Defining the Requirements of a Machine Vision System for Factory Automation

Many key tasks in the manufacture of products, including inspection, orientation, identification, and assembly, require the use of visual techniques. Nothing beats human vision for versatility, but human weaknesses limit productivity in a manufacturing environment. Boredom, distraction, fatigue, and sometimes even malice can degrade human performance in vision-related factory tasks such as inspection. Factory automation utilizing a machine vision system in such tasks can bring many benefits.

Machine vision systems can perform repetitive tasks faster, more accurately, and with greater consistency over time than humans. They can reduce labor costs, increase production yields, and eliminate costly errors associated with incomplete or incorrect assembly. They can help automatically identify and correct manufacturing problems on-line by forming part of the factory control network. The net result is greater productivity and improved customer satisfaction through the consistent delivery of quality products.

Implementing a cost-effective machine vision system, however, is not a casual task. The selection of components and system programming must accurately reflect the application’s requirements. In addition, selection decisions need to consider more than the initial component costs. Factors such as the time required for system development, installation, and integration with the factory system, the operator training (and retraining) costs, project management, maintenance, and software upgrades and modification, all contribute to the total cost of ownership for the system and should be evaluated before investing in a specific system design.

Define the Requirements

One of the first things to do in selecting a machine vision system for a factory automation task is to closely define the requirements. There are a number of critical questions to ask up front:

What task does the system need to perform?
Different tasks may require different vision capabilities. Inspection requires an ability to examine objects in detail and evaluate the image to make pass/fail decisions. Assembly, on the other hand, requires the ability to scan an image to locate reference marks (called fiducials) and then use those marks to determine placement and orientation of parts. A machine vision system designed for the one task may not be well suited to the other.

What are the key visual performance criteria?
The vision system’s lighting, camera and lens must perform adequately. Factors such as the smallest object or defect to detect, the texture of the parts, the measurement accuracy needed, the image size (field of view), speed of image capture and processing, and the need for color all affect lighting, camera and lens choices.

What are the environmental factors?
Some cameras are better for stationary views while others are more suitable for viewing moving objects. Temperature, humidity, vibration, and the like can impose needs for protecting the vision system components. The physical space available for installing the system can restrict camera and lens choices. Beyond the system’s physical requirements, developers should also consider the operational requirements. Questions to address include:

Who will program the system?
If the expertise to configure the system is not available in-house, the user must depend on third-party support to make changes and correct errors in the vision system’s programming. If the system needs periodic changes, such as to inspect a new product line or to interface with new production equipment, the question of programming becomes particularly important. A system that has been set up for a single task so that the system integrator needs to reconfigure it for new settings can result in production systems being shut down for extended periods while alterations are underway. A system set up with enough flexibility to allow factory personnel to make such adjustments may cost more to create, but will save production time later.

What equipment must the vision system interface with?
A vision system that only activates a solenoid to eject failed parts from a production line is considerably easier to implement than one that also reports results to a quality control network or that controls the operation of production equipment based on inspection results. Similarly, a system that must interact with a human operator has different needs than one that interfaces only to other machines.
What information must the system provide?
Machine vision systems in factory automation seldom operate in a stand-alone mode. Instead, they send information to other parts of the factory enterprise for a variety of purposes. Quality traceability, for instance, requires that the vision system either log or report inspection results to the enterprise. Highly controlled operations, such as pharmaceutical manufacturing, may also require the logging of access to and changes made in the vision system, sending such data to secure storage on the company network.

What are the operator requirements?
The extent to which human intervention and control of the machine vision system is required affects many system elements, particularly software. If operators are required to periodically change inspection criteria, such as acceptance tolerances that, the software must support such changes. Software may also need to provide security to prevent unauthorized access and parameter changes, and include safeguards to avoid the introduction of erroneous parameter values. Software design can affect the type and degree of training operators will require as well as the ease of system maintenance and modification.

Building a Machine Vision System
While the answers to these questions depend on the application, all machine vision systems for factory automation share some fundamental attributes and behaviors. Vision systems all must have an image to inspect a scene or object, operating on a continuous basis, and at the fastest practical speed. Systems all operate by using the following steps:

- Position the part or camera so that the camera can view the part
- Capture an image with a camera
- Process the image
- Take action based on the image processing results
- Communicate results to operators and other factory systems

Because of this commonality, examination of a specific application such as inspection of objects on an assembly line will illustrate methods by which developers can build a suitable machine vision system for their application.

The essential elements of an inspection system, shown in Figure 1, include a delivery system, the vision system, the response system, and sensors to trigger image capture and system response. The delivery system positions the part for inspection. The vision system, which includes camera, optics, lighting, and image processor, captures and processes the object image to determine a pass/fail response. The response system takes the required action as well as communicating results to operators or other systems. The sensors serve to trigger the vision and response systems, identifying when the object is positioned properly for the systems to perform their tasks.

The illustrations in Figure 2 show how some typical applications are handled. The reading of an identification number (2a) requires close-up imaging, front lighting, and optical character recognition software. Inspection of packaged water aerators (2b) requires an entire package view and color imaging. Inspecting the fill level in a detergent bottle (2c) requires back lighting and the ability to detect the position of the liquid’s surface.
Ensuring Factory Integration

While factory and production specialists need to understand the essential steps of vision system design, they seldom have the in-depth knowledge and experience needed to develop the vision system itself. Thus, the selection of a third-party supplier and/or system integrator is an essential step in ensuring the efficient integration of a vision system into factory automation.

One of the first factors to consider is resolving the sometimes opposing needs of the system design and the runtime operations. To control design costs the system should have a well-specified and bounded task. This makes development and programming simpler and allows optimization of components such as camera, lighting, and optics. To lower total cost of ownership, however, flexibility and other runtime considerations must also be given priority, and these can complicate the design task.

One key runtime consideration that affects design is system portability: the ability to reconfigure the system for use in a different production line or to accommodate slight variations in environment or specifications. A system that targets a single task with fixed specifications is easier to develop but will require vendor involvement to make even small changes in operation. Designing for flexibility and extendibility of the system requires greater effort, but can give the users the ability to accommodate changing requirements without vendor assistance, saving time and costs.

A flexible vision system will offer a number of options for communicating with third-party factory equipment, operators, and the factory enterprise rather than be restricted to the initial requirements. An extendible system will have additional functions available beyond the minimum needed to address immediate concerns, which will simplify future modifications and enhancements.

Keeping in mind all these various performance, operational, and future-oriented considerations can seem a daunting task, but the rewards for doing so are substantial. Machine vision is a key technology for improving the quality and productivity of manufacturing lines though factory automation.

Machine Vision in Action

Engineering Specialties, Inc. (ESI) is job shop manufacturer of metal stampings, mechanical assemblies, wire forms, springs, and other component parts primarily for the automotive industry, and sells to medium-to-large original equipment manufacturers worldwide. ESI is ISO/TS-16949 certified, and quality is very important to them. The company used to rely solely on its manufacturing process to produce a quality product, and in addition, did a lot of visual sorting. This was not terribly effective.

ESI was looking to add vision to the automated assembly machines to insure quality assemblies, and chose DALSA’s Vision Appliances because of the Sherlock software capabilities. The software incorporates a wide variety of tools for the types of inspections that were needed for their particular parts. In addition, DALSA’s application support was superior to the competition.

In the automotive industry, any defects can cost lives, which is why ESI uses vision systems to ensure that the high volume of automotive parts that they sell have zero defects. One specific challenge ESI encountered prior to using vision, was hand inspecting rubber seals, purchased overseas, for flash. This was time consuming and not completely reliable. After adding two vision cameras to the automated assembly machine they were able to check for any flash on the seal as they were assembling it to a screw – saving countless hours and resulting in a 100% defect free product.

ESI ships millions of parts a month that are inspected by its vision systems. They ship with zero defects, which could never be attained without the use of DALSA’s Vision Appliances with Sherlock software. The company estimated that is has saved tens of thousands of dollars by inspecting automatically rather than by hand sorting and there have been enormous savings as a result of not having to sort parts at customer facilities. More importantly, since using DALSA’s vision systems they have not had a single quality problem with any customers. Insuring ESI’s reputation as a supplier of quality, defect-free products is immeasurable.

ESI will continue to include high volume automated assemblies, and DALSA’s Vision Appliances and software will be an integral component of their custom-designed machines and the assemblies they produce.