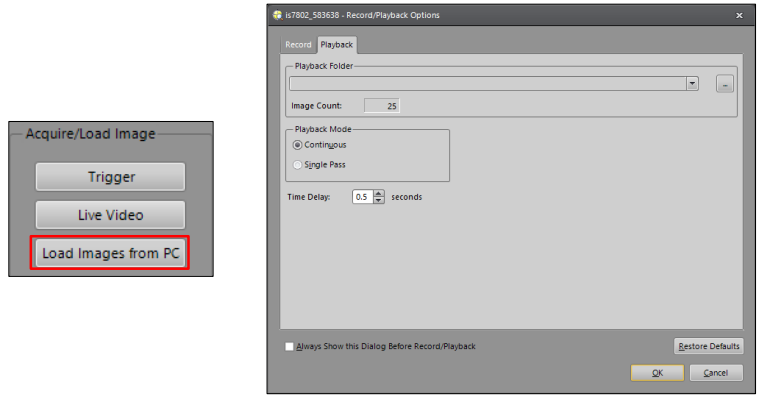


Section 2 | Slide 9 COGNEX

We are already connected to the camera; the next step is to **Set up the Image**.

- **Get Image** – Where is the image being captured?
- **Acquisition Settings** – How is the image being acquired? This is where the trigger, exposure, light and focus can be controlled.
- **Calibration** – A critical operation in precision alignment applications. Errors in calibration can have subtle but important effects on results.

Acquire / Load Image

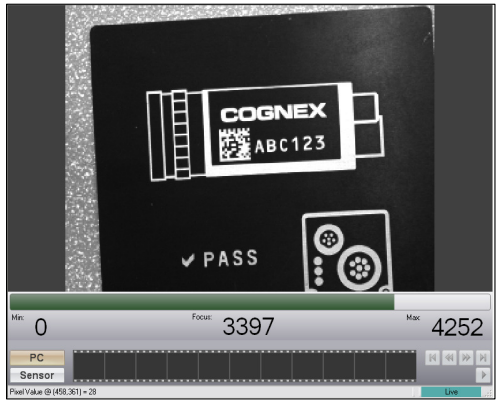


Section 2 | Slide 10 COGNEX

The **Acquire** / **Load Image** group box allows you to instantly:

- Acquire an image – single shot (manual acquisition)
- Display live video
- Load previously acquired images from a PC

Live Image – Focus Metric



Section 2 | Slide 11 COGNEX

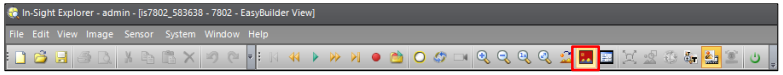
For each captured image, a **Focus Metric** is calculated based on the image related to its Z position. This results in a focus curve data – the peak of the focus curve corresponds to the best focus axis and the Z height of the imaged surface. In order to capture this data the user must be offline.

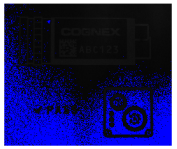
The benefits of the focus metric data:

- Helps determine image focus
- Degree in which the image includes the smallest resolvable features
- Uses ComputeImageSharpness

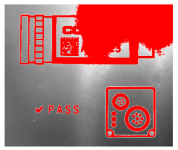
Image Saturation Tool

Show Brightness Feedback toolbar button assists with obtaining a good image

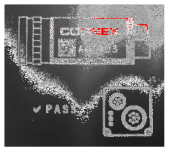




Not bright enough



Too bright



Good

- Goal is not to have blue or red span a feature and background
- Thresholds for blue/red are set in System→Options (more later)

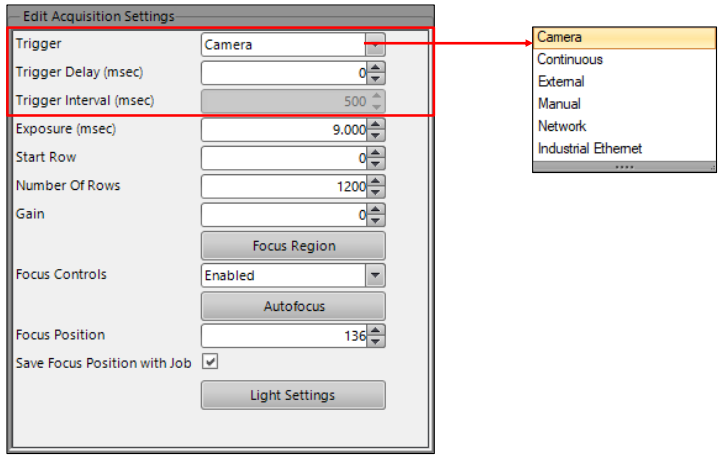
Section 2 | Slide 12 COGNEX

Red or blue shown on the image is not necessarily a problem if it is limited to the background or limited to a feature. It can indicate a problem when it overlaps a feature and the background.

The leftmost image needs to have more brightness. This can be accomplished with more lighting, a larger lens aperture, and/or a longer exposure. The middle image needs to have less brightness. This can be accomplished with less lighting, a smaller lens aperture, and/or a shorter exposure. The rightmost image is good. Even though there is some red, it is limited to features and does not overlap into the background.

The greyscale threshold is set in System→Options, with defaults of 5 (blue below 5) and 240 (red above 240).

Edit Acquisition Settings – Trigger



The **Edit Acquisition Settings** group box allows you to:

- Adjust the acquisition trigger controls
- Compensate for exposure and brightness
- Control lights for In-Sight cameras

Trigger for Online mode

- **Camera** – Trigger (+) and Trigger (-) connections (aka Hardware)
- **Continuous** – Enables free running image acquisitions (pseudo-live)
- **External** – Trigger via discrete input (via IO board)
- **Manual** – Enables image acquisition when pressing <F5>
- **Network** – Slave acquisition in Master / Slave set-up
- **Real-Time Ethernet**

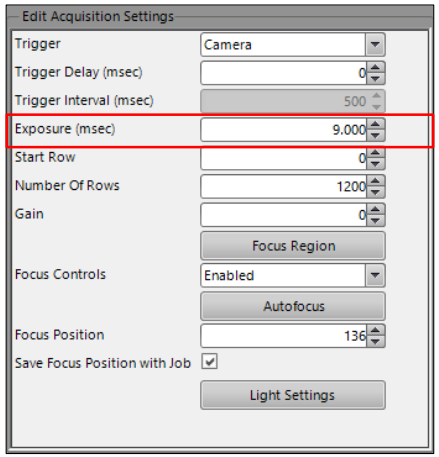
Trigger Delay

- Allows you to specify a delay, in milliseconds (0 to 10,000), between the time the trigger is received and the time the In-Sight vision system begins the acquisition.
  - The Trigger control must be in either Camera or Network to enable this functionality
  - The delay is accurate to the requested millisecond, plus or minus the maximum line exposure time, which is 64 microseconds
  - If Acquisition Start or Strobe is the specified Signal Type in the Outputs step, these outputs will be delayed by the specified time

Trigger Interval

- Allows you to specify an interval in milliseconds (0 to 10,000; default is 500), between acquisitions when the trigger control is set to Continuous.

Edit Acquisition Settings – Exposure



Exposure

- Allows you to specify the exposure time. When the In-Sight vision system receives a trigger signal, light is integrated in the image sensor array for the specified duration.
- **NOTE**: *When connected to an In-Sight 5604 or 5614 line scan vision system, the exposure time is set in microseconds.*

Auto-Exposure

- Allows the vision system to automatically determine the exposure. This control helps to compensate for inconsistent lighting conditions, such as reflections from shiny metal surfaces, shifting shadows and background lighting changes.
  - **Continuous** – Activates the vision system automatically to adjust the exposure, depending upon light conditions, for every image acquisition.
  - **Single-shot** – Adjusts the vision system's exposure based on the first image acquisition; the exposure settings will remain for each subsequent image acquisition.

Exposure Region Button

- Allows you to define a specific area of the image to be exposed during image acquisition. This is useful in situations where only part of the image is consistently darker of brighter.

Max Exposure Time

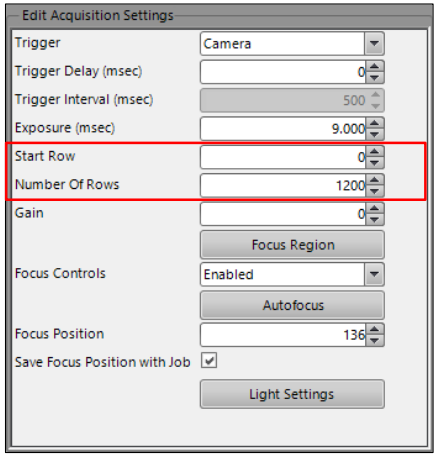
- Allows you to specify the maximum exposure time used when determining the proper exposure.

Target Brightness

- Brightness = percentage of saturated pixels in Auto Exposure region (0-100%)

  NOTE: *Either Continuous or Single-shot need to be selected from the Auto-Exposure drop-down menu, to enable this functionality.*

Image Sensor Transfer Controls



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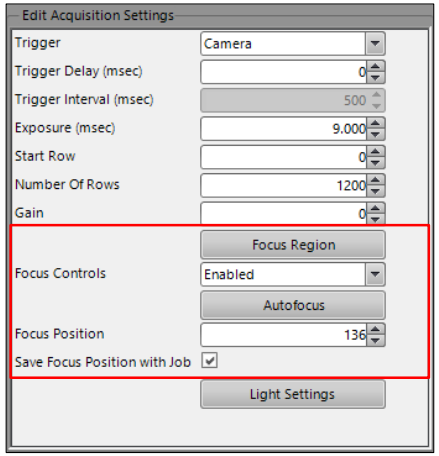
The **Image Sensor Transfer Controls** allow you to define at what row of the image sensor (CCD or CMOS) the image will begin to be transferred, and how many rows of the image sensor will be used to construct the image.

In-Sight vision systems capture all images using asynchronous reset and progressive scan,; greyscale In-Sight vision systems produce 8-bit images, while color In-Sight vision systems produce 24-bit images. The image acquisition process begins within approximately 250 µs for all vision systems, and proceeds as follows:

1. The image sensor integrates light for the duration of time specified by the Exposure Controls.
2. The image accumulated in the image sensor is transferred, row-by-row, into a serial shift register.
3. For every row transfer, the vision system clocks the shift register, pixel-by-pixel, out of the image sensor.
4. The transfer begins at the Start Row and proceeds for the specified Number of Rows.

Start Row defines the first row to be transferred from the image sensor into memory on the In-Sight vision system.
Number of Rows defines the number of rows to be transferred into memory on the In-Sight vision system.

Focus Controls



Section 2 | Slide 16 COGNEX

The **Focus Controls** are used to control the focus position of the lens on supported In-Sight 7000 series vision systems, by either automatically focusing the lens or moving the lens to a specific focus position.

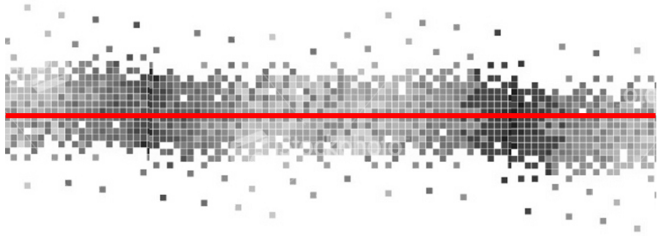
NOTE: *The Focus Controls only work when the vision system is offline.*

Focus Controls defines whether the Focus Controls are enabled. By default, if a sensor has a valid default focus position, the Focus Controls are enabled, if a focus position has not been established, the Focus Controls are disabled.
Autofocus Button automatically focuses the lens, to maximize image sharpness within the region.
Focus Position moves he lens to a specific focus position and acquires a new image.
Save Focus Position with Job defines whether the focus position will be saved with the job and applied to the lens whent eh job is reloaded. By default, the checkbox is checked.

Calibration – What is it?

All vision tools operate in the pixel world

What does it mean to be 108 pixels long?



Section 2 | Slide 17 COGNEX

What does it mean to be 108 pixels long?

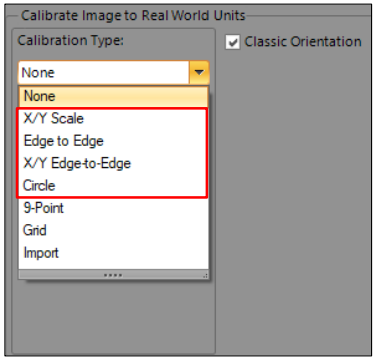
This changes with each camera environment based on:

1. Working distance (part to camera)
2. Mounting of the camera (directly over or at an angle)
3. Optics used (lens)

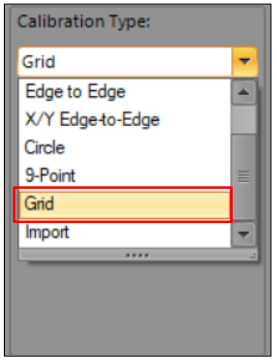
To get real-world, meaningful coordinates, such as inches or millimeters, it is necessary to calibrate. This relates the real world to the pixel world.

Calibration

Scale Calibration



Grid Calibration



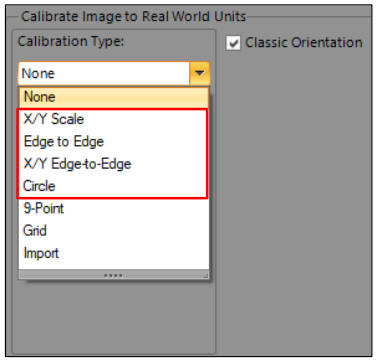
Section 2 | Slide 18 COGNEX

There are two types of calibration in EasyBuilder:

In **Scale Calibration**, you identify a distance on the image and tell EasyBuilder what that distance is in real-world units, such as mm. EasyBuilder already knows what the distance is in terms of pixels, so it can then convert the distance from pixels to real-world.

In **Grid Calibration**, you place a standard grid pattern (dots or squares) under the camera and tell EasyBuilder what the real-world distance is between dots or the size of the checkers. EasyBuilder locates all the dots or corners of squares and creates a table that relates each distance in pixels to its corresponding distance in real-world units. That table is stored in the job by the function that does all this (CalibrateGrid).

Calibration: Scale



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Scale Calibration is useful in applications where you are inspecting a part or object and you know the real-world measurement of the part or object. It does not account for radial, barrel, or perspective distortion.

The **X/Y Scale** is used when you know the X and Y scale values for calculating a simple calibration.

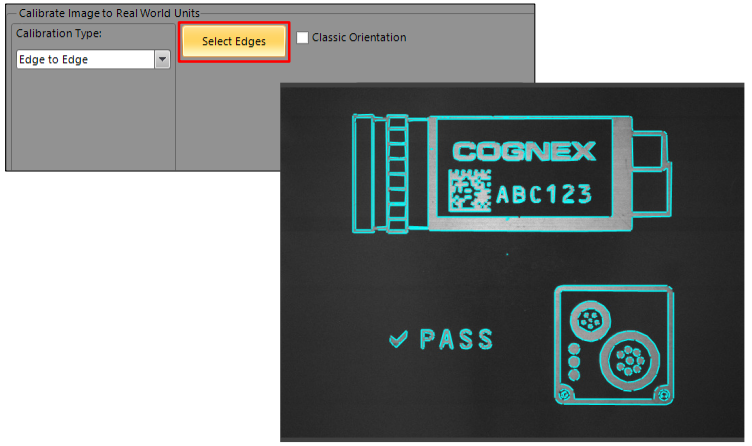
Edge to Edge is used when you know the distance between two edge features.

X/Y Edge-to-Edge is used when you know the distance between two edge pairs; one in the horizontal direction, and another in the vertical direction. Combining the horizontal measurement and dimension with the vertical measurement and dimension creates two independent scales.

Circle is used when you know the diameter of a circular feature.

The real life units are used for reporting purposes.

Calibration: Scale – Edge to Edge



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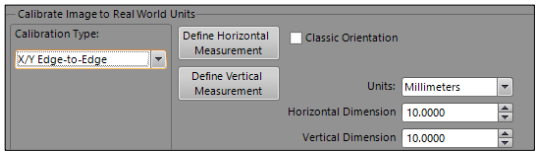
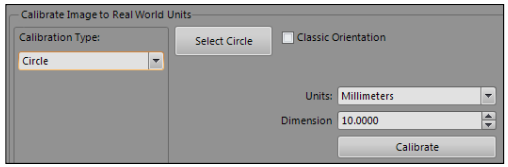
EasyBuilder will examine your image and give you a selection of *Smart Features* that it has automatically detected (highlighted in cyan).

NOTE: *The Scale Calibration options do not account for lens distortion, therefore, for the greatest degree of accuracy, ensure that the In-Sight system is mounted perpendicular to the inspected surface. Otherwise, consider using Grid Calibration to remove the distortion and more accurately calibrate your image.*

Calibration: Scale – X/Y Edge-to-Edge & Circle

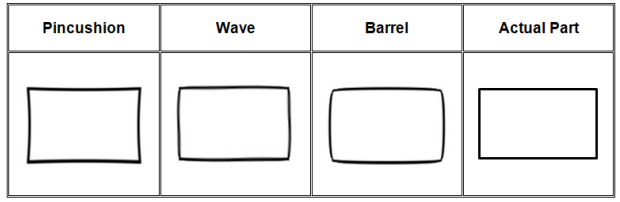


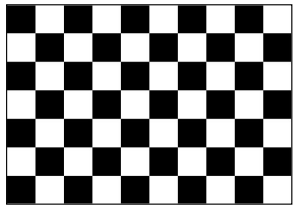


X/Y Edge to Edge calibration is used when you know the distance between two edge pairs; one in the horizontal direction and another in the vertical direction. Combining the horizontal measurement and dimension with the vertical measurement and dimension creates two independent scales.

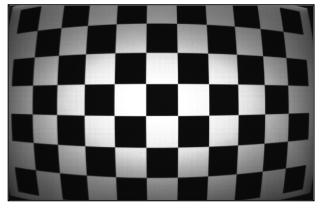
Circle calibration is used when you know the diameter of a circular feature.

Lens Distortion





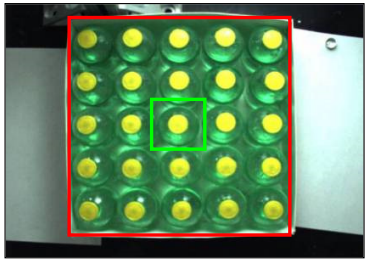
Undistorted Image



Barrel Distortion

Lenses have distortion effects on the image

Lens Distortion



Application Example (barrel distortion):

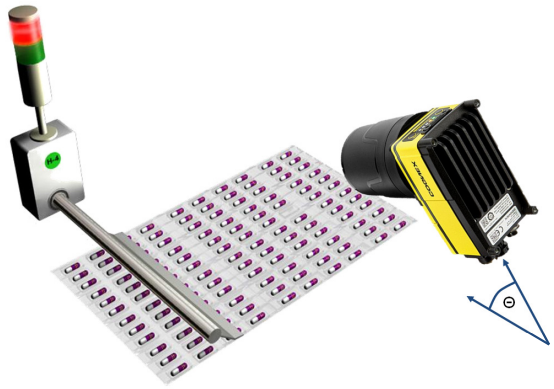
Use grid calibration so the bottles in the red region will be located as *accurately* as the bottle in the green region.

Section 2 | Slide 23 COGNEX

Grid calibration is a form of non-linear calibration. The benefits of non-linear calibration include:

- Accurate location of objects at the edges of the image
- Vision sensor mounting flexibility: allows you to maintain accuracy even when perpendicular mount is physically impossible

Perspective Distortion



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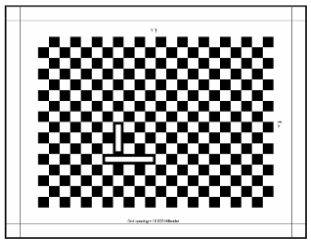
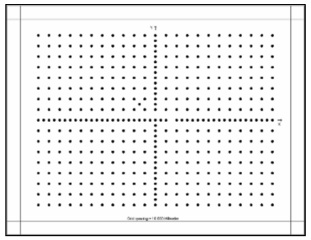
Cameras that are not mounted perpendicular to the surface exhibit perspective distortion. Objects' dimensions are skewed depending on the angle and location.

Grid Calibration (non-linear calibration)

Uses a commercial-quality grid with known distances

- Checker square
- Dot to dot





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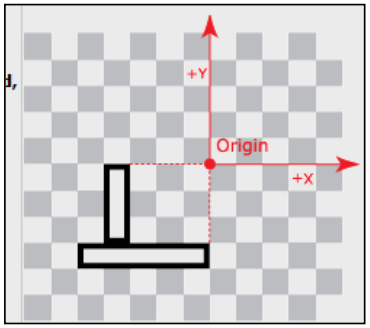
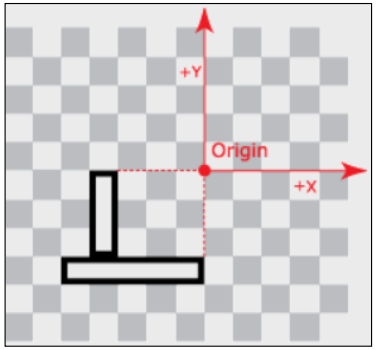
Tile vertices (the point where the corners of four tiles meet) are used to determine the feature location; vertices can be accurately located when the sensor is up to 45 degrees perpendicular to the surface; provides a fiducial marker to determine the grid's origin and identify the grid's orientation in real-world space.

NOTE: *Checkerboard checks must be at least 15 pixels wide.*



Grid Calibration– Checkerboard with Fiducial



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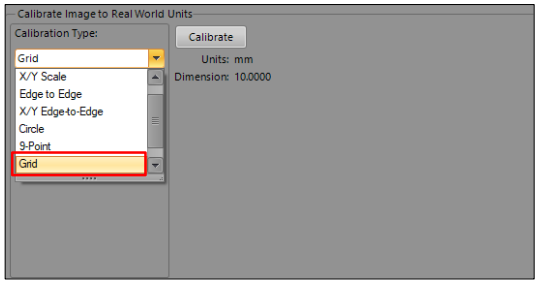
The fiducial for a checkerboard grid is the pattern of two rectangles shown above. It defines the origin (0,0) and the angle of the grid, which is useful for aligning to the coordinates of a robot.

Calibration: Grid



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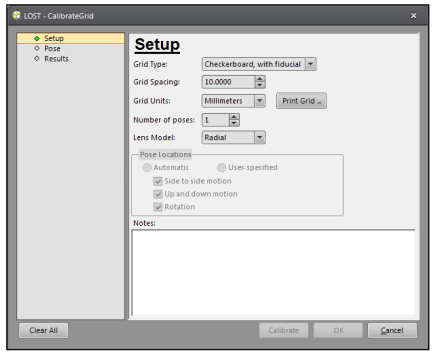
The **Grid Calibration** option creates a 'map' of the image area by acquiring an image of a grid pattern of either dots or checkerboard squares. This option then relates the found features of the grid (the dots or intersections of squares) to the user-specified grid spacing of the grid pattern. This process creates a highly accurate computation that can then be used to transform distorted features into their correct shape.

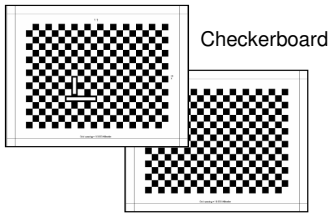
Calibrating an In-Sight vision system enables you to more accurately locate objects at the edges of images, and provides greater mounting flexibility, including the ability to mount the In-Sight vision system up to 45° from the inspection surface.

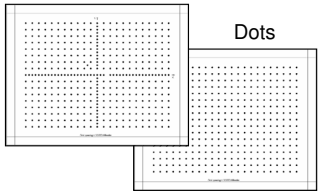
This is useful in machine vision applications which require a higher degree of accuracy in reporting results, such as gauging, and vision guided robotic applications. It does account for radial, barrel, or perspective / skew distortion.

Clicking the Calibrate button will launch the CalibrateGrid dialog.

Grid Calibration – Setup







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The **Setup** parameters allows the user to specify the following:

The **Grid Spacing** specifies either the size of the square in a checkerboard pattern, or the distance from center to center of the does in a grid-of-dots pattern (.0000001 to 9999999; default = 10).

The **Grid Type** that will be used to construct the calibration: Checkerboard, with fiducial; Checkerboard, no fiducial; Dots, with fiducial; or Dots, no fiducial.

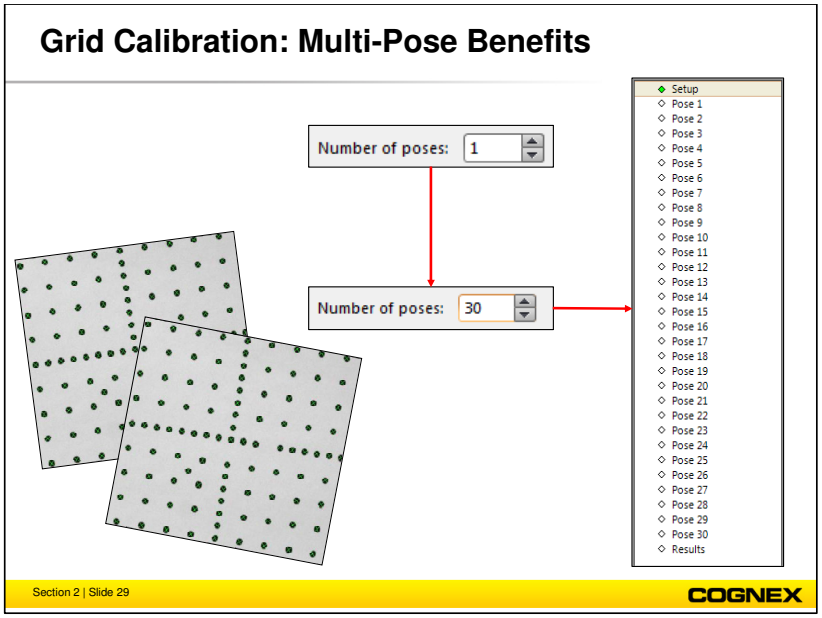
The **Grid Units** specifies the real-world measurement units (Microns, Millimeters (default), Centimeters, or Inches) that the calibration will be based upon.

Number of Poses specifics the number of poses that will be required to complete the calibration. Multiple poses are required when a single calibration pattern cannot fill the field of view. In this type of calibration, the calibration pattern is placed in various known physical locations to cover the field of view. Each position of the calibration pattern is called a pose.

Lens Model specifies the type of distortion correction (Radial (default) or Projection) to use based on the type of lens being used to acquire the image.

- *Radial* refers to distortion that affects any optical lens where the magnification is different at the edges of the field of view than at the center of the field of view.
- *Projection* refers to distortion introduced when the vision system's optical axis is not perpendicular to the scene being acquired.

When done with step 1, click on **Pose** in the list on the left.



The **Number of Poses** specifies the number of poses that will be required to complete the calibration. Multiple poses are required when a single calibration pattern cannot fill the field of view. In this type of calibration, the calibration pattern is placed in various known physical locations to cover the field of view. Each position of the calibration is called a pose.

Grid Calibration can process 1 to 30 poses.

What are the benefits of multi-pose calibration?

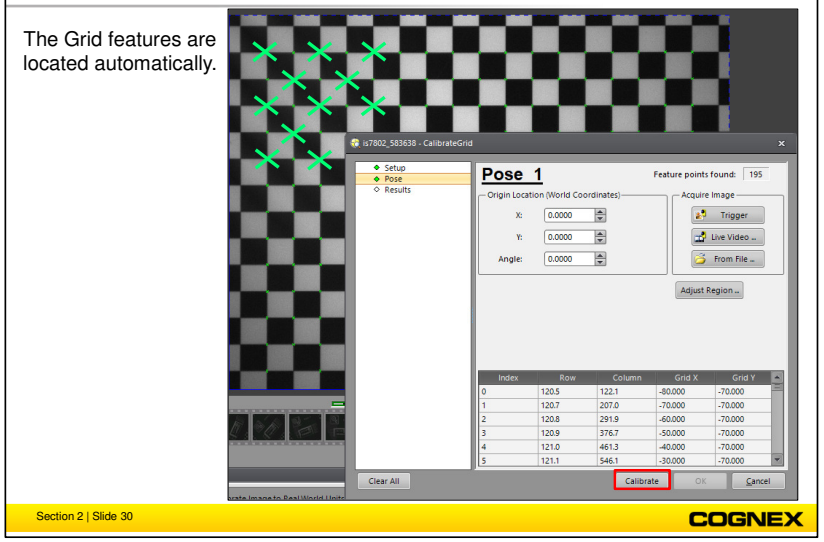
For Large Field of View:

- Use a smaller, less cumbersome calibration plate.
- Take multiple poses throughout the field of view to calibrate the entire image.

For Highly Distorted Images:

- Pose multiple times to bring in a large number of calibration points.

Benefit – a more accurate calibration.



Place the grid under the camera and acquire an image.

The **Origin Location (World Coordinates)** specifies the X and Y location of the origin in real-world coordinates; in the event of a discrepancy between the angular relationship of the grid's axes and the real-world axes, the Angle may be specified, as well.

Feature Points Found displays the total number of extracted feature points to be used in the calibration.

Acquire Image specifies how the image will be acquired.

- *Manual* specifies that an image will be acquired after manually pressing the Manual Trigger button.
- *Live Mode* specifies that the In-Sight vision system will enter live video mode, where the focus of the vision system may be adjusted.
- *From File* specifies that an image will be loaded using the Open Image dialog.

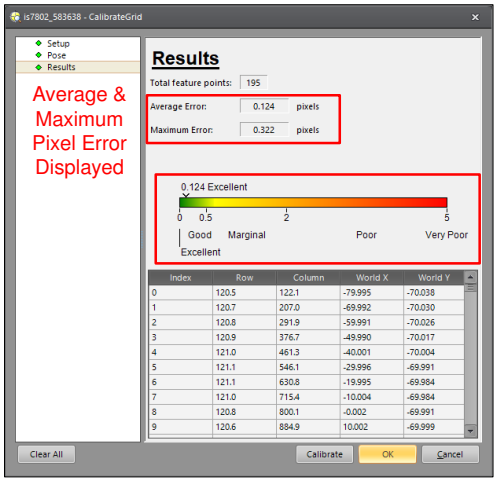
Grid Axes specifies the grid axes of the calibration pattern when a calibration pattern without a fiducial is selected.

Adjust Region launches interactive graphics mode to define a region of interest for the calibration; only features within the region of interest will be used in the calibration.

Feature points Table displays the feature points extracted from the image in their pixel row / column coordinates, as well as their calibration pattern location in grid coordinates (X,Y), relative to the origin. The X and Y coordinates are updated anytime the origin value changes. Extracted feature points are graphically displayed by a green colored 'x' at each feature location. Selecting a feature point from the table or clicking on a feature point in the graphical display, will highlight the feature in both locations and show its coordinates graphically.

Click the **Calibrate** button.

Grid Calibration – Results



Results shows the following information:

Total Feature Points displays the total number of feature points that were extracted and used in the calibration. ≤
Average Error displays the average error, in pixels, during the calibration.
Maximum Error displays the maximum error, in pixels, during the calibration.

The **Calibration Graphic** displays a graphic representation of the calibration.

- *Excellent* = Error ≤ 0.25
- *Good* = 0.25 < Error ≤ 0.50
- *Marginal* =0.50 < Error ≤ 2.0
- *Poor* = 2.0 < Error ≤ 5.0
- *Very Poor* = 5.0 < Error

Calibration Guidelines

You are calibrating the setup

- Keep calibration setup identical to production setup
- Limit calibration to region of interest containing feature(s) of interest
- Calibrate periodically

Keep the calibration set-up identical to the production set-up:

- Keep calibration object and part in the same plane
- Limit calibration to region of image features of interest

Calibrate periodically – whenever you think that the setup may change (each shift, daily, etc.).

Summary

- Images are composed of **pixels**, each represented by:
  - X,Y coordinate
  - Greyscale value (0-255)
- Three ways to get image:
  - Manual Trigger (F5)
  - Live Video: used to set up part
  - Load Images from PC
- **Scale Calibration** converts pixel world to real world
- **Grid Calibration** and **Transform** convert pixels to real-world units and also compensate for lens distortion

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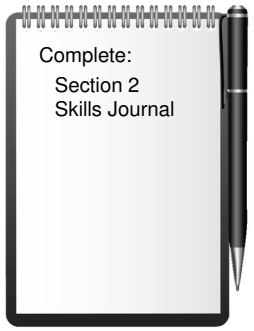
In this section we covered the following topics:

- Images are composed of pixels, each represented by:
  - X,Y coordinate
  - Greyscale value (0 – 255)
- Three ways to get image:
  - Manual Trigger (F5)
  - Live Video: used to set up part
  - Load Images from PC
- Scale Calibration converts pixel world to real world
- Grid Calibration and Transform convert pixels to real world units and also compensate for lens distortion

Skills Journal



Lab Exercise

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Complete:

Skills Journal (image designed by pngtree)

Lab Exercise