

# 1

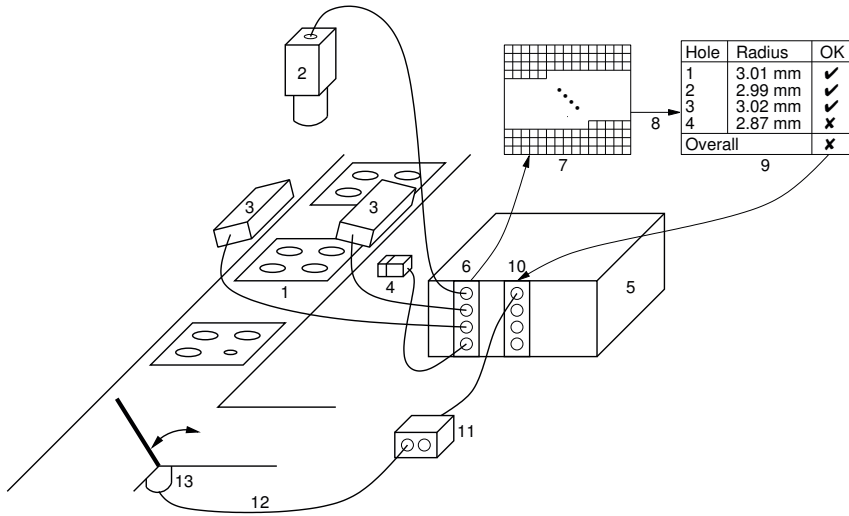
## Introduction

Machine vision is one of the key technologies in manufacturing because of increasing demands on the documentation of quality and the traceability of products. It is concerned with engineering systems, such as machines or production lines, that can perform quality inspections in order to remove defective products from production or that control machines in other ways, e.g., by guiding a robot during the assembly of a product.

Some of the common tasks that must be solved in machine vision systems are as follows (Fraunhofer Allianz Vision, 2003):

- Object identification is used to discern different kinds of objects, e.g., to control the flow of material or to decide which inspections to perform. This can be based on special identification symbols, e.g., character strings or bar codes, or on specific characteristics of the objects themselves, such as their shape.
- Position detection is used, for example, to control a robot that assembles a product by mounting the components of the product at the correct positions, such as in a pick-and-place machine that places electronic components onto a printed circuit board (PCB). Position detection can be performed in two or three dimensions, depending on the requirements of the application.
- Completeness checking is typically performed after a certain stage of the assembly of a product has been completed, e.g., after the components have been placed onto a PCB, to ensure that the product has been assembled correctly, i.e., that the right components are in the right place.
- Shape and dimensional inspection is used to check the geometric parameters of a product to ensure that they lie within the required tolerances. This can be used during the production process but also after a product has been in use for some time to ensure that the product still meets the requirements despite wear and tear.
- Surface inspection is used to check the surface of a finished product for imperfections such as scratches, indentations, protrusions, etc.

Figure 1.1 displays an example of a typical machine vision system. The object (1) is transported mechanically, e.g., on a conveyor belt. In machine vision applications, we would often like to image the object in a defined position. This requires mechanical handling of the object and often also a trigger that triggers the image acquisition, e.g., a photoelectric sensor (4). The object is illuminated by a suitably chosen or



**Figure 1.1** The components of a typical machine vision system. An image of the object to be inspected (1) is acquired by a camera (2). The object is illuminated by the illumination (3). A photoelectric sensor (4) triggers the image acquisition. A computer (5) acquires the image through a camera–computer interface (6), in this case a frame grabber. The photoelectric sensor is connected to the frame grabber. The frame grabber triggers the strobe illumination. A device driver assembles the image (7) in the memory of the computer. The machine vision software (8) inspects the objects and returns an evaluation of the objects (9). The result of the evaluation is communicated to a PLC (11) via a digital I/O interface (10). The PLC controls an actuator (13) through a fieldbus interface (12). The actuator, e.g., an electric motor, moves a diverter that is used to remove defective objects from the production line.

specially designed illumination (3). Often, screens (not shown) are used to prevent ambient light from falling onto the object and thereby lowering the image quality. The object is imaged with a camera (2) that uses a lens that has been suitably selected or specially designed for the application. The camera delivers the image to a computer (5) through a camera–computer interface (6), e.g., a frame grabber. The device driver of the camera–computer interface assembles the image (7) in the memory of the computer. If the image is acquired through a frame grabber, the illumination may be controlled by the frame grabber, e.g., through strobe signals. If the camera–computer interface is not a frame grabber but a standard interface, such as IEEE 1394, USB, or Ethernet, the trigger will typically be connected to the camera and illumination directly or through a programmable logic controller (PLC). The computer can be a standard industrial PC or a specially designed computer that is directly built into the camera. The latter configuration is often called a smart camera. The computer may use a standard processor, a digital signal processor (DSP), a field-programmable gate array (FPGA), or a combination of the above. The machine vision software (8) inspects the objects and returns an evaluation of the objects (9). The result of the evaluation is communicated to a controller (11), e.g., a PLC or a distributed control

system (DCS). Often, this communication is performed by digital input/output (I/O) interfaces (10). The PLC, in turn, typically controls an actuator (13) through a communication interface (12), e.g., a fieldbus or serial interface. The actuator, e.g., an electric motor, then moves a diverter that is used to remove defective objects from the production line.

As can be seen from the large number of components involved, machine vision is inherently multidisciplinary. A team that develops a machine vision system will require expertise in mechanical engineering, electrical engineering, optical engineering, and software engineering.

To maintain the focus of this book, we have made a conscious decision to focus on the aspects of a machine vision system that are pertinent to the system until the relevant information has been extracted from the image. Therefore, we will forgo a discussion of the communication components of a machine vision system that are used after the machine vision software has determined its evaluation. For more information on these aspects, please consult Caro (2003); Berge (2004); Mahalik (2003).

In this book, we will try to give you a solid background on everything that is required to extract the relevant information from images in a machine vision system. We include the information that we wish someone had taught us when we started working in the field. In particular, we mention several idiosyncrasies of the hardware components that are highly relevant in applications, which we had to learn the hard way.

The hardware components that are required to obtain high-quality images are described in Chapter 2: illumination, lenses, cameras, and camera–computer interfaces. We hope that, after reading this chapter, you will be able to make informed decisions about which components and setups to use in your application.

Chapter 3 discusses the most important algorithms that are commonly used in machine vision applications. It is our goal to provide you with a solid theoretical foundation that will help you in designing and developing a solution for your particular machine vision task.

To emphasize the engineering aspect of machine vision, Chapter 4 contains a wealth of examples and exercises that show how the machine vision algorithms discussed in Chapter 3 can be combined in non-trivial ways to solve typical machine vision applications.

