June 2020

# IIoT and industrial line scan cameras

## Introduction

As consumers have become more conscious of quality, the improvement of product quality has become a more critical issue than ever before at production sites in various industries. However, in the past, the performance of pre-shipment inspection devices was insufficient, and many products were subject to manual inspection. Manual inspections missed defects due to test accuracy variations among inspectors and have sometimes caused quality issues in the market. It is now very costly to provide sufficient labor to avoid quality issues. Thus, there is a growing demand for the introduction of high accuracy and consistent automatic pre-shipment inspection.

On the other hand, in recent years, as typified by buzzwords such as IIoT and Industry 4. 0, production sites have become increasingly intelligent due to the rapid increase in the processing speed of semiconductors and the development of data analysis software such as AI. By gathering information on each production site and processing them in an integrated manner, it has become possible to ensure full-count tests and the traceability of all shipping products on the market that were not possible until now. The line scan camera is a type of industrial camera that is very effective in realizing a high-accuracy full-count test, which is currently increasingly demanding.

This article summarizes the features, applications, and application examples of line scan cameras, mainly targeting those who are currently working hard to enhance the quality of their products at various production sites. I hope that you will read this paper willingly and deepen your understanding of the line scan camera.

## 1. What is a line scan camera?

Inspection of products and components, generally performed in the manufacturing industry, can be divided mainly into contact type and non-contact type, depending on whether or not the inspection equipment is brought into contact with a test object. The advantages and disadvantages of each are summarized below.

| Inspection system | Advantages | Disadvantages |
|---|---|---|
| Contact-type | ・Measurement can be performed accurately regardless of the type and shape of the object. | ・May damage the test object<br>・May take a long time to test. |
| Non-contact type | ・There is a possibility that a wide range can be inspected and measured at high speed without variation. | ・When there are many types and shapes of test objects, the accuracy and versatility of test may be inferior.<br>・Equipment may be expensive |

Previously, human tests were mainly conducted at production sites. Human inspection has problems such as variations in inspection accuracy by inspectors and high cost due to

time-consuming procedures. In many cases, it wasn't easy to perform manual contact inspection of all products, and only sampling inspection of some products was conducted.

In contrast, in recent years, attempts have been made at production sites in various industries to inspect the whole number by non-contact automatic test, which enables high-speed inspection. The most common non-contact test method is a light-based inspection method. The features are summarized below based on the type of light used.

| Type | Wavelength | Characteristics and Benefits of Testing | Demerits |
|---|---|---|---|
| Infrared rays | 780nm～1mm | ・By using specific wavelength bandwidth, it is possible to test, identify, and measure various features such as moisture, sugar content, ingredients, and temperature of test objects. | ・Device is expensive due to special lenses and sensors.<br>・It takes time to find an effective wavelength bandwidth. |
| Visible light | 380nm～780nm | ・The same test as visual inspection is possible.<br>・The cost of equipment is relatively inexpensive | ・Only what is actually visible can be examined |
| Ultraviolet rays | 10nm ～380nm | ・Magnetic powder method by attaching fluorescent magnetic particles to test objects, penetrant inspection method by applying fluorescent materials, etc. | ・Magnetic powder method is only applicable to magnetizations.<br>・The life of sensors is relatively short. |

Among the above three wavelengths of light, in recent years, the cost of SWIR lighting LEDs and light-receiving devices with wavelengths ranging from 780 nm to 2,500 nm, has been dramatically reduced. SWIR is currently attracting wide attention, particularly in the food industry, since there is a possibility that SWIR can be used to test objects which could not be tested with visible light at a deployable expense at production sites.

## 2. Features of line scan cameras

### 2.1 Structure and Features of Line scan cameras

First, let's look at the structure of a line scan camera. The line scan camera is an industry camera using visible light or infrared light. Unlike a general rectangular camera (area camera), a camera captures a test object on a very slender screen with only one or several lines of light-receiving pixels.

As shown in Figure 1a below, unlike the area camera sensor, which captures a view on a rectangular screen (Figure 1b), the light-receiving sensor of the line scan camera has a linear array of

light-receiving devices. However, as shown in Figure 2, the shape of the camera is generally the same rectangular parallelepiped as that of a general camera.

Figure 1a Line scan camera sensor

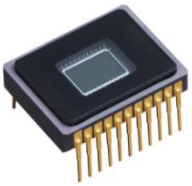

Figure 1b Area camera sensor

Figure 2 An example of a line scan camera (without a lens)

The reason why cameras that can take pictures of only a few lines are used is that it is easy to take pictures of test objects seamlessly at sites where test objects are constantly moving like a production line. The actual shooting conditions are shown below. When using an area camera, it is necessary to take pictures at predetermined intervals in synchronism with the movement of the test object while keeping an overlapping area at all times to prevent the occurrence of a location that is not taken as shown in Figure 3a. In addition, before starting the analysis, it is necessary to generate a series of images without overlapping multiple images (stitching process). The overhead of this processing can prove to be disadvantageous for real-time analysis during the test.

On the other hand, in the case of a line scan camera, images are taken continuously line by line. (Figure 3b) Thus, it becomes possible to take continuous images easily without stitching process.

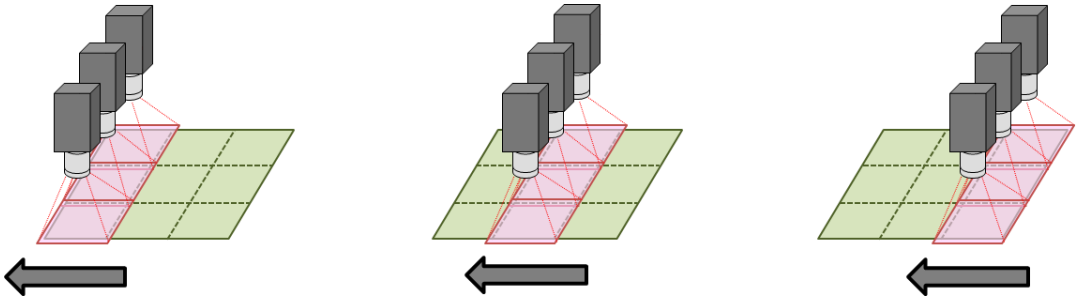

Figure 3a Image shooting process using area cameras

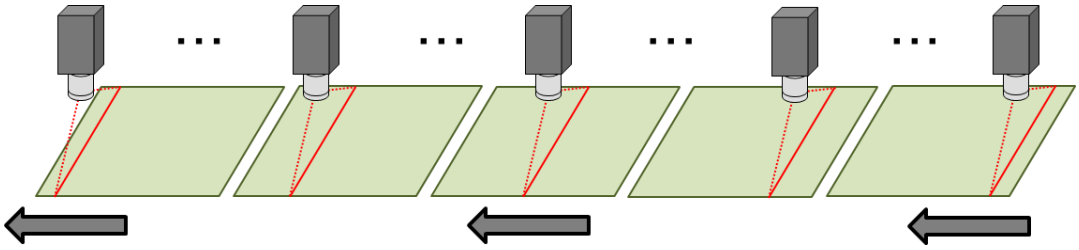

Figure 3b Image shooting process using a line scan camera

The number of pixels, sensitivity, and image transfer rate differ between the line scan camera and the area camera, as shown below. We can easily understand that line scan cameras are suitable for tests in environments where products and components always flow at high speed, such as factory lines.

| Functioning | Line scan camera | Area camera |
|---|---|---|
| Number of horizontal pixels | Up to around 16000 | Up to around 4,000 |
| Size and sensitivity of image sensor | Relatively large size, high sensitivity, and high resolution | Relatively small size and less sensitivity (images can be bright as a whole) |
| Image transfer rate to the PC or processing unit | High speed image transfer up to 80,000 line per second (80 kHz) is possible because only one to several lines need to be transferred | The maximum transfer rate for VGA size images is up to 1,500 fps (1.5 KHz) because rectangular frames need to be transferred. |
| Lighting | The irradiation range can be uniaxial and images without illumination unevenness can be obtained. | It is difficult to set the optimum lighting condition for uniformly irradiating the entire frame. |

**2.2 Multi-color support**

It is possible to use line scan cameras in black and white mode and multi-color mode. Figure 4 shows the configuration of a line scan camera that measures the luminance of each color of all pixels for each line by dividing the incoming light into three colors: B (Blue), G (Green), and R (Red). Other significant methods to support multi-color are a three-line method which utilizes sensors with three lines and Bayer color method for general-purpose cameras.

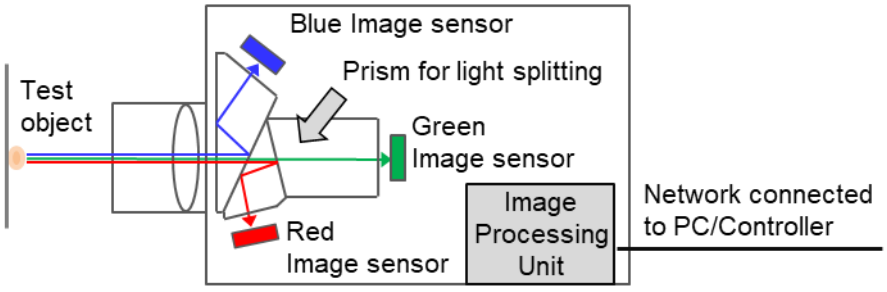


Figure 4 Multicolor line scan camera

**2.3 Analysis using shortwave infrared (SWIR) light**

By using a sensor that senses up to the SWIR wavelengths (between 780 nm and 2500 nm) as a light-receiving device, measuring the luminance of reflected light or transmitted light in the SWIR wavelength range, as well as visible light, becomes possible. Besides, by replacing a sensor of a multi-color camera described above with a sensor that senses SWIR light, a camera that can analyze

a combination of three wavelengths including SWIR, such as B/G/SWIR, can also be realized.

The use of near-infrared radiation enables the detection of contamination by foreign matter and corrosion that cannot be distinguished by visible light. Figure 5 shows images of salt, sugar, and water taken using visible light and SWIR light (from 950 nm to 1,700nm). We can see that salt and sugar that are indistinguishable in visible light are easily distinguished using SWIR light. Water also appears black because it absorbs SWIR light near 1,450 nm.

It has been actively tried to use SWIR light with the optimum wavelength for each test object to remove foreign matter and to test for corrosion and packaging scratches at the production sites of foods and their raw materials.

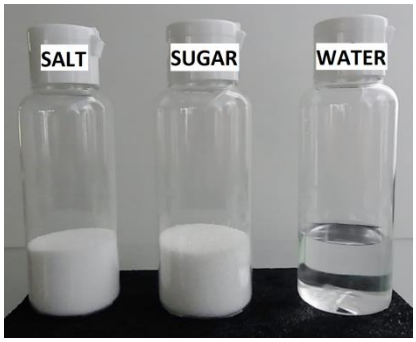


Figure 5a Imaging in visible light

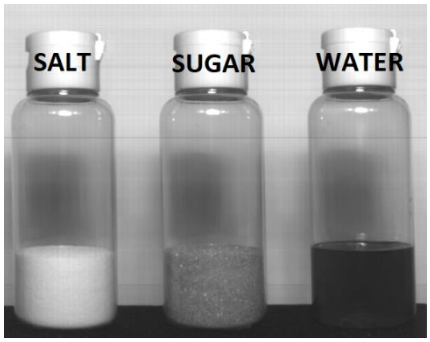


Figure 5b Imaging in near infrared rays

## 3. 3D Line Profile Camera

So far, we have introduced cameras that capture objects two-dimensionally. This section introduces a 3D line profile camera, a three-dimensional imaging camera that irradiates a moving test object with a line of laser light and measures the height of the test object based on the position on the sensor where the reflected light is projected. Like a line scan camera, this camera can take continuous images and generate three-dimensional images. Figure 6a shows an image of the inspection with a 3D line profile camera, and Figure 6b shows a simple principle diagram of the 3D measurement.

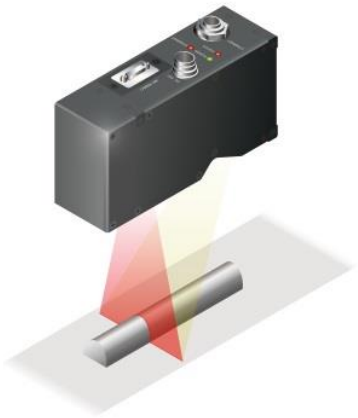

Figure 6a Inspection with a 3D line profile camera

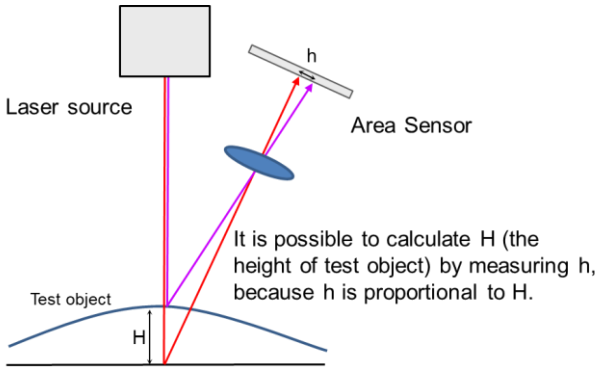


Figure 6b Principle of the inspection using 3D line profile camera

Figure 7 shows an image taken with a 3D line profile camera. The height is represented by color. The blue is the surface on which the pumpkin is placed, and the color change to green, yellow, and red indicates that the height increases. You can see that the appearance of the upper surface of the pumpkin can be observed.

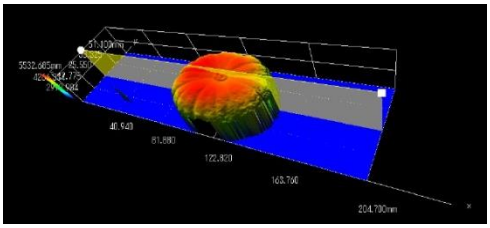

Figure 7 Image of pumpkin captured by 3D line profile camera (Image analysis software is used)

## 4. Examples of the use of line scan cameras

Line scan cameras which can inspect test objects which are moving fast are used for a variety of test applications such as printed materials, films, flat panels, cans, and components. Below are the examples.

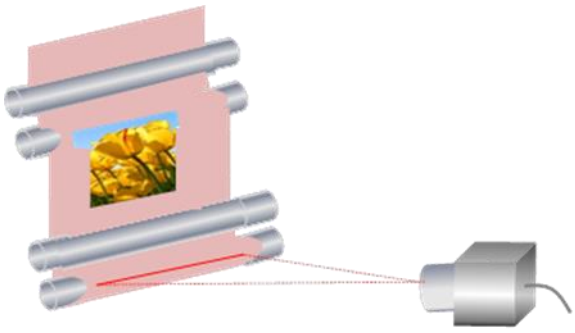

Figure 8a Inspection of color printing

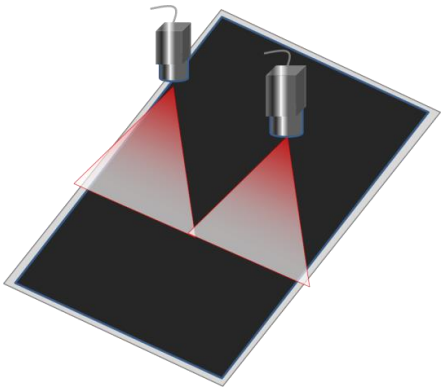

Figure 8b Inspection of LCD panel

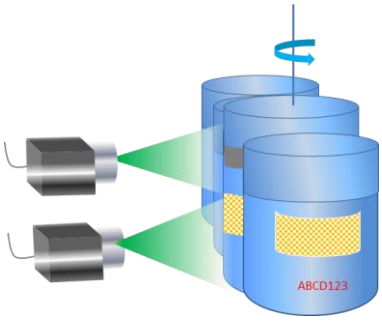


Figure 8c Inspection of cylindrical test object
(Inspection of floating of lids, design of labels, etc.)

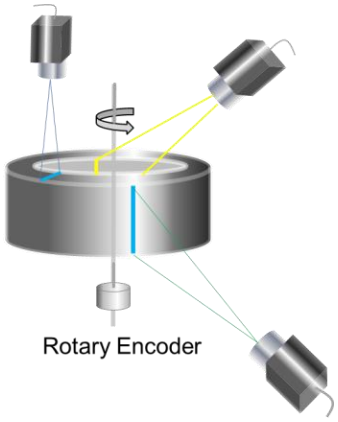


Figure 8d Inspection of cylindrical components

## 5. CMICRO's lineup of line scan cameras

The lineup of line scan cameras and 3D line-profile cameras of CMICRO Corporation, one of the significant suppliers of line scan cameras in Japan, is shown below.

| Series/Model Name | Type | Number of pixels of the sensor |
|---|---|---|
| White-eye Series<br>FCS16K/12K/800/600/400A<br>FXS/ FXD 800A/ 400A | **Monochrome** line scan camera<br>(CMOS sensor)<br>FC: CameraLink i/f, FX: CoaXPress i/f | FC: 16384/12288/8192/<br>6144/4096<br>FX: 8192 / 4096 |
| CM series<br>CMS200 / 100 P | **Monochrome** line scan camera<br>(CCD sensor) | 2048 / 1024 |
| Albatross series<br>TFB200 / 100 P | **Color** line scan camera<br>(Prism spectroscopic) | 2048 / 1024 |
| TRB400T | **Color** line scan camera<br>(3-line system) | 4096 |
| Nighthawk Series<br>NHB050H / NDB100H | **Near infrared** line scan camera<br>Single / Dual (Prism spectroscopic) | 512 / 1024 x 2 |
| Kingfisher series<br>KFB200 /<br>KFB080 | **3D line profile** camera<br>Long WD model /<br>High resolution model | Resolution<br>40 μm (H), 100 μm (W) /<br>10 μm (H), 50 μm (W) |

Please contact the following phone number or email address for details regarding line scan cameras. In addition to the cameras mentioned above, CMICRO has many kinds of cameras and boards that CMICRO has developed by entrusted development. Please feel free to consult us if new development is necessary due to the discontinuation of devices or for the improvement of performance.

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