## MACHINE VISION

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.

Machine Vision refers to the use of industrial cameras, lenses, and lighting to perform automated, visual inspection of manufactured products.

Machine vision provides a fast, reliable way to inspect parts inline. With machine vision, every part coming down a high-speed line can be imaged and inspected, to ensure 100% quality control.

In the factory processes, machine vision can automate various inspections such as appearance inspections that check defects and faults, presence-absence checks, product type verifications, measurements, code readings.

### Machine Vision Basics

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.

### Benefits of Machine Vision

Vision improves quality and productivity, while driving down manufacturing costs

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 specific 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 | Change-overs 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 floor space | Vision system vs. operator |

## Machine Vision Applications

### GIGI: Guidance, Identification, Gauging and Inspection

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).

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 include:

- Guidance
- Identification
- Gauging
- Inspection

This 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.

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.

## Identification

### Vision enable technologies read codes and alphanumeric characters

A machine vision system for part identification and recognition reads barcodes (1-D), data matrix codes (2-D), 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.

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 2-D 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

**Measuring distances and locations to assess specification adherence**

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.

## Inspection

**Identifying defects, irregularities and other manufacturing flaws**

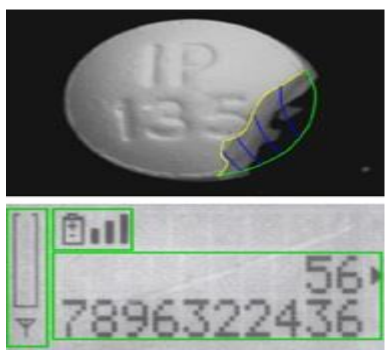
A machine vision system for inspection detects defects, contaminants, functional flaws, and other irregularities in manufactured products. Examples include inspecting tablets of medicine for flaws, displays to verify icons or confirm pixel presence, or touch screens to measure the level of backlight 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.

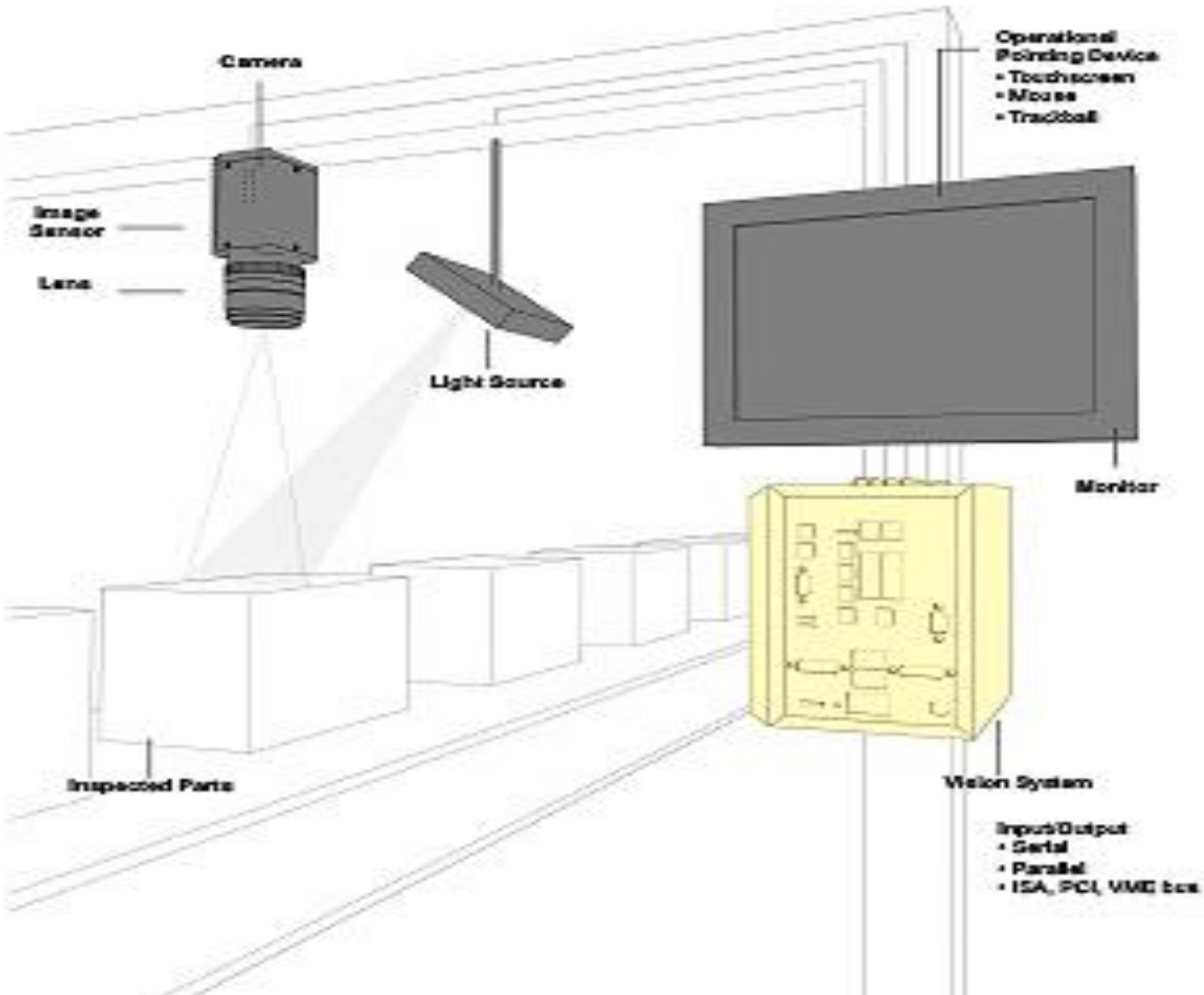
Machine vision systems designed for inspection monitor the visual appearance of the observed material. Using statistical analysis, the system automatically identifies potential defects in the material's surface and classifies the defects into groups based on similarity in contrast, texture and/or geometry.

Most machine vision systems include a library of software tools that perform different types of inspections and let you incorporate multiple inspections from captured images. The versatility and industry range of machine vision inspection can be seen in the following list of typical machine vision inspection tasks:

- Determine the position of an object, for example, to verify proper label placement
- Ensure the package integrity of medical products, such as checking that medicine vials are fully closed and secured with tamper-proof seals
- Verify that an object's properties meet quality standards, such as the position and volume of glue beads used in automobile transmissions
- Inspect manufactured goods and identify flaws, such as surface scratches, bent needle tips, and incomplete solder traces
- Count items, such as pills in a blister pack, bottles in a case, and components of a kit
- Check on characteristics of completed assemblies, such as the inclusion of consumer safety inserts and the completion of an assembly operation
- Detect tool wear in machining operations before parts are out of spec
- Measure dimensions on a microscopic level, such as the gap on a spark plug



**Components of Machine Vision**




Success of a vision system is dependent on the use of key components

The major components of a machine vision system include the lighting, lens, image sensor, vision processing, and communications. Lighting illuminates the part to be inspected allowing its features to stand out so they can be clearly seen by camera. The lens captures the image and presents it to the sensor in the form of light. The sensor in a machine vision camera converts this light into a digital image which is then sent to the processor for analysis.

Vision processing consists of algorithms that review the image and extract required information, run the necessary inspection, and make decision.

Finally, communication is typically accomplished by either discrete I/O signal or data sent over a serial connection to a device that is logging information or using it.

Most machine vision hardware components, such as lighting modules, sensors, and processors are available commercial off-the-shelf (COTS). Machine vision systems can be assembled from COTS, or purchased as an integrated system with all components in a single device.

The various components of a machine vision system include:

- Lighting
- Lenses
- Vision Processing
- Image Sensor
- Communications

**Machine Vision Lighting**

Lighting is one of the most critical aspects of machine vision applications. Failure to properly illuminate a target can result in the loss of information and productivity. A lighting technique involves a light source and its placement with respect to the part and the camera. Cognex vision systems offer various combinations of external and integrated lighting options based on the environment and application.

**Machine Vision Lenses**

The lens captures the image and delivers it to the image sensor in the camera. Lens will vary in optical quality and price, the lens used determines the quality and resolution of the captured image. Most vision system cameras offer two main types of lenses: interchangeable lenses and fixed lenses. Interchangeable lenses are typically C-mounts or CS-mounts.

The right combination of lens and extension will acquire the best possible image. A fixed lens as part of a standalone vision system typically uses autofocus, which could be either a mechanically adjusted lens or a liquid lens that can automatically focus on the part. Autofocus lenses usually have a fixed field of view at a given distance.

**Machine Vision Image Sensor**

**An essential component to image capture**

The camera’s ability to capture a correctly-illuminated image of the inspected object depends not only on the lens, but also on the image sensor within the camera. Image sensors typically use a charge coupled device (CCD) or complementary metal oxide semiconductor (CMOS) technology to convert light (photons) to electrical signals (electrons). Essentially the job of the image sensor is to capture light and convert it to a digital image balancing noise, sensitivity and dynamic range. The image is a collection of pixels. Low light produces dark pixels, while bright light creates brighter pixels. It's important to ensure the camera has the right sensor resolution for the application. The higher the resolution, the more detail an image will have, and the more accurate measurements will be. Part size, inspection tolerances, and other parameters will dictate the required resolution.

**Vision Processing**

Processing is the mechanism for extracting information from a digital image and may take place externally in a PC-based system, or internally in a standalone vision system. Processing is performed by software and consists of several steps. First, an image is acquired from the sensor. In some cases, pre-processing may be required to optimize the image and ensure that all the necessary features stand out. Next, the software locates the specific features, runs measurements, and compares these to the specification. Finally, a decision is made and the results are communicated.

While many physical components of a machine vision system (such as lighting) offer comparable specifications, the vision system algorithms set them apart and should top the list of key components to evaluate when comparing solutions. Depending on the specific system or application, vision software configures camera parameters, makes the pass-fail decision, communicates with the factory floor, and supports HMI development.

**Communications**

**Connecting machine vision components**

Since vision systems often use a variety of off-the-shelf components, these items must coordinate and connect to other machine elements quickly and easily. Typically, this is done by either discrete I/O signal or data sent over a serial connection to a device that is logging information or using it. Discrete I/O points may be connected to a programmable logic controller (PLC), which will use that information to control a work cell or an indicator such as a stack light or directly to a solenoid which might be used to trigger a reject mechanism.

Data communication by a serial connection can be in the form of a conventional RS- 232 serial output, or Ethernet.

Some systems employ a higher-level industrial protocol like Ethernet/IP, which may be connected to a device like a monitor or other operator interface to provide an operator interface specific to the application for convenient process monitoring and control.