Machine Vision Reborn: What Vision Sensors Offer And How They Can Be Used For The Automotive Manufacturing Industry

By Robert Lee, Vision Product Marketing,
Omron Electronics, LLC.

A new generation of machine vision technology has begun to emerge, known as vision sensors. This technology has become possible due to the combination of newer microelectronics, high capacity memory, fast embedded processors and the migration and availability of "high-end" vision algorithms and technology. All of this forms the basis for the development of "smart cameras" or vision sensors.

The vision sensor offers many of the commonly used features offered on high-end and PC-based vision systems while placing these features in a self - contained, easy-to-use, low cost package. Typically, most vision sensors fall in the $1K to $8K price range for a complete package. With the constantly increasing demand for higher quality and flexibility in manufacturing, many manufactures are looking for better, low cost ways to satisfy these requirements. Vision sensors can be used to satisfy these requirements in a practical and cost efficient way.

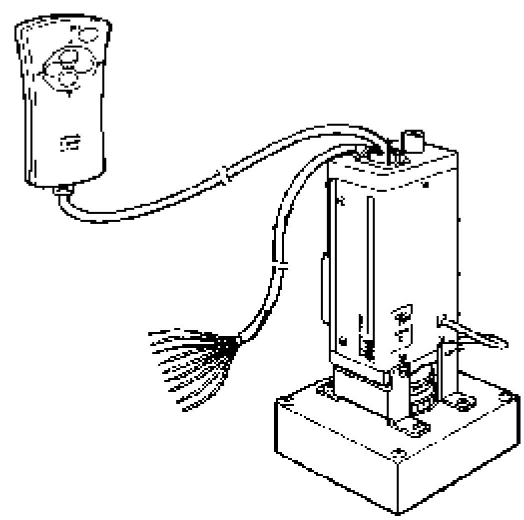
This session will present many of the features and functionality that low cost vision sensors possess and enable their ease of use. These include binary, grayscale and color sensing methods, pull down menus and Windows based setup software, measurement tools and several communication methods. This session will explore how these sensors can be used to improve quality and inspection in manufacturing lines. By using vision sensors at key points along the manufacturing line, rejection of parts can be achieved before significant value and labor is added. The session will also show how 100% inspection with vision sensors can also be used to eliminate random sampling or tedious manual inspection methods. It will explore how vision sensors can assist in the manufacturing automation process. With the use of these sensors, users can eliminate complex sensing installations and use the sensors to provide position feedback and process control information.

Defining A Vision Sensor

What defines a vision sensor? What makes it different than say, a PC-based machine vision system? Vision sensors can come in many different packages, with many options, features and software functionality embedded inside. But vision sensors share some common traits that give them their ease-of-use and low cost.

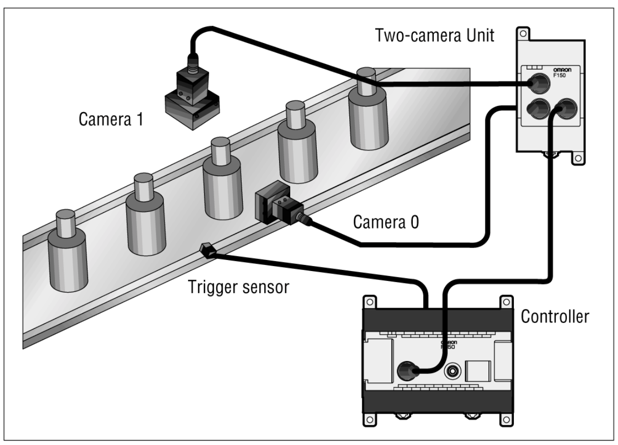
Vision Sensor Hardware

First, lets discuss the hardware that can make-up a vision sensor. Vision sensors are typically proprietary systems requiring only limited or in some cases, no third party components to function completely. Vision sensor hardware can be generalized two ways. The first type of hardware configuration is a self-contained, all in one hardware package containing the camera (including the CCD - Charged Coupled Device), processor, memory and I/O (inputs/outputs). Some variations will brake-out the I/O to an external terminal strip or provide external wiring to be hooked up by the user to a terminal strip, PLC, etc. These self contained variants may also contain the lens and lighting or provide for a means to use variable lenses, typically C-mount style (common to CCTV equipment), and a choice of lighting solutions that can be used with the camera/controller.



An example of a self-contained camera/processor/light source/lens--Omron's F30 Vision Sensor.

The second type of hardware configuration consists of a remote mountable camera cabled to a separate controller/processor. The remote mount camera can vary from a self contained unit with built in light source and lens or a typical C-mount lens ring, allowing the user to provide their own lens and a light source provided and controlled separately by the user. These types of cameras typically resemble the cameras used with PC-based systems in that they are typically small, 2” X 2” square or smaller with a ¼-20 mounting hole for fixturing the camera. However, most of the cameras available in these packages are not interchangeable with other model types or another manufacturers camera. These cameras are typically proprietary and can only be used within that manufacturers hardware package. Some vision sensor hardware packages are capable of accepting two cameras into a single controller for simultaneous processing. Omron’s F150-3 is an example of this. The controller also typically contains the I/O and will provide a self-contained wiring hook-up, typically terminal strips or wire clamps, or provide an external brake-out wiring solution.



An example of a two camera sensor with separate controller—Omron’s F150-3 Vision Sensor.

Lighting
The lighting and lenses available for these systems can vary from one manufacturer to the next. The lighting solutions can range from LED, fluorescent, halogen and even strobe lighting. Third party lighting present an even larger array of solutions for most lighting requirements. Use of lighting will not be discussed in this session. Please consult the manufacturer or lighting supplier for the best solution to your applications.

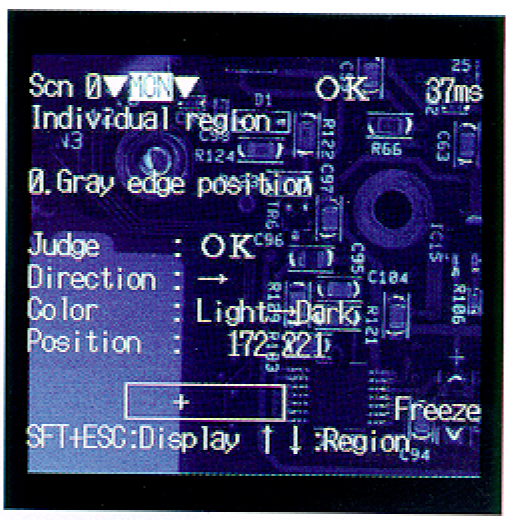
Communication
Some vision sensor hardware packages may also contain communications capability. This can include RS-232C, RS-422, Ethernet and even DeviceNet, providing a way to communicate more complex information back and forth from the vision sensor to an external system, like a PLC or PC. Some vision sensors even allow for a networked array of units to be used when more than one camera is required.

Image Resolution
The image resolution on vision sensors can vary depending on the manufacturer and the limitations of the type of sensor. Most vision sensors fall within an image resolution range of 200 H (horizontal) X 190 V (vertical) pixels to as large as 640 H X 480 V pixels. Be aware that the camera pixel resolution does not always represent the pixel resolution that can be processed by the controller/processor. Always check for the processing resolution in pixels. Most vision sensors are also similar in the way that they capture and process an image. The image is captured by the CCD and passed to a frame grabber or buffering sub-system. The image is then converted to a digital representation of the image and then processed in monochrome or color. From this point on though, most of the similarities end. The processing, depending on the memory limits and software capabilities, are where many differences come to light.

Vision Sensor Software
The software, or in some cases, what is sometimes referred to as firmware, is what gives a vision sensor its functionality and measurement capabilities. The software is also the part of the system that will impose some of the hidden limitations each sensor may posses.

Some vision sensors use an internal program that can only be manipulated by push buttons or switches. These types of vision sensors typically have a fixed program that is setup by using these buttons or switches to configure how the vision sensor will be used and its sensitivity. For example, they can be used to teach a model, set the field-of-view options or set the threshold for pass/fail. Typically these types of vision sensors do not require a monitor or PC and software to set them up. An example of this type of vision sensor would be Omron’s F10. This vision sensor uses a visible projected target area to allow the user to see what will be in the field-of-view as the sensor is being taught. For these types of vision sensors, nothing is required to use them other than the vision sensor its self.

Most other vision sensors use two types of software to set up and configure the sensor. The first and most common type of software uses a self-contained menu or command system that usually appears superimposed over the cameras image. This type of software system can use many different methods to setup and configure the functions, including communications and measurements of the vision sensor. Some vision sensors use a pull-down menu system, like Omron's F150 and F400 vision sensors. A Windows© like spreadsheet is used by another manufacturers vision sensor and a PLC ladder like format to configure yet another manufacturers' vision sensor. Despite the method of setup and configuration used, the fact that the software is self-contained in the vision sensor means that all of its functionality can be used without any external equipment like a PC. This also means that these vision sensors are typically limited in functionality by the limitations of their built-in software.



Omron's F150-2 Vision Sensor menu screen.

The second type of software runs on a PC to create the setup and configuration while either communicating with the vision sensor or off-line, requiring the setup and configuration to then be downloaded when connected to the sensor. This type of software can typically also be used on-line to operate and troubleshoot the setup while still on-line with the vision sensor. This typically means that a larger degree of functionality can be drawn from a library stored on the PC to create the vision sensor's "personality." Then only the necessary functionality is downloaded or stored in the vision sensor, allowing the maximization of the sensor's built-in memory. This also means that functionality can be added to the vision sensor by upgrading the software and libraries on the PC. The limitation for this type of software can be that in order to make small adjustments to the vision sensor in a manufacturing line, the user must connect the sensor to a PC.

Some vision sensors will allow both types of setup and configuration software to be used. The Omron F150-3 vision sensor can use a PC based software package to setup and configure the functionality of the sensor, allowing for upgraded libraries and maximizing the sensor's memory. Once disconnected from the PC, the setup and configuration can then be tweaked on-line using its built-in, on-screen drop-down menu system.

Some software functions common to many vision sensors include electronic shutter speed adjustment to accommodate moving objects, electronic filtering of edges to enhance or smooth them in an image and background suppression or BGS to help eliminate Background noise in an image.

The types of easy-to-use hardware and software described, at the price range listed earlier in this session, can best be used to define what the differences are between low-end vision sensors and PC-based or high-end vision systems. As vision sensors increase in functionality and capability with each upgrade and new model, and the prices decrease on PC-based vision systems, the lines defining this type of machine vision equipment will certainly converge.

Vision Sensor Functionality

Vision sensor functionality is made up from a sum of its different parts. This session will concentrate on the primary parts to give an idea of what a user can expect and will need to consider in order to use a vision sensor for an application. The parts discussed consist of vision sensing methods, measurement functions, I/O and communication. Before using any machine vision product, a user should evaluate what will be required of the machine vision system in order to accomplish the application. Based on the user requirements, it may not be possible to use a vision sensor. On the other hand, after reviewing the requirements, a user may find that a high-end vision system is not necessary and a vision sensor can complete the application. A discussion of some of the ways to consider using vision sensors will be presented later in this session.

Vision Sensing Method

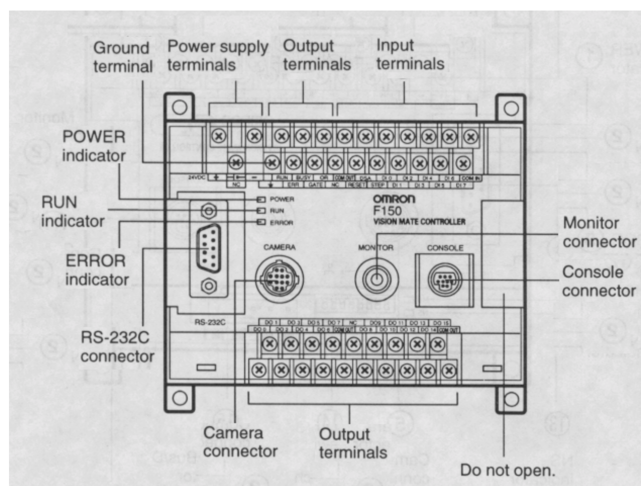
The first point of functionality is to consider what type of vision sensing method will be used. One of the primary aspects to consider in order to succeed with any vision application is what type of sensing method will produce the maximum contrast between the objects and features being measured and any other aspects visible in the field-of-view. Besides lensing and lighting, both important considerations for producing maximum contrast, a user can use a monochrome or color vision sensing method to also maximize contrast. Monochrome vision sensors, depending on their available functionality, can use binary or grayscale sensing methods. A binary vision sensor allows object features to be silhouetted by converting each pixel to either black or white based on a threshold setting. A grayscale sensor can measure an object based on gradients or shades of gray from black to white, typically up to 256 levels. Color vision sensors can allow for the isolation of parts of the image based on their color. The two color sensing methods presently available are red, green and blue or RGB and hue, saturation and intensity or HSI. HSI is a mathematical conversion from RGB allowing greater color definition. Omron's F400 color vision sensor is an example of a vision sensor using HSI for color definition. To isolated colors in an image, two color detection methods are used. Color pick-up allows a user to select a feature in an image, thereby selecting its color or color filters, which allow a color to be chosen from a reference, thereby isolating any features in the image within that colors range.

Measurement Functions

Vision sensors can offer a wide array of measurement functions and tools. The most simplistic of these functions are pattern matching, like Omron's F10 and binary pixel counting. This functionality is typically offered on the more basic vision sensor products. From there, the more advanced vision sensors can incorporate these functions along with many more complex measurement functions or tools. Some of these functional tools typically include field-of-view calibration and position compensation. Some of the typical measurement functions include center-of-gravity, area size, rotation detection, edge detection, edge pitch, dimensioning, grayscale and color surface defect detection, model or pattern search, blob analysis, optical character verification (OCV) and even 2D barcode reading.

I/O Functionality

The type and number as well as the way that a vision sensor can control or use its available inputs and outputs are also what determines its ability to satisfy a users application. The number of inputs on vision sensors can range from just remote teach and triggering or gating functions, to inputs that can be used to control the operational functionality of the sensor. The outputs can range from simple pass/fail measurement status to being configurable by the user based on measurement results or even calculations or equations setup by the user. These outputs are typically available in NPN or PNP polarities. Some vision sensors allow the user to determine each outputs' polarity individually in the software. Some vision sensors even provide handshaking I/O to provide critical timing and synchronization with external devices such as PLC's. Vision sensor I/O can provide functionality on very different levels. The user must assess what is necessary to correct signal inputs and outputs to help determine the correct vision sensor I/O required.



Omron's F150 Vision Sensor I/O layout.

Communication

The communication provided by vision sensor manufacturers will also determine if a vision sensor will work for a user's application. Communication capability can also expand the use of a vision sensor in an application. For example, data derived from a measurement by a vision sensor can be used or collected for statistical process control – SPC, or it can be used to control or assist in the process itself. The data may provide positional feedback to a robot for pick and place applications or color purity feedback across an objects surface, allowing for adjustments in dye amounts. Communication methods available include basic serial communication, for example, RS-232C, RS-422 or more advanced communication, like DeviceNet or Ethernet. Some of these communication methods allow for the vision sensor to be placed on a factory network directly, or to communicate over a industrial network with controllers or PLC based systems.

Vision Sensors And Quality

One of the first things that come to mind when considering machine vision is quality control. But in the past, machine vision systems were concentrated in single locations providing multiple and sometimes very complicated inspections usually requiring many cameras and angles to make these inspections work, making them expensive and complex to setup and maintain. So in turn, their usage would be limited to production lines and products whose production and quality concerns could justify the complexity and expense. Vision sensors bring a new alternative to the world of visual inspection. They also bring a new way of planning and thinking about how these inspections can be done. Instead of concentrating on a single inspection point to catch problems or defects, sometimes after significant value has been added to the product, vision sensors allow the inspections to be broken down into simpler measurements done at stages all along the manufacturing process. In many cases, allowing rejection before value is added to the product. This can significantly reduce rework costs as well. Vision sensors also allow for 100% inspection in the line instead of random or audit inspections.

Vision Sensor Placement

Because of their low cost, ease of use and compact size, vision sensors can be place at the point of assembly or manufacturing process to inspect each individual stage for defects or improper assembly. This also allows for the product or assembly to be rejected before moving on to the next stage. This can relate to less overall scrap and complex rework. This can easily be planned for and implemented on new manufacturing or assembly lines, and due to the flexible nature of vision sensor hardware and software, it is also possible to place these sensors into existing assembly and manufacturing processes. Because of the vision sensors ease of use, many models can be set and adjusted by PLC's or other control equipment, as well as set, adjusted and monitored by maintenance or operation personnel. Eliminating the need for engineering to get involved in simple adjustments or product/line changeovers.

Water Pump Inspection Example

For example, after a machining process on a water pump housing, the housings mounting holes must be present, of the correct diameter and in the correct spacing in relation to each other. This application could use a grayscale vision sensor to inspect the hole using a back light to illuminate the housing from bellow. Using edge detection tools, the edge of each side of a hole could be determined and the diameter calculated. A center of gravity tool could be used over each hole to determine each holes center, then calculating their relation to each other using the equation functionality to determine if the spacing is correct. Depending on the vision sensor capabilities, program digital outputs to report the pass/fail results to a PLC to reject bad parts. If communications are possible, the vision sensor can report hole diameters for SPC data and tooling wear monitoring.

Eliminate Complex Sensing

For many inspection applications, vision sensors can be used in place of complex sensing arrays or multiple measurement sensors. By eliminating complex fixturing and typically extensive engineering and maintenance requirements, vision sensors can actually save money and improve reliability.

Stamping Example

For this example, multiple interior care body plates are being stamped or pressed into their proper shape. The press must have the previous parts cleared out completely before the next set of parts are stamped out or the die can be severely damaged. Instead of creating a complex array of proximity or photoelectric sensors through out the die area, using a single or multiple binary based vision sensors can be used to make sure key locations on the die have been cleared before allowing the press to cycle again.

Assembly Pin Identification Example

Depending on the type of engine assembly, a different height pin must be pressed into the assembly. A pattern matching vision sensor could be taught for each pin height. Before each style of assembly is run on the line, a PLC can set the bank memory position in the vision sensor for the correct corresponding pin model. After being pressed into the assembly, each pin is then inspected and compared to the model. The assembly is then rejected if the pin is incorrect before the assembly moves to the next stage. The vision sensor eliminates the need for multiple sensors or a complex measurement sensor. The vision sensor can be taught new parts on the line remotely by the PLC or operator, saving change over time.

Off-line Inspection

Vision sensors are economical enough to use for off-line inspection requirements in place a manual inspection. For simple parts and sub-assemblies where cost and over-complexity of high-end vision systems prohibited the use of machine vision inspection, vision sensors low cost and ease-of-use now make this possible. For many automotive part suppliers, even one bad part or sub-assembly can cause the rejection of an entire batch of product. Under these conditions, 100% inspection is a must. It is now more cost effective and reliable to replace manual inspection with vision sensors.

Wire Harness Inspection Example

For an automotive wiring assembly supplier, 100% inspection of a wiring harness for correct color wiring presence and placement in a connector is critical. The use of a color vision sensor will give the ability to detect the wires by their colors. Feeding the wire harnesses down a conveyor, for example, under the color camera, the sensor can use a color pick-up mode to detect each wire by color. By setting up measurement regions to search for each color required at a particular location on the connector, the vision sensor can verify the presence and correct placement of each wire on the connector. Position compensation can be used if the location of each wire harness varies on the conveyor. Pass/fail outputs can trigger a rejection if the part fails. This method can also be used to sort the wire harnesses as well.

Vision Sensors Assist In Automation

Vision sensors are an effective and low cost means of providing feedback in the assembly and manufacturing process. Because of some of the output and communications capabilities, vision sensors can be used in many different ways to provide visual measurement and feedback. This measurement feedback can be used to assist with the identification of parts by 2D barcode, shape or color, provide feedback of location markings to robotics and sort parts based on many different kinds of criteria.

Part Identification And Sorting

Vision sensors can be used to identify parts using several different means. The vision sensor can be positioned in a line to read a 2D barcode located on a part, then transmit the data to a PLC for handling. The vision sensor can also be located above the line looking down on a conveyor for example. Using a search tool, the vision sensor can search for a part that matches a model in memory. When the proper match is found, a signal can also be sent to a PLC for handling or directly control tooling from its outputs. A color vision sensor can be used in the same manner to sort parts based on their color and with a search model as well.

Motion Control And Robotics Assistance

Typically, motion control and robotics move according to a preprogrammed set of coordinates. But for applications where parts may be loosely placed on a flat belt conveyor for example, actual coordinate feedback is required in order to manipulate or retrieve a part. An additional example would be if parts were taken from a part feeder and placed into an assembly, with the alignment being critical, and the assembly's position was not reliable for blind placement. A stationary vision sensor could provide feedback of the position of a reference mark on the assembly that could be used as an offset referenced by the robotics for fine adjustments to the motion path. For most advanced vision sensors, X, Y and rotation coordinates can be transmitted along with measurement data to the motion control system.

With the use of the communications capabilities of some vision sensors, data from measurements and calculations as well as setup and configuration information can be transmitted to and from the vision sensor. This information and setup data can be communicated from a PLC or other types of control systems to provide the feedback and control necessary to provide the assistance needed to accomplish these applications.

Vision Sensors Solve Applications

Machine vision has been assisting in automotive manufacturing and assembly for many years. As with many technologies, with time comes enhancements and improvements. The vision sensor is the next progression in general-purpose machine vision. Vision sensors continue to offer greater functionality, reliability, ease-of-use, flexibility and compact size at the same low-cost price range with each new generation of products.

With the need for ever increasing quality and 100% inspection requirements, and the need for more and more advanced manufacturing and assembly techniques, vision sensors provide the needed edge to accomplish many of these tasks and applications. Manufacturers of vision sensors continue to answer those needs with more advanced, high quality vision sensor products.

Vision sensors come in an ever-increasing range of functionality that can fit many applications. By offering advanced measurement and inspection tools, flexible I/O configurations, easy-to-use operator and configuration interfaces and flexible communication options, the applications vision sensors can solve are becoming limitless. As more advances become available and cost continues to drop in microelectronics, image sensing and software, vision sensors will continue to over come limitations to increase their capability to solve tougher and more complex applications. Take a look to see what a vision sensor can do for your next application.