AI FOR FACTORY AUTOMATION

COGNEX

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AI: IT'S EVERYWHERE

From the phones in our pockets to the reality of self-driving cars, the consumer economy has started to tap into the power of artificial intelligence (AI). AI has emerged as a foundational technology in the speech, text, and facial recognition that we use in our mobile and wearable devices and is now beginning to be used in many other applications—from medical diagnostics to Internet security—to predict patterns and make critical business decisions. This same technology is now migrating into advanced manufacturing practices for quality inspection and other judgment-based uses.

In essence, AI teaches robots and machines to do what comes naturally to humans: to learn by example. New, low-cost hardware has made it practical to deploy bio-inspired, multi-layered “deep” neural networks that mimic neuron networks in the human brain. This gives manufacturing technology amazing new abilities to recognize images, distinguish trends, and make intelligent predictions and decisions. Starting from a core logic developed during initial training, AI-enabled neural networks can continuously refine their performance as they are presented with new images, speech, and text.

AI-based image analysis combines the specificity and flexibility of human visual inspection with the reliability, consistency, and speed of a computerized system. AI models can precisely and repetitively solve difficult vision applications that would be tedious to develop and frequently impossible to maintain using traditional machine vision approaches. These models can distinguish unacceptable defects while tolerating natural variations in complex patterns. And they can be readily adapted to new examples without re-programming their core algorithms.

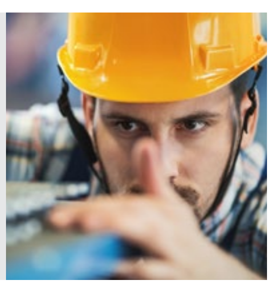
AI-powered software can perform judgment-based part location, inspection, classification, and character recognition challenges more effectively than humans or traditional machine vision solutions. Increasingly, leading manufacturers are turning to AI-based solutions to solve their most sophisticated automation challenges.

MACHINE VISION FOR ASSEMBLY AUTOMATION

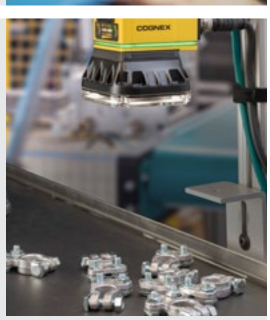
Gone are the days when humans directly managed factory lines. Today, machines automate manufacturing, assembly, and material handling tasks. Machine vision systems equipped with precision alignment and identification algorithms and guidance capabilities have made it possible to manufacture compact modern components that could not be built manually. On a production line, machine vision systems can inspect hundreds or thousands of parts per minute reliably and repeatedly, far exceeding the inspection capabilities of humans.

For decades, machine vision systems have taught computers to perform inspections that detect defects, contaminants, functional flaws, and other irregularities in manufactured products. Machine vision excels at the quantitative measurement of a structured scene because of its speed, accuracy, and repeatability. 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, and inspect them with greater reliability and less error (Figure 1).

Human Inspectors



Machine Vision



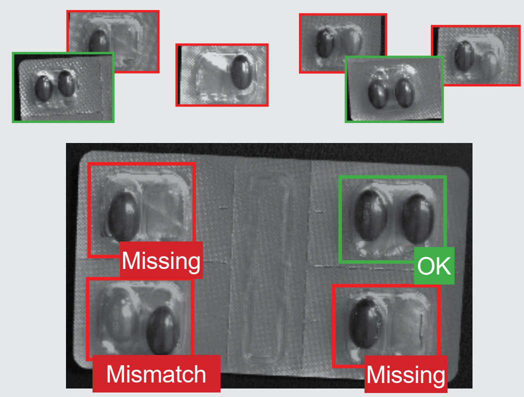
- **+ Speed**
- **+ Accuracy**
- **+ Repeatability**
- **+ Inspect details too small to be seen by the human eye**

Figure 1. *Human inspectors are skilled at learning by example and appreciating acceptable deviations from the control. Machine vision, by contrast, offers the speed and robustness that only a computerized system can.*

AI SOLUTIONS CAN BE POWERED BY DIFFERENT BASE TECHNOLOGIES

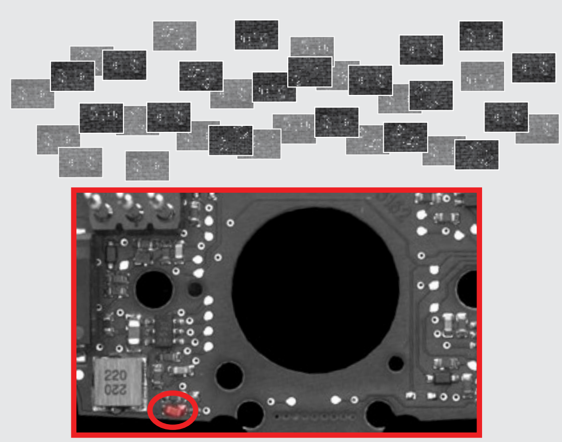
Edge learning: Deploy in minutes

Edge learning is a subset of AI in which processing takes place on-device, or “at the edge,” using a pre-trained set of algorithms. The technology is simple to setup, requiring smaller image sets and shorter training and validation periods than traditional deep learning-based solutions.



Deep learning: Analyze fine details

Capable of processing large, detailed image sets, deep learning is designed to automate complex or highly customized applications. The technology enables users to analyze vast image sets quickly and efficiently, while differentiating between acceptable and unacceptable anomalies, to deliver accurate results.



AI Compared to Other Inspection Methods

Compared to Human Visual Inspection, AI is:	Compared to Traditional Machine Vision, AI is:
More consistent Operates 24x7 and maintains the same level of quality on every line, every shift and every factory.	**Designed for hard-to-solve applications** Solves complex inspection, classification and location applications impossible or difficult with classic rule-based algorithms.
More reliable Identifies every defect outside of the set tolerance.	**Easier to configure** Applications can be set up quickly, speeding up proof of concept and development.
Faster Identifies defects in milliseconds, supporting high-speed applications and improving throughput.	**Tolerates variations** Handles defect variations for applications that require an appreciation of acceptable deviations from the control.

THE CHALLENGE OF VARIABILITY

Traditional machine vision systems perform reliably with consistent, well-manufactured parts. They operate via step-by-step filtering and rule-based algorithms that are more cost-effective than human inspection. But algorithms become unwieldy as exceptions and defect libraries grow. Certain traditional machine vision inspections, such as final assembly verification, are notoriously difficult to program due to multiple variables that can be hard for a machine to isolate such as lighting, changes in color, curvature, and field of view (Figure 2).

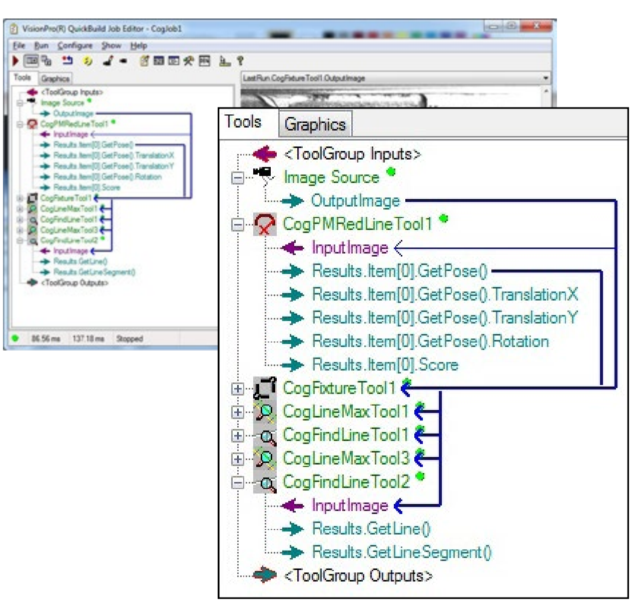


Figure 2. *Application developers may struggle to program complex inspections involving deviation and unpredictable defects into a rule-based algorithm.*

Although machine vision systems tolerate some variability in a part's appearance due to scale, rotation, and pose distortion, complex surface textures and image quality issues introduce serious inspection challenges. Machine vision systems struggle to appreciate variability and deviation between very visually similar parts (Figure 3). Inherent differences or anomalies may or may not be cause for rejection, depending on how the user understands and classifies them. "Functional" anomalies, which affect a part's utility, are almost always cause for rejection, while cosmetic anomalies may not be, depending upon the manufacturer's needs and preference. Most problematically, these defects are difficult for a traditional machine vision system to distinguish between.

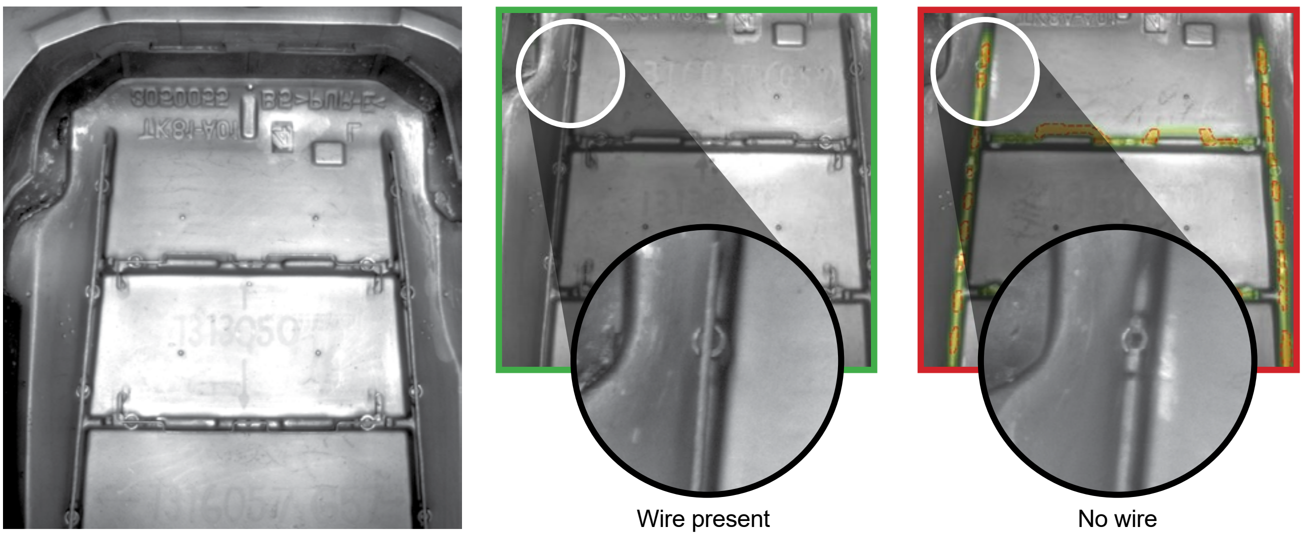


Figure 3. *Confusing and glaring backgrounds can make it difficult for traditional machine vision systems to appreciate slight differences between images. In this case, an AI-based model sees beyond the metal surface and specular glare to check for missing wire bands in a car trim assembly.*

ADVANTAGES OF HUMAN INSPECTION

Unlike traditional machine vision, humans are adept at distinguishing between subtle cosmetic and functional flaws, as well appreciating variations in part appearance that may affect perceived quality. Though limited in the rate at which we can process information, humans are uniquely able to conceptualize and generalize. We excel at learning by example and are capable of distinguishing what really matters when it comes to slight anomalies between parts. This makes human vision the best choice, in many cases, for the qualitative interpretation of a complex, unstructured scene—especially those with subtle defects and unpredictable flaws (Figure 4).

For example, humans are much more accurate when dealing with deformed and otherwise hard-to-read characters, complex surfaces, and cosmetic defects. For many of these applications, machines cannot compete with humans for their appreciation of complexity.

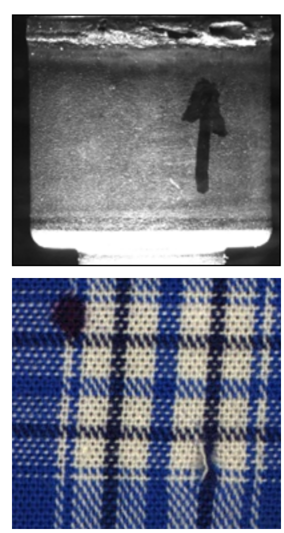


Figure 4. *Examples of complex scenes that human vision excels at distinguishing.*

AI FOR COMPLEX INSPECTIONS

AI-enabled models can help machines overcome their inherent limitations by marrying the self-learning of a human inspector with the speed and consistency of a computerized system.

As the examples in Figure 5 show, AI-based image analysis is especially well-suited for cosmetic surface inspections that are complex in nature: patterns that vary in subtle but tolerable ways, and where position variants can preclude the use of methods based on spatial frequency. AI excels at addressing complex surface and cosmetic defects, like scratches and dents on parts that are turned, brushed, or shiny. Whether used to locate, read, inspect, or classify features of interest, AI-based image analysis differs from traditional machine vision in its ability to conceptualize and generalize a part's appearance based upon its distinguishing characteristics—even when those characteristics subtly vary or sometimes deviate.

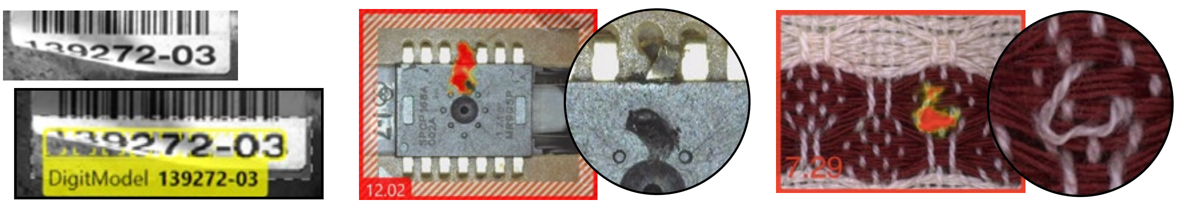


Figure 5. *AI-based image analysis excels at identifying cosmetic and functional anomalies that machine vision struggles with, and it does so more quickly and reliably than a human inspector.*

CHOOSING BETWEEN TRADITIONAL MACHINE VISION AND AI

The choice between traditional machine vision and AI depends upon the type of application being solved, the amount of data being processed, and processing capabilities. Indeed, for its many benefits, AI is not the right solution for many applications. Traditional rule-based programming technologies are better at gauging and measuring, as well as performing precision alignment. In some cases, traditional vision may be the best choice to fixture a region of interest precisely, and AI to inspect that region. The result of an AI-based inspection may then be passed back to traditional vision to take accurate measurements of the defect size and shape.

AI complements rule-based approaches, and it reduces the need for AI domain expertise to construct an effective inspection. Instead, AI has turned applications that previously required vision expertise into engineering challenges solvable by non-vision experts. AI transfers the logical burden from an application developer, who develops and scripts a rule-based algorithm, to an engineer training the system. It also opens a new range of possibilities to solve applications that have never been attempted without a human inspector. In this way, AI makes machine vision easier to work with, while expanding the limits of what a computer and camera can accurately inspect. Figure 6 below identifies the most suitable applications for traditional machine vision and for AI-based approaches, including those well-suited to either.

When to Deploy Traditional Machine Vision vs. AI-Based Image Analysis

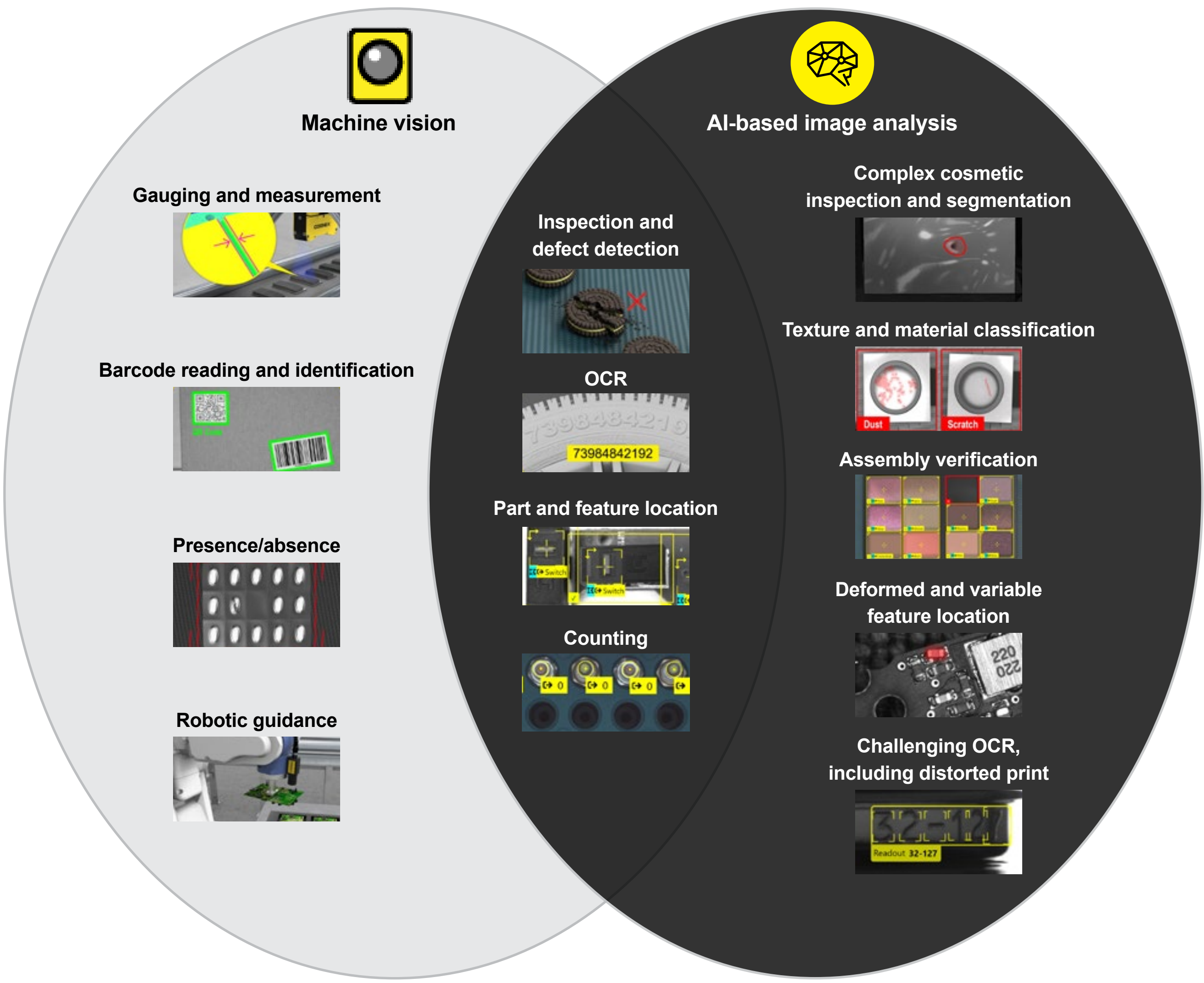


Figure 6. *AI-based image analysis and traditional machine vision are complementary technologies, with overlapping abilities as well as distinct areas where each excels. Some applications may involve both technologies.*

CONCLUSION

Increasingly, industry is turning to AI technology to solve manufacturing inspections too complicated, time-consuming, and costly to program using traditional rule-based algorithms. This will make it possible to automate previously unprogrammable applications, reduce error rates, and quicken inspection times. AI offers manufacturers the possibility to solve problems that challenge traditional machine vision applications, and to do so with greater robustness and reliability.

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