APPLYING MACHINE VISION

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Preface

This book is written for the prospective end user of machine vision technology, not the designer of such systems. It is intended to provide the reader with sufficient background to separate machine vision promises from machine vision reality and permit intelligent decisions regarding machine vision applications.

The emphasis of this text is on understanding an application and the implication of the technical requirements on both the staging and the image-processing power required of the machine vision system. Most vendors concede the most significant elements of a successful application are lighting, optics, sensor, and camera—the staging. In many cases, optimized staging will result in the need for less compute power in the machine vision system. Inevitably, more compute power requires more time and is generally more expensive.

The first chapter is designed to provide some insight as to what stage of the innovation cycle machine vision finds itself today. Parallels are also made between machine vision and human vision.

Considering, as noted, that at least 50% of any application revolves around "staging" issues, Chapters 2 and 3 discuss lighting, optics, cameras, and sensors. Chapter 4 reviews briefly the state of the art of machine vision technology. Products fall into two camps: less expensive systems that do not perform elaborate processing on images but rather rely on inherent contrast upon which to base a decision, and those that are computationally intensive and incorporate a provision for enhancing images in order to make reliable decisions on images with less contrast. Chapter 5 includes a review of three-dimensional machine vision tactics.

Chapter 6 reviews tactics to employ as one proceeds to deploy machine vision systems within one's factory. Following the procedure should reduce the risk associated with undertaking the installation of this new technology for the first time. Chapter 7 is an attempt to assess the effects of emerging technology on the future potential of machine vision.

The appendices include a discussion of some alternative nondestructive examination techniques one may want to consider before proceeding with a machine vision application as well as a glossary of terms and list of current machine vision vendors. Because of the state of the technology and marketplace, consolidation is taking place. In any given application scenario, it is important to identify a vendor who not only offers the most suitable techniques but one who has relevant experience as well.

NELLO ZUECH

Yardley, Pennsylvania
September 1988

Acknowledgments

During the course of my career, I received substantial counsel on electro-optical issues from many colleagues. The results of those "hallway meetings" can be found throughout this book. Among those who made a lasting impact on my career from my Schlumberger and ORS Automation days are Richard Hahn, B. J. Tucker, Steve Duckett, Joe Wilder, Gary Fitton, Dave Fitzpatrick, Ed Kornstein, and Peter Godertier. Others who have added to my understanding of electro-optics and machine vision include Perry West, Kevin Harding, and Hal Schroeder. Without their influence, this book would not have been possible.

Contents

Chapter 1

Machine Vision Concepts

Machine vision, or the application of computer-based image analysis and interpretation, is an emerging technology. Successful techniques in manufacturing tend to be very specific and often capitalize on clever "tricks" associated with manipulating the manufacturing environment. Nevertheless, many useful applications are possible with existing technology. These include finding flaws (Figure 1.1), identifying parts (Figure 1.2), gauging (Figure 1.3), determining *X, Y,* and *Z* coordinates to locate parts in three-dimensional space for robot guidance (Figure 1.4), and collecting statistical data for process control and record keeping (Figure 1.5).

Machine vision is a term associated with the merger of one or more sensing techniques and computer technologies. Fundamentally, a sensor (typically a television-type camera) acquires electromagnetic energy (typically in the visible spectrum; i.e., light) from a scene and converts the energy to an image the computer can use. The computer extracts data from the image (often first enhancing or otherwise processing the data), compares the data with previously developed standards, and outputs the results usually in the form of a response.

It is important to realize in what stage of the innovation cycle machine vision finds itself today. Researchers who study such cycles generally classify the stages as (1) research, (2) early commercialization, (3) niche-specific products, and (4) widespread proliferation. In the research stage, people that are experts in the field add new knowledge to the field. In the early commercialization phase, entreprenuerial researchers develop products that are more like "solutions looking for problems." It requires a good deal of expertise to use these products.

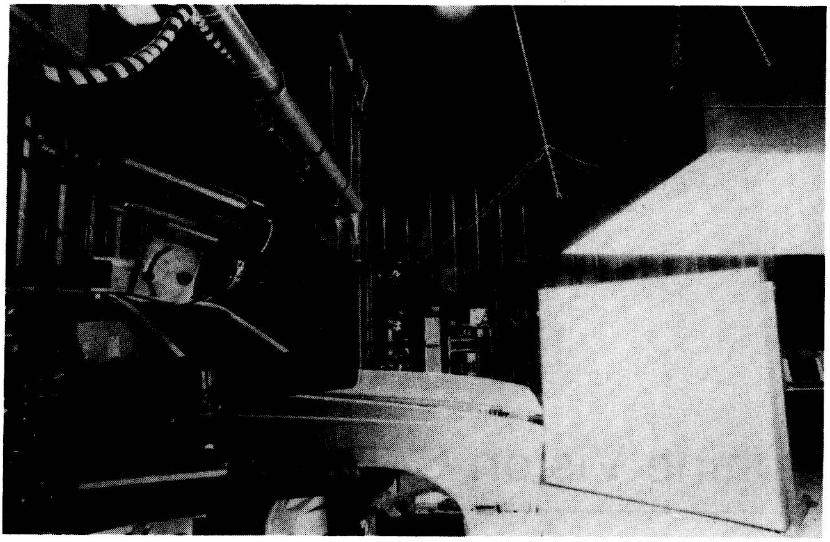

Figure 1.1 Paint inspection system that looks for cosmetic defects in auto body immediately after paint spray booth.

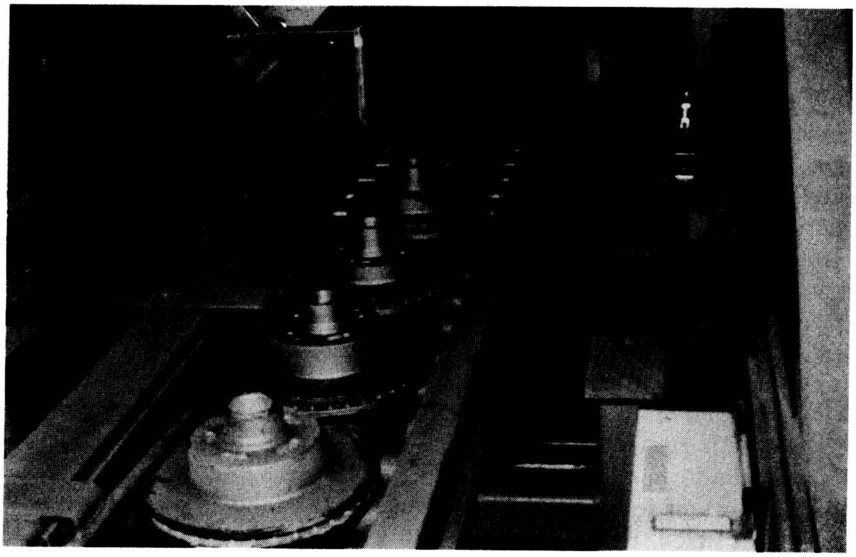

Figure 1.2 Vision system installed at General Motors identifies one of several gray iron castings coming down common conveyor to separate them.

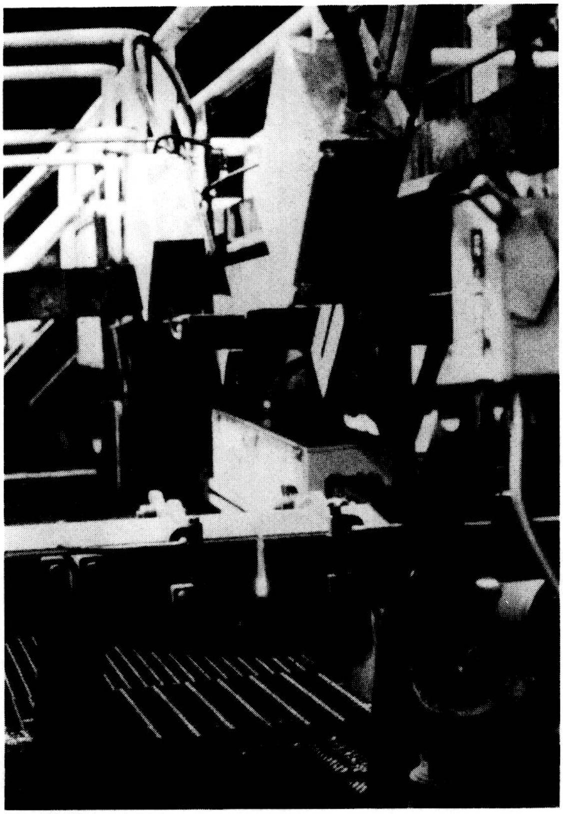

Figure 1.3 System installed on steel line by OPCON designed to measure cylindrical property of billet.

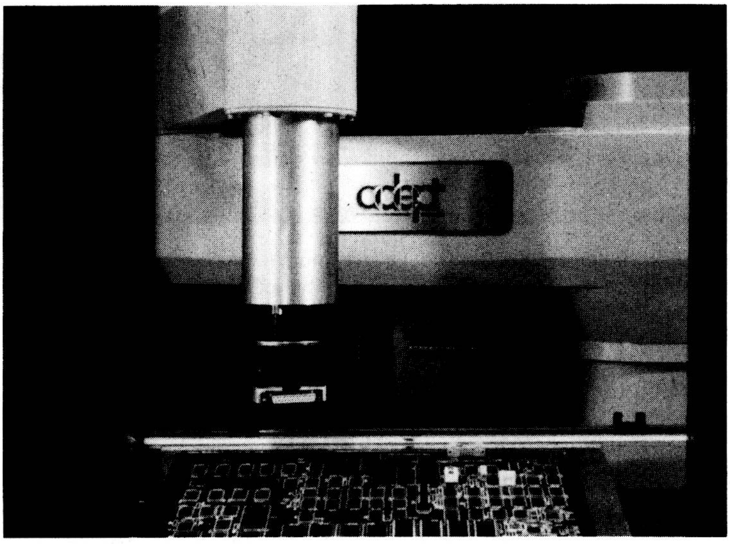

Figure 1.4 Adept vision guided robot shown stuffing components into printed circuit board.

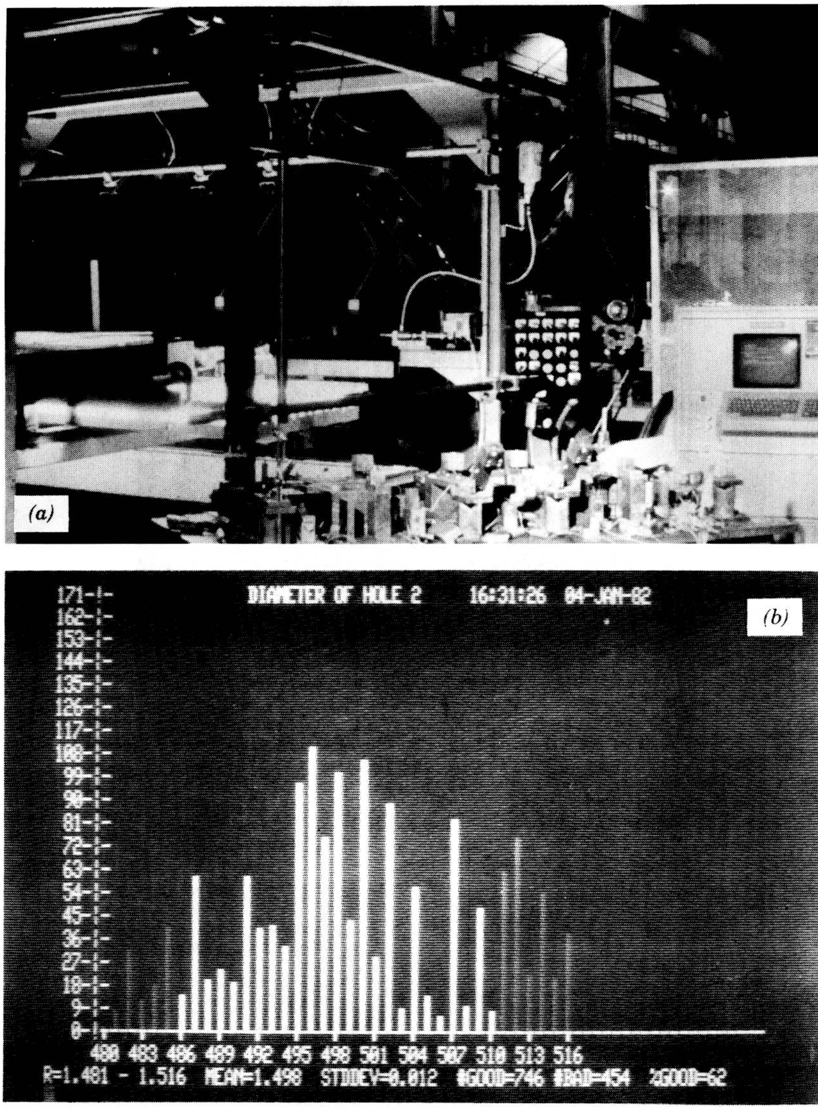

Figure 1.5 Automatix system at end of stamping line examining hole presence and dimensions to monitor punch wear (*a*) and example of data (*b*).

Stage 3 sees the emergence of niche-specific products. Some suggest this is the stage computers find themselves in today. While the fact a computer is being used may be disguised, it still requires an understanding of the application to use them successfully.

Stage 4 is characterized by technology transparency—the user does not know anything about it, other than it is useful. Most car drivers understand little about how a car operates, other than it does when you turn the key. Interestingly, when the car was a "stage 2" technology, a driver also had to be able to service it because of frequent breakdowns experienced. Since then an infrastructure of service stations has emerged to support the technology. In stage 2 there were over 1100 car manufacturers in the United States alone!

Clearly, if the computer is conceded to be a stage 3 technology today and one looks at the characteristics of other technologies when they were in stage 2, machine vision is now a stage 2 technology. There are over 100 companies in the business. This means that one should have some level of understanding of the technology to apply it successfully. Machine vision is far from a commodity item. The first step is to become informed—the very purpose of this book.

1.1 HUMAN VISION VERSUS MACHINE VISION

Significantly, machine vision performance today is not equal to the performance one might expect from an artificially intelligent eye. One "tongue-in-cheek" analysis by Richard Morley and William Taylor of Gould's Industrial Automation Section quoted in several newspaper articles suggests that the optic nerve in each eye dissects each picture into about one million spatial data points (picture elements). Retinas act like 1000 layers of image processors. Each layer does something to the image (a process step) and passes it on. Since the eye can process about 10 images per second, it processes 10,000 million spatial data points per second per eye.

A computer program was written to emulate the retina. A PDP-10 (not exactly a typical lap computer) can process one layer of one picture in 160 sec. In other words, a single eye has a compute power equal to 1.6 million PDP-10's.

To put machine vision in perspective, the typical system operates at less than 10 million operations per second, and some with special hardware may operate at speeds up to 400 million operations per second under certain circumstances. Significantly, the specification of MIPS, MOPS, and so on, generally has little relevance to actual system performance. Both hardware and software architectures affect a system's performance, and collectively these dictate the time needed to perform a complete imaging task.

Based on our eye–brain capacity, current machine vision systems are primitive. The range of objects that can be handled, the speed of interpretation, and the susceptibility to lighting problems and minor variations in texture and reflectance of objects are examples of limitations with current technology. On the other hand, machine vision has clear advantages when it comes to capacity to keep up with high line speeds (Figure 1.6). Similarly, machine vision systems can conduct multiple tasks or inspection functions in a virtually simultaneous manner on the same object or on different objects

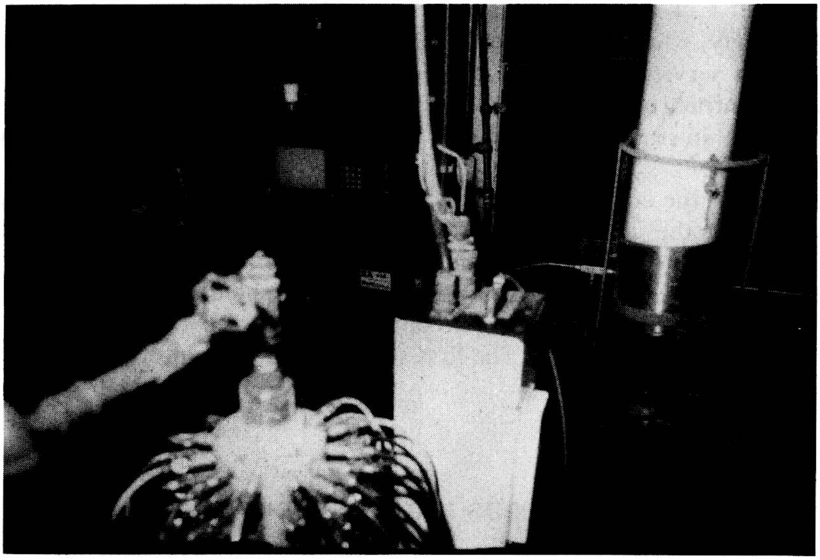

Figure 1.6 Zapata system inspects bottle caps to verify presence and integrity of liners at rates of 2600 min^{-1}.

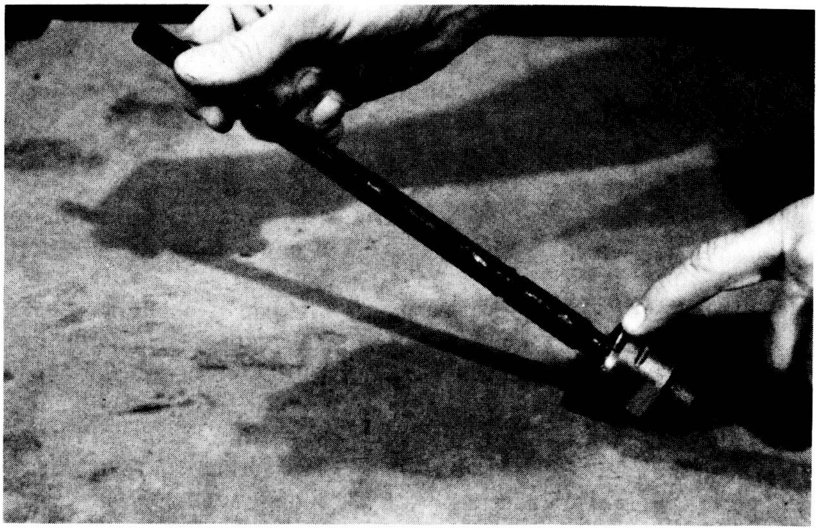

Figure 1.7 Automatix system with multiple cameras inspects tie rod to verify presence of thread, assembly, completeness, and swage angle.