IP-6 1267

MILITARY TECHNICAL COLLEGE

CAIRO - EGYPT

MACHINE VISION SYSTEMS: FUNDAMENTALS AND APPLICATIONS

M. F. ABDIN* & N. S. MOHAMED*

ABSTRACT

Machine Vision (MV) is an Artificial Intelligence (AI) technique that is getting a lot of attention over the past decade or so, and in which there has been some notable achievements. It is the most important area necessary to advance the state-of-the art of industrial robots, and it is likely that MV will have an even greater impact in the area of automated inspection. Although the field is still in its infancy, a rapid growth in industrial vision applications is expected for this decade.

The purpose of this paper is to define and distinguish this area from other fields related to computer vision. The paper also, discusses the role of MV in the area of automated inspection in the metal working industry with emphasis on the necessity and the role of MV in the advance of the state-of-the art of industrial robots, thus clarifying one of the most important key technologies of the high level automated production within the factory of the future. The paper also, clarifies some aspects in MV such as the matter of resolution, how computer recognition works, modelling machine vision, etc...

* Assistant Professor, Design & Prod. Èng. Dept., Faculty of Eng., Ain Shams Univ., Cairo, EGYPT.
Now visiting Profs., Ecole de Génie, Univ. de Moncton, N.B., E1A 3A9, CANADA.

INTRODUCTION

Vision systems are the latest technology to find widespread application in manufacturing and distribution areas. These systems utilize video technology to present a picture to a processor which digitizes the image it "sees" to generate a numeric representation of the picture. This picture may be numbers, letters, bar codes or any image presented to the camera [1].

Recent advances in computer vision systems including binary, gray scale and stereo, force and tactile sensors, end effectors, manipulator arm hardware and control strategies have resulted in considerable technological development. Combined with the drastically decreased costs of computer hardware, largely as a result of VLSI (Very Large Scale Integration) [2] . It is expected that significant advances in computer assisted manufacturing, particularly in the field of flexible automated assembly, will result.

Clearly the potential use of the machine vision is in an adaptable automatic manufacturing sequence. This paper discusses the concept of MV and specifically addresses the several roles of MV and its application in the Factory Of the Future (FOF), so that true adaptability can become a reality.

DEFINITION OF MACHINE VISION

MV is defined as the industrial application of computer vision [3]. Computer vision may be considered to be the information-processing task of understanding a scene from its projected images.

Other fields such as image processing and pattern recognition also utilize computers in vision tasks. However, we can distinguish these fields by categorizing them as follows [4]:

Image Processing; is a signal processing task that transforms an input image into a more desirable output image through processes such as noise reduction, contrast enhancement and registration.

Pattern Recognition; is a classification task that classifies images into predetermined categories.

ELEMENTS OF MACHINE VISION

MV systems have two primary elements: the camera, which serves as the eye of the system and a computer video image analyzer. Lighting is also an important consideration.

The Cameras; are either vidicons or solid-state cameras.

Vidicons generate analogue electrical signals from conventional television cameras. Solid-state cameras generate an electronic signal proportional to incident light, they are self-scanning with precision permanently etched in their silicon structure and transmit signal representing the scene being analyzed in periodic "packets" of information.

Lighting; some of common illumination sources are tungsten, quartz halogen, quartz iodine, fluorescent, and mercury -or xenon- arc lamps, as well as various flash lamps, laser and L.E.D. sources. The common ways to configure these sources are shown in Fig. 1.

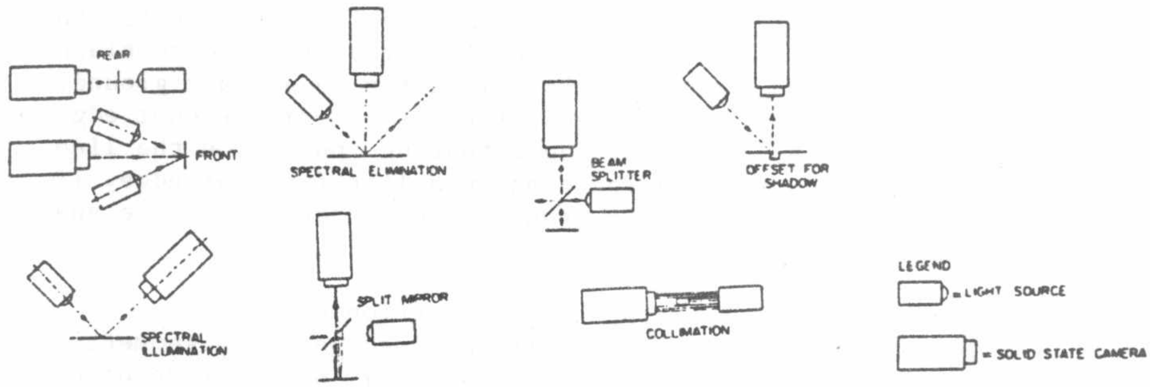


Fig. 1. Basic light techniques [5]

The use of two or more light sources (Fig. 2) is a solution to the effects caused by shadowing; as shadowing causes the object to block the light before it actually reaches the imaged line, thus distorting the part image.

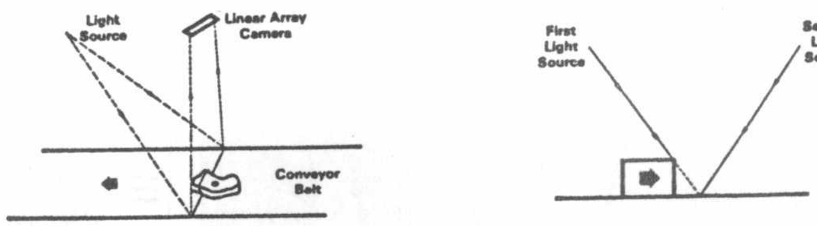


Fig. 2. Basic lighting principle with two light sources [6]

HOW COMPUTER RECOGNITION WORKS

Recognition involves several steps [7,8]:

1. The objects in the television camera image are reduced to their

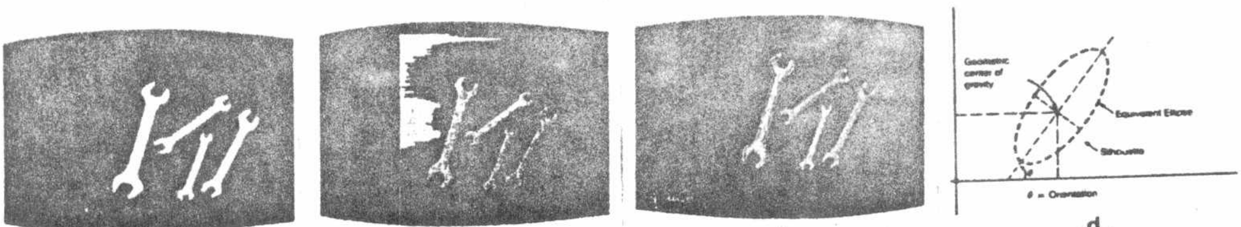
silhouettes by setting all the gray-scale intensities in the object's background to black and all the object intensities to white. This silhouetting is done as the image is scanned from the TV camera, using a technique called thresholding, Fig. 3a.

2. As an aid to threshold determination, the vision system displays a histogram of the intensities encountered in a typical scene, Fig. 3b. If the scene has sufficient contrast, the histogram will have two peaks: a dark one for the background and a bright one for the objects. The threshold value will then be the bottom of the "valley" between peaks.

3. Next, the outlines of the silhouettes are traced, Fig. 3c. Tracing is done by systematically scanning the image for silhouette edges, starting in the upper left hand corner and moving line by line to the bottom. A transition from black to white (left edge) or white to black (right edge) signals the edges of a white silhouette on a black ground. Whenever the computer encounters an edge point, it determines what edge the point belongs to by examining neighbouring points on the line above. It then enters the point's location in a list for that edge. If the point is isolated, however, the system assumes a new silhouette and creates a new list.

4. Next, the system computes the location and orientation of the silhouettes. A silhouette's location is defined as its geometric center of gravity; and its orientation, as the orientation of an ellipse that has the same area, Fig. 3d.

5. Finally, the system attempts to match the silhouettes to the examples stored in its memory. A close match is considered recognition. The closeness of a match is determined by scoring individual feature matches and then weighting and combining the individual scores to create a total score. By adjusting the weighting factors, it is possible to recognize objects with variable features.



-a- -b- -c- -d-

Fig. 3. Example showing how a vision system sees in two dimensions [7]

VISION PROCESSING

The camera scans a scene at a rate of 1/60 Second. A stream of information from the picture elements (pixels) of the camera representing a two dimensional image of the scene is fed serially into the camera interface, digitizer and processing computer. Two types of processing are used: Binary processing and Gray scale image analysis.

Binary Processing; is a black and white type analysis in which pixel values are recorded as either "0" or "1". It can be used for geometric analysis and edge detection, but can not be utilized for analysis which requires that surface characteristics be quantified.

Gray Scale; is used for advanced analysis, in which information may be required to aid complex part recognition or for the analysis of surface characteristics (i.e. texture, shade, pattern, etc.). The gray level is a quantized measurement of image irradiance or brightness. The representation of the image as an array of brightness values is obtained from the digitizer. Various vision systems utilize different numbers of gray levels. For analysis by a 16-bit microprocessor, gray level scales are generally even digital power numbers: 4, 16, 64 or 256.

A comparison of binary and gray level processing is presented in Fig. 4.

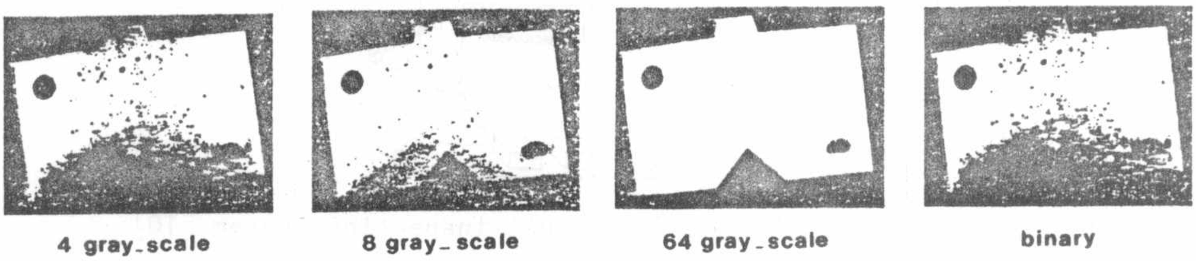


Fig. 4. A comparison of binary and gray level processing [9]

RESOLUTION

If the digital representation of an image is given by a discrete function $f(i,j)$, $0 \leq i \leq M$ and $0 \leq j \leq N$, 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, MV system resolution is limited to 320x480 matrix pixel. This results in a resolution of 1/320, or 0.3%.

MACHINE VISION APPLICATIONS

One of the important fields of application of MV is in robotics. Without sensory feedback, an industrial robot can not intelligently interact with its environment. The most valuable sense that can be provided to a robot, to establish information about the environment and feedback direction control, is vision. Such intelligence, for example, permits adaptive motion control in which sensory information is used to modify the commands to a programmable manipulator. Depth perception for robot involves various sensors, such as stereo vision, structured light, lasers and ultrasound, that can be used for range mapping of scenes. The following are some applications of MV:

Vision in automated inspection: On-line factory inspection, although it is not a dangerous job, it can be tedious and unrewarding, and it is difficult, if not impossible, to maintain concentration on the small details of fast-moving objects for hours at a time, day after day [10]. A typical configuration of an automated inspection system is given in Fig. 5. The system is a high-speed microprocessor-based unit that accepts video camera signals and analysis their images. The analyzer then provides output signals based on its calculations. Typical output signals might control assembly-line hardware for separating good and bad parts, or for separating different kinds of parts on the same line.

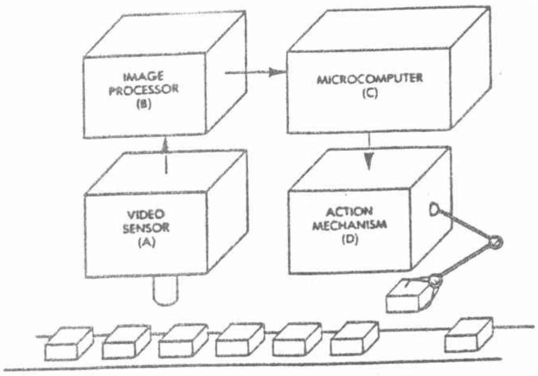


Fig. 5. Diagram of automated visual inspection system [10]

Vision in robotic assembly: Fig. 6, represents the elements of an assembly robot system. The system is composed of a pair of articulated robots and a vision interaction system. The system is called an Intelligent Assembly Robot as the robots used have the capability of determining their own motion based on visual information, while conventional robots merely repeat what they are taught.

The structure of the vision system is shown in Fig. 7. A process computer controls the image processor, executes various recognition procedures, and communicates with the robot controllers through interfaces. The image processor is composed of five processing units linked by an image data bus.

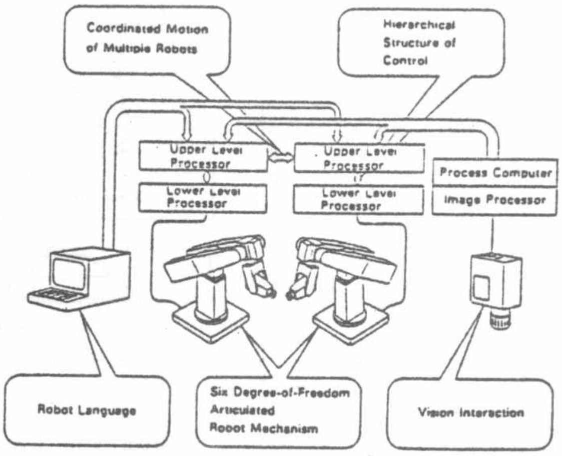


Fig. 6. Elements of assembly robot system [11]

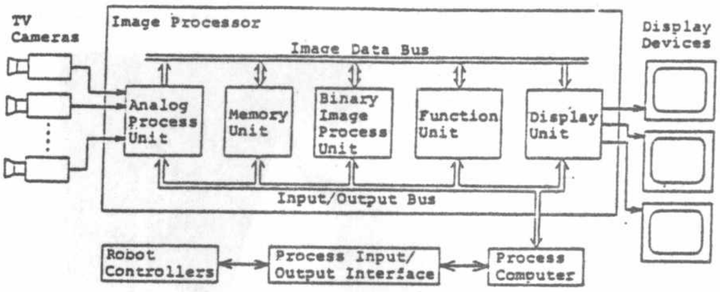


Fig. 7. Configuration of vision system [11]

Vision in robotic welding: Welding is the most important job for robotized equipment. MV systems used for welding are of two types:

* Two-pass system: a scanning pass followed by a welding pass.
* Single pass system: a combined see-and-weld pass.

Fig. 8, shows the configuration of welding robot with vision system. An optical slit pattern is projected from the laser pattern projection unit. The pattern is transformed by the surface shape of the part to be welded and detected by the image detection unit. This pattern information is transferred from the image detection unit to the image processing unit. The image processor outputs the relative position of the point to be welded after calculating directly the cross correlation values between a "template image" (an image memorized in teach mode) and an "actual image" (an image detected in repeat mode). The desired value in the servo system is produced on the basis of the output from the image processor.

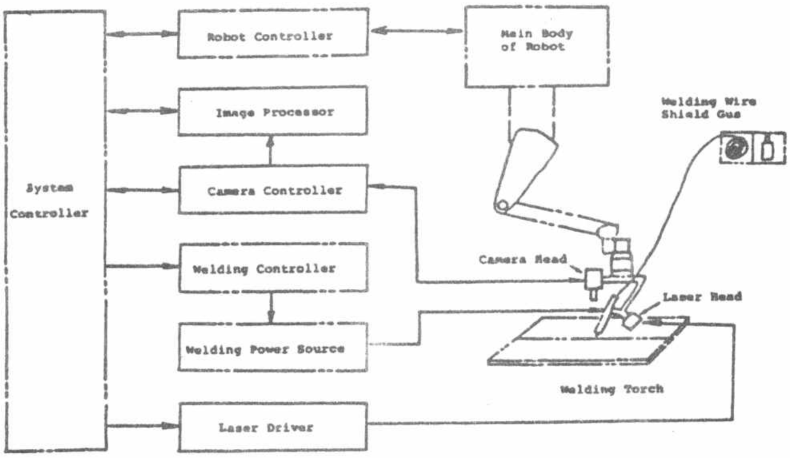


Fig. 8. Configuration of welding robot with vision system [12]

<u>Vision in robotic bin Picking:</u> The bin picking problem has been generally considered to be one of the greatest challenges in the area of robotic intelligence. The goal is to direct a robot to pick up randomly oriented parts. Fig. 9, Shows a robot with vision system for bin picking application.

Fig. 9. Robot and MV system for bin picking application [10]

Vision in robotic spray painting: Spray painting robots are generally synchronized by pulse generators affixed to the monorail which transports the parts to be painted. Parts are sensed by limit switches or photocells. Where a variety of shapes of parts or models are being painted, a vision system may be utilized to direct the robot control to select the appropriate spraying pattern. The integration of such a vision system with a painting robot is diagrammed in Fig. 10.

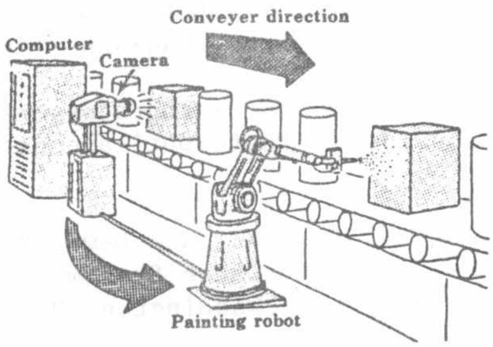


Fig. 10. Diagram of painting robot [4]

CONCLUSIONS

Machine vision currently enjoys the position of being one of the most exciting emerging technologies in manufacturing. In this paper machine vision's fundamentals and applications have been described. The vision system has formed a technological foundation for industrial robots and relevant technologies upon the experiences of previous robots. Further efforts are being made towards more practical implementation of each branch of the technology; namely, robot mechanism, control, vision system; and towards the promotion of extensive use of such machine vision technologies in industry.

ACKNOWLEDGEMENT

Work presented in this paper has been partially supported by grants received from the National Science and Engineering Research Council of Canada and the University of Moncton.

REFERENCES

1. Solits, D.J., "Automatic Identification System: Strengths, Weaknesses and Future Trends", Industrial Engineering, 17, 55-59, Nov. (1985).

2. Holzer, A.J., "Advances in Computer Controlled Robots for Use in the Manufacturing Industry", Int. Conf. on Manufacturing Engineering, Melbourne, Australia, 241-246, Aug. 25-27 (1980).

3. Gevarter, W.B., "An Overview of Computer Vision", National Bureau of Standards Report No. NBSIR 82-2582, Sept. (1982).

4. Miller, R.K., "Machine Vision for Robotics and Automated Inspection", Vol. I, SEAI Technical Publications, Madison (1985).

5. Hopwood, R.K., "Minicomputers and Microprocessors in Optical Systems", Proc. of Society of Photo-Optical Instrumentation Engineers, S. 230, 72-82 (1980).

6. Ward, M.R.; Rossol,L.; Holland,S.W.; and Dewar,R., "Consight: A Practical Vision-Based Robot Guidance System", 9th. Int. Symposium and Exposition on Industrial Robot, Washington, D.C., 195-212, March 13-15 (1979).

7. Kinucan, P., "How Smart Robots are Becoming Smart", High Technology, 1, 32-40, Sept/Oct (1981).

8. Robertson, G.I., "Hierarchical Control of Intelligent Robot and Vision Allows Plug-In System Integration", Proc. of AUTOFACT IV, SME, 11-35 to 11-50 (1982).

9. Miller,R.K., "Artificial Intelligence Application for Manufacturing", SEAI Technical Publication, Madison (1985).

10. Artely. J.W., "Automated Visual Inspection Systems Can Boost Quality Control Affordably", Industrial Engineering, 14, 28-32, Dec. (1982).

11. Kono, M.; Horino, H.; and Isobe, M., "Intelligent Assembly Robot", Hitachi Review, 30, no. 4, 221-216 (1981).

12. Toda, H. and Masaki, I., "Kawasaki Vision System - Model 79A", 10th Int. Symposium on Industrial Robots, Milan, Italy, March 4-7 (1980).