DEEP LEARNING FOR FACTORY AUTOMATION

Combining artificial intelligence with machine vision

COGNEX

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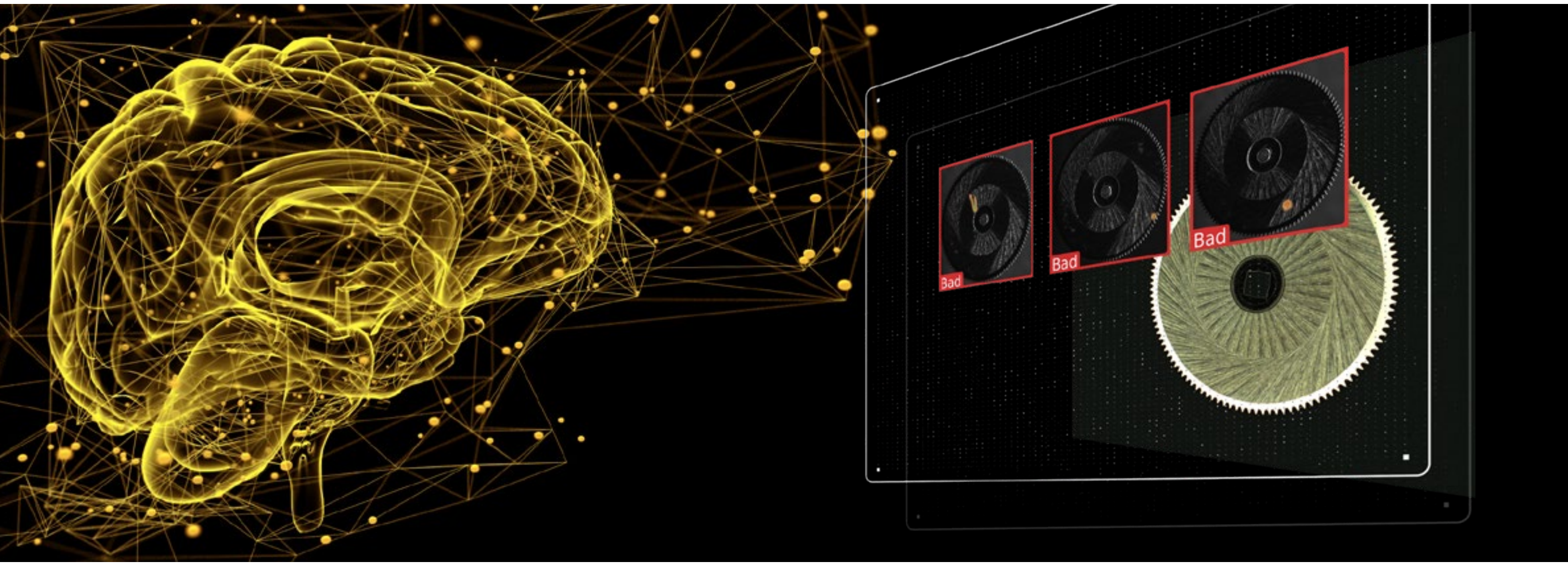
COMBINING ARTIFICIAL INTELLIGENCE WITH MACHINE VISION



WHAT IS DEEP LEARNING?

From the phones in our pockets to the reality of self-driving cars, the consumer economy has started to tap into the power of deep learning's neural networks. Deep learning 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, deep learning 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, deep neural networks can continuously refine their performance as they are presented with new images, speech, and text.

Deep learning-based image analysis combines the specificity and flexibility of human visual inspection with the reliability, consistency, and speed of a computerized system. Deep learning 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. Deep learning 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.

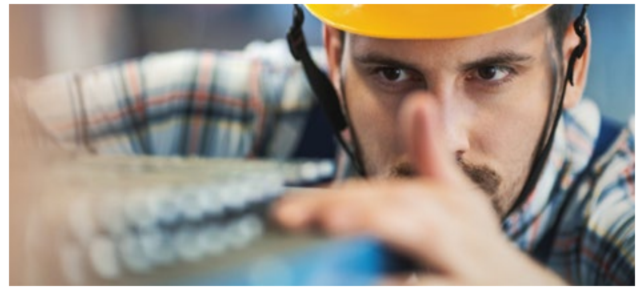
Deep learning-based software can perform judgment-based part location, inspection, classification, and character recognition challenges more effectively than humans or traditional machine vision solutions. Increasingly, leading manufacturers are turning to deep learning solutions and artificial intelligence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

MACHINE VISION FOR ASSEMBLY AUTOMATION

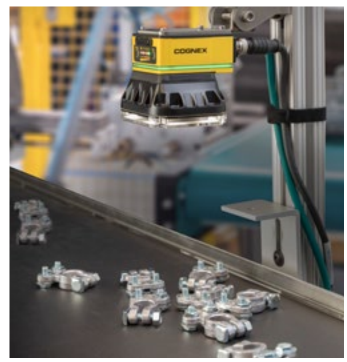
Gone are the days when humans directly managed factory lines. Today, machines automate manufacturing, assembly, and material handling tasks. Machine vision systems equipped with precision alignment and identification algorithms and guidance capabilities have made it possible to manufacture compact modern 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.*

Deep Learning Compared to Other Inspection Methods

Compared to Human Visual Inspection, Deep Learning is:	Compared to Traditional Machine Vision, Deep Learning 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).

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.

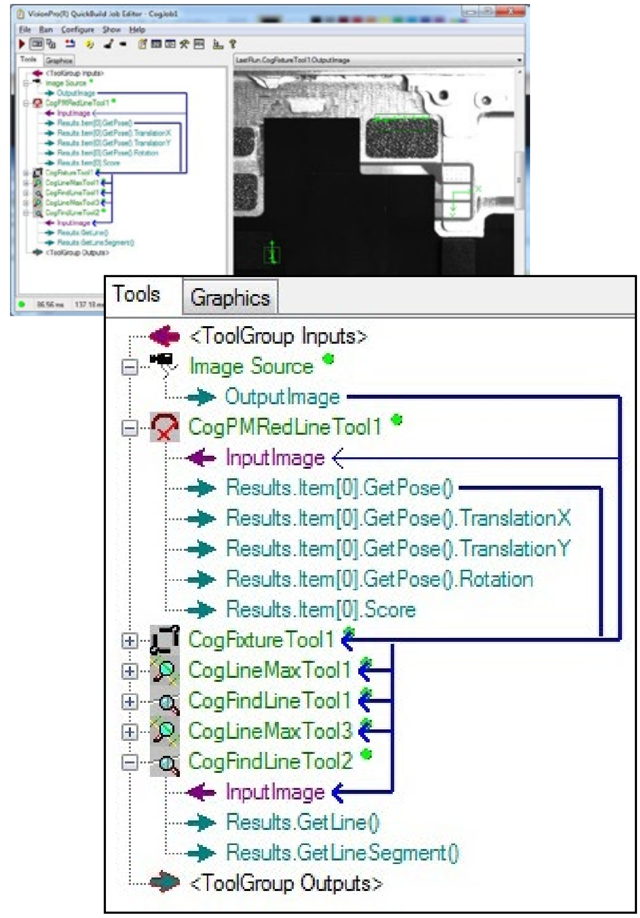


Figure 2. *Application developers may struggle to program complex inspections involving deviation and unpredictable defects into a rule-based algorithm.*

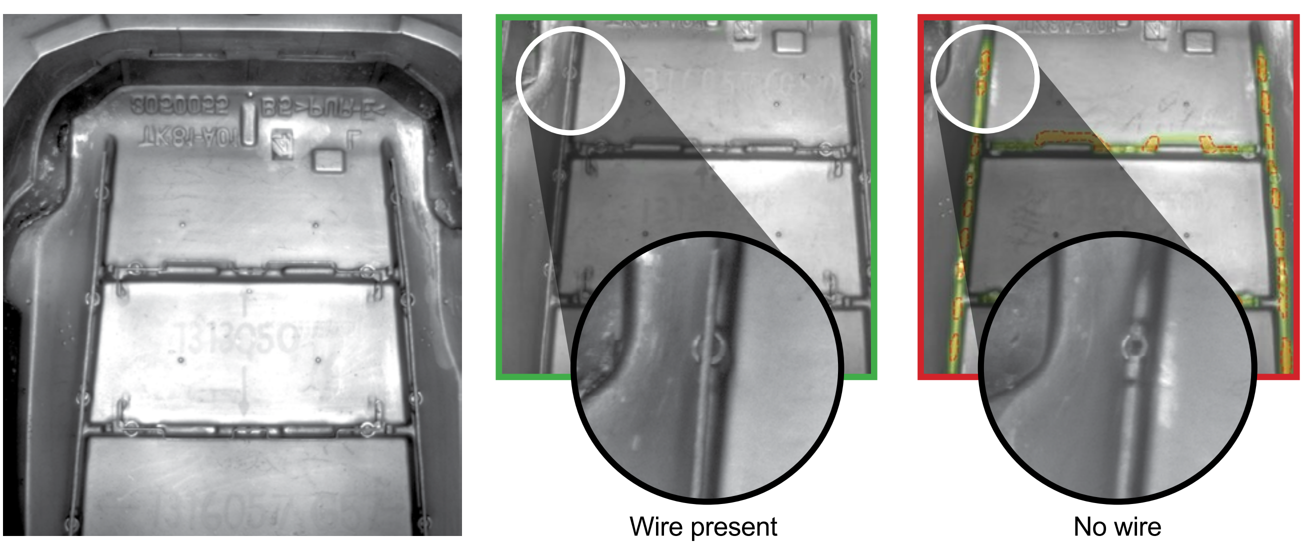


Figure 3. *Confusing and glaring backgrounds can make it difficult for traditional machine vision systems to appreciate slight differences between images. In this case, a deep learning-based model sees beyond the metal surface and specular glare to check for missing wire bands in a car trim assembly.*

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).

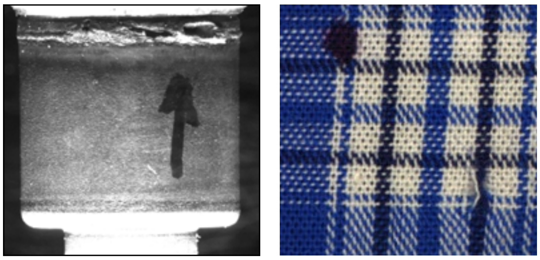


Figure 4. *Examples of complex scenes that human vision excels at distinguishing.*

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.

DEEP LEARNING FOR COMPLEX INSPECTIONS

Deep learning 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, deep learning-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. Deep learning 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, deep learning-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.

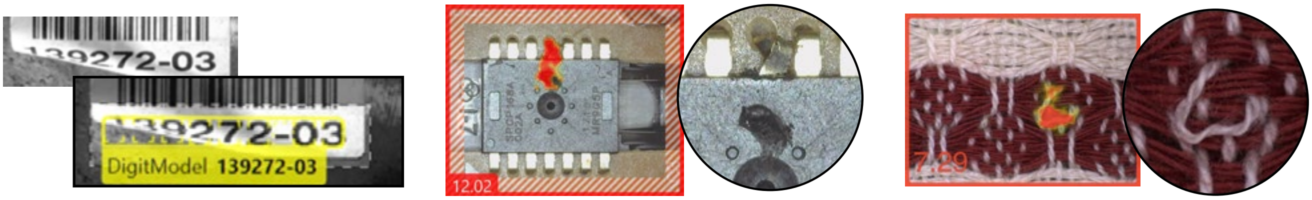


Figure 5. *Deep learning-based image analysis excels at identifying cosmetic and functional anomalies that machine vision struggles with, and it does so more quickly and reliably than a human inspector.*

CHOOSING BETWEEN TRADITIONAL MACHINE VISION AND DEEP LEARNING

The choice between traditional machine vision and deep learning depends upon the type of application being solved, the amount of data being processed, and processing capabilities. Indeed, for its many benefits, deep learning 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 deep learning to inspect that region. The result of a deep learning-based inspection may then be passed back to traditional vision to take accurate measurements of the defect size and shape.

Deep learning complements rule-based approaches, and it reduces the need for deep vision domain expertise to construct an effective inspection. Instead, deep learning has turned applications that previously required vision expertise into engineering challenges solvable by non-vision experts. Deep learning 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, deep learning 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 deep learning-based approaches, including those well-suited to either.

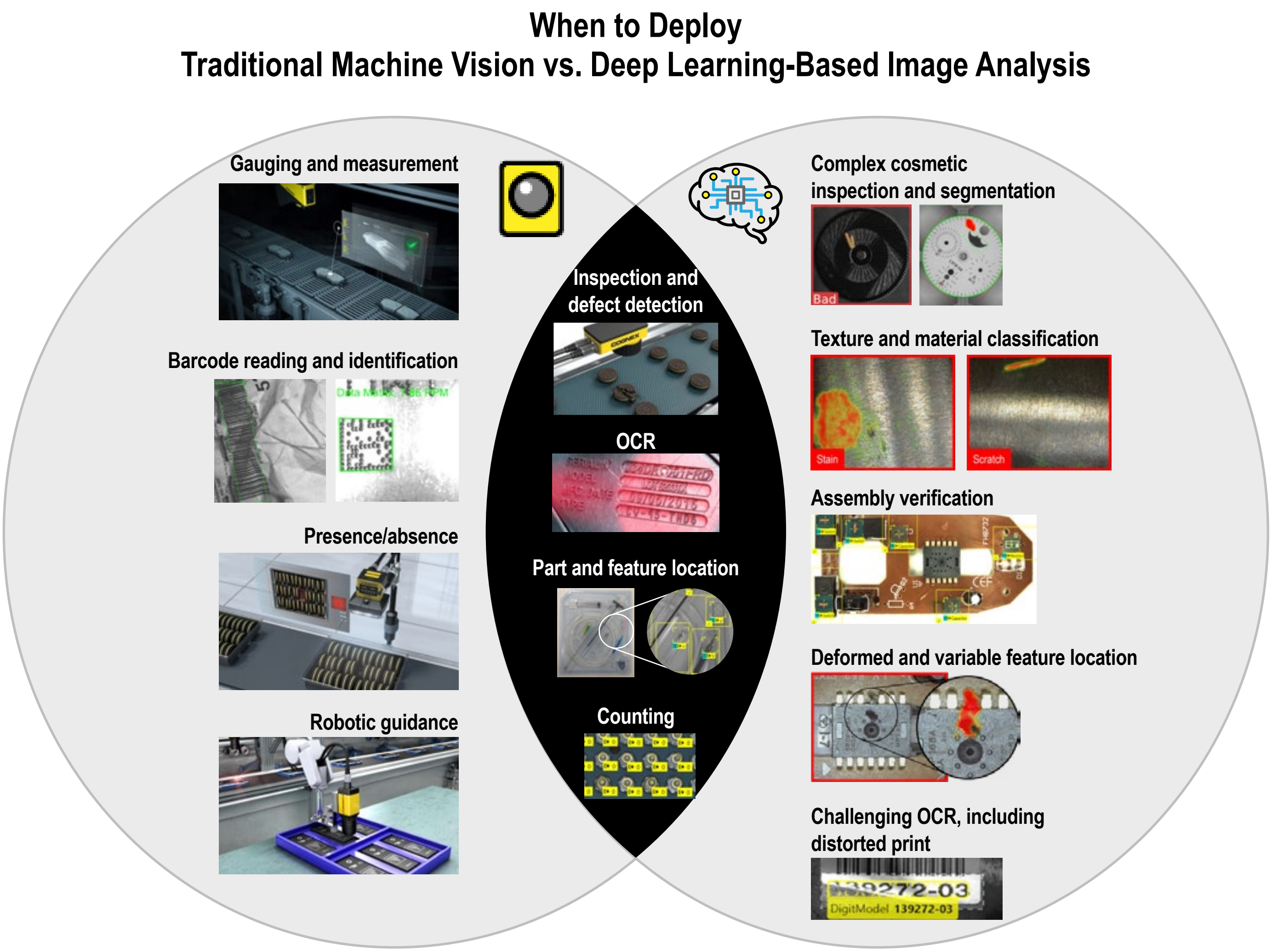


Figure 6. *Deep learning-based image analysis and traditional machine vision are complementary technologies, with overlapping abilities as well as distinct areas where each excels. Some applications may involve both technologies.*

CONCLUSION

Increasingly, industry is turning to deep learning 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. Deep learning offers manufacturers the possibility to solve problems which challenge traditional machine vision applications, and to do so with greater robustness and reliability.

COGNEX DEEP LEARNING SOLUTIONS

Cognex Deep Learning is the first set of deep learning-based vision solutions designed specifically for factory automation. The field-tested, optimized and proven technology is based on state-of-the-art machine learning algorithms.

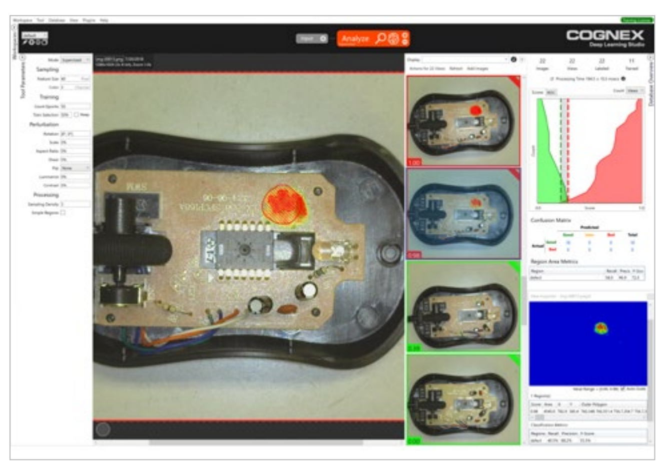
Rather than following a rule-based approach to solving inspection challenges, like traditional machine vision applications, Cognex's deep learning solutions learn to spot patterns and anomalies from reference image examples. Deep learning automates and scales complex inspection applications that until now still required human inspectors such as defect detection and final assembly verification.

In-Sight ViDi

In-Sight® ViDi deep learning applications are deployed on the In-Sight D900 smart camera without the need for a PC, making deep learning technology accessible to non-programmers. It uses the familiar and easy-to-use In-Sight software platform which simplifies application development and factory integration.

VisionPro Deep Learning

VisionPro Deep Learning software combines a comprehensive machine vision tool library with advanced deep learning tools inside a common development and deployment framework. It simplifies the development of highly variable vision applications and allows engineers to build flexible, highly customized deep learning solutions tailored to their specific needs.



BUILD YOUR VISION

2D VISION SYSTEMS

Cognex machine vision systems are unmatched in their ability to inspect, identify and guide parts. They are easy to deploy and provide reliable, repeatable performance for the most challenging applications.

www.cognex.com/machine-vision



3D VISION SYSTEMS

Cognex In-Sight laser profilers and 3D vision systems provide ultimate ease of use, power and flexibility to achieve reliable and accurate measurement results for the most challenging 3D applications.

www.cognex.com/3D-vision-systems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Cognex vision software provides industry leading vision technologies, from traditional machine vision to deep learning-based image analysis, to meet any development needs.

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BARCODE READERS

Cognex industrial barcode readers and mobile terminals with patented algorithms provide the highest read rates for 1D, 2D and DPM codes regardless of the barcode symbology, size, quality, printing method or surface.

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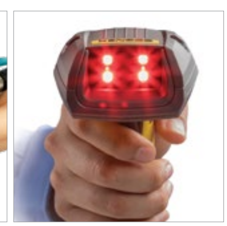


COGNEX

Companies around the world rely on Cognex vision and barcode reading solutions to optimize quality, drive down costs and control traceability.

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