INTRODUCTION TO MACHINE VISION

A guide to automating process & quality improvements

COGNEX

TABLE OF CONTENTS

WHAT IS MACHINE VISION

According to the Automated Imaging Association (AIA), machine vision encompasses all industrial and non-industrial applications in which a combination of hardware and software provide operational guidance to devices in the execution of their functions based on the capture and processing of images. Though industrial computer vision uses many of the same algorithms and approaches as academic/educational and governmental/military applications of computer vision, constraints are different.

Industrial vision systems demand greater robustness, reliability, and stability compared with an academic/educational vision system and typically cost much less than those used in governmental/military applications. Therefore, industrial machine vision implies low cost, acceptable accuracy, high robustness, high reliability, and high mechanical, and temperature stability.

Machine vision systems rely on digital sensors protected inside industrial cameras with specialized optics to acquire images, so that computer hardware and software can process, analyze, and measure various characteristics for decision making.

As an example, consider a fill-level inspection system at a brewery (Figure 1). Each bottle of beer passes through an inspection sensor, which triggers a vision system to flash a strobe light and take a picture of the bottle. After acquiring the image and storing it in memory, vision software processes or analyzes it and issues a pass-fail response based on the fill level of the bottle. If the system detects an improperly filled bottle—a fail—it signals a diverter to reject the bottle. An operator can view rejected bottles and ongoing process statistics on a display.

Machine vision systems can also perform objective measurements, such as determining a spark plug gap or providing location information that guides a robot to align parts in a manufacturing process. Figure 2 shows examples of how machine vision systems can be used to pass or fail oil filters (right) and measure the width of a center tab on a bracket (left).

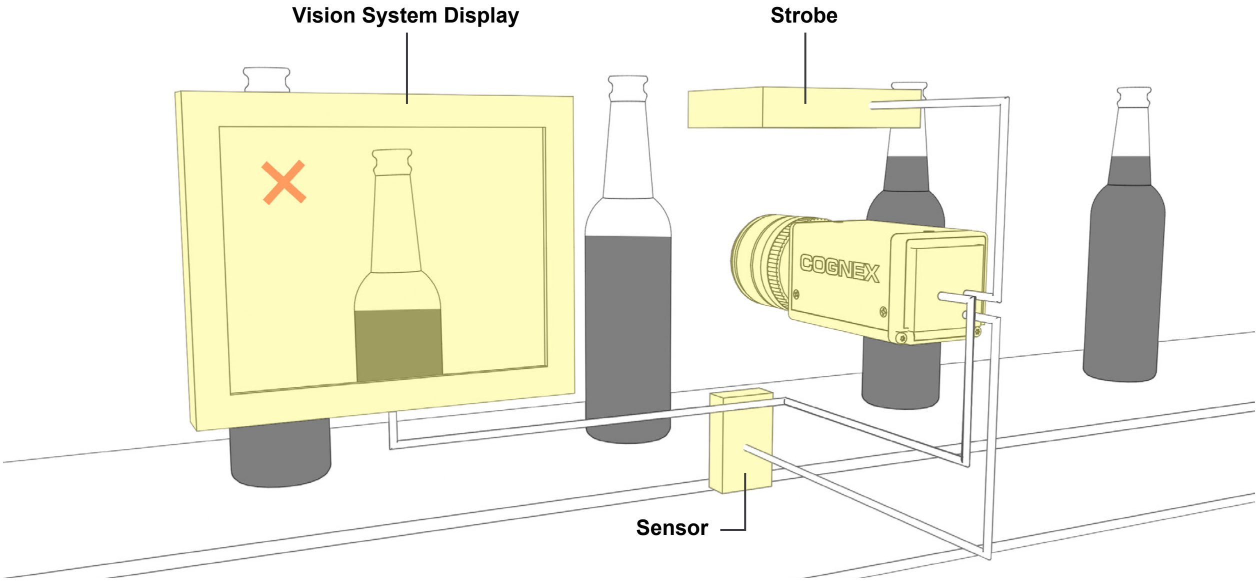


Figure 1. Bottle fill-level inspection example

The fill-level inspection system in this example permits only two possible responses, which characterizes it as a binary system:

1. Pass if the product is good
2. Fail if the product is bad.

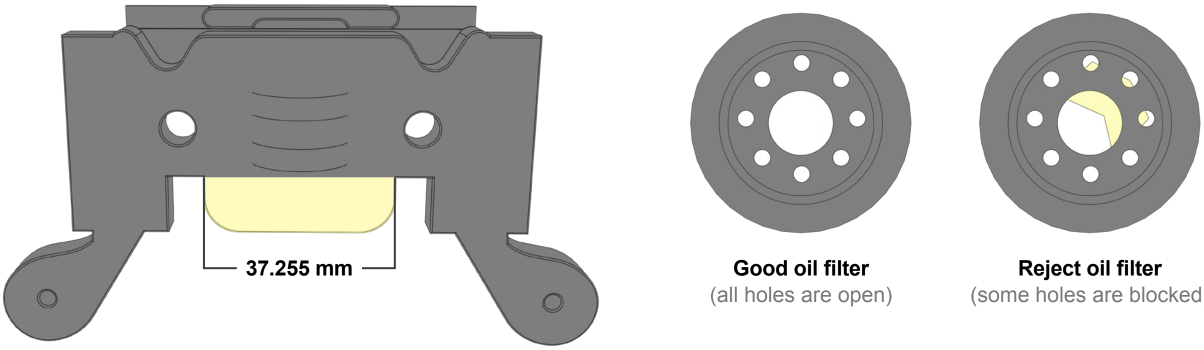


Figure 2. Machine vision systems can process real-time measurements and inspections on the production line, such as a machined bracket (left) or oil filters (right).

BENEFITS OF MACHINE VISION

Where human vision is best for qualitative interpretation of a complex, unstructured scene, machine vision excels at quantitative measurement of a structured scene because of its speed, accuracy, and repeatability. For example, on a production line, a machine vision system can inspect hundreds, or even thousands, of parts per minute. A machine vision system built around the right camera resolution and optics can easily inspect object details too small to be seen by the human eye.

In removing physical contact between a test system and the parts being tested, machine vision prevents part damage and eliminates the maintenance time and costs associated with wear and tear on mechanical components. Machine vision brings additional safety and operational benefits by reducing human involvement in a manufacturing process. Moreover, it prevents human contamination of clean rooms and protects human workers from hazardous environments.

Machine vision helps meet strategic goals

Strategic Goal	Machine Vision Applications
Higher quality	Inspection, measurement, gauging, and assembly verification
Increased productivity	Repetitive tasks formerly done manually are now done by Machine Vision System
Production flexibility	Measurement and gauging / Robot guidance / Prior operation verification
Less machine downtime and reduced setup time	Changeovers programmed in advance
More complete information and tighter process control	Manual tasks can now provide computer data feedback
Lower capital equipment costs	Adding vision to a machine improves its performance, avoids obsolescence
Lower production costs	One vision system vs. many people / Detection of flaws early in the process
Scrap rate reduction	Inspection, measurement, and gauging
Inventory control	Optical Character Recognition and identification
Reduced floorspace	Vision system vs. operator

MACHINE VISION APPLICATIONS

Typically the first step in any machine vision application, whether the simplest assembly verification or a complex 3D robotic bin-picking, is for pattern matching technology to find the object or feature of interest within the camera's field of view. Locating the object of interest often determines success or failure. If the pattern matching software tools can not precisely locate the part within the image, then it can not guide, identify, inspect, count, or measure the part. While finding a part sounds simple, differences in its appearance in actual production environments can make that step extremely challenging (Figure 3). Although vision systems are trained to recognize parts based on patterns, even the most tightly controlled processes allow some variability in a part's appearance (Figure 4).

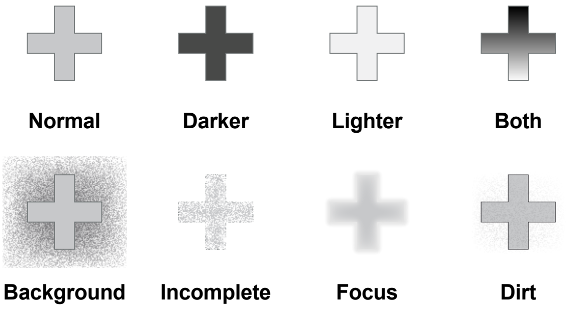


Figure 3.

Appearance changes due to lighting or occlusion can make part location difficult.

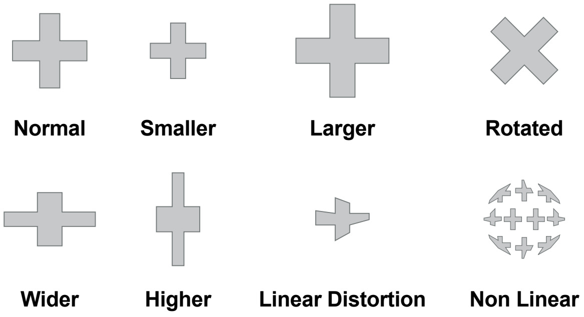


Figure 4.

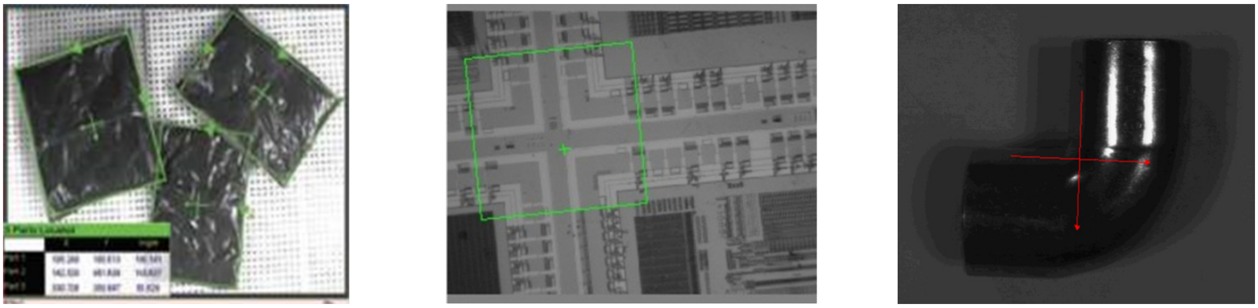
Part presentation or pose distortion effects can make part location difficult.

To achieve accurate, reliable, and repeatable results, a vision system's part location tools must include enough intelligence to quickly and accurately compare training patterns to the actual objects (pattern matching) moving down a production line. Part location is the critical first step in the four major categories of machine vision applications. The categories are guidance, identification, gauging, and inspection, which can be remembered by the acronym (GIGI).

GUIDANCE

Guidance may be done for several reasons. First, machine vision systems can locate the position and orientation of a part, compare it to a specified tolerance, and ensure it's at the correct angle to verify proper assembly. Next, guidance can be used to report the location and orientation of a part in 2D or 3D space to a robot or machine controller, allowing the robot to locate the part or the machine to align the part. Machine vision guidance achieves far greater speed and accuracy than manual positioning in tasks such as arranging parts on or off pallets, packaging parts off a conveyor belt, finding and aligning parts for assembly with other components, placing parts on a work shelf, or removing parts from bins.

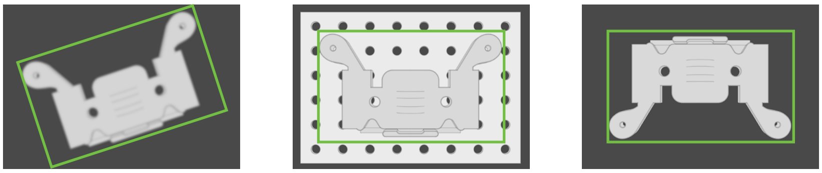
Guidance can also be used for alignment to other machine vision tools. This is a very powerful feature of machine vision because parts may be presented to the camera in unknown orientations during production. By locating the part and then aligning the other machine vision tools to it, machine vision enables automatic tool fixturing. This involves locating key features on a part to enable precise positioning of caliper, blob, edge, or other vision software tools so that they correctly interact with the part. This approach enables manufacturers to build multiple products on the same production line and reduces the need for expensive hard tooling to maintain part position during inspection.



Tomato sauce packets **Printed circuit board** **90 degree elbow**

Figure 5a. Examples of images used in guidance.

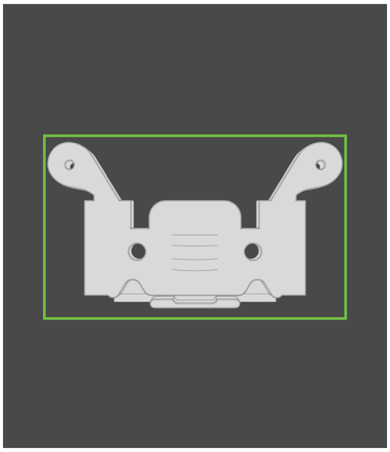
Sometimes guidance requires geometric pattern matching. Pattern matching tools must tolerate large variations in contrast and lighting, as well as changes in scale, rotation, and other factors while finding the part reliably every time. This is because location information obtained by pattern matching enables the alignment of other machine vision software tools.

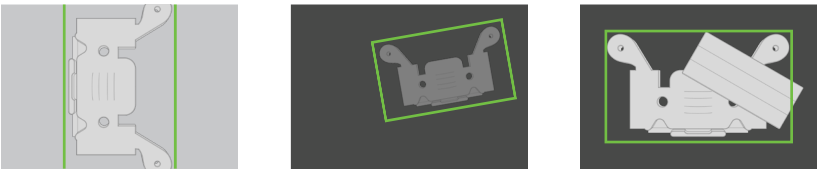


Out of Focus

Confusing Background

180º Rotation





Trained Part

Reversed Polarity

Scale Change/ Dim Lighting

Occlusion

Figure 5b. Pattern matching can be challenging.

IDENTIFICATION

A machine vision system for part identification and recognition reads barcodes (1D), DataMatrix codes (2D), direct part marks (DPM), and characters printed on parts, labels, and packages. An optical character recognition (OCR) system reads alphanumeric characters without prior knowledge, whereas an optical character verification (OCV) system confirms the presence of a character string. Additionally, machine vision systems can identify parts by locating a unique pattern or identify items based on color, shape, or size.

DPM applications mark a code or character string directly on to the part. Manufacturers in all industries commonly use this technique for error-proofing, enabling efficient containment strategies, monitoring process control and quality-control metrics, and quantifying problematic areas in a plant such as bottlenecks. Traceability by direct part marking improves asset tracking and part authenticity verification. It also provides unit-level data to drive superior technical support and warranty repair service by documenting the genealogy of the parts in a sub-assembly that make up the finished product.

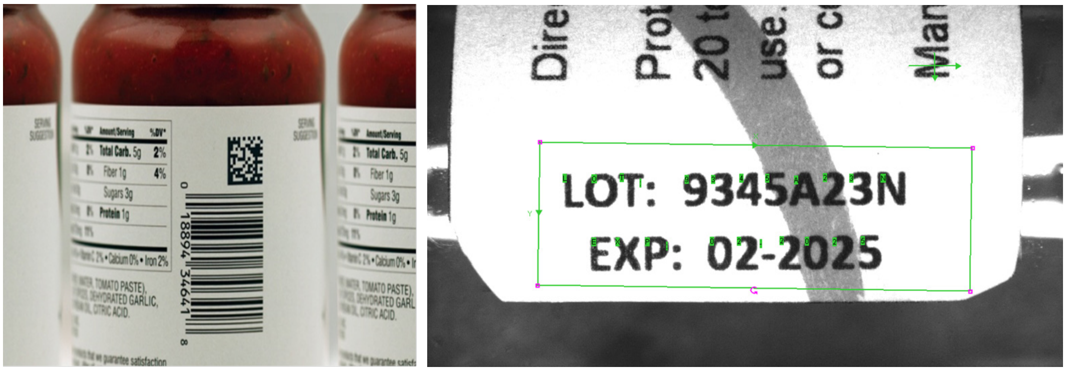


Figure 6. Identification techniques can range from simple barcode scanning to OCR.

Conventional barcodes have gained wide acceptance for retail checkout and inventory control. Traceability information, however, requires more data than can fit in a standard barcode. To increase the data capacity, companies developed 2D codes, such as Data Matrix, which can store more information, including manufacturer, product identification, lot number, and even a unique serial number for virtually any finished good.

GAUGING

A machine vision system for gauging calculates the distances between two or more points or geometrical locations on an object and determines whether these measurements meet specifications. If not, the vision system sends a fail signal to the machine controller, triggering a reject mechanism that ejects the object from the line.

In practice, a fixed-mount camera captures images of parts as they pass the camera's field of view and the system uses software to calculate distances between various points in the image. Because many machine vision systems can measure object features to within 0.0254 millimeters, they address a number of applications traditionally handled by contact gauging.

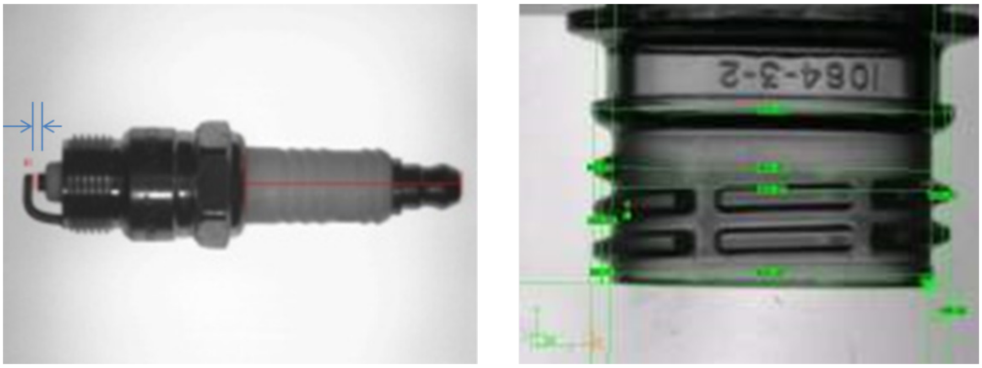


Figure 7. Gauging applications can measure part tolerances to within 0.0254 millimeters.

INSPECTION

A machine vision system for inspection detects defects, contaminants, functional flaws, and other irregularities in manufactured products. Examples include inspecting tablets of medicine for flaws, displays to verify icons or confirm pixel presence, or touch screens to measure the level of backlight contrast. Machine vision can also inspect products for completeness, such as ensuring a match between product and package in the food and pharmaceutical industries, and checking safety seals, caps, and rings on bottles.

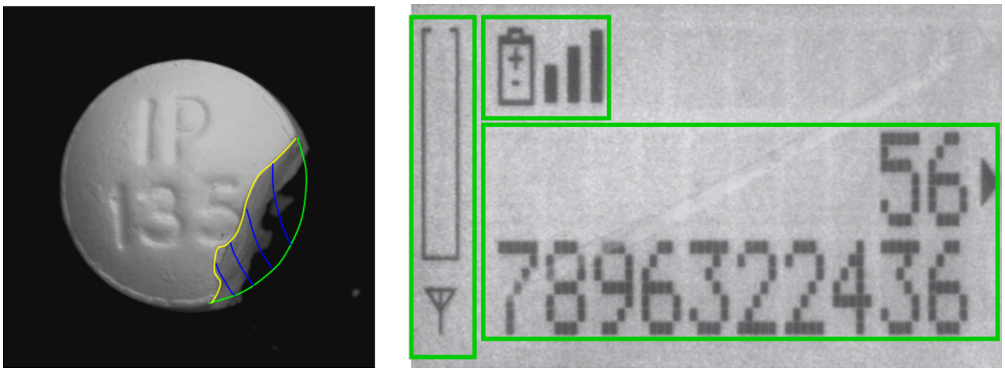


Figure 8. Machine vision systems can detect defects or functional flaws.

DIFFERENT TYPES OF MACHINE VISION SYSTEMS

Broadly speaking, there are 3 categories of machine vision systems: 1D, 2D and 3D.

1D VISION SYSTEMS

1D vision analyzes a digital signal one line at a time instead of looking at a whole picture at once, such as assessing the variance between the most recent group of ten acquired lines and an earlier group. This technique commonly detects and classifies defects on materials manufactured in a continuous process, such as paper, metals, plastics, and other non-woven sheet or roll goods, as shown in Figure 9.

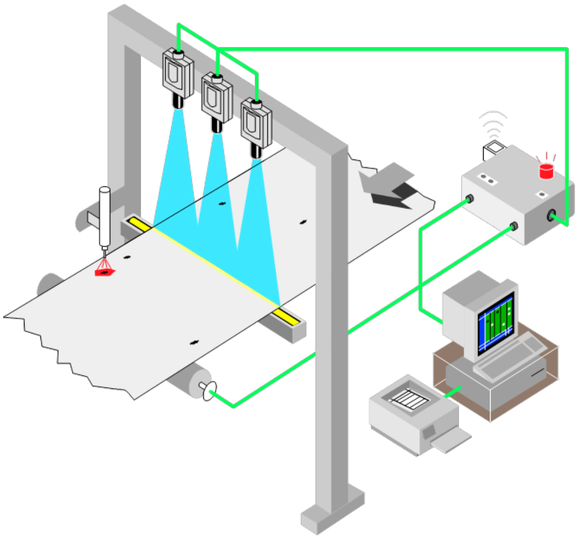


Figure 9. 1D vision systems scan one line at a time while the process moves. In the above example, a defect in the sheet is detected.

2D VISION SYSTEMS

Most common inspection cameras perform area scans that involve capturing 2D snapshots in various resolutions, as shown in Figure 10. Another type of 2D machine vision–line scan–builds a 2D image line by line, as shown in Figure 11.

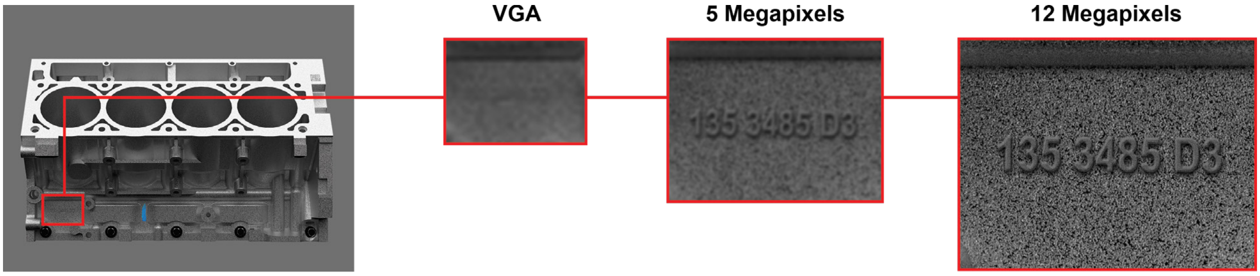


Figure 10. 2D vision systems can produce images with different resolutions.

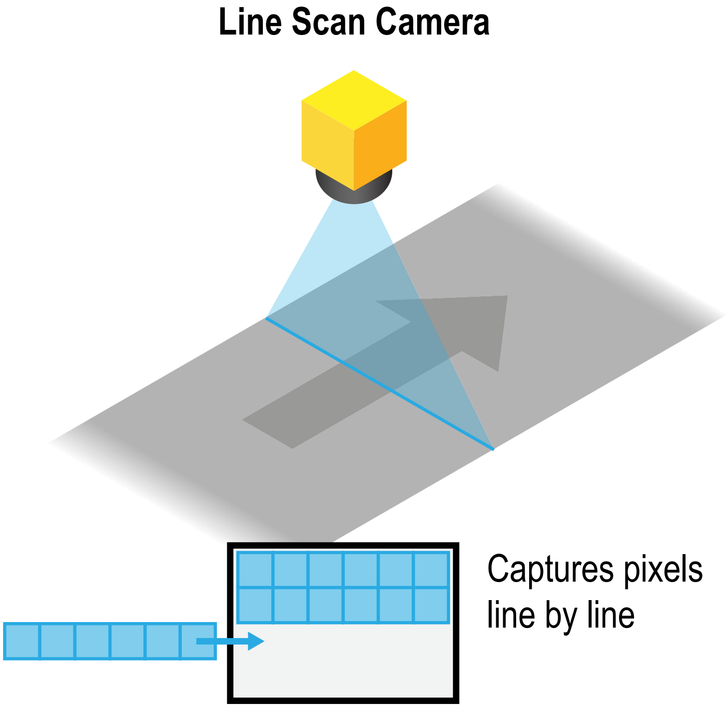
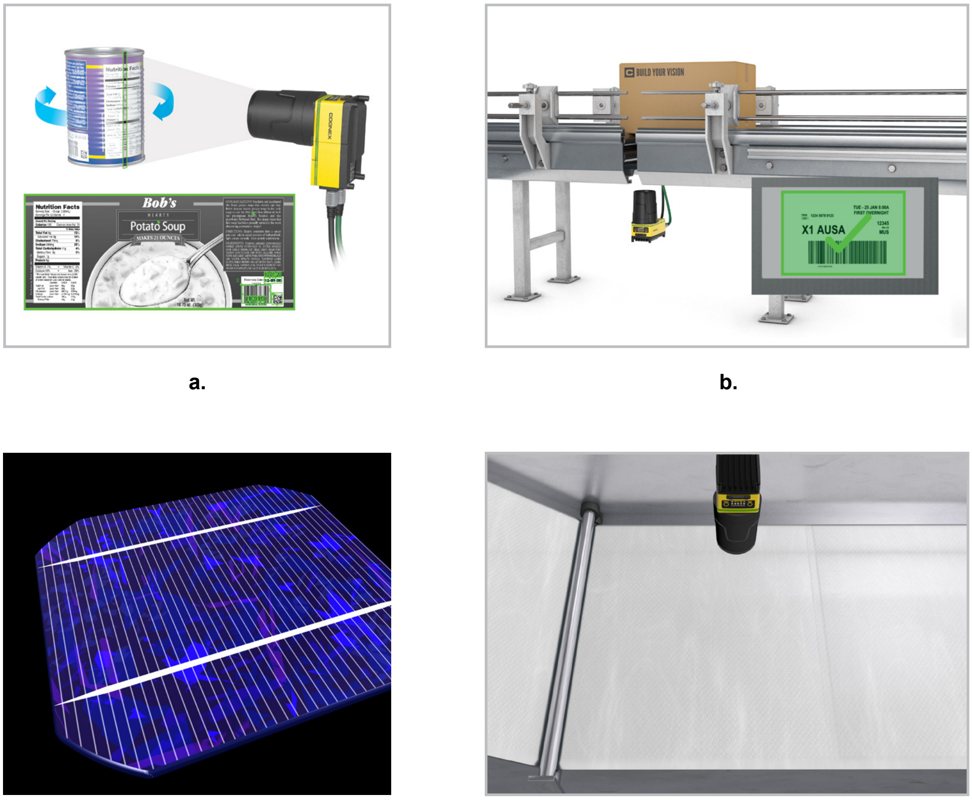


Figure 11. Line scan techniques build the 2D image one line at a time.

AREA SCAN VS. LINE SCAN

In certain applications, line scan systems have specific advantages over area scan systems. For example, inspecting round or cylindrical parts may require multiple area scan cameras to cover the entire part surface. However, rotating the part in front of a single line scan camera captures the entire surface by unwrapping the image. Line scan systems fit more easily into tight spaces for instances when the camera must peek through rollers on a conveyor to view the bottom of a part. Line scan systems can also generally provide much higher resolution than traditional cameras. Since line scan systems require parts in motion to build the image, they are often well-suited for products in continuous motion.



a.

b.

c.

d.

Figure 12. Line scan cameras can (a.) unwrap cylindrical objects for inspection, (b.) add vision to space-constrained environments, (c.) meet high-resolution inspection requirements, and (d.) inspect objects in continuous motion.

3D SYSTEMS

3D machine vision systems typically comprise multiple cameras or one or more laser displacement sensors. Multi-camera 3D vision in robotic guidance applications provides the robot with part orientation information. These systems involve multiple cameras mounted at different locations and “triangulation” on an objective position in 3-D space.

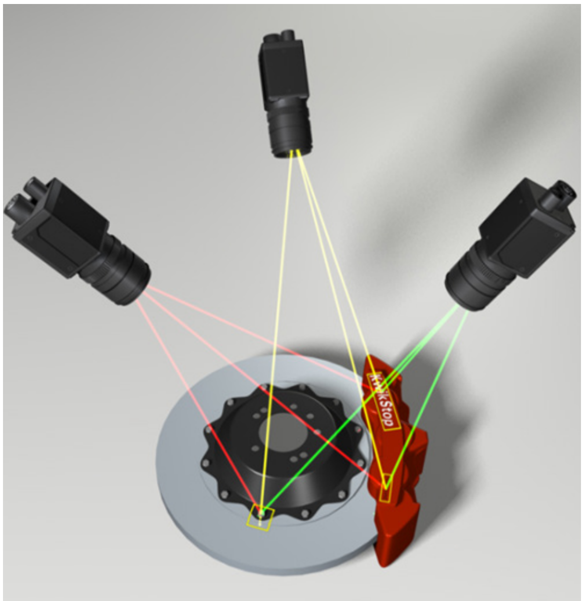


Figure 13. 3D vision systems typically employ multiple cameras.

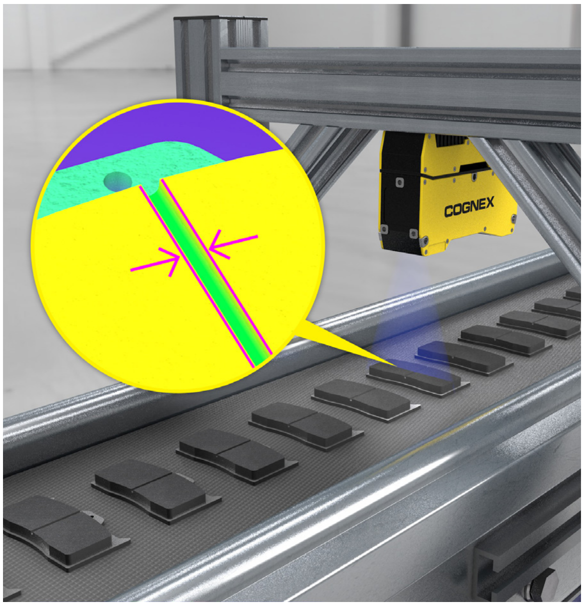


Figure 14. 3D inspection system using a single camera.

In contrast, 3D laser-displacement sensor applications typically include surface inspection and volume measurement, producing 3D results with as few as a single camera. A height map is generated from the displacement of the reflected lasers’ location on an object. The object or camera must be moved to scan the entire product similar to line scanning. With a calibrated offset laser, displacement sensors can measure parameters such as surface height and planarity with accuracy within 20 µm. Figure 14 shows a 3D laser displacement sensor inspecting brake pad surfaces for defects.

CONCLUSION

Machine vision is the automatic extraction of information from digital images for process or quality control. Most manufacturers use automated machine vision instead of human inspectors because it is better suited to repetitive inspection tasks. It is faster, more objective, and works continuously. Machine vision can inspect hundreds or even thousands of parts per minute, and provides more consistent and reliable inspection results 24 hours a day, 7 days a week.

Measurement, counting, location, and decoding are some of the most common applications for machine vision in manufacturing today. By reducing defects, increasing yield, facilitating compliance with regulations and tracking parts with machine vision, manufacturers can save money and increase profitability.

For more information on how machine vision can help your organization reduce waste, minimize downtime, and improve processes contact Cognex

Or visit these online resources for more information:

- Cognex Machine Vision
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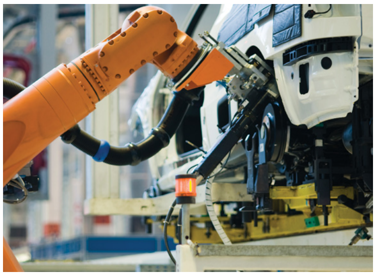

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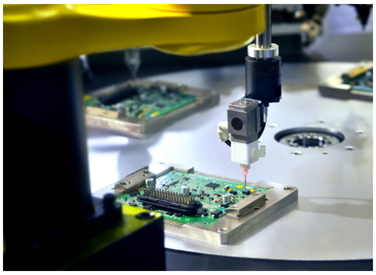

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IN MACHINE VISION AND BARCODE READING

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