A Vision of the Future:

The Role of Machine Vision Technology in Packaging and Quality Assurance

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February 11, 2009

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Introduction

Soup packages zoom by at over 200 per minute. My eyes glaze over and I find it harder and harder to focus on the task at hand. Three other engineers stand in a row beside me, waiting for the next group to come relieve us of our duty. We are a packaging team. A new package component was just launched and so we scan the packages, looking for defects. As a defective one jets by, I yell to a colleague further down the line to grab it. This is the moment that I learn to appreciate the importance of machine vision to packaging.

That afternoon, my co-workers and I were tired and our eyes were sore. Even with the four of us diligently searching for defective products, we cannot be sure that we caught them all. A machine vision system could. A machine vision system does not get tired or make mistakes. It does not get distracted or lose focus. A machine vision system offers industrial line flexibility while improving accuracy, reducing cost and decreasing the need for line operators.

The Machine Vision Association of the Society of Manufacturing Engineers and the Automated Vision Association/Robotics Industry Association defines machine vision as “the use of devices for optical, non-contact sensing to automatically receive and interpret an image of a real scene in order to obtain information and/or control machines or processes” (Zuech 17-20).

The purpose of this essay is to discuss the benefits of machine vision in packaging quality assurance. First, a brief history of machine vision and the simple mechanics of a basic system will be reviewed. Then the relationship between quality assurance, HACCP plans, and machine vision systems will be examined followed by a brief explanation of each of the common types of machine vision applications. Lastly, the future of machine vision will be forecasted.

The History of Machine Vision

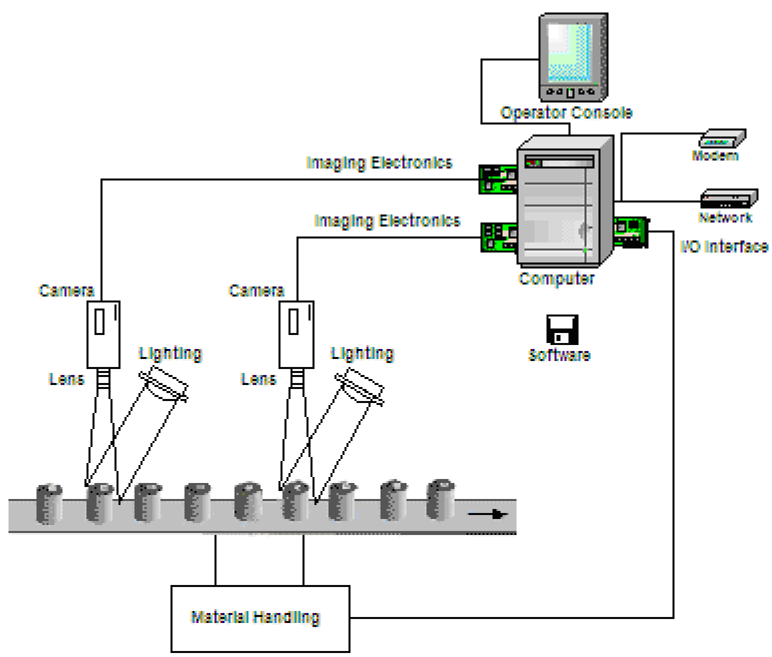
The beginnings of machine vision were developed in the late 1940s and early 1950s with initial research into artificial intelligence. This is also when the military began applying image analysis. This concept did not become industrialized until the 1960s and 70s. At this point, Massachusetts Institute of Technology developed an image analysis system that could control a robotic arm for applied industrial uses. In the 1980s, machine vision took off and saw great expansion on the industrial level. At this point, grayscale machine vision algorithms, single board image processors, and cameras for industrial applications became commercially available. Machine vision became a production line staple in many industries.

The 1990s brought a boom of growth to the machine vision industry. The advancement of computer technology was the main driver behind this expansion. Processing chips made it possible to create smart cameras, which can not only collect the image data, but it can also extract information from these images without using a computer or other external processing unit. In the 2000s and continuing on in present day, the machine vision industry continues to see growth. The availability and affordability of digital camera systems greatly increased the accuracy and abilities of machine vision. Because of these advances in technology, machine vision has ceased being a futuristic idea and is now widely accepted and used within the manufacturing industry for applications including quality assurance and control.

Mechanics

The basic components of a machine vision system consist of image acquisition devices (lighting, optics/lens, and camera), a computer, and operating software. The process begins by illuminating the object with the lighting. The optics then couples the image to the camera sensor. The camera then converts the image from optical to analog or digital so that it can be understood by the computer. The computer, in combination with the imaging software and hardware, can then process the image. (See Figure 1) (High-Tech Digital)

Figure 1 (High Tech Digital, Inc.)



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Quality Assurance

The most common application of machine vision in packaging and production is the monitoring of product quality on the manufacturing line. Quality assurance plays an extremely important role in the success of a commercial product.

HACCP

One way to improve quality in food and pharmaceutical products is to implement a HACCP plan. Hazard Analysis Critical Control Point (HACCP) plans aim to prevent hazards rather than inspect for them. There are seven steps to creating a HACCP plan:

1. Conduct a hazard analysis
2. Identify critical control points
3. Establish critical limits for each critical control points
4. Establish critical control point monitoring requirements
5. Establish corrective actions
6. Establish record keeping procedures
7. Establish procedures for ensuring the HACCP system is working as intended.

Once the HACCP plan is created and decided upon, it must then be implemented. Machine vision systems are an important aspect of implementing and maintaining HACCP plans.

Monitoring the established critical control points (step four) can be accomplished by using a machine vision system. When machine vision is used, cameras are placed at the predetermined critical control points (CCPs) which are identified in step two. The machine vision systems can also record the number and percent of flaws at the specific critical control points which satisfies a portion of the record keeping procedures outlined in step six of the original plan. When properly implemented in the HACCP plan, machine vision can ensure the quality and integrity of the product/package system.

Every industry, product, and packaging line has different critical control points. An example of some critical control points of the pharmaceutical industry can be found in Table 1. Every CCP on a line can have a customized system in place to monitor for flaws and information. Some of the more common machine vision systems include: inspection, verification, recognition, identification, location analysis, and data collection (Zuech). One or more vision system may be included at each of the critical control points on the line. In the following paragraphs, each of these systems will be discussed along with a brief summary of a case study concerning a current or possible packaging application.

Table 1 (Hernández)

APPLICATIONS OF MACHINE VISION INSPECTION

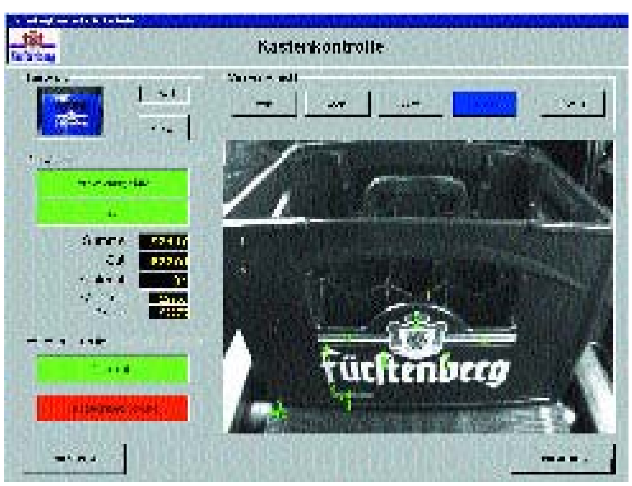
Primary Packaging: Solid Dosage and Liquids	**Primary Packaging: Solid Dosage Blister and Pouch**	**Secondary and End-of-Line Packaging**
Bottle, vial integrity	PVC/aluminum film integrity	Components integrity
Net content	Product	Cartoning, tray packing, case packing, palletizing operations
Closure integrity	Foil printing	
Seal integrity	Die-cutting/CR perforation	
Labeling integrity		

Inspection

There are two types of inspection: gauging and flaw detection. Gauging inspection collects quantitative correlation to design data as a way to assure that the measurements of the object are within the specification of design. Flaw detection, or cosmetic inspection, inspects the objects for unwanted defects (Zuech).

Fürstlich Fürstenberg Brewery installed a turnkey Cognex system that quality inspects for flaws. Fürstlich Fürstenberg Brewery packages their beer in polyethylene terephthalate bottles. The secondary packaging for these bottles is a 24 count reusable plastic case. There are two possible flaws with these cases that the brewery is concerned with: the damaged caused by rough handling, and the dirt and previous price tags from past uses. Previously, a visual check was performed manually. This proved to be time consuming and inefficient. To solve this issue, the line was fitted with a four camera machine vision system. This system scanned for the programmed flaws and accepted or rejected the cases (see Figure 2). The Fürstlich Fürstenberg Brewery has seen great success with their new system and has seen improvement in the quality of their reuseable cases. (Hartman)

Figure 2 (Hartman 1)



Verification

Verification simply assures that the operation is running correctly and that there are no flaws in fabrication (Zuech). In a case study titled “Automated Inspection and Machine Vision on the Packaging Line”, Wayne Johnson discusses how he implemented a machine vision system on the packaging line for The Upjohn Company. The Upjohn Company produces and packages pharmaceuticals. They wanted to install a system to monitor productivity, control line processes, and eliminate the need for an operator to physically monitor the system. The majority of their needs involved a verification system to assure that the lot numbers and expiration dates were printed correctly and legibly. They also wanted on line verification of legibility for all other printed materials and packaging materials. To do this they installed several machine vision systems. Label placement is monitored by an Automatic Inspection Device (A.I.D.), which verifies that the labels are in the correct location on the bottle and records all that are rejected. A Filtec Level Monitoring system verifies fill levels by usimg a Banner Photo Eye to send gamma rays through the bottles and check them for a proper fill level. It then records the number of accepted and rejected bottles. Allen Bradley Bar Code Scanners read the copy bar codes on all printed materials to verify that the copy is correct on all labels, inserts, cartons, and shippers. The scanner also records the number of products that are packaged. With these systems in place, consumer complaints have dropped significantly and employee complaints about vision fatigue have ceased almost entirely (Johnson).

Recognition

Recognition uses descriptors known to the machine that are associated with the object to identify that particular object on the line. Identification is similar to recognition, but identification uses symbols that are found directly on the object to determine the category it belongs in. (Zuech). Recognition and identification can be very useful in a fast paced packaging environment. For example, a company that packages string beans may use a machine vision system to identify between a small string bean and a large string bean. The system would recognize the shape and size and then classify the object into one of multiple categories. Depending on the category that it belongs in, the machine vision system can send signals to the conveyor or a machine on the conveyor to send the product to one of multiple destinations.

Location Analysis

There are two types of location analysis: position and guidance. Position location analysis simply assesses the position of an object relative to the line. Guidance location analysis assesses the position of an object as well, but then uses this information to provide feedback to direct an activity on the line. (Zuech). The United States Mint in San Fransisco uses guidance location analysis machine vision systems to package proof coins with robotics (See Figure 3). Proof coins are high quality collector's coins, so they must be handled with care. Originally, the mint required five operators to carton the coins. Some flaws occurred from mishandling of the coins which can result in costly consumer complaints. The new, automated system that was implemented required only two operators and performed the task in half the time. A CI Vision system was in place to verify that the coins were being placed correctly and to analyze the location of the coins so that the robotic arm can pick and place the coin with accuracy. The automation has significantly increased efficiency and reduced employee injury and complaints (Rice).

Figure 3 (Rice 1)

<u>Data Collection</u>

Data collection is an application of machine vision that is commonly used in quality assurance. It simply classifies each object that it “sees” and logs that data into its system. The system can then alert the user if the distribution is out of the specified range. If the technology is capable, it can also take action to correct the problem. For example, a cracker packaging company was having issues on their line with their gluing system.

The secondary folding cartons for the crackers have tabs on both the top and bottom of the package that must be glued down. The gluer must keep the glue within a specific temperature range in order for the adhesive to be effective. This was occasionally an issue because the temperature monitor on that machine was not accurate enough. A programmed machine vision system is put in place down the line from where the cartons are glued. It scans for cartons that have a flap that is not tucked down. When the system identifies a carton with this error, it does not take any action but to log the information. However, this system is programmed to an accept/reject percentage level of 98.5%. When more than 1.5% of the cartons going through the gluer are flawed, the screen turns a flashing red and a buzzer sounds. This signals to the line operators that there is an issue with the gluer. The machine could also be set up to automatically correct this problem by sending a signal to the control on the gluing machine that will increase the temperature to a level at which the glue is effective.

Looking Ahead

The future of machine vision will be advanced through flexibility, smart technology and advances in software and hardware. Machine vision systems have been continually improving in cost, performance and ease of use for many years now. The current economic climate has been discouraging research and development in many fields, including technology. It is predicted, however, that machine vision will see even greater technological growth than the average for industrial hardware.

Advancements will include greater flexibility. As product manufacturers begin to install flexible lines that can run multiple products, machine vision will need to advance in this area to keep up. Advancements in LEDs (light emitting diodes) will also directly affect machine vision systems because they are most often used as the lighting source.

Smart Technology

A growth in "smart" technology for machine vision is also likely. This will include higher quality and more affordable smart cameras. Smart cameras, which were briefly mentioned in the history of machine vision, are stand alone vision systems. The camera itself contains a processor which eliminates the need for a computer or other processing system. Smart cameras also usually contain several of the following: matrix or linear image sensor, image digitalization circuitry, image memory, program and data memory, communication interface (Ethernet, for example), I/O lines, lens, built in illumination device (most commonly LED), and a real time operating system. These cameras have been available for over 20 years, but have just recently become small and affordable enough for a production facility to justify using them in place of traditional vision systems. In fact, these smart cameras have increased in quality and decreased in price so much in the recent past that they have seen a vast amount of expansion. In fact, there has been no machine vision technology that has seen such explosive growth as the smart camera, and according to a study by the Automated Imaging Association, the 2010 North American revenues of smart camera technology are expected to be $174.2 million. That is $75 million more than the total revenues of 2005. (Iversen)

Software and Hardware Improvements

As computer and software technology progress, the packaging industry will see these updates applied to vision systems as well. Software advancements will increase user-friendliness by simplifying set up and usage. A variety of people with very different skill levels will be working with this machine so it is imperative that both the process engineer and the line operator can easily use this system. Currently, there are extensive training programs that can be put in place when implementing a new machine vision system. If the software can simply be updated to increase usability, it may eliminate the need for these costly and time consuming training programs.

Hardware speed has also increased and is continually improving. According to John E. Agapakis, vice president of research and development for RVSI Acuity CiMatrix, "Until recently, the standard broadcast TV frame rate of 30 Hz was considered 'real time.' However, digital machine vision cameras, which run at higher rates, require processing at a faster real-time rate than conventional video. New vision-processing hardware readily supports image acquisition from such nonstandard cameras." (Agapakis 1) Faster hardware leads to a faster system. If a vision system is a bottleneck in the production line, faster hardware could eliminate that bottleneck by allowing the system to process information faster and therefore scan more items per second. Increasing speed in hardware could also be applied to the potential image resolution. If higher resolution systems are implemented, they will pick up even smaller details and flaws, which will make the entire quality assurance system more accurate and precise. This could be especially useful to the pharmaceutical industry, where every detail is important and product integrity must be absolutely intact to ensure quality and consumer safety.

Conclusion

Machine vision, although it is currently common in many packaging facilities, is still an emerging technology. The history of machine vision and current applications in quality assurance and HACCP clearly shows that it is an integral part of developing and maintaining a production facility. The wide variety of applications makes this technology extremely flexible and innovative. In the future, we should expect to see advances in the quality and popularity of machine vision.

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