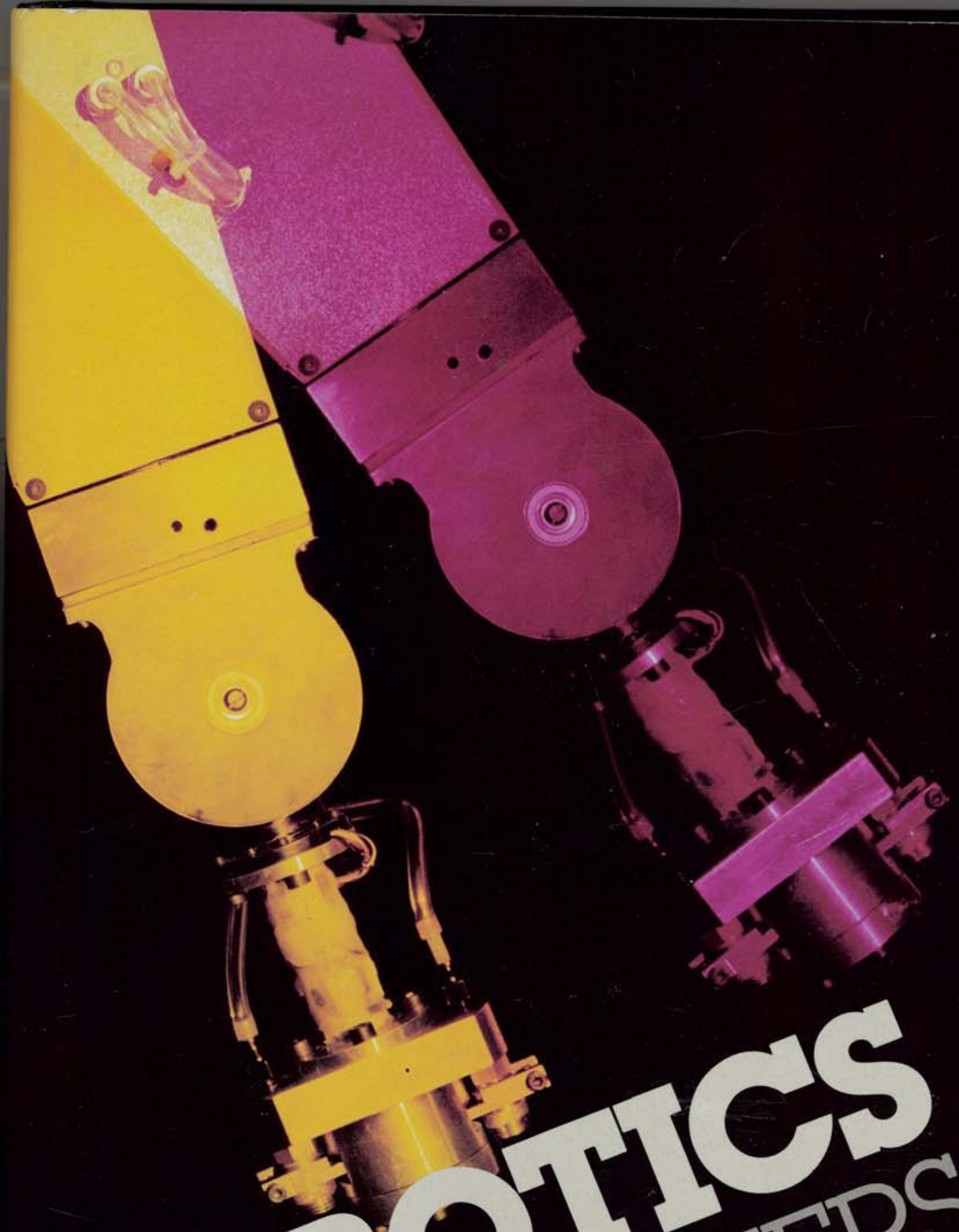

ROBOTICS FOR ENGINEERS

YORAM KOREN

ROBOTICS FOR ENGINEERS

by Yoram Koren

Head, Robotics Laboratory
Technion—Israel Institute of Technology

McGraw-Hill Book Company

New York St. Louis San Francisco Auckland Bogotá Hamburg Johannesburg London Madrid Mexico Montreal New Delhi Panama Paris São Paulo Singapore Sydney Tokyo Toronto

Contents

CHAPTER 1

Basic Concepts in Robotics

Industrial robots are beginning now to revolutionize industry. These robots do not look or behave like human beings, but they do the work of humans. Robots are particularly useful in a wide variety of industrial applications, such as material handling, painting, welding, inspection, and assembly. Even more impressive, however, is the new perspective that robots may bring to the factory of the future. Current research efforts focus on creating a "smart" robot that can "see," "hear," "touch," and make decisions.

1.1 INTRODUCTION

Industrial robots, as other modern manufacturing systems, are advanced automation systems that utilize computers as an integral part of their control. Computers are now a vital part of industrial automation. They run production lines and control stand-alone manufacturing systems, such as various machine tools, welders, inspection systems, and laser-beam cutters. Even more sophisticated are the new robots that perform various operations in industrial plants and participate in full automation of factories.

A revolutionary change in factory production techniques and management is predicted by the end of the twentieth century. Every operation in this factory of the future, from product design to manufacturing, assembly, and product inspection, would be monitored and controlled by computers and performed by industrial robots and intelligent systems. It is well to keep in mind that this automatically controlled factory is nothing more than a new phase in the industrial revolution that began in Europe two centuries ago and progressed through the following stages:

Construction of simple production machines and mechanizations were the first steps in this revolution that started in 1770.

Fixed automatic mechanisms and transfer lines for mass production came along as the second step at the turn of this century. The transfer line is an organization of manufacturing facilities for faster output and shorter production time. The cycle of operations is simple and fixed and is designed to produce a certain fixed product.

Next came machine tools with simple automatic control, such as plug-board controllers to perform a fixed sequence of operations, and copying machines in which a stylus moves on a master copy and simultaneously transmits command signals to servo drives.

The introduction of a new technology, numerical control (NC) of machine tools, in 1952, opened a new era in automation.

The logical extension of NC was computerized numerical control (CNC) for machine tools (1970), in which a minicomputer is included as an integral part of the control system.

Industrial robots have been developed simultaneously with CNC systems. The first commercial robot was manufactured in 1961, but they did not play a major role in manufacturing until the late 1970s.

The next logical extension of the two preceding steps is the fully automatic factory, which requires unprecedented involvement of computer-controlled systems and robots operating in concert in the production and assembly processes.

The new era of automation, which started with the introduction of NC machine tools, was undoubtedly stimulated by the digital computer. Digital technology and computers enabled the design of more flexible automation systems, namely systems which can be adapted by programming to produce or assemble a new product in a short time. Actually, *flexibility* is the key word which characterizes the new era in industrial automation. Robots and manufacturing systems are becoming more and more flexible with progress in computer technology and programming techniques.

1.2 ADVANTAGES AND APPLICATIONS OF ROBOTS

The term *robot* comes from Czech and means "forced labor." The term in its present interpretation was invented by the Czech writer Karel

Capek in his 1921 *R.U.R.*, which stands for Rossum's Universal Robots. Although Capek's robots look like people, they do not have human feelings, and they work twice as hard as human beings.

Industrial robots do not look like human beings but they do the work of humans. The concept of an industrial robot was patented in 1954 by G. C. Devol (U.S. Patent No. 2988237). Devol describes how to construct a controlled mechanical arm which can perform tasks in industry. The first industrial robot was installed by Unimation Inc. in 1961, and since then thousands of robots have been put to work in industry in the United States, Japan, and Europe.

The present industrial robots are actually mechanical handling devices that can be manipulated under computer control. A typical structure of a robot system is shown in Fig. 1-1. The mechanical handling device, or the manipulator, emulates one arm of a human being, and similarly has joints, denoted sometimes as shoulder, elbow, and wrist. The wrist contains pitch, yaw, and roll orientations. The joints are driven by electric, pneumatic, or hydraulic actuators, which give robots more potential power than humans.

The computer, which is an integral part of every modern robot system, contains a control program and a task program. The control program is provided by the robot manufacturer and enables the control of each joint of the robot manipulator. The task program is provided by the user and specifies the manipulator motions required to complete a specific job. Task programs are generated either by leading the robot through the required job or by using off-line programming languages. When a programming language is used, the robot computer also contains a language processor which interprets the task programs and provides the data required by the control program to direct the robot's motions. The control program uses the task program as data, and therefore, for every job a new task program must be generated by the user.

The industrial robot can do a human's work much more effectively. Robots work two shifts a day (three shifts in Japan), 8-hours per shift. They do not take breaks or go on strike, and they know neither weariness nor boredom. In Chrysler's Jefferson plant, 200 human welders on the assembly line were replaced by 50 robots.† These robots work two shifts, and the assembly line's output has increased by almost 20 percent.

American industry hopes that robots will provide an answer to one of its major problems: the decline in productivity. From 1947 to 1965, United States productivity increased by 3.4 percent a year. The growth rate decreased to 2.3 percent in the next decade, then dropped to below 1 percent in the late 1970s, and in 1980 the rate became nega-

†*Time*, December 8, 1980, p. 72.

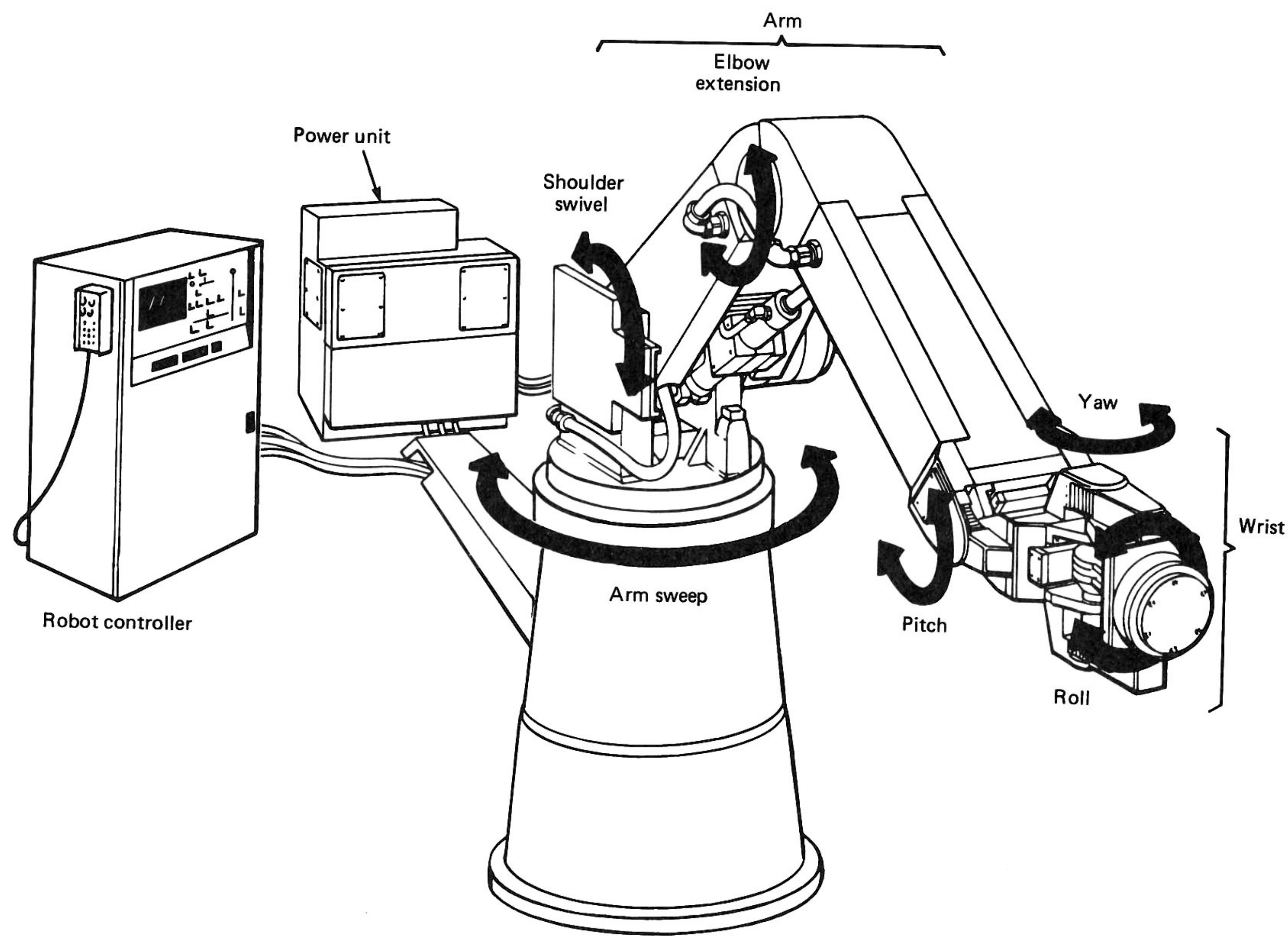

FIG. 1-1 Industrial robot system. (Cincinnati Milacron.)