KEYENCE

BASIC TECHNIQUES

GUIDE FOR IMPLEMENTING VISION SYSTEMS

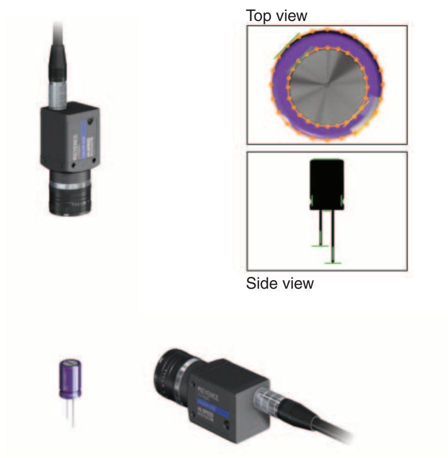
DIMENSIONAL INSPECTION TECHNIQUES

Automated total inspection using image processing techniques can be valuable for preventing the outflow of defective products. Visual inspection is vital for assuring the function and performance of products by eliminating flaws, burrs, chips or dents. This guide featuring KEYENCE's latest vision system, the CV-3000 Series, explains parameters for visual inspection using a machine vision system. The important points and technique examples described here will certainly help in selecting the optimal product.

TYPICAL APPLICATIONS OF DIMENSIONAL INSPECTION

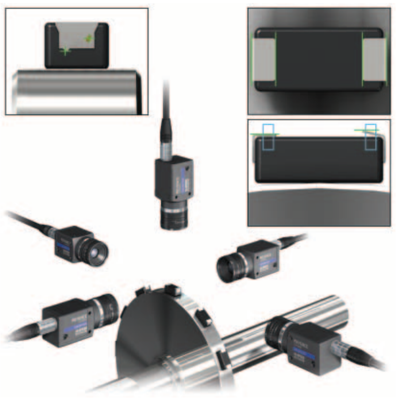
Dimensional and visual inspections of condensers

A variety of condenser inspections can be performed with a vision system.



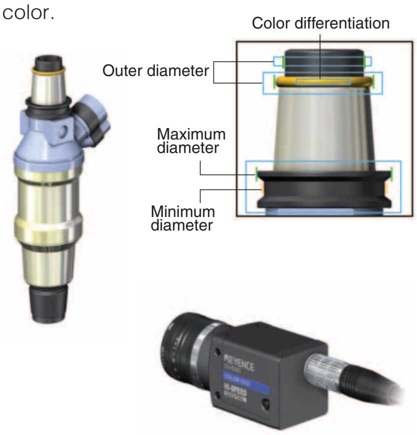
Multi-directional inspection of electronic parts

Defects or displaced pins of electronic parts can be detected with a vision system.



Improper assembly inspection of injectors

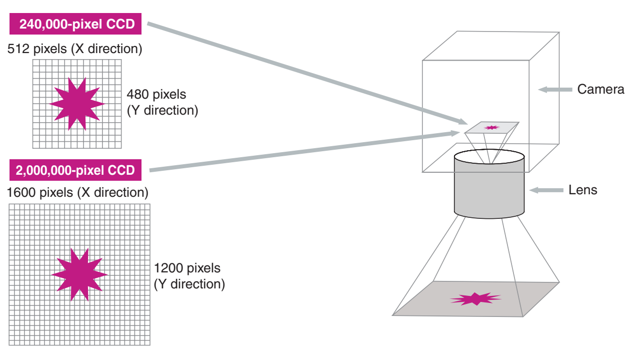
Improper assembly of injector components can be checked with a vision system by measuring the shape or differentiating the color.



PIXEL RESOLUTION

Vision system users who conduct dimensional inspections are often concerned about finding the maximum resolution. First, it is necessary to define the concept behind the pixel resolution of a vision system. Pixel resolution is determined by the number of pixels of the CCD used in a camera and the view size. A CCD is a picture element used in general digital cameras and consists of tiny elements (pixels) that convert brightness intensity to electric signals. Standard 240,000-pixel to 2,000,000-pixel cameras are generally used in factory automation. The field of view is the viewing range captured by the camera. The size can be freely adjusted depending on the camera used.

The pixel resolution is the actual pixel size (mm/inch) and can be easily determined with the following formula.



Pixel resolution = Field of view (Y direction) (mm) ÷ CCD pixels in the Y direction

* CCD pixels in the Y direction of a 240,000-pixel camera = 480 pixels
* CCD pixels in the Y direction of a 2,000,000-pixel camera = 1200 pixels

Pixel resolution (reference value)

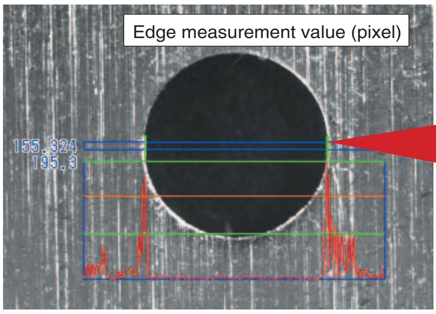
Unit [mm]

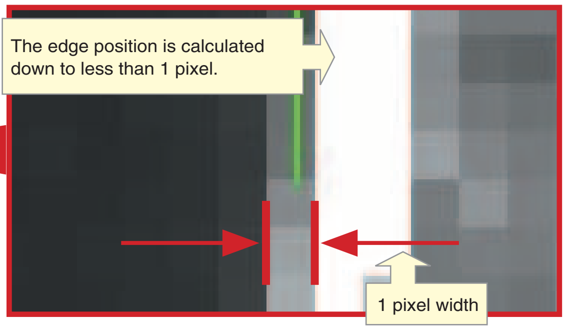
Field of view	1	5	10	20	30	50	100	200	500
240,000 pixels	0.002	0.010	0.021	0.042	0.063	0.104	0.208	0.417	1.042
2,000,000 pixels	0.0008	0.004	0.008	0.017	0.025	0.042	0.083	0.167	0.417

The table above indicates that the pixel resolution is better with a narrower field of view and a 2,000,000-pixel camera.

SUBPIXEL PROCESSING

In the previous section we learned that the pixel resolution can be defined as the image size per pixel, however, the position of a target can also be measured below 1 pixel using an internal extrapolation calculation applied by the CV vision system. In particular, the CV-3000 Series can perform this “Sub-pixel processing” down to 1/1000 of a pixel. The following example shows that the hole diameter is measured with an Edge width tool. An edge is defined as a change in brightness that occurs in a linear fashion on the image. The CV-3000 can find the position of this edge with a resolution down to 1/1000 of a pixel.

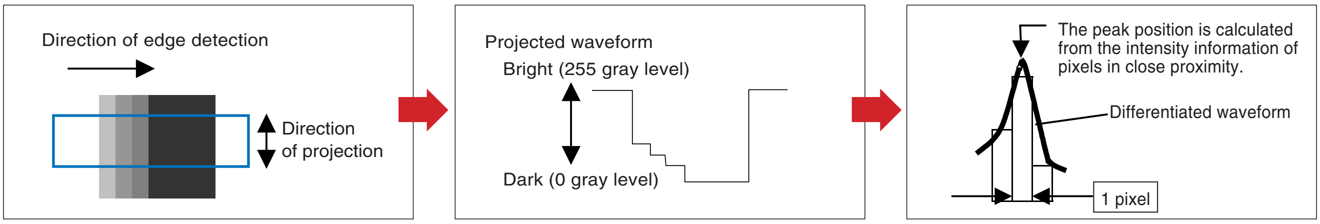




Brightness change is represented in one pixel, but this is converted to a projected waveform and then differentiated. The peak of the differentiated waveform is calculated as an approximative edge position.

Subpixel principle

The average value of brightness in the direction of the edge detection area is calculated to obtain a projected waveform. The projected waveform is differentiated and the peak position is calculated as an edge position.



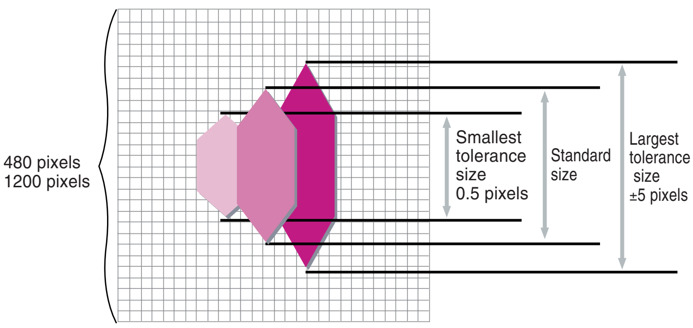
Subpixel processing and repeatability

When measuring targets with the same dimensions using a vision system, how consistent are the results? This is also a typical question from vision system users, but it depends on a variety of factors. In a typical example under ideal conditions.
(the brightness contrast is very clear, there is no vibration, and illumination conditions are stable) the Edge tool of the CV-3000 Series may provide a repeatability of approx. 0.1 pixel.

JUDGMENT TOLERANCE

How can the minimum tolerance of the CV-3000 Series be determined? Tolerance means the threshold used to differentiate non-defective products from defective products. This is determined by the size of view and the number of CCD pixels, but ±5 pixels may be considered the ideal measurement. This is because the number of pixels to stably detect the tolerance should be approx. 10 times the repeatability, and the repeatability is approx. 0.1 pixel under ideal conditions, as mentioned earlier. Therefore, assuming that the repeatability is 0.5 pixel to be safe, ±5 pixels, which is 10 times the repeatability, should be the minimum tolerance. Of course, the tolerance can be lower with improved conditions. ±5 pixels can be converted to an actual value (mm) with the following formula.

Actual tolerance value [mm] = 5 pixels ÷ CCD pixels in the Y direction



Minimum tolerance (reference value) Unit [mm] Typical example

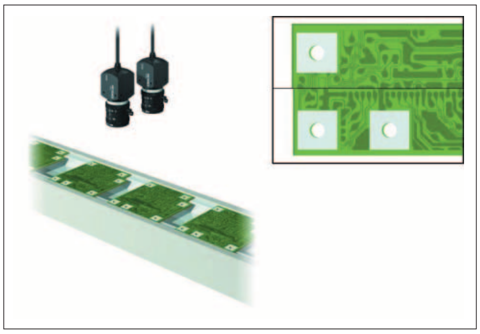
Field of view	1	5	10	20	30	50	100	200	500
240,000 pixels	0.01	0.05	0.10	0.21	0.3	0.52	1.0	2.1	5.2
2,000,000 pixels	0.004	0.02	0.04	0.08	0.13	0.21	0.4	0.8	2.1

CALCULATING THE MAXIMUM LINE SPEED

How fast can our vision systems inspect targets?

Applications involving an intermittent feed

In applications with an intermittent feed, targets stop for a certain period of time for detection.



The number of targets that can be detected per minute can be calculated based on the processing speed of the vision system.

Maximum number of inspections per minute = 60 (sec.) ÷ Processing speed of the vision system (sec.)

Ex.) If the processing speed of the vision system is 20 ms,
Maximum No. of inspections per minute = 60 sec. ÷ 0.02 sec. = 3000 times/min. (= 50 times/sec.)

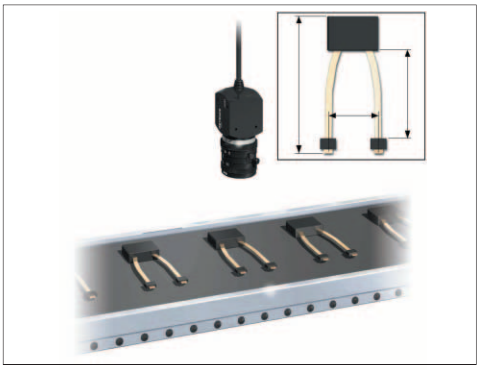
Actual processing speeds can vary depending on the camera type and inspection setting of the vision system. While most simple applications can run at 20 ms, it is always best to test the conditions of the inspection using actual targets.

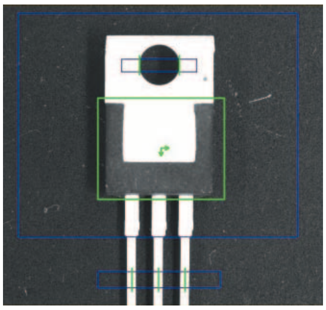
If there is a required processing speed for the vision system, the calculation is as follows:

Required processing speed for the vision system (ms) = 1 (sec.) ÷ Required No. of inspections (times/sec.) x 1000

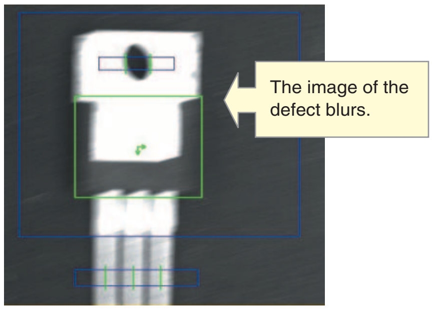
Applications involving a continuous feed

When targets travel within the field of view of the camera without stopping, the camera's shutter speed should be taken into consideration.





High-speed shutter image



Low-speed shutter image

Shutter speed = Required tolerance [mm] ÷ Line speed [mm/sec.]

For example, when capturing images of electronic parts with a camera on a continuously moving line, if the shutter speed (exposure time) is not fast enough for the line speed, the captured image is blurred. In order to prevent the blur, the shutter speed needs to be set so that the object travels no more than 1/10th the required tolerance value while the image is being captured by the camera.

Example) Detection tolerance = 0.2 mm
Line speed = 200 mm/sec.
Shutter speed = 0.2 mm ÷ 10 ÷ 200 mm/sec. = 1/10000
The ideal shutter speed is faster than 1/10000.

Image processing time

If the processing speed of the vision system is fast, inspection on a high-speed line is definitely possible.
So, how long is required for the processing time of a typical dimensional inspection?
As mentioned earlier, inspection time can vary greatly depending on the processing power of the vision system and the configuration settings for a specific application. However, the table below provides an estimated baseline for the time required to capture and process an image.

Image processing time (reference value)

Typical example*[1]

	240,000-pixel monochrome camera	240,000-pixel color camera	2,000,000-pixel monochrome camera	2,000,000-pixel color camera
Minimum capture interval	17 ms	17 ms	60 ms	60 ms
Image processing time	20 ms	33 ms	71 ms	92 ms

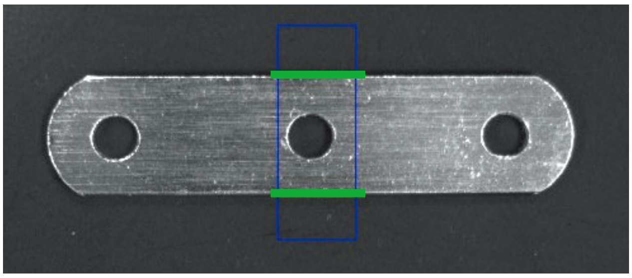
* Either the Pattern search, Edge width, or Edge pitch tools of the CV-3000 Series are used.

* The minimum capture interval means the fastest shutter speed using the Double buffer function of the CV-3000.

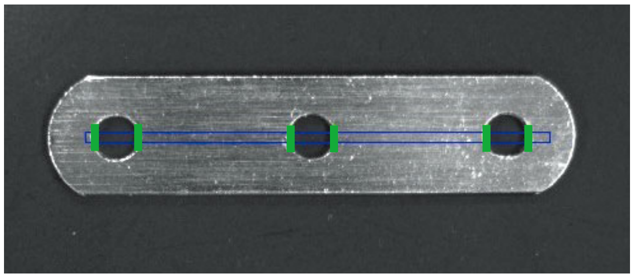
* The image processing time means the time from the trigger input to the completion of image processing.

TYPICAL INSPECTION TOOLS FOR DIMENSIONAL INSPECTION

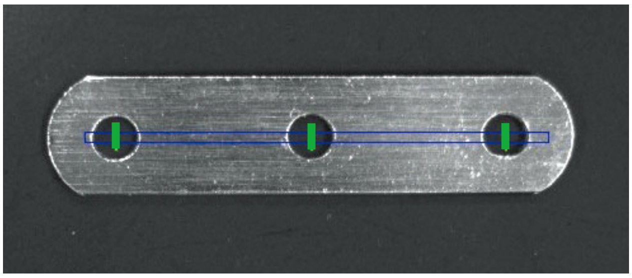
1. Inspecting the maximum outside dimension with the Edge width tool



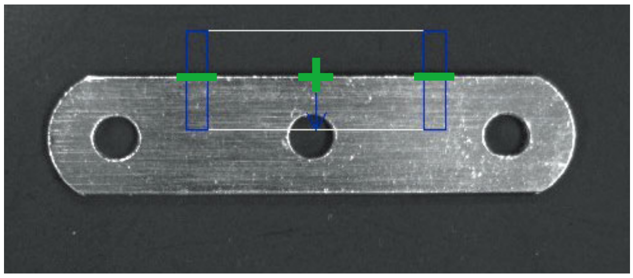
2. Gap inspection with the Edge pitch tool



3. Center pitch inspection with the Edge pitch tool



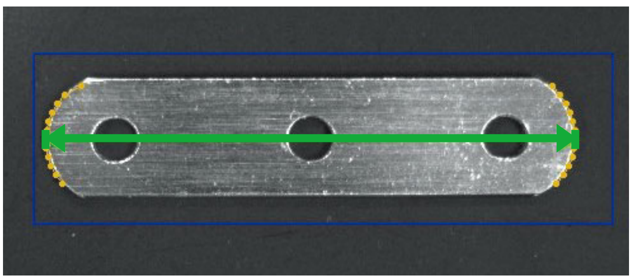
4. Tilt angle inspection with the Edge angle tool



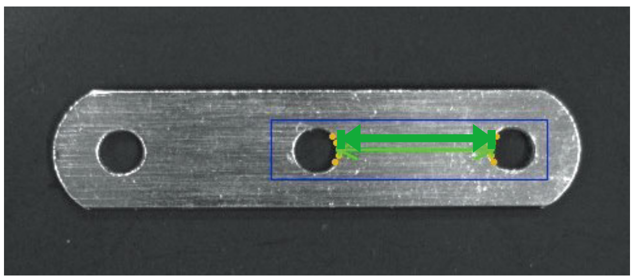
MAXIMUM/MINIMUM WIDTH INSPECTION WITH THE TREND EDGE WIDTH TOOL

The Trend edge position (width) tool detects the edge position of each point by scanning narrow edge windows in a set inspection area. It enables detection of the edge width of many points in one window, ensuring detection of even slight differences on a target surface.

5. Inspecting the maximum outside dimension with the Trend edge width tool



6. Inspecting the minimum inside dimension with the Trend edge width tool

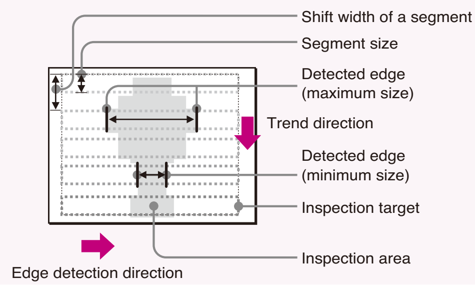


PRINCIPLE OF THE TREND EDGE WIDTH TOOL

Detection principle

The edge width and edge position of each point is detected while moving narrow segments in fine pitch increments.

- To detect the precise position, Reduce the segment size.
- To cut the processing time, Reduce the shift width of the segment (segment shift).
- What is the trend direction? It means the direction to shift the segment.



Please visit: www.keyence.com

SAFETY WARNING
Please read the instruction manual carefully in order to safely operate any KEYENCE product.

KEYENCE GLOBAL HEADQUARTERS

1-3-14, Higashi-Nakajima, Higashi-Yodogawa-ku, Osaka, 533-8555, Japan PHONE: +81-6-6379-2211

AUSTRIA
Phone: +43 22 36-3782 66-0 Fax: +43 22 36-3782 66-30
BELGIUM
Phone: +32 27 16 40 63 Fax: +32 27 16 47 27
CANADA
Phone: +1-905-696-9970 Fax: +1-905-696-8340
CHINA
Phone: +86-21-68757500 Fax: +86-21-68757550
CZECH REPUBLIC
Phone: +420 222 191 483 Fax: +420 222 191 505
FRANCE
Phone: +33 1 56 37 78 00 Fax: +33 1 56 37 78 01
GERMANY
Phone: +49 61 02 36 89-0 Fax: +49 61 02 36 89-100
HONG KONG
Phone: +852-3104-1010 Fax: +852-3104-1080
HUNGARY
Phone: +36 1 802 73 60 Fax: +36 1 802 73 61
ITALY
Phone: +39-02-6688220 Fax: +39-02-66825099
JAPAN
Phone: +81-6-6379-2211 Fax: +81-6-6379-2131
KOREA
Phone: +82-31-642-1270 Fax: +82-31-642-1271
MALAYSIA
Phone: +60-3-2092-2211 Fax: +60-3-2092-2131
MEXICO
Phone: +52-81-8220-7900 Fax: +52-81-8220-9097
NETHERLANDS
Phone: +31 40 20 66 100 Fax: +31 40 20 66 112
POLAND
Phone: +48 71 36861 60 Fax: +48 71 36861 62
SINGAPORE
Phone: +65-6392-1011 Fax: +65-6392-5055
SLOVAKIA
Phone: +421 2 5939 6461 Fax: +421 2 5939 6200
SWITZERLAND
Phone: +41 43-45577 30 Fax: +41 43-45577 40
TAIWAN
Phone: +886-2-2718-8700 Fax: +886-2-2718-8711
THAILAND
Phone: +66-2-369-2777 Fax: +66-2-369-2775
UK & IRELAND
Phone: +44-1908-696900 Fax: +44-1908-696777
USA
Phone: +1-201-930-0100 Fax: +1-201-930-0099

WW1-0129

CVDimension1-WW-L-E 0129-1 600777 Printed in Japan