MACHINE VISION

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MACHINE VISION

Contents

1

Machine Vision—A Data Acquisition System

Machine vision is not an end unto itself! It represents a piece of the manufacturing/quality control universe. That universe is driven by data related to the manufacturing process. That data is of paramount importance to upper management as it relates directly to bottom-line results. For competitiveness factors top management can not delegate responsibility for quality control. Quality assurance must be built in–a totally integrated function–integrated into the whole of the design and manufacturing process. The computer is the means to realize this integration.

Sophisticated manufacturing systems require automated inspection and test methods to guarantee quality. Methods are available today, such as machine vision, that can be applied in all manufacturing processes: in-coming receiving, forming, assembly, and warehousing and shipping. However, hardware alone should not be the main consideration. The data from such machine vision systems is the foundation for computer integrated manufacturing. It ties all of the resources of a company together–people, equipment and facilities.

It is the manufacturing data that impacts quality, not quality data that impacts manufacturing. The vast amount of manufacturing data requires examination of quality control beyond the traditional aspects of piece part inspection, into areas such as design, process planning, and production processes.

The quality of the manufacturing data is important. For it to have an impact on manufacturing it must be timely as well as accurate. Machine vision systems when properly implemented automate the data capture and can in a timely manner be instrumental in process control. By recording this data automatically from vision systems, laser micrometers, tool probes and machine controllers, input errors are significantly reduced and human interaction minimized.

Where data is treated as the integrator, the interdepartmental data base is fed and used by all departments. Engineering loads drawing records. Purchasing orders and receives material through exercise of the same data base which finance also uses to pay suppliers. Quality approves suppliers and store results of incoming inspection and tests on these files. The materials function stocks and distributes parts and manufacturing schedules and controls the product flow. Test procedures stored drive the computer aided test stations and monitor the production process.

The benefits of such an "holistic" manufacturing/quality assurance data management system include:

Increased productivity:
 – reduced direct labor
 – reduced indirect labor
 – reduced burden rate

increased equipment utilization

increased flexibility

reduced inventory

reduced scrap

reduced lead times

reduced set-up times

optimum balance of production

reduced material handling cost and damage

predictability of quality

reduction of errors due to:
 – operator judgement
 – operator fatigue
 – operator inattentiveness
 – operator oversight

increased level of customer satisfaction

Holistic manufacturing/quality assurance data management involves the collection (when and where) and analysis (how) of data that conveys results of the manufacturing process to upper management as part of a factory-wide information system. It merges the business applications of existing data processing with this new function.

It requires a partnership of technologies to maximize the production process to ensure efficient manufacturing of finished goods from an energy, raw material, and economic perspective. It implies a unified systems architecture and information center software and data base built together. This integrated manufacturing, design and business functions computer based system would permit access to data where needed as the manufacturing process moves from raw material to finished product.

Today such a data driven system is possible. By placing terminals, OCR readers, bar code readers and machine vision systems strategically throughout a facility it becomes virtually paperless. For example, at incoming receiving upon receipt of material, receiving personnel can query the purchasing file for open purchase order validation, item identification and quality requirements. Information required by finance on all material receipts is also captured and automatically directed to the accounts payable system.

The material can then flow to the mechnical and/or electrical inspection area where automatic test equipment, vision systems, etc. can perform inspection and automatically record results. Where such equipment is unavailable, inspection results can be entered via a data terminal by the inspector. Such terminals should be user friendly. That is, designed with tailored keys for the specific functions of the data entry operation.

Actual implementation of such a data driven system will look different for different industries and even within the industry different companies will have different requirements because of their business bias. For example, a manufacturer of an assembled product who adds value with each step of the process might collect the following data:

receiving inspection:
  a. total quantity received by part number
  b. quantity on the floor for inspection
  c. quantity forwarded to production stock
  d. calculation of yield

inventory with audit (reconciliation) capability:
  a. ability to adjust, eg. addition of rework

- b. FIFO/LIFO
- c. part traceability provisions
- d. special parts

production:

- a. record beginning/end of an operation
- b. ability to handle exceptions–slow moving or lost parts
- c. ability to handle rework
- d. ability to handle expedite provisions
- e. provide work in process by part number, operation
- f. provide process yield data by:
  - – part number
  - – process
  - – machine
- g. current status reporting by:
  - – part number
  - – shop order number
  - – program operation
  - – rejection
- h. activity history of shop order in process including rework
- i. shop orders awaiting kitting
- j. shop orders held up because of component shortages
- k. history file for last "X" months
- l. disc and terminal utilization

quality:

Provide hard copy statistical reporting data (pie charts, bar diagrams, histograms, etc.)

data input devices:

- a. OCR
- b. bar code readers
- c. keyboards
- d. test equipment
- e. machine vision systems

personnel:

- a. quality control inspectors
- b. production operators
- c. test technicians

With appropriate sensor technology the results include unattended machining centers. Machine mounted probes, for example, can be used to set up work, part alignment and a variety of in process gaging operations. Microprocessor-based adaptive control techniques are currently available which can provide data such as:

tool wear
tool wear rate greater or less than desired
work piece hardness different from specification
time spent
percentage of milling vs. drilling time, etc.

Quality assurance can now use CAD/CAM systems for many purposes; for example, to prove numerical control machine programs, and provide inspection points for parts and tools.

After the first part is machined, inspection can be performed on an off-line machine vision system analogous to a coordinate measurement machine using CAD developed data points. This verifies the NC program contains the correct geometry and can make the conforming part. At this point QA buys off the program software. While the program is a fixed entity and inspection of additional parts fabricated for shape conformance is not needed, inspection is required for elements subject to variables: machine controller malfunction, cutter size, wrong cutter, workmanship, improper part loading, omitted sequences and conventional machining operations. This may necessitate sample inspection of certain properties–dimensions, for example, and a 100% inspection for cosmetic properties–tool chatter marks, for example.

The CAD/CAM system can be used to prepare the inspection instructions. Where automatic inspection is not possible, a terminal at the inspection station displays the view the inspector sees along with pertinent details. On the other hand, it may be possible in some instances to download those same details to a machine vision system for automatic conformance verification. CAD systems can also include details about the fixturing requirements at the inspection station. This level of automation eliminates the need for special vellum overlays and optical comparator charts. The machine vision's vellum or chart is internally generated as a referenced image in the computer memory.

While dimensional checks on smaller parts can be performed by fixturing parts on an X-Y table that moves features to be examined under the television camera, larger objects can be similarly inspected by using a robot to move the camera to the features to be inspected or measured. Again, these details can be delivered directly from CAD data.

Analysis programs for quality monitoring can include:

– Histogram which provides a graphic display of data distribution. Algorithms generally included automatically test the data set for distribution, including skewness, kutosis and normality.

– Sequential plots which analyze trends–to tell, for example, when machine adjustments are required.

– Feature analysis to determine how part data compares with tolerance boundaries.

– Elementary statistics programs to help analyze data of workpiece characteristics–mean, standard deviation, etc.

– X-bar and R control chart programs to analyze the data by plotting information about the averages and ranges of sequences of small samples taken from the data source.

A computer aided quality system can eliminate paperwork, eliminate inspection bottlenecks and expedite manufacturing batch flow. The quality function is the driver that merges and integrates manufacturing into the factory of the future.

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2

Machine Vision Hardware

Machine vision systems have two primary elements: the camera, which serves as the eye of the system, and a computer video analyser. Lighting is also an important consideration. The camera, which may use a vidicon or solid-state sensor, scans a scene at a rate of 1/60 second. The sensor converts spatial data into a time varying signal where time relates to position and intensity to the analog signal level at that time. This stream of information from the camera, representing a two-dimensional image of the scene, is fed serially into the camera interface, digitizer and processing computer.

The pixel is the individual element in a digitized array, and may refer to the picture elements of either a solid-state camera or vidicon camera.

VIDICONS

Many vision systems analog electrical signals are from conventional closed-circuit television cameras with vidicons (also plumbicons and silicon target vidicons). Vidicons have some disadvantages which are leading to their replacement in machine vision systems by solid-state sensors. Vidicons depend on an electron beam scanned across an image target to create a signal electrostatically. That beam is deflected and experiences geometric distortion. Camera tubes also have lag, the trailing-comet-like image produced when a moving light is seen against a dark background. Bright lights can burn and damage a tube target. All of these phenomena can cause distortion of the camera signal, resulting in erroneous information being passed to the video image analyzing computer. In addition, video tube cameras are fragile and subject to damage from shock and vibration.

SOLID STATE CAMERAS

Silicon detectors called charge-coupled devices (CCD's) were invented at Bell Laboratories in 1969 by William Boyle and George Smith. These devices generate an electronic signal proportional to incident light. Silicon is known to absorb photons in the range of 200 to 1100 nm. CCD's are self-scanning, with precision permanently etched in its silicon structure, and transmit signals representing the scene being analyzed in periodic discrete "packets" of information easily understood by the interfaced computer.

Solid-state image sensors are generally enclosed at integrated circuit packages with ground and polished glass or quartz windows. They are usually a monolithic silicon chip that contains the photosensors and associated readout circuitry. Figure 2-1 shows the four basic architectures of a solid-state image sensor. The first structure uses photodiodes as detectors and a digital shift register to sequentially interrogate the photodiodes, and is depicted in the figure as combination A. The second architecture, combination B, is commonly referred to as a charge-coupled device which uses the field-induced photo-detector as the pixel and the analog shift register to shift the information from the pixel to the output terminal. The third structure, shown as combination C, combines the field-induced photo-detector with the digital shift register in an effort to obtain the higher density with existing technology. The final structure uses photodiodes combined with an analog shift register for readout and is commonly called a CCPD or charge-coupled photodiode array.[1]

Operationally, a solid-state image sensor converts incident light to electric charge which is integrated and stored until readout. The integrated charge is directly proportional to the intensity of the light impinging on the sensing elements. Readout is initiated by a periodic start or transfer pulse. The charge information is then sequentially read out at a rate determined by clock pulses applied to the image sensor. The output is a discrete time analog representation of the spatial distribution of light intensity across the array.[1]

Figure 2-2 shows a block diagram of typical image sensor support circuitry and required sensor clocking waveforms. Referring to the video output waveform in Figure 2-2, the darkened pixels 5, 6, 7 and 8 could relate to the diameter of the cable in the sketch. If the analog video is compared to a threshold voltage, then the digital

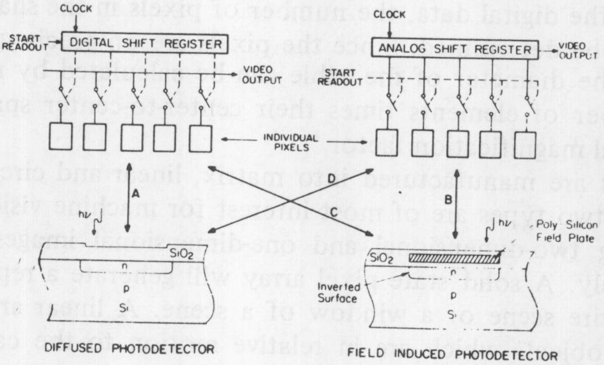

Figure 2-1. Four basic architectures of a solid-state image sensor.[1]

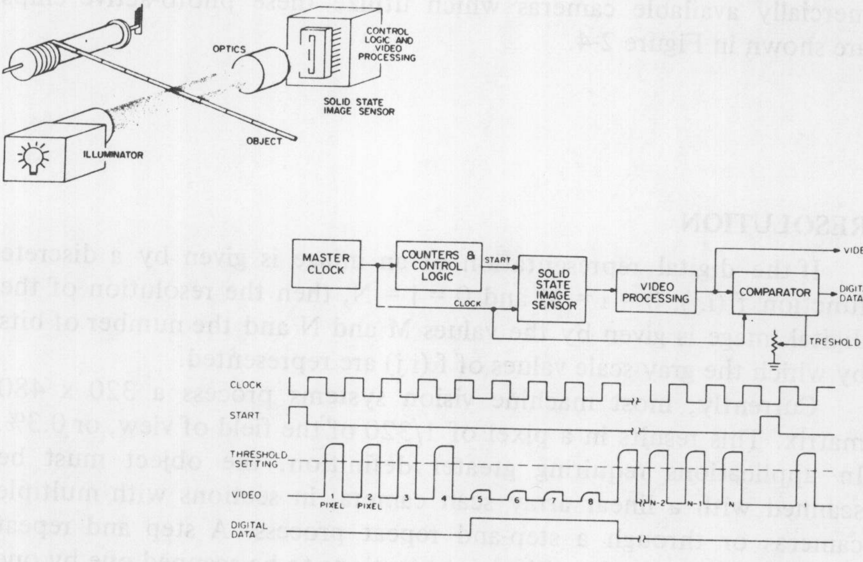

Figure 2-2. Solid-state image sensor drive requirements. The sketch of an object measurement depects a measurement situation which may generate the data shown.[1]

data pulse shown can be generated. By counting the number of clock pulses in the digital data, the number of pixels in the shadow of the cable can be determined. Since the pixels are on precise geometrical centers, the diameter of the cable can be calculated by multiplying the number of elements times their center-to-center spacing times the optical magnification factor.[1]

CCD's are manufactured into matrix, linear and circular arrays. The first two types are of most interest for machine vision systems, producing two-dimensional and one-dimensional images of scenes respectively. A solid state pixel array will generate a representation of an entire scene or a window of a scene. A linear array may be used for objects which are in relative motion to the camera, such as parts moving on a conveyor.

SOLID-STATE MATRIX ARRAYS

Some solid-state matrix arrays are shown in Figure 2-3. Commercially available cameras which utilize these photo-active chips are shown in Figure 2-4.

RESOLUTION

If the digital representation of an image is given by a discrete function f (i.j), 0 = i = M and 0 = j = N, then the resolution of the digital image is given by the values M and N and the number of bits by which the gray scale values of f (i.j) are represented.

Currently, most machine vision systems process a 320 x 480 matrix. This results in a pixel of 1/320 of the field of view, or 0.3%. In applications requiring greater definition, the object must be scanned with a linear array scan camera, in sections with multiple cameras or through a step-and repeat process. A step and repeat scanner can divide the object into sections to be scanned one by one by using X-Y translation. Processing speed, of course, is proportional to both the number of pixels and object positioning time.