Application Note | Case Study | Technology Primer | **White Paper**

Machine Vision and Process Control

Manufacturing processes that depend on visual inspection for quality control can often improve quality and reduce labor costs by using machine vision. Machine vision is generally better than human vision in inspection and control tasks that are fast, precise, and repetitive. A machine vision system also needs to control "hands" to move parts into its field of view, to sort parts, change process settings, or guide assembly.

Human vision is remarkably robust to changes in angle of view, changes in lighting, and can ignore minor variations in parts, for example the texture of a part's finish. Machine vision is not as robust, and so requires parts to be placed within a known field of view and the part lighting needs to be carefully controlled. Machine vision is also less tolerant of part variations, which can be a benefit if these variations indicate defects. To its credit, a machine vision system can make hundreds of precise measures per second and, once installed, is cheap and reliable labor.

Elements of Machine Vision

Figure 1 shows components in a vision system used to the dimensions of stamped metal parts made by a progressive punch press. The manufacturer was measuring sample parts off-line, so die wear or damage was not detected until thousands of bad parts were produced. The vision system, built by Faber Industrial Technologies (www.faberinc.com), inspects each part and stops production when the part dimensions show that a die is worn or damaged.

Most machine vision systems have the components shown in Figure 1: part positioning, lighting, lens, one or more cameras, part-in-place sensor, a vision processor and an interface to process and motion control systems.

In this application the punch press moves a part on a strip of parts into the camera's field of view. Collimated light (a column of parallel rays) behind the part is formed into an image by a telecentric lens (a lens that only accepts parallel light rays). The image is recorded by a DALSA camera and analyzed by an IPD Vision Appliance™, a computer specialized for machine vision and built by DALSA. The part-in-place sensor triggers image acquisition based on an index hole in the part's carrier strip. The Vision Appliance signals a PLC to shut down the stamping process if the inspection fails.

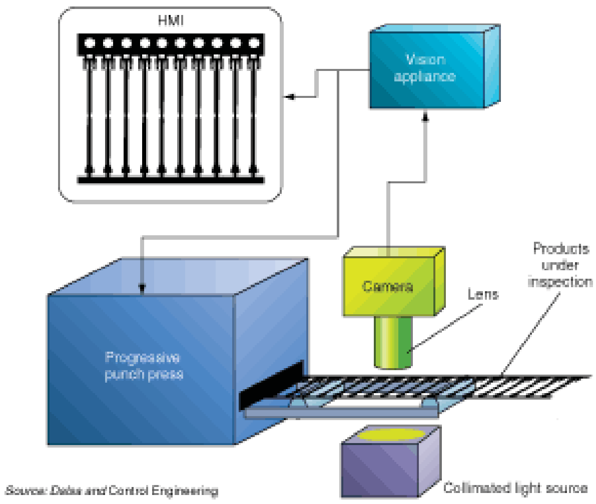

Figure 1 - Components of a machine vision system

The "brains" of the vision system are DALSA's Sherlock™ or iNspect™ software running on the Vision Appliance. Both these packages have intuitive, graphical user interfaces that make it easy to develop machine vision inspection and control applications, even it you are not very familiar with machine vision.

Hand-Eye Coordination

The Vision Appliance has to communicate with motion and process control systems to be effective. Physically, this communication is through digital inputs and outputs, RS-232 lines, or Ethernet. When communicating with PLCs (Programmable Logic Controllers) or motion control hardware (such as the Motoman robot controllers), the Vision Appliance typically uses standard protocols, some of which are listed in Table 1.

Table 1 – Some Protocols Supported by the Vision Appliances

Protocol	Media / SubProtocols	Vendor(s)
Modbus	RS-232, TCP/IP	Various
Ethernet-IP	UDP/IP, TCP/IP	Allen-Bradley and others
Control Logix	Ethernet/IP, Explicit Messages	Allen-Bradley
SNP	RS-232	GE Fanuc
SRTP	TCP/IP	GE Fanuc
MRC/XRC	RS-232	Motoman
MELSEC	RS-232	Mitsubishi
Omron C	RS-232	Omron

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The model for interaction with a PLC is one of "variables" where a variable is a data item, such as a short integer, that can be set and read by both the Vision Appliance and the PLC. A better model might be one of "events and variables" where an event is a signal that indicates a change of state (CoS) of either the Vision Appliance or the PLC. However, the traditional model is only variables.

A "conversation" between the Vision Appliance and a PLC driving a robot might be:

- Vision Appliance loads variables in the PLC with the coordinates of a part to pick up
- Vision Appliance signals a CoS to the PLC by setting a flag in another variable
- PLC instructs the robot to move and signals success by setting a flag variable in the Vision Appliance

Because there are no "events" PLCs have to poll for flags that indicate a CoS. The Vision Appliances have a special feature where variables can be marked as "events" such that any change to the variable immediately causes the Vision Appliance to react.

This coordination between the vision system and the process or motion control systems can range from simple defective part removal to sophisticated control of the manufacturing process. A common use of machine vision is reading a product's barcode, date and lot code using optical character recognition (OCR), or recognizing the product's label. This information is used to sort products, check date codes, and insure that the correct label is on a product.

An extreme example of closing a process control loop is guiding anti-missile guns on a battleship. The incoming missile is detected by a vision system using an infrared camera. The gun is then directed by the vision system and motion control to destroy the missile and the results are checked by the vision system. When we asked the engineer how long the vision system had to "close" this loop, he said (with no hint of humor), "About 30 milliseconds. Any more than that and you are dead."

Can it?

We finish with an example of sophisticated machine vision, process control, and motion control: the de-palletizing (unloading a pallet) of 1 gallon cans. These cans ship on a pallet with six layers of 56 cans per layer, each layer separated by a slip sheet – a large rectangle of cardboard. The top layer of cans is covered by another slip sheet and a "picture frame" – an open rectangle of wood that prevents the straps that bind the pallet stack from damaging the top layer of cans. The customer was using manual labor to remove cans from the pallet stack and put them into the fill line. To reduce labor costs and improve speed, this can de-palletizing was automated by Faber Industrial Technologies (www.faberinc.com).

The automated process starts when the forklift operator removes a pallet stack from a truck, puts it on a conveyer, and cuts the binding straps. Part-in-Place sensors and AC motor drives on the conveyer are used to queue up to four pallet stacks for de-palletizing by a vision-guided robot.

The camera is mounted slightly to one side of the pallet stack and so views the stack at an angle. The robot arm is equipped with custom end effectors (the robot's "hands") for gripping the components of the pallet stack. Images of the pallet stack are processed by a DALSA IPD Vision Appliance, which identifies the components of the pallet stack and guides the robot in removing these components.

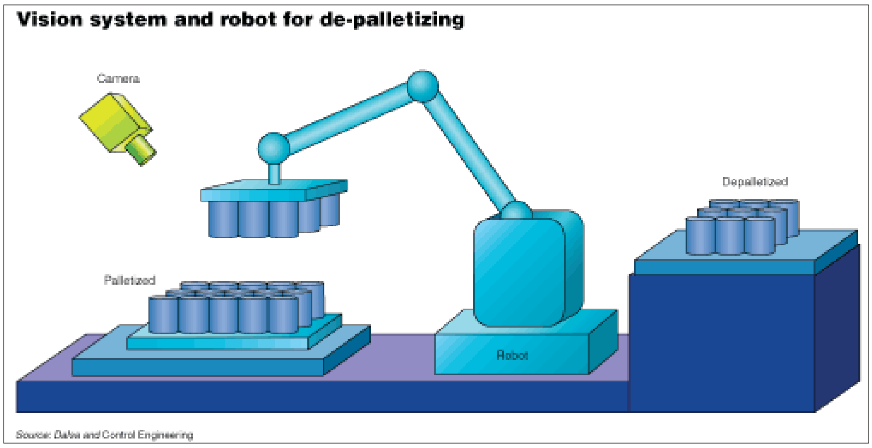

Diagram of vision system and robot for de-palletizing. (1) Pallet stacks are queued up on the left. The camera (2) views the stack slightly off axis. The robot arm's end effectors (3) pick up elements of the pallet stack. Cans are delivered to a conveyer (4) to the fill station, while other material is stacked for return to the can manufacturer.

The vision system first finds the "picture frame" and determines its position and rotation (X, Y and theta). It then directs the robot to remove the picture frame using suction cups and stack it in a pile. The top slip sheet is then found and also removed by the robot's suction cups. This exposes the top layer of cans.

The vision system finds each can by looking for the roughly circular, bright rim of the can. When a can is found, the vision system compares its measured position to a calibrated reference position for each can. If any can is more than 30 mm off from its reference position, the process is stopped until

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the operator corrects the can position. If this is not done, the robot's end effectors will come down and crush the out-of-place can. As you can imagine, that's not good.

When all cans are within tolerance of the required position, the robot end effectors comes down and picks up half (26) of the cans and places them onto the fill line. The robot then picks up the other half of the cans and puts them on the fill line. Then the next slip sheet is removed to expose the next layer of cans and these are removed. This process repeats until the pallet is exposed. The robot then uses another "gripper" in its end effectors to remove the pallet and stack it in a pile.

As layers of cans are removed, the apparent size of the cans decreases due to perspective – the viewed reduction in object size with increasing distance. The off-center camera also introduces additional lens and perspective distortions, such that the cans openings appear to be ovals of varying sizes.

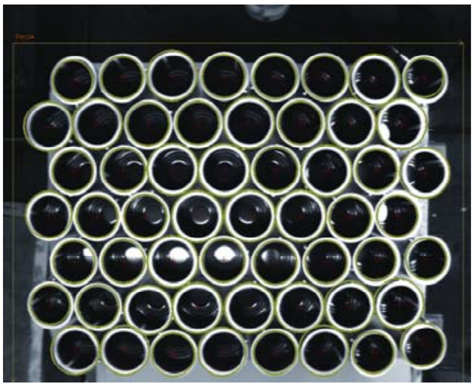
The challenges for the vision system are to recognize each of the components and to locate the center opening of each can, despite shifts in pallet location and rotation and despite fairly large changes in the apparent size of the cans due to perspective distortion and minor changes in the shape of the can rim due to lens and perspective distortion.

The robot's end effectors pick up half the cans in a pallet stack layer and loads them onto the fill station conveyer (center, behind the lifted cans). The yellow and green suction cups are used to remove the "picture frame" and slip sheets.

These challenges were met using DALSA's Sherlock software and an IPD VA41 Vision Appliance. The image on the left shows the camera's view of a layer of cans with the found can rims marked in green and the measured position (can center) as a red cross.

The vision system's view of a layer of cans with the computed location of can rims marked in green.
As always, lighting is a key part of the solution. Directed, fluorescent lighting was used highlight the can rims while not illuminating the interiors too much and also provide good illumination to find the "picture frame" and base pallet. A second key was to know, in advance, exactly where each can center should be, using the calibrated reference positions. This limited the search range for each can rim and so increased speed and decreased the chances of other bright patterns – such as the interior of some cans – from being considered as a can rim. Third, the X,Y and theta position of the "picture frame" was easy to find and limited the search range for subsequent layers in the pallet stack. Last, a different program or "recipe" was used for each layer of material on pallet stack, so that the visual component detection and location could be "tuned" for each layer and material.

The vision system communicates with the Motoman robot's motion control system through RS-232. Once the location of each layer and element was determined by the vision system, the robot's motions were automatic, that is, there was no visual feedback to correct and control the motion.



The vision system's view of a layer of cans with the computed location of can rims marked in green.

Summary

We have described the elements of a machine vision system and how a vision system interacts with control systems and motion control hardware. The examples should give you an idea of the wide range of applications for machine vision in process control – from simple measurements on stamped parts to robot guidance. Machine vision is now quite easy to add to your process and many of the concepts and methods will be familiar to you from other control systems.

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