DS1000 Series Displacement Sensors Technical Reference

4/28/2014
Version 1.1.0

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VisionPro

5481712, 5495537, 5548326, 5583954, 5602937, 5640200, 5751853, 5768443, 5825913, 5850466, 5872870, 5901241, 5943441, 5978080, 5978521, 5987172, 6005978, 6039254, 6064388, 6075881, 6137893, 6141033, 6167150, 6215915, 6240208, 6324299, 6381366, 6381375, 6411734, 6421458, 6459820, 6490375, 6516092, 6563324, 6658145, 6687402, 6690842, 6697535, 6718074, 6748110, 6771808, 6804416, 6836567, 6850646, 6856698, 6920241, 6959112, 6963338, 6973207, 6975764, 6985625, 6993177, 6993192, 7006712, 7016539, 7043081, 7058225, 7065262, 7088862, 7164796, 7190834, 7242801, 7251366, 7313761, EP0713593, JP3522280, JP3927239

DataMan

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CVL

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OMNIVIEW

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CVL Vision Library

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SMD 4

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BGA II and BGA III

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Wire Bonder

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About this Manual

The *DS1000 Series Displacement Sensors Technical Reference* provides detailed information on the operational theory and concepts of the Cognex DS1000 Series Sensors.

How the DS 1000 Series Sensor Works

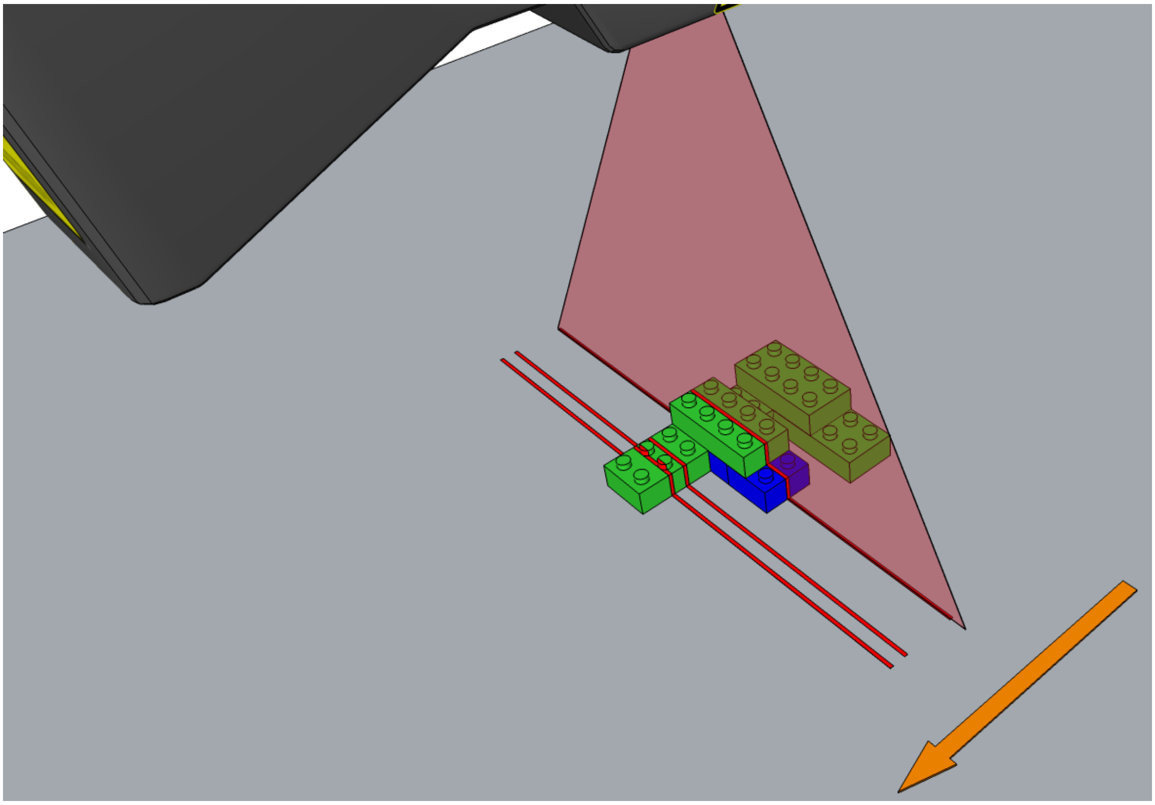
Basic Operation

A DS 1000 Series Sensor can return information about the 3D shape or size of objects that are difficult to visualize using regular 2D cameras.

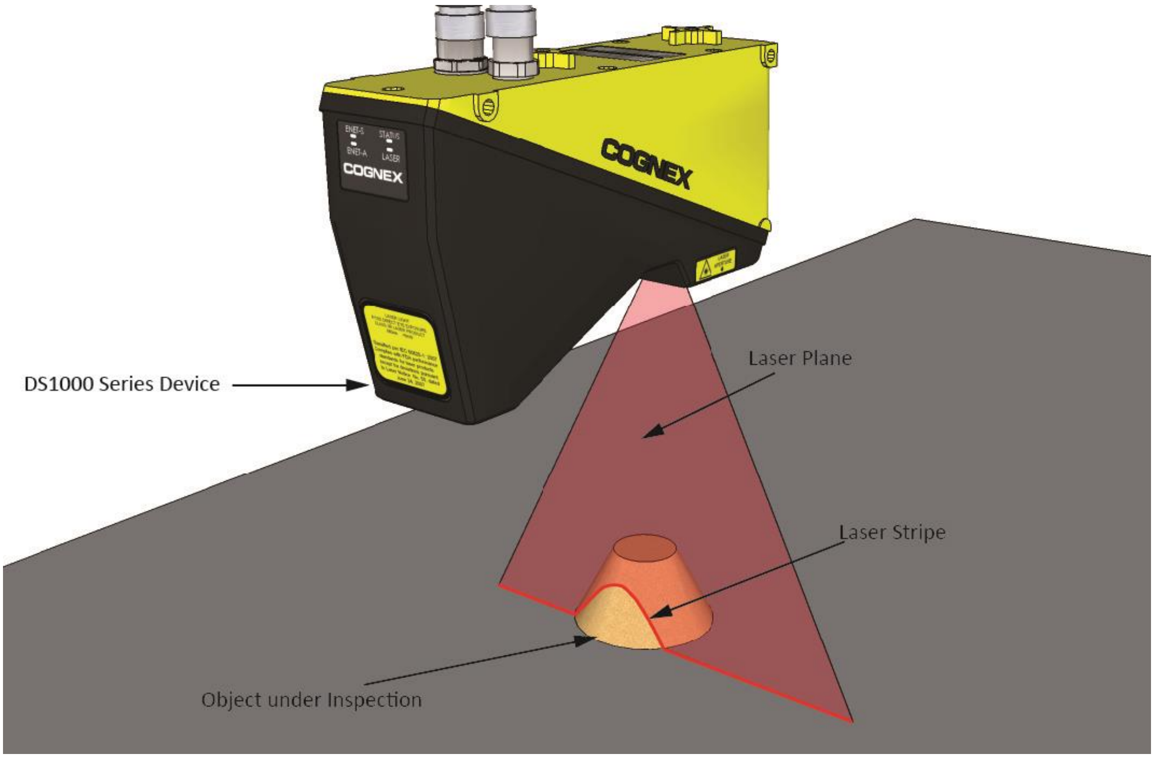
From a sensor, the VisionPro acquisition system can acquire the Range images that can be used to determine the three-dimensional (typically height, volume, or tilt) profile of objects passing under the sensor. The following overview illustrates how the sensor works with a typical application.

The following overview illustrates how the sensor works with a typical application.

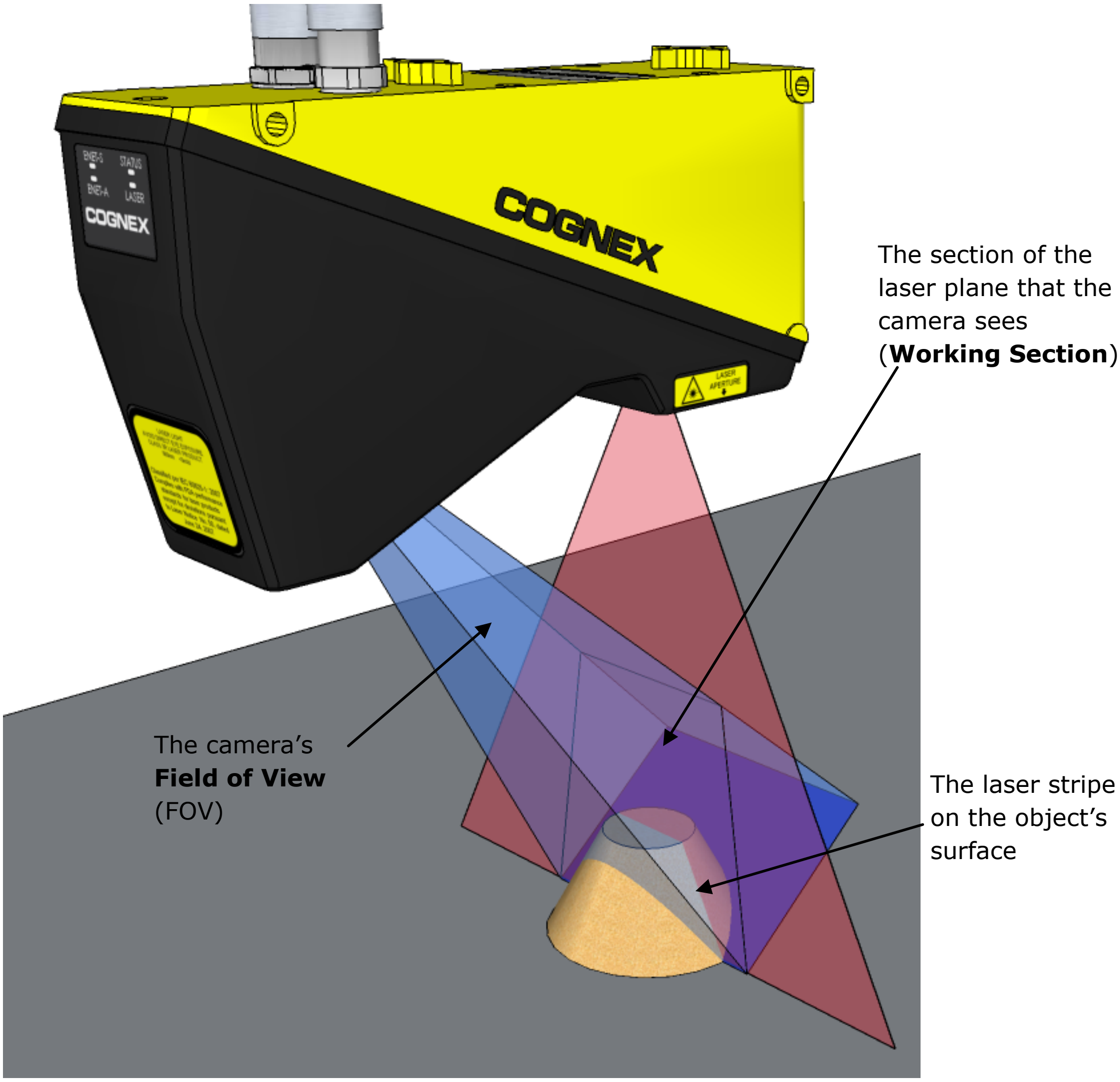
1. Place the object you want to measure on a conveyor belt equipped with an encoder.
2. As the object passes under the sensor, it acquires a series of images (**intensity images**).



3. In each acquired image, the sensor locates and measures the position of the apparent laser line (the brightest pixels).



4. The sensor then transforms each **intensity image** into the corresponding rows of the range image (see the following sections). Each individual row at this step is stitched together thus forming the **range image**.



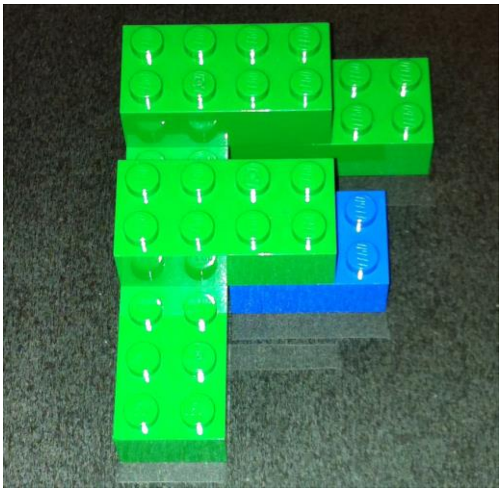
There are certain image distortions that derive from the fact that the camera has a fixed-point aspect, it has a lens, and that the object is moving under the sensor. However, Cognex's VisionPro software makes various adjustments (calibration) and, as a result, the range image does not show these unwanted optical effects.

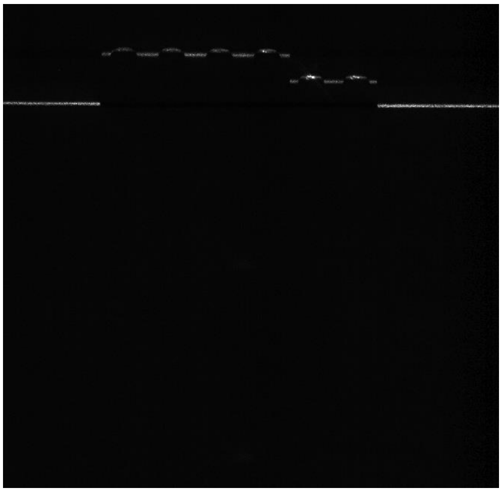
Intensity Image

The sensor projects a triangular laser plane onto the object under inspection, illuminating its surface. The illumination results in a laser stripe, the shape of which is determined by the surface of the object.

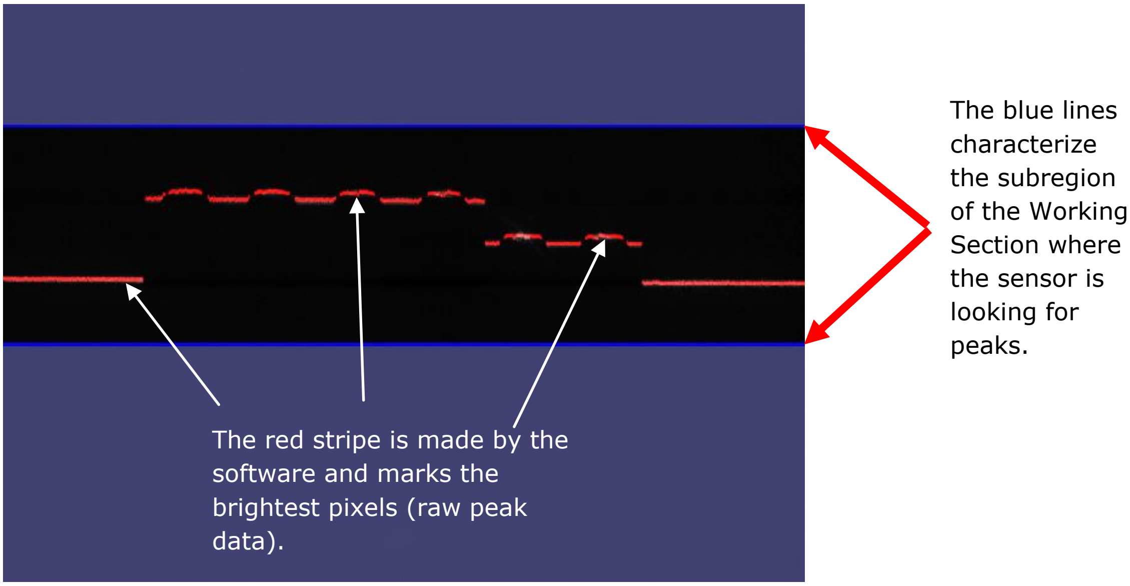
The shape of the laser stripe provides exact height profile information of the object.

The left figure illustrates the laser stripe as seen from the position of the camera; the right one is one actual Intensity Image (of a part of the object on the left). This is an image that the camera sees through its filter:



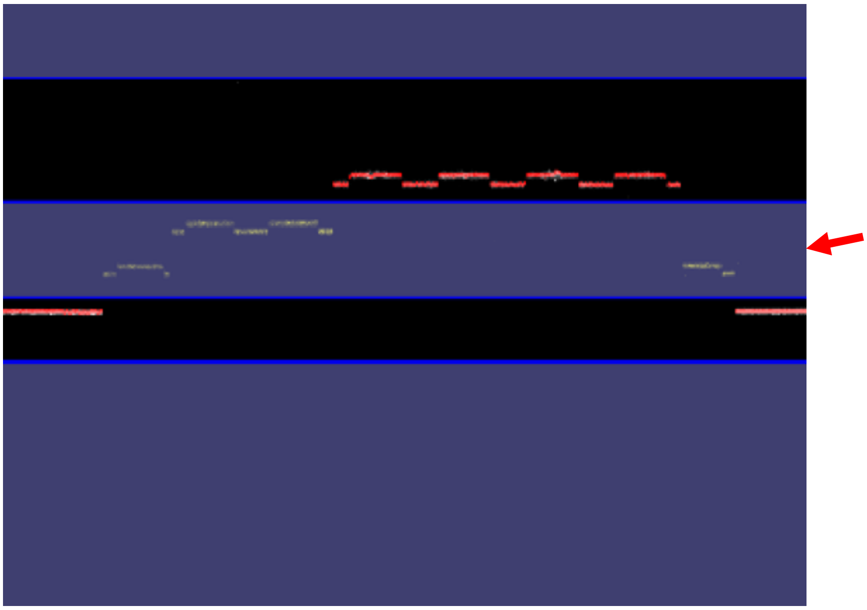


The DS 1000 Series Sensor gets the raw (uncalibrated) peak data from the bright stripe curve finding algorithm, which seeks for the brightest pixels that correlate to the tallest heights and marks them with red.



For best results, the laser line in the image should not extend outside the red overlay graphics. For this, reduce the **acquisition exposure parameter** until the laser line does not extend outside the red overlay.

Recommended default acquisition setting: Contrast = 0

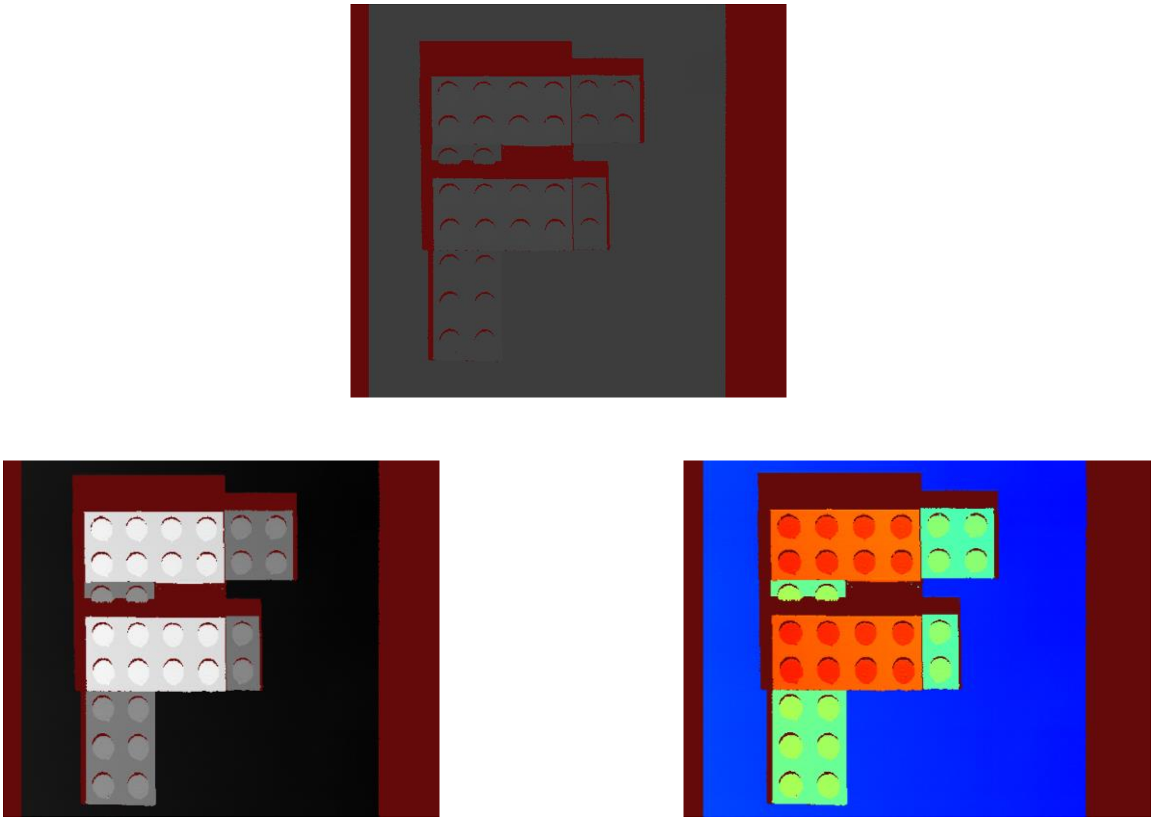


If you are interested in two separate height ranges and not in the gap separating them, you may increase the acquisition speed of your sensor by specifying a gap in which bright stripe curve finding should not be performed.

You can specify the two height ranges of interest as two detection zones in which bright stripe curve finding should be performed. You can choose whether there should be a gap between them or they should be bridged (that is, the bottom of the lowest zone and the top of the highest zone define a united detection zone without any gap).

Range Image

A range image is a 16-bit greyscale image containing height profile information in real world coordinates. This is an actual range image with different color maps applied (color maps in the second row):



How Range Images Are Created

A range image is generated from a series of acquired intensity images. *Each row of the range image corresponds to one intensity image*. A row of the range image is generated by expressing the calibrated peak data obtained from the intensity image in greyscale pixel values.

Factory calibration transforms the raw peak data into real-world coordinates as well as removes distortions such as camera lens and perspective distortion.

For example, this is a row of height values (in millimeters) from a single intensity scan:

0	0	0	0	0	0	3	5	7	9	11	13	15	15	15	15	15	13	11	9	7	5	3	0	0	0	0	0	0

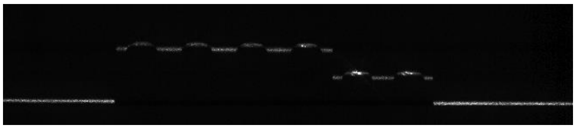
These values are then turned into one row of the greyscale range image:

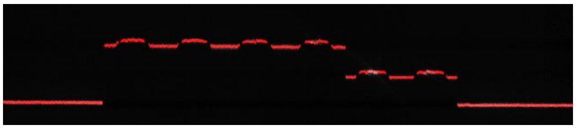
These images are then assembled and the whole picture of the object passing under the laser is created. This is called a range image.

The following illustration describes the process of range image generation:

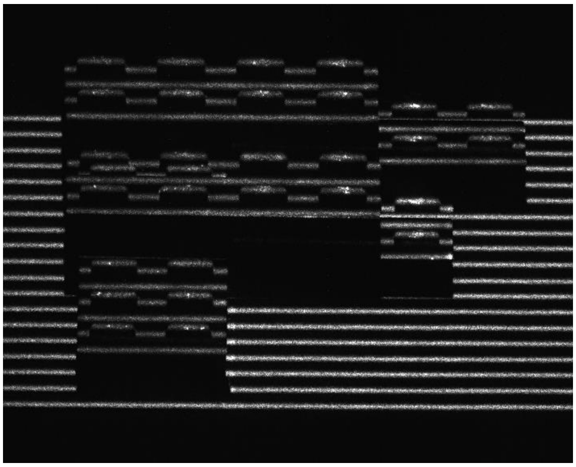
The **intensity images** are acquired as the object passes under the device.

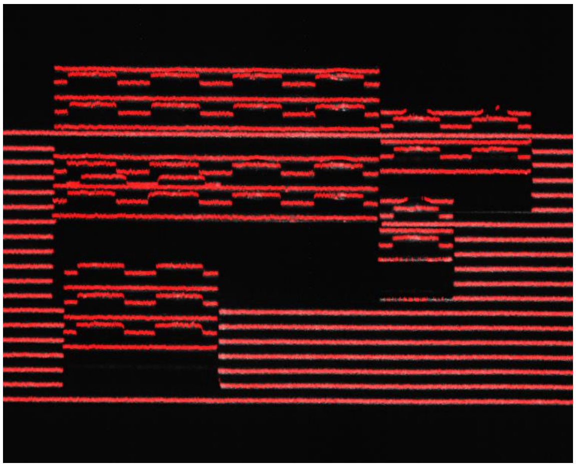
The bright stripe curve algorithm finds the brightest pixels (**intensity with graphics**).





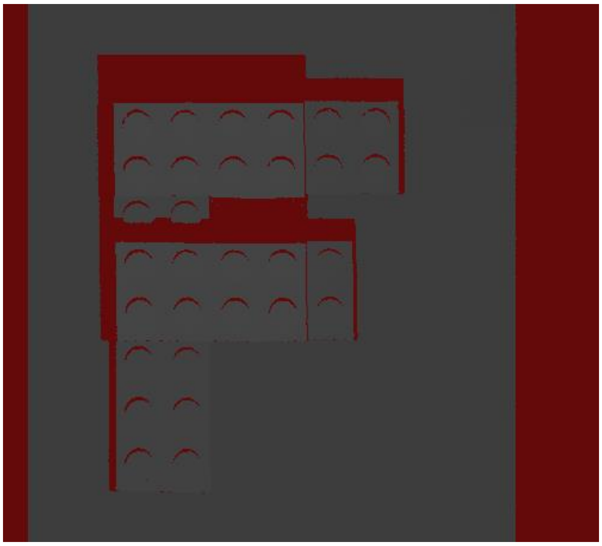
These rows together build up the shape of the object.





VisionPro then creates the **range image** with the appropriate correction (lens, perspective).

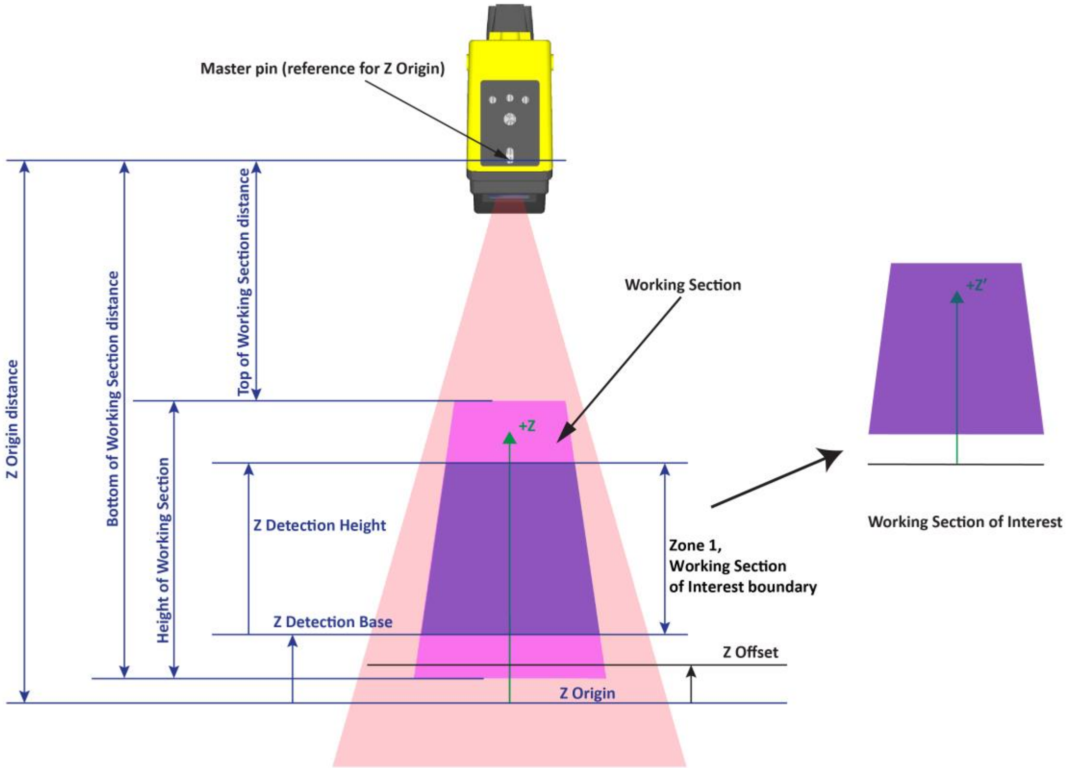
The final range image contains all 3D information about the object that have been acquired during the scanning process.



NOTE: The intensity image and the raw image data are processed by the sensor itself, while the range image is created on your PC, using VisionPro software tools.

Reading Distance and Field of View

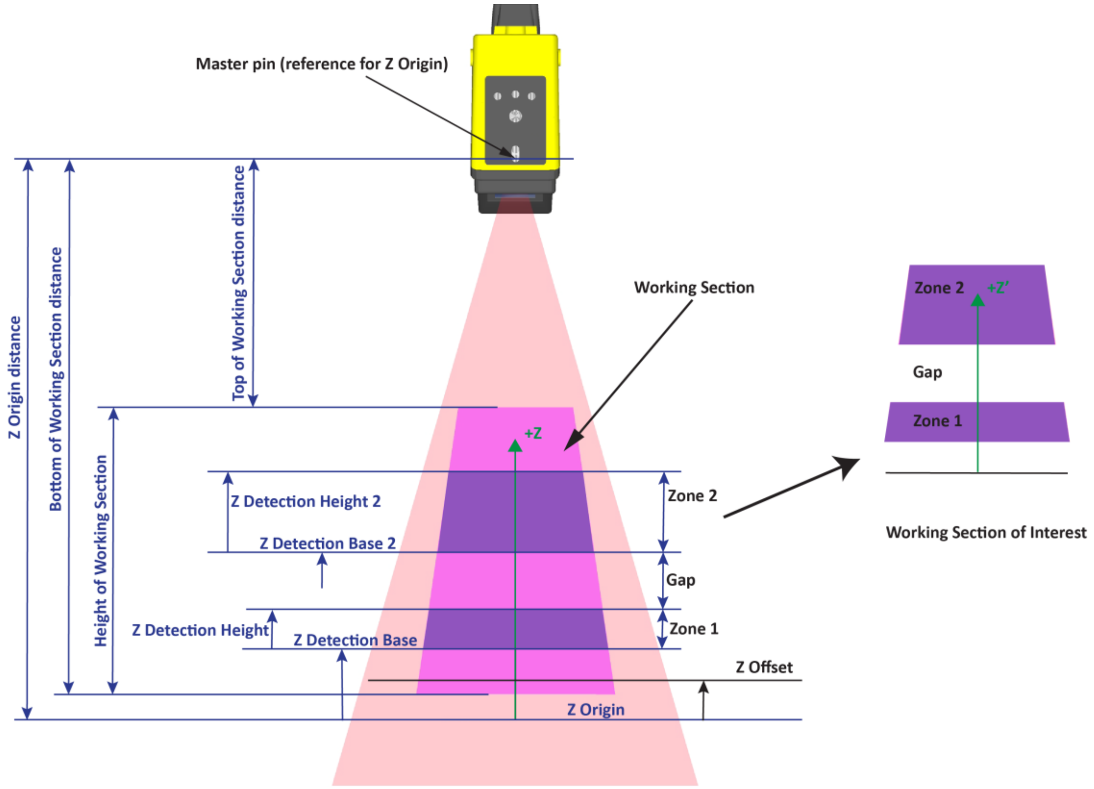
All sensors have the same range of working distances (minimum and maximum detectable surface distance from sensor). Surfaces that are further or closer than the documented maximum and minimum distance will not be seen by the camera (invisible pixels will be replaced with the zero value by default).



The Z Origin is at a fixed distance measured in the Z direction from the center of the Master Pin of the sensor as specified in the DS1000 Series Displacement Sensors Quick Reference Guide.

By default, Zone 1 is the height range in which heights will be detected (in mm); the **Z Detection Base** and **Z Detection Height** parameters define this height range. The intersection of this height range and the Working Section defines the Working Section of Interest, which is typically the subregion of the Working Section. The overlap of the Working Section and the Working Section of Interest defines the region in which the bright stripe curve finding algorithm is performed. Pixels beyond this region are ignored.

You may define a second height range for the Working Section of Interest, Zone 2, by enabling it and setting the **Z Detection Base 2** and **Z Detection Height 2** parameters. This is useful when you are interested in two height ranges separated by a gap, and you are not interested in the height ranges of the gap. By specifying a gap in the Working Section of Interest, the acquisition speed of the sensor may be increased. Heights in the gap are not detected by the sensor.



If Zone 1 and Zone 2 are enabled, the Working Section of Interest is defined as follows:

- If Zone 1 and Zone 2 are not bridged (default), a gap exists between the two zones in which detection is not performed.
- If Zone 1 and Zone 2 are bridged, Zone 1 and Zone 2 are combined into a single zone starting at the bottom of the lowest zone and ending at the top of the highest zone.

Missing Pixels in the Range Image

Due to sensor-to-sensor variations, when used in **Intensity** or **Intensity-with-Graphics** mode, certain working distances may appear to be visible in the intensity image (i.e. you can see the laser line on a surface) that are not actually within the specified range, and consequently will not appear in the range image. This may confuse users, since in **Intensity** mode they can visually see that the camera lens can see the laser line, yet the range image shows missing pixels.

Only surfaces within the specified working section will appear in the range image.

Coordinate Systems

We define the following coordinate systems in connection with the DS 1000 Series Sensors:

(1) Sensor 3D Space	Physically accurate / right-handed 3D coordinate system rigidly affixed to the sensor. Units: mm
(2) Image 3D Space	Left-handed, the origin is at the upper-left corner of first pixel in image. Units: pixels (X/Y) pixel values (Z)

Sensor 3D Space

The DS 1000 Series Sensor's *Sensor 3D* coordinate system is defined by:

- the *laser plane* (X and Y axes)
- the extrapolated position of the *mounting pins*

The projected laser plane is measured and it defines the X-axis. The Y-axis is perpendicular to the X-axis – therefore to the laser plane as well.

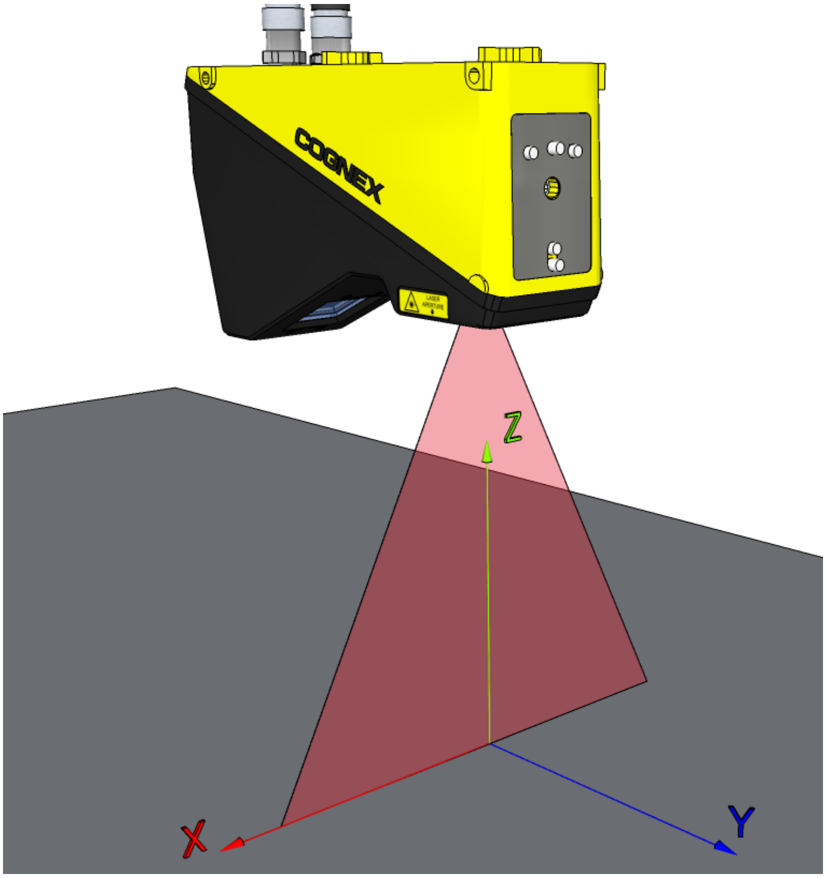
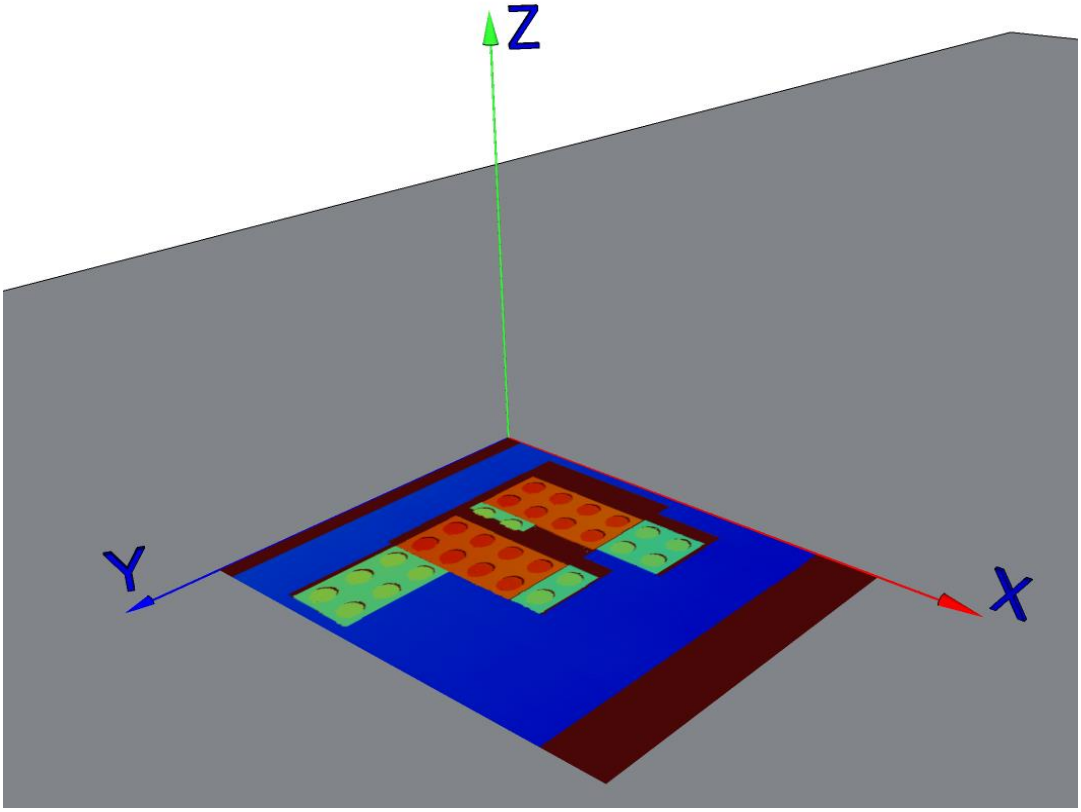


Image 3D Space

Information appearing in range images is expressed in the Image 3D Space.

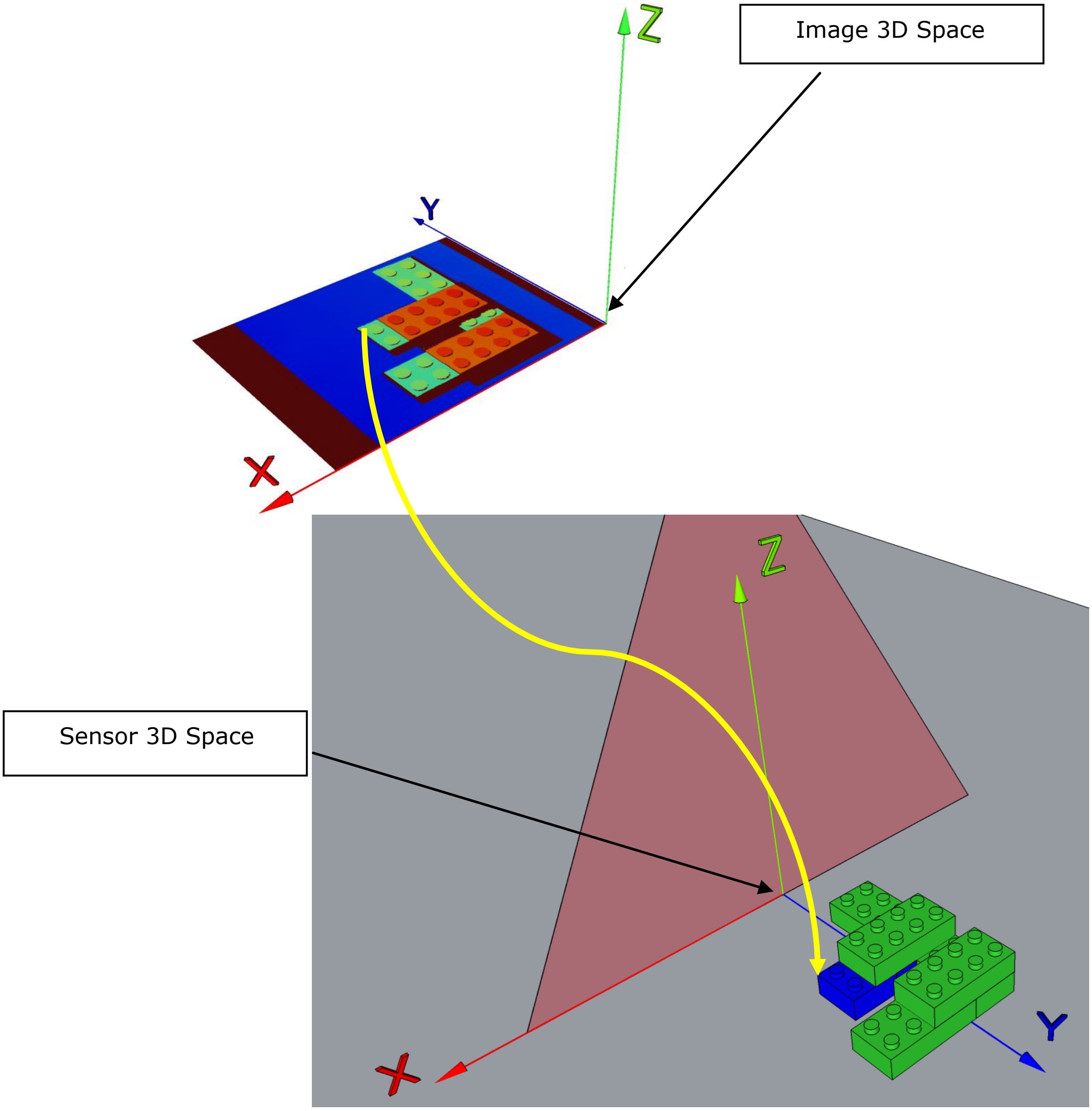
The Working Section of the sensor is defined as the cross-section of the laser plane and what the sensor can see. Although different sensors may be oriented slightly differently, the range images are explicitly limited to a *canonical working section* so that all sensors induce exactly the same range image extents.

The units in this coordinate system are defined in pixel values (X,Y). Z contains the height information.



Transformation from Image 3D to Sensor 3D Space

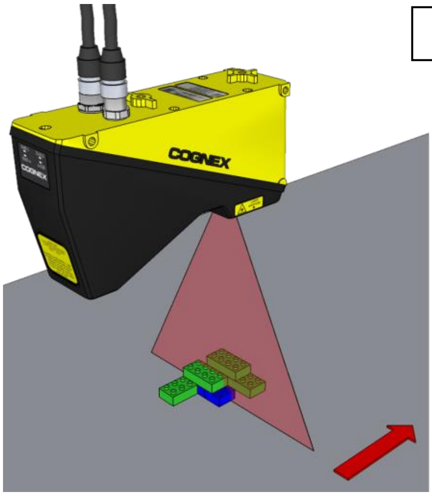
A pixel location (X,Y) and the belonging height value (Z) in the Image 3D Space of the range image corresponds to a real physical point in the Sensor 3D Space. See the illustration below:

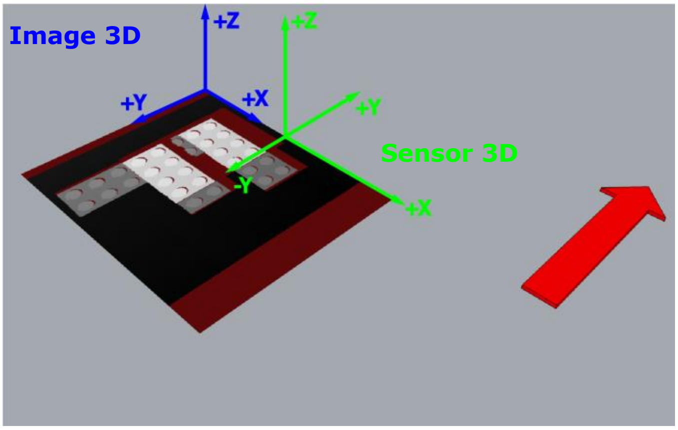


Motion Direction

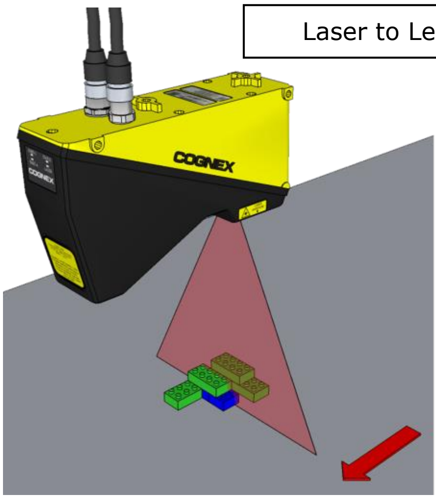
As the illustration shows below, the motion direction changes the appearance of the pixels (unless row order correction is applied) and also the location of the origin of Sensor3D space in the image.

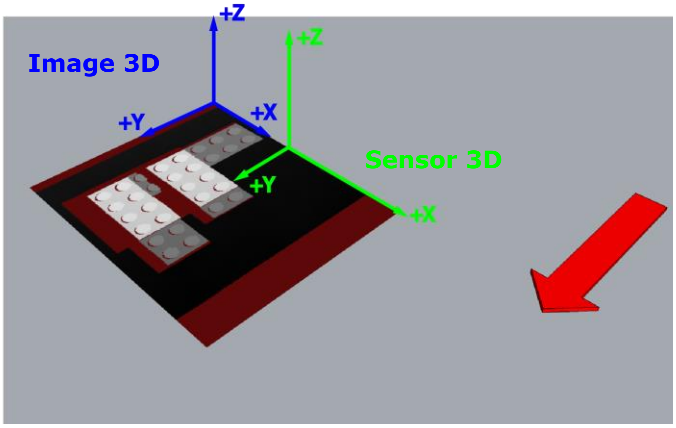
Lens to Laser



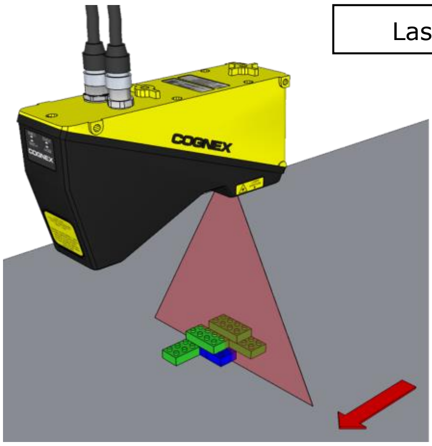


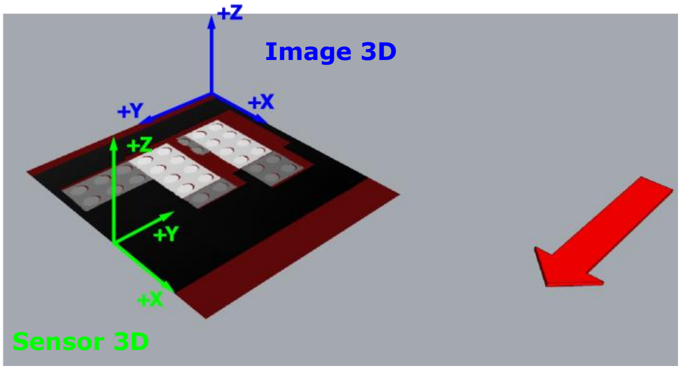
Laser to Lens without Row Order Correction





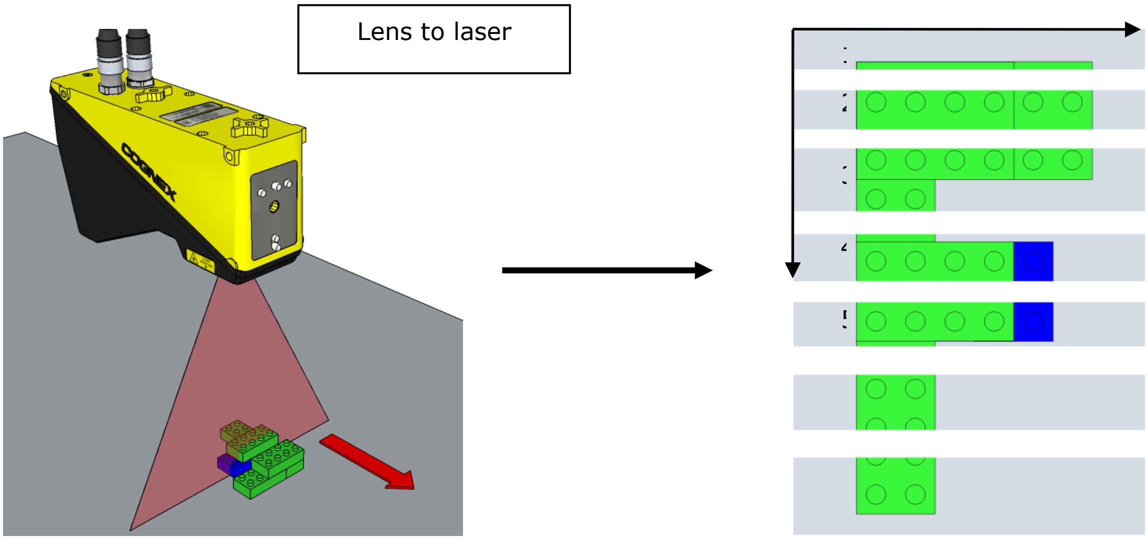
Laser to Lens with Row Order Correction

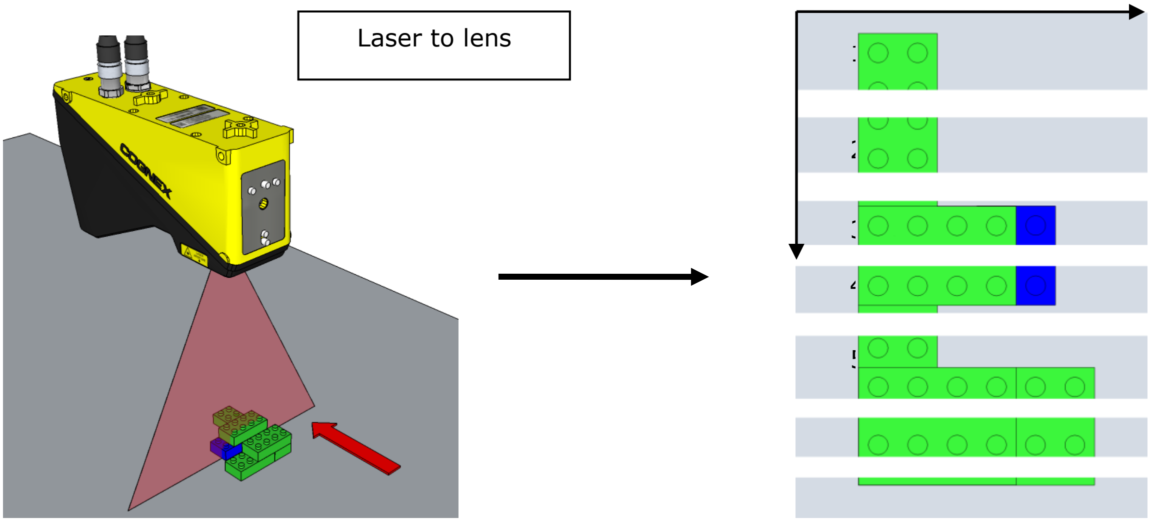




Why Does Changing Motion Mirror the Pixels?

As the same object arrives from opposite directions, the first acquired pixels are made from the other end of the object (assuming that the object is not rotated). As the software stitches them together in the order of arrival and builds up the image, the result is that the object from one of the two directions looks mirrored.

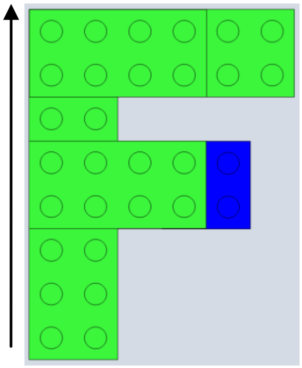




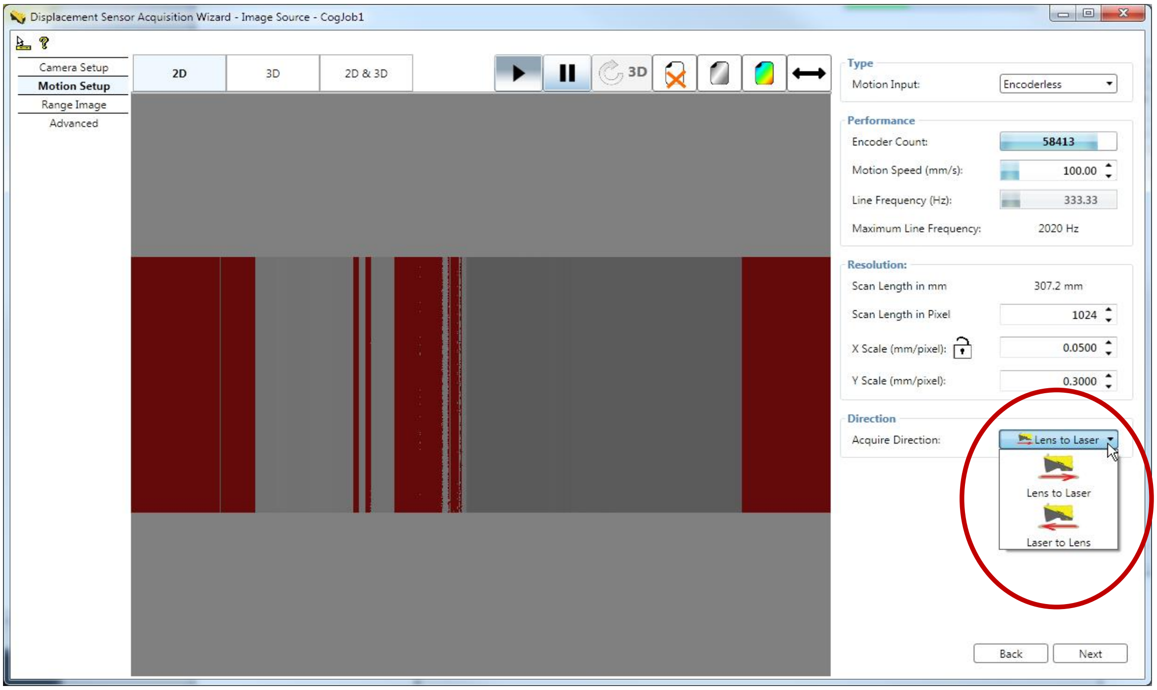
To avoid confusion, the following sections act as a short guide about the motion directions and range images of the same object.

Here is our familiar Lego® block.

As this is an asymmetric 'F' letter, let us say that it has a default orientation which is how we see it in print in general.



In VisionPro, you can simulate either changing the *motion direction of the conveyor belt* or the *orientation of the device*. These settings are in the MotionSetup tab in the Acquisition Wizard.



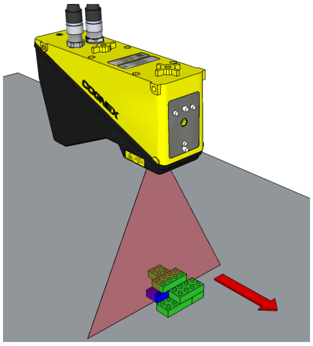
Positive Encoder Direction settings

VisionPro provides the Positive Encoder Direction setting, which basically means the **moving direction** of the conveyor belt **below** the sensor. These settings are provided to help prevent physical reorientation of the conveyor belt.

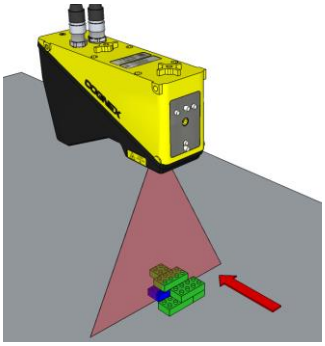
Positive Encoder Direction settings

We can scan this F letter with the sensor in two ways. (For the sake of simplicity, let us say that we are interested in only those two ways in which the axis of the object movement is parallel with its default direction.) Namely, *Lens-to-laser*, and *Laser-to-lens*.

Lens to laser

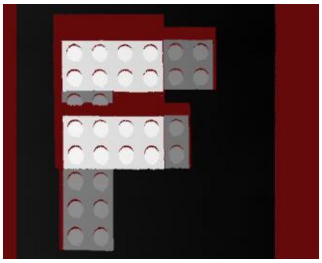


Laser to lens

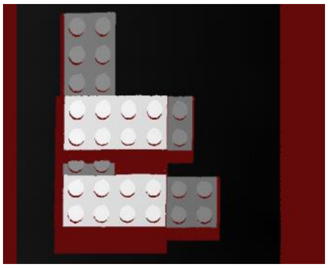


These are the results of the two scans, respectively, with some colormap applied to illustrate height differences. Let us call them *Range Image 1* and *Range Image 2*.

Lens to laser –
Range Image 1



Laser to lens –
Range Image 2



Acquire Direction Settings

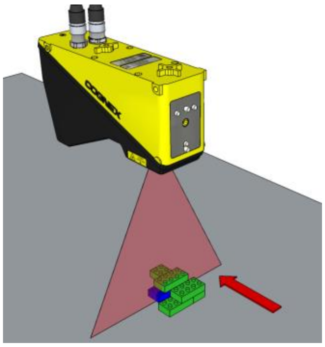
VisionPro provides the Acquire Direction setting, which means the **orientation** of the sensor **above** the conveyor belt. These settings are provided to help prevent physical reorientation of the device.

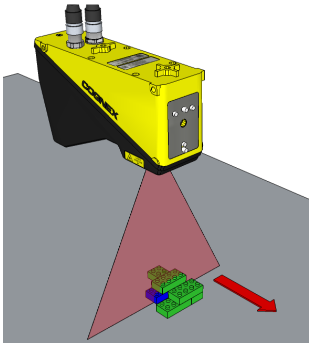
Acquire Direction settings

Laser to lens

Lens to laser

We can scan this F letter with the sensor in two ways. (For the sake of simplicity, let us say that we are interested in only those two ways in which the axis of the object movement is parallel with its default direction.) Namely, *Lens-to-laser*, and *Laser-to-lens*.

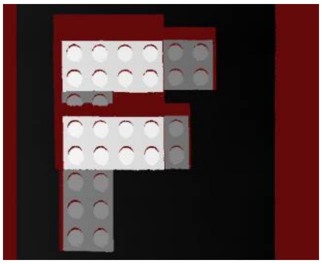


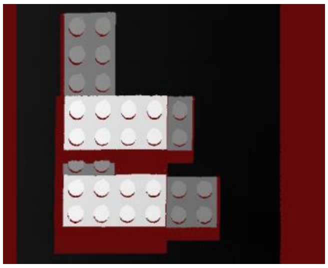


Laser to lens – Range Image 1

Lens to laser – Range Image 2

These are the results of the two scans, respectively, with some colormap applied to illustrate height differences. *Range Image 1* and *Range Image 2*.





Conclusion

Although the variety of settings provides four possible ways altogether to scan an object, the result will be two range images that are the mirrored varieties of each other. Furthermore, the two range images contain the same physical information about the object.