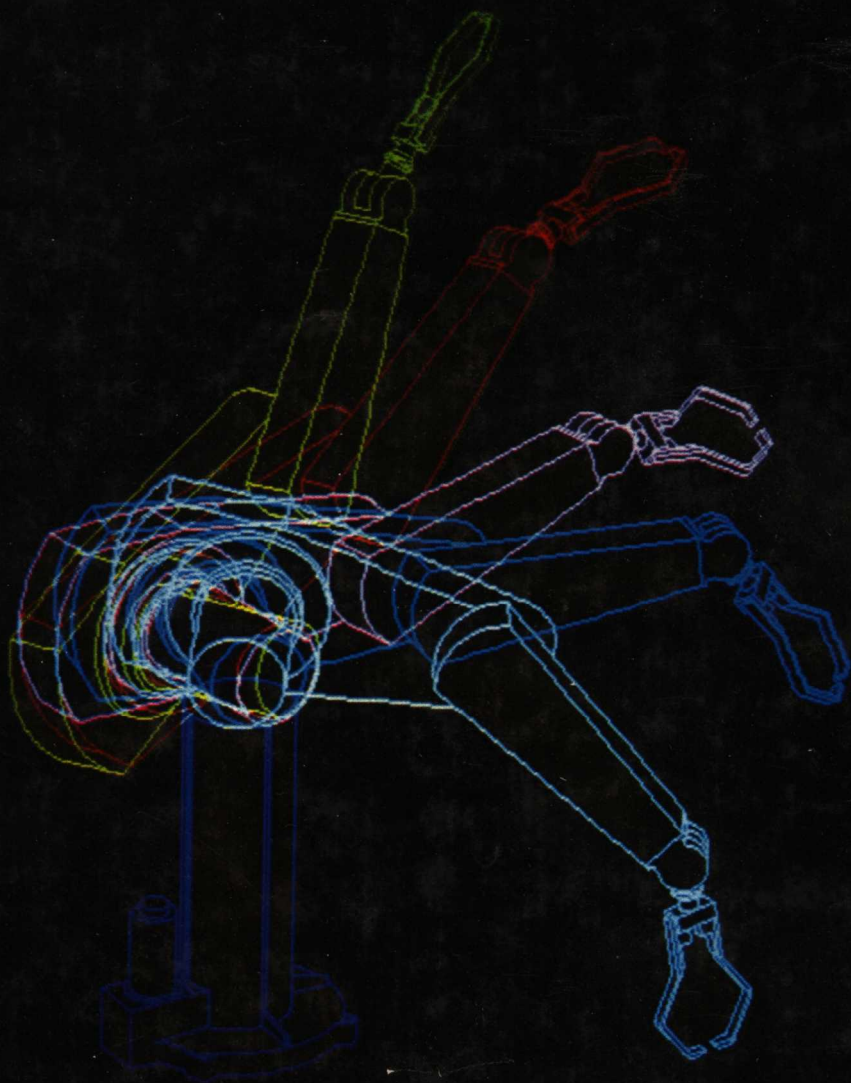


ROBOTICS

An Introduction

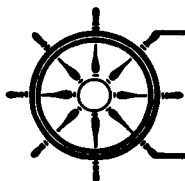


Douglas R. Malcolm, Jr.

Robotics

An Introduction

Douglas R. Malcolm, Jr.
GMFanuc, Inc.



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Preface

Robotics: An Introduction is a state-of-the-art introduction to flexible automation for technical students who will install, repair, or develop robotic systems in an industrial environment. It is intended for use in engineering technology programs at the post-secondary level, but it is also suitable for use in industrial technology curricula, as well as for in-service industrial training programs. Industrial managers, applications engineers, and production personnel who desire to become familiar with robotics or to introduce it into their production facilities will find this presentation useful.

The text requires an understanding of electronic circuits and devices, as well as a familiarity with digital logic circuits and the basics of microprocessors. While not essential, an understanding of the principles of mechanics and fluid power is also helpful.

The presentation incorporates a variety of robotic systems taken from industry. The real-world examples provide literacy in the basic terminology of the subject and illustrate contemporary applications. It is assumed that many readers, after completing this text, will pursue further studies in robotics.

An introduction to basic robotic terms and components is presented in Chapter 1. The various levels of technology within the robotics industry are highlighted in this chapter. Chapter 2 identifies and defines the geometries associated with robots and describes the basic features of the manipulator. Chapter 3 explores the relationship between the robot controller and the manipulator, as well as the electronic circuits of the robot controller. Chapter 4 introduces the basic structure of robot command data and the programming structures that are found in the various robots.

Chapter 5 describes those components that are operational aids for the robot—components such as teach pendants, the operator's panel, and peripheral programming devices. Chapter 6 introduces the hydraulic and pneumatic drive systems used to power the robot manipulator, while Chapter 7 explains the electric drives that are used. Servo system control of the various degrees of freedom found on the manipulator is described in Chapter 8.

The basic concepts of the mechanics of the manipulator are explained in Chapter 9. Mechanical linkages used to convert the drive power into manipulator power are discussed, along with various styles of interfacing between the peripheral devices and robotic systems, in Chapter 10.

The devices known as end effectors are described in Chapter 11. Sensors, such as the vision and the tactile types, are discussed in Chapter 12. Applications of robots, including material handling, machine loading/unloading, die casting, and welding, are described in Chapter 13. Chapter 14 deals with the social-economic impact that robotics will have on U.S. industry and what can be done to prepare for this new industrial movement.

The author gratefully acknowledges the input received from many robotics manufacturers, colleagues in the robotics industry, and instructors of robotics courses. Thanks are due to numerous individuals and firms for providing up-to-date technical information and photographs and, in many cases, for granting permission to use copyrighted material in the book. Appreciation is extended to the following companies: ASEA Robotics, Inc.; Automatix, Inc.; GMFanuc, Inc.; Hobart Brothers Company; and The DeVilbiss Company.

Special thanks are expressed to fellow personnel at GMFanuc, Inc. who offered encouragement and ideas for this text. Sincere thanks are also extended to those robotics instructors who reviewed the original manuscript and offered suggestions, many of which were incorporated into the final draft: Dr. Bill J. Rose, Oakland Community College, Auburn Heights, MI; Dr. James B. McCord, College of DuPage, Glen Ellyn, IL; Professor Clifford T. Fitzgerald, Wentworth Institute of Technology, Boston, MA; and Professor Wayne K. Bolt, Chattanooga State Community College, TN. Thanks are also extended to the Production Department of Breton Publishers for their skill in improving the original presentation both editorially and conceptually.

Finally, I extend my heartfelt thanks to my children Pam, Doug, and Robbie for understanding when their father had to spend a great deal of time on this project. And last, but not least, I thank my wife Ruth for all her help. Without my family's encouragement and love and support, this book could never have been written.

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Introduction to Robotics

OBJECTIVES

Upon completing this chapter, you should be familiar with:

- Robot terminology,
- Basic components of robots,
- Robot motion,
- Robot technology levels.

INTRODUCTION

The industrial robot and its operation is the topic of this text. The industrial robot is a tool that is used in the manufacturing environment to increase productivity. It can be used to do routine and tedious assembly line jobs, or it can perform jobs that might be hazardous to the human worker. For example, one of the first industrial robots was used to replace the nuclear fuel rods in nuclear power plants. A human doing this job might be exposed to harmful amounts of radiation. The industrial robot can also operate on the assembly line, putting together small components, such as placing electronic components on a printed circuit board. Thus, the human worker can be relieved of the routine operation of this tedious task. Robots can also be programmed to defuse bombs, to serve the handicapped, and to perform functions in numerous applications in our society.

The robot can be thought of as a machine that will move an end-of-arm tool, sensor, and/or gripper to a preprogrammed location. When the robot arrives at this location, it will perform some sort of task. This task could be welding, sealing, machine loading, machine unloading, or a host of assembly jobs. Generally, this work can be accomplished without the involvement of a human being, except for programming and for turning the system on and off.

In this chapter, you will become familiar with the various

components used to establish a robotic system. As you will see, robotic systems have different levels of technology that enable the robot to be a very simple operating machine or a complex, flexible, automated manufacturing cell.

ROBOT TERMINOLOGY

In this section and in the following sections, the basic terminology of robotic systems is introduced. Also, the fundamental components of a robotic system are identified and defined. Succeeding chapters of the text will expand on the basic terminology and definitions, giving more detailed information.

A **robot** is a reprogrammable, multifunctional manipulator designed to move parts, materials, tools, or special devices through variable programmed motions for the performance of a variety of different tasks. This basic definition leads to other definitions, presented in the following paragraphs, that give a complete picture of a robotic system.

Preprogrammed locations are paths that the robot must follow to accomplish work. At some of these locations, the robot will stop and perform some operation, such as assembly of parts, spray painting, or welding. These preprogrammed locations are stored in the robot's memory and are recalled later for continuous operation. Furthermore, these preprogrammed locations, as well as other program data, can be changed later as the work requirements change. Thus, with regard to this programming feature, an industrial robot is very much like a computer, where data can be stored and later recalled and edited.

The **manipulator** is the arm of the robot. It allows the robot to bend, reach, and twist. This movement is provided by the manipulator's axes, also called the **degrees of freedom** of the robot. A robot can have from 3 to 16 axes. In the remainder of this text, the term *degrees of freedom* will always relate to the number of axes found on a robot.

The **tooling** and **grippers** are not part of the robotic system itself; rather, they are attachments that fit on the end of the robot's arm. These attachments connected to the end of the robot's arm allow the robot to lift parts, spot-weld, paint, arc-weld, drill, deburr, and do a variety of tasks, depending on what is required of the robot.

The robotic system can also control the work cell of the operating robot. The **work cell** of the robot is the total environment in which the robot must perform its task. Included within this cell may be the controller, the robot manipulator, a work table, safety

features, or a conveyor. All the equipment that is required in order for the robot to do its job is included in the work cell. In addition, signals from outside devices can communicate with the robot in order to tell the robot when it should assemble parts, pick up parts, or unload parts to a conveyor.

BASIC COMPONENTS

The robotic system has three basic components: the manipulator, the controller, and the power source. A fourth component, the end effector, is found on some robotic systems. These components are described in the following subsections.

Manipulator

The manipulator, which does the physical work of the robotic system, consists of two sections: the mechanical section and the attached appendage. The manipulator also has a base to which the appendages are attached. Figure 1-1 illustrates the connection of the base and the appendage of a robot.

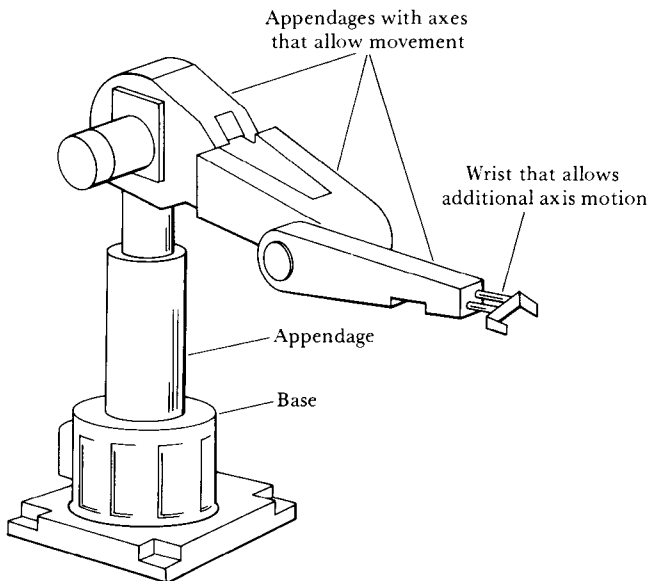


Figure 1-1 Basic Components of a Robot's Manipulator

The base of the manipulator is usually fixed to the floor of the work area. Sometimes, though, the base may be movable. In this case, the base is attached to either a rail or a track, allowing the manipulator to be moved from one location to another. For example, one robot could work at several presses, loading and unloading each press.

As mentioned previously, the appendage extends from the base of the robot. The **appendage** is the arm of the robot. It can be either a straight, movable arm or a jointed arm. The jointed arm is also known as an *articulated arm*.

The appendages of the robot manipulator give the manipulator its various axes of motion. These axes are attached to a fixed base, which, in turn, is secured to a mounting. This mounting ensures that the manipulator will remain in one location.

At the end of the arm, a wrist (see Figure 1-1) is connected. The wrist is made up of additional axes and a wrist flange. The *wrist flange* allows the robot user to connect different tooling to the wrist for different jobs.

The manipulator's axes allow it to perform work within a certain area. As mentioned earlier, this area is called the work cell of the robot, and its size corresponds to the size of the manipulator. Figure 1-2 illustrates the work cell of a typical assembly robot. As the robot's physical size increases, the size of the work cell must also increase.

The movement of the manipulator is controlled by actuators, or drive systems. The **actuator**, or **drive system**, allows the various axes to move within the work cell. The drive system can use electric, hydraulic, or pneumatic power. The energy developed by the drive system is converted to mechanical power by various mechanical

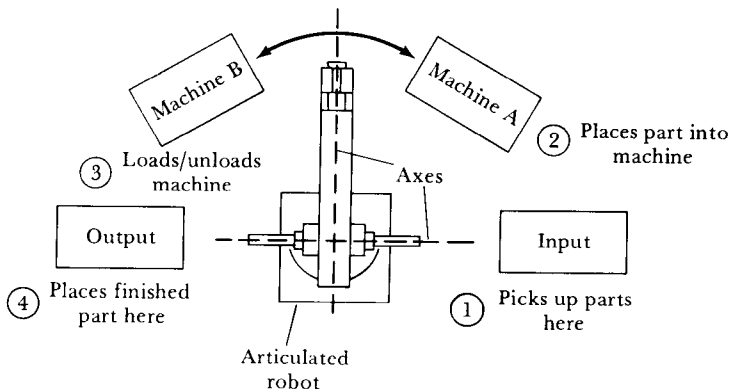


Figure 1-2 Elements of a Work Cell from the Top