An Overview of Industrial Vision Systems

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ABSTRACT

This paper gives an overview of Machine Vision Technology and its industrial applications. Industrial vision has become a key technology with ever increasing demands regarding product quality and documentation. Machine vision provides innovative solutions in the direction of industrial automation. Machine vision technology improves productivity and quality management and provides a competitive advantage to industries that employ this technology. Machine vision systems can be used for inspecting and identifying parts, accurately measuring dimensions, or guiding robots or other machines during pick-and-place and other assembly operations. Machine vision has been used in many industries such as: electronics, medical devices, consumer goods, semiconductor and packaging.

Keywords— Machine vision, automated visual inspection, image analysis

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1. INTRODUCTION

Machine vision provides innovative solutions in the direction of industrial automation. The introduction of the automation has revolutionized the manufacturing in which complex operations have been broken down into simple step-by-step instruction that can be repeated by a machine.

Human experts are performed the quality control and visual inspections. The use of vision systems in inspection and motion control applications imposes several real-time constraints on image processing. However, constantly increasing performances and decreasing costs of machine vision software and hardware make vision measuring systems more advantageous than the conventional measuring systems. These vision systems can be used to precisely measure variables such as distance, angle, position, orientation, colour, etc.

The productivity and quality management have been improved by machine vision technology and it provides a competitive advantage to industries that employ this technology. Vision systems' use have encouraged in general manufacturing automation because of the continuous improvements in cost, performance, algorithmic robustness and ease of use.

2. OVERVIEW OF MACHINE VISION SYSTEMS

In industries many visual inspection and quality control are performed by human experts. In many situations, humans can do better than machines but they are slower than the machines and get tired quickly but sometimes the inspection tends to be tedious or difficult. Computer vision may effectively replace human inspection in such demanding cases.

Figure 1 illustrates the structure of a typical industrial vision system. First, a computer is employed for processing the acquired images. This is achieved by applying special purpose image processing analysis and classification software. Images are usually acquired by one or more cameras placed at the scene under inspection. The positions of the cameras are usually fixed. In most cases, industrial automation systems are designed to inspect only known objects at fixed positions. The scene is appropriately illuminated and arranged in order to facilitate the reception of the image features necessary for processing and classification. These features are known in advance. When the process is highly time-constrained or computationally intensive and exceeds the processing capabilities of the main processor, application specific hardware (e.g., DSPs, ASICs, or FPGAs) is employed to alleviate the problem of processing speed.

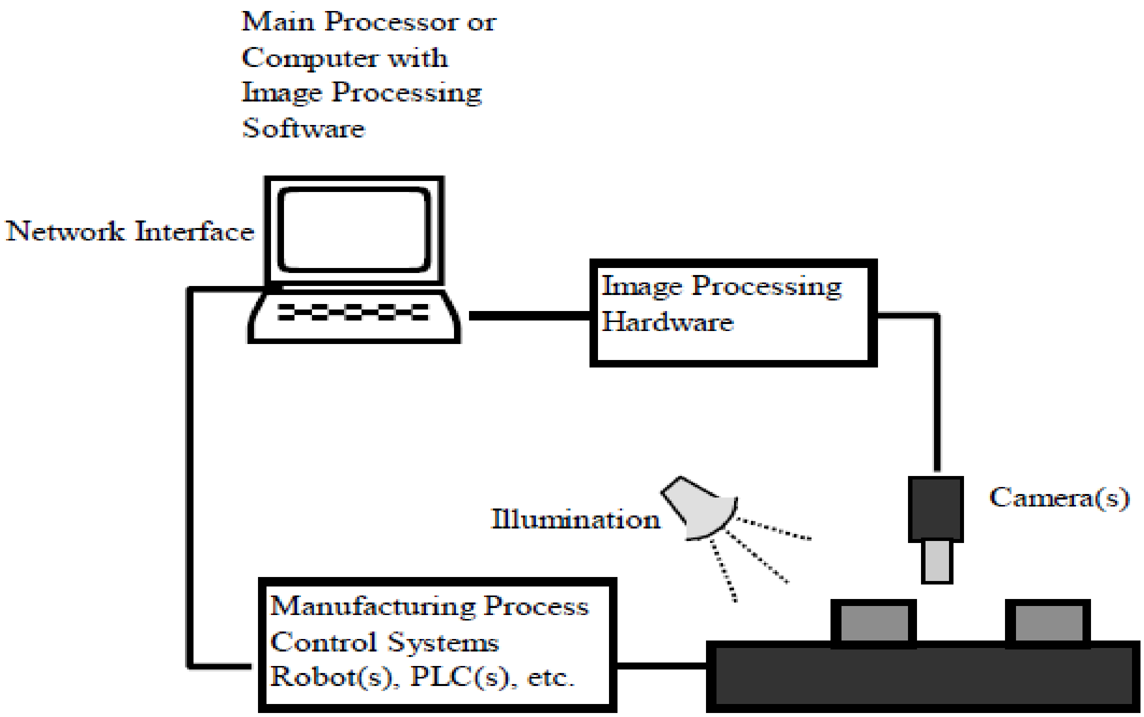

Fig-1: A typical industrial vision system

An industrial inspection system computes information from raw images according to the following sequence of steps:

- **Image acquisition:** Images containing the required information are acquired in digital form through cameras, digitisers etc.
- **Image processing:** Once images have been acquired, they are filtered to remove background noise or unwanted reflections from the illumination system. Image restoration may also be applied to improve image quality by correcting geometric distortions introduced by the acquisition system (e.g., the camera).
- **Feature extraction:** A set of known features, characteristic for the application domain, is computed, probably with some consideration for non-overlapping or uncorrelated features, so that better classification can be achieved. Examples of such features include size, position, contour measurement via edge detection and linking, as well as and texture measurements on regions. Such features can be computed and analyzed by statistical or other computing techniques (e.g. neural networks or fuzzy systems). The set of computed features forms the description of the input image.
- **Decision-making:** Combining the feature variables into a smaller set of new feature variables reduces the number of features. While the number of initial features may be large, the underlying dimensionality of the data, or the intrinsic dimensionality, may be quite small. The first step in decision making attempts to reduce the dimensionality of the feature space to the intrinsic dimensionality of the problem. The reduced feature set is processed further as to reach a decision. This decision, as well as the types of features and measurements (the image descriptions) computed, depends on the application. For example, in the case of visual inspection during production the system decides if the produced parts meet some quality standards by matching a computed description with some known model of the image (region or object) to be

recognized. The decision (e.g., model matching) may involve processing with thresholds, statistical or soft classification.

3. ELEMENTS OF VISION SYSTEMS

A typical block diagram of a machine vision system is shown in Fig 2. The main components of machine vision systems have described. In machine vision systems the tasks such as image acquisition, processing, segmentation, and pattern recognition are conceivable. The function of an image acquisition is to transform the optical image data into an array of numerical data which may be manipulated by the computer. The machine vision system shown in Fig 2 includes systems and sub systems for various processes whereas the big rectangles represent the sub systems and the small rectangles represent the parts which gathered the information. The preprocessing, segmentation, feature extraction and other functions can be performed utilizing this digitized image. Classification and interpretation of image can be done at this stage and considering the same description, the actuation operation can be performed in order to interact with the scene. The actuation sub system, therefore provides an interaction loop with the original scene in order to adjust or modify any given condition for a better image taking.

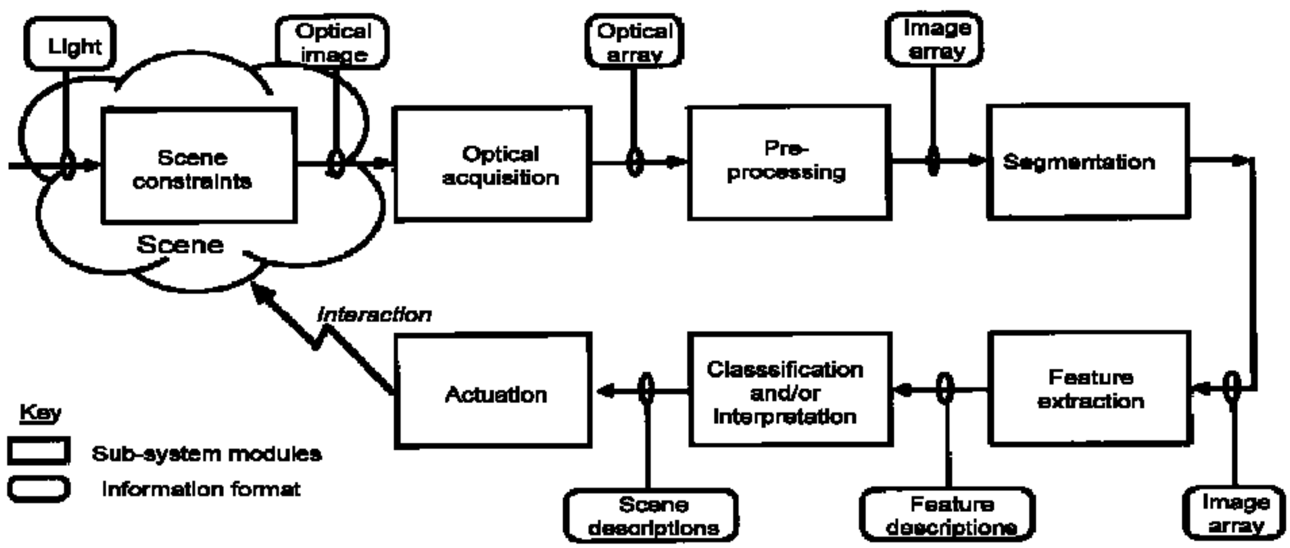

Fig-2: A typical block diagram of a machine vision system

4. TYPES OF MACHINE VISION SYSTEMS

Typically, the machine vision systems are classified as:- 1D, 2D, and 3D systems.

4.1 ID Machine System

1D vision analyzes a digital signal one line at a time instead of looking at a whole picture at once, such as assessing the variance between the most recent group of ten acquired lines and an earlier group. This technique commonly detects and classifies defects on materials manufactured in a continuous process, such as paper, metals, plastics, and other non-woven sheet or roll goods.

4.2 2D Machine System

In 2D machine vision systems, the inspection cameras perform area scans that involve capturing 2D snapshots in various resolutions. This can be used to identify defects, and thereby improve processes and productivity in manufacturing facilities.

4.3 3D Machine System

3D machine vision systems typically comprise multiple cameras or one or more laser displacement sensors. Multi-camera 3D vision in robotic guidance applications provides the robot with part orientation information. These cameras are mounted at different locations and “triangulation” on an objective position in 3-D space.

5. CLASSIFICATION OF INDUSTRIAL VISION APPLICATIONS

Mostly applications of modern industrial vision system are related to at least one of the following four types of inspection:

1. Inspection of *dimensional quality*
2. Inspection of *surface quality*
3. Inspection of *correct assembling (structural quality)*
4. Inspection of *accurate or correct operation (operational quality).*

A formalization of the above categorization is attempted in the following, by probing further onto the characteristics of products being inspected. Table 1 gathers some of the most ordinary inspected features of products.

Table 1: Potential features of inspected products.

Dimensional	Dimensions, shape, positioning, orientation, alignment, roundness, corners	
Structural	Assembly	Holes, slots, rivets, screws, clamps
	Foreign objects	Dust, bur, swarm
Surface	Pits, scratches, cracks, wear, finish, roughness, texture, seams-folds-laps, continuity	
Operational	Incompatibility of operation to standards and specifications	

Despite the inherent differences in the nature of the four categories of quality inspection, they are all reduced to the action of confirmation of quality standards satisfaction, which is, in most cases, a binary ("yes/no") decision. Fig 3 illustrates this relationship.

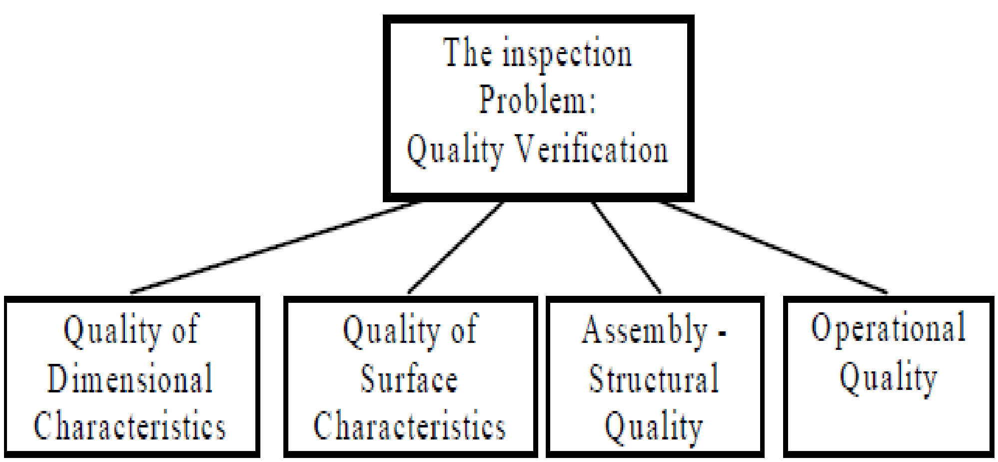

Fig-3: Major categories of industrial vision applications.

The industrial vision applications can also be classified based on features whose measurements do not affect the inspection process (may take any value) allowing the system to be independent on these types of features. The set of such features defines the so-called "Degrees of Freedom" (DoFs) of the inspection process, the commonly DoFs met in the industrial world are shown in Fig-4. The "Degrees of Freedom" (DoFs) of objects are strongly related to the variances of their characteristics and that are considered to be a measure of the flexibility of the vision system.

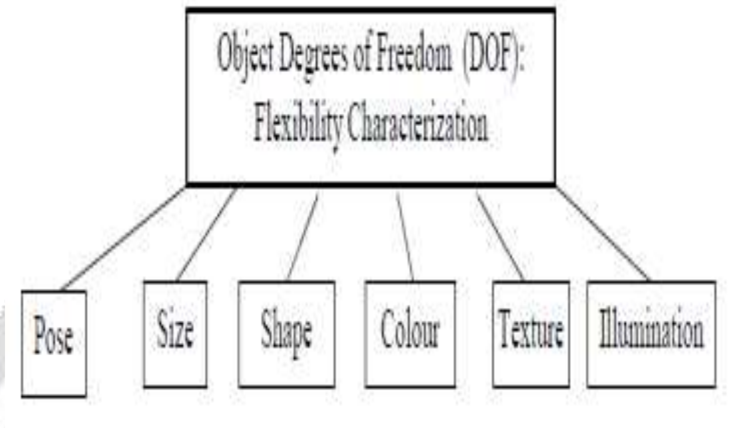

Fig-4: Major DoFs of industrial vision systems.

The less the DoFs the stronger the dependency of the inspection system on the application for which it is originally designed. Therefore, systems with low DoFs are less likely to be expandable. High levels of variability, on the other hand, are characteristic of more general or expandable systems. To allow many DOFs, the system must employ sophisticated image classification approaches based on carefully selected models and algorithms, as to minimize its dependency on the inspected item and its potential deformations. Moreover, the more the DoFs of a system the greater its potential for expandability. For example, the system can be enhanced to detect new types of defects if additional image processing and analysis functions are introduced to the system and applied independently from the old ones to capture more image features (e.g., capture surface in addition to dimensional characteristics). The above considerations concerning the proposed classification based on DoFs reveals a known trade-off in the design of inspection systems between flexibility, complexity and cost which is not obvious in other classifications.

5.1 DIMENSIONAL QUALITY

Checking the industrial vision systems whether the dimensions of an object are within specified tolerances or the objects have the correct shape, are ordinary tasks for industrial vision systems. These tasks involve inspection of geometrical characteristics of objects in two or three dimensions.

5.2 SURFACE QUALITY

Such tasks involve: inspecting objects for scratches, cracks, wear, or checking surfaces for proper finish, roughness and texture. Significant labour savings are achieved in textile, wood and metal industries employing vision systems for fault detection and quality verification.

5.3 STRUCTURAL QUALITY

Checking for missing components (e.g., screws, rivets, etc.) on assembled parts or checking for the presence of foreign or extra objects (e.g., leaves, little sticks) are typical tasks of this class of quality inspection.

5.4 OPERATIONAL QUALITY

According to the manufacturing standards, Inspection of operational quality is related to the verification of correct or accurate operation of the inspected products.

6. EXAMPLES OF INDUSTRIAL VISION SYSTEMS APPLICATION

6.1 FOOD INDUSTRY

Machine Vision has been used in food industry for the past two decades to assure the quality of the products. Machine vision has been successfully implemented for applications ranging from simple inspection to complex robot guidance8. Vision based inspection systems reduce human interaction with the examined goods, categorize generally faster than human beings, and tend to be more reliable in their product classification. Food industries use vision based inspection systems for testing the quality of products such as meat, fruits and vegetables, bakery products etc.

6.2 TEXTILE INDUSTRY

Machine vision has been used in textile industry. By detecting the impurities, the inspection of the cotton quality is done. An image acquisition board working within the PC and the lighting system are required to identify the impurities the color video camera. Because illumination or color of the light sources affects the apparent cotton color, the cotton is illuminated in the day light amps under controlled environment. The video input will convert into RGB by the image acquisition system. At the end, depending on color discrimination between cotton and impurities, the computer identifies the impurities in cotton using iso discrimination.

6.3 ELECTRONIC INDUSTRY

PCB is one of the most important components in electronics industries. A Printed Circuit Board (PCB) mechanically supports and electrically connects electronic components. Machine vision is widely incorporated in PCB manufacturing industries. It is used for detecting the defects in PCBs, distinguishing and identifying specific PCBs.

6.4 TILE INDUSTRY

Machine vision is these days implemented in tile and ceramic industries for inspection of the colour, defects, quality and finish of the products. Automatic colour grading for industrial inspection of plain and patterned ceramic tiles was proposed31. Here, by spatial variation of illumination over a tile is represented by a second order 2D polynomial whose coefficients are computed using least square error fitting, the tiles are graded and sorted. Failure Detection and Isolation in Ceramic Tile Edges Based on Contour Descriptor Analysis was implemented. The irregularities in the ceramic tile edges are inspected by edge detection technique using histograms.

6.5 AUTOMATIVE INDUSTRY

The automotive industry can be considered as a quality critical industry. Vision technology is applied directly on the assembly line. Also, the car component sub-suppliers specializing in quality production, such as brake systems, gearboxes... etc.

7. CONCLUSION

We have presented an overview of industrial vision systems including components, types and types of industrial vision applications. Vision automated system replaces the hardship of manual labour. Vision based systems acquire images, process them and perform contactless examination. In many industrial applications, machine vision has been employed and there are numerous possibilities for incorporating machine vision to produce better results than manual labour.

The hardware and software trends highlighted above will continue and even intensify in the future. Faster hardware, more intelligent tools and better application software development and deployment environments all will enable a broader and deeper proliferation of image processing in manufacturing. Machine Vision systems are versatile and have immense future potential and scope for improvement in various fields.

REFERENCES

[1] E. R. Davies, "Automated Visual Inspection," in Machine Vision, vol. Chapter 19, 2nd Edition ed: Academic Press, 1998, pp. 471-502.

[2] Chin, R. T. and Harlow, C. A., 1982. Automated Visual Inspection: A Survey.*IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 6, pp. 557-573.

[3] Malamas E, Petrakis EGM, Zervakis M, Petit L, Legat JD. A Survey on Industrial Vision Systems. Application and Tools, Image and Vision Computing. 2003 Feb; 2(2):171-88.

[4] MITAL, Anil; GOVINDARAJU, M.; SUBRAMANI, A comparison between manual and hybrid methods in parts inspection. Integrated Manufacturing Systems, 1998, 9.6: 344-349.

[5] Machine Vision and Applications. Springer Berlin Heidelberg, 2014. ISBN 1432-1769.

[6] J. L. C. Sanz and D. Petkovic, "Machine Vision Algorithm for Automated Inspection of Thin-Film Disk Heads," IEEE Trans. on PAMI, vol. 10, pp. 830-848, 1988.

[7] Prinya Tantaswadi, "Machine Vision for Automated Visual Inspection of Cotton Quality in Textile Industries Using ColorIsodiscrimination Contour", *Technical Journal vol 1 No. 3*, July august 1999 pg. 110 to 113.

[8] C. Bahlmann, G. Heidemann, and H. Ritter, "Artificial Neural Networks for Automated Quality Control of Textile Seams," Pattern Recognition, vol. 32, pp. 1049- 1060, 1999.

[9] A. R. Novini, "Fundamentals of Machine Vision Inspection in Metal Container Glass Manufacturing," presented at Vision '90 Conference, 1990.

[10] Zhou Junjing, DuanJianmin and Yu Hongxiao. "Machine-Vision Based Preceding Vehicle Detection Algorithm: A Review" ,Proceedings of *the 10th World Congress on Intelligent Control and Automation* July 6-8, 2012, pg. 4617-4622.