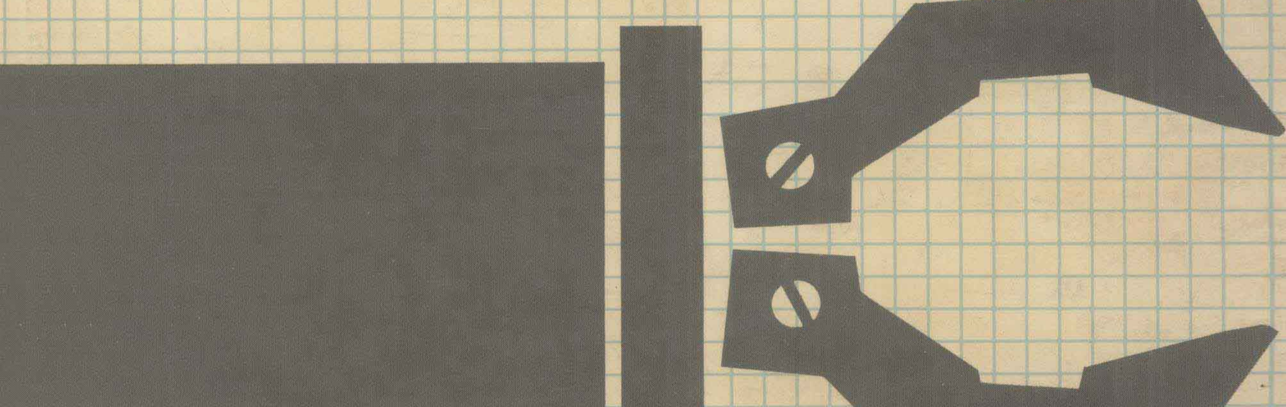
PRACTICAL ROBOTICS

SYSTEMS, INTERFACING AND APPLICATIONS



Practical Robotics
Systems, Interfacing, and Applications

William C. Burns, Jr.
Janet Evans Worthington

A RESTON BOOK
Prentice-Hall
Englewood Cliffs, New Jersey 07632

Library of Congress Cataloging in Publication Data

Burns, William C.
Practical robotics.

1. Robotics. I. Worthington, Janet Evans,
1942– . II. Title.
TJ211.B87 1986 629.8'92 85-11934
ISBN 0-8359-5779-9

A Reston Book
Published by Prentice-Hall
A Division of Simon & Schuster, Inc.
Englewood Cliffs, NJ 07632

10 9 8 7 6 5 4 3 2 1

Printed in the United States of America

To our families

Barbara, Billy, & Bryan Burns

Gary, Rachael, Evan, & Nicky Worthington

Preface

The time is fast approaching when the actual production of goods will be accomplished by machines and the control of the machines will be in human hands. When this time comes, machines will be doing what they do best—producing goods—and people will be doing what they do best—making judgments. One current innovation that will help to make this possible is the robot.

The purpose of this book is to provide an overview of robotic technology. It explores the basic principles of sensory systems, data acquisition systems, actuation systems, and control systems. One aspect of this book that makes it unique is the attention given to hardware, which makes this text a practical guide for technicians.

Because this book focuses on both concepts and hardware, it can serve not only as textbook, but also as a useful tool for anyone connected with the field of robotics. Thus the book can serve as a much-needed handbook for robotic technicians and at the same time can benefit the layman who wishes to understand the relationships that exist between high technology and society. To this end, the authors have made every effort to present concepts in a readable and understandable fashion.

To aid the reader in developing an understanding of robotic technology, objectives have been provided at the beginning of each chapter. These will help to make the readers aware of the concepts that they are supposed to grasp. In addition, problems are presented at the end of each chapter so that readers may test their level of competence and check their ability to apply information contained in the chapter. Finally, summary paragraphs are included at the end of each chapter to reinforce the important concepts covered. By using these learning aids, readers will be able to move sequentially through the text and establish a firm foundation in robotics.

The authors wish to express their gratitude to Dean Don Hagen of the Community and Technical College of West Virginia Institute of Technology for his help and support in the preparation of this book. In addition, thanks go to Patricia Urbas Metheny, Patty Hopkins, Harold Lundsford, and Dr. Lynda Ewen for their assistance. Most of all, the authors wish to send a big thank you to the members of their families for their patience and understanding throughout the year that this book was being written.

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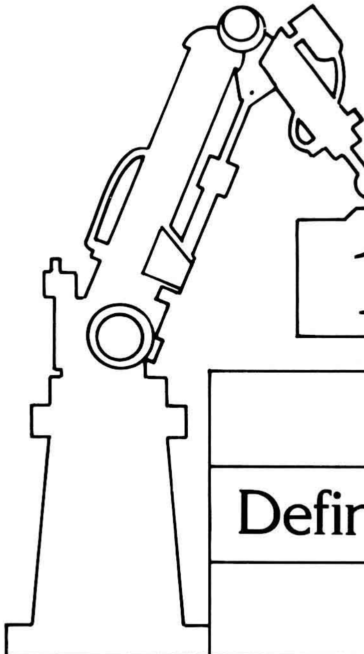


1

Definition of Robot

OBJECTIVES:

After completing this chapter, the reader will be able to:

- Define the terms robot and industrial robot.
- Explain the differences between human movement and intelligence and robotic movement and intelligence.
- Differentiate between hard automation and the use of robots.

Media Images of the Robot

Many young people today have an image of robots that is based primarily on their experiences with cartoons, movies, television, and novels. They see the robot not as a mechanical machine, but as a human made up of tin, bolts, and wires. These images are drawn from many sources, but most prominent are popular movies and television series, such as "Star Wars" and "Star Trek." These media portray robots as shining, human-like creatures who have a will of their own. In most cases, these robots display a full range of emotions and human characteristics. They love, hate, perform acts of bravery, and express fear. In fact, however, the robots that exist today are as far from their movie counterparts as everyday existence is from soap operas. Actually, most robots in use today are industrial robots that are made up of one or possibly two arms. They are employed in industry to perform a variety of tasks, from welding a seam to loading boxes.

Definitions of the Robot

The word "robot" was derived from the Czechoslovakian word *robota*, which means forced labor. The most commonly accepted definition for a robot is the one set up by the Robotics Industries Association (formerly the Robot Institute of America). According to them, a robot is "a reprogrammable, multifunctional manipulator designed to move materials, parts or specialized devices through variable programmed motions for the performance of a variety of tasks."

A closer look at this definition reveals several unique features of the robot. First of all, the robot can be programmed to perform a particular task. If this is to be done, a human must first figure out how the task is to be done by thinking through the entire sequence of motions and operations, and then write a program that will allow the robot to carry out those motions. Second, the robot is not limited to one set of motions; it is reprogrammable. This means that when a specific operation is no longer needed, the robot can be moved to a different operation and programmed for it.

In addition, the robot is multifunctional, which means it may be used in different ways. The different tasks may even be a part of one program or operation. For example, the robot might move a work piece to a machine and load it into the machine. Then it might insert a cutting tool and control the cutting of the work piece. Finally, it might unload the piece and store it in an appropriate area.

This definition stresses the flexibility of the robot by pointing out how it can be changed to meet special needs. But this definition does not cover all aspects of robots, for people view robots from their own unique perspectives and then define them based on those views. Businessmen see robots as providing the means of increasing productivity. Supporters of robots welcome these devices, since they take over the hazardous, tedious tasks that people have had to perform. Workers and labor leaders, however, tend to view robots as devices that put people out of jobs.

Whatever the individual's viewpoint may be, robots are devices that imitate human manipulation. Robots, however, are built by people, programmed by people, and maintained by people; hence, they are what people make them.

Differences Between the Human and the Robot

While home or personal robots move, talk, and grasp objects, the industrial robot generally consists only of one or two arms with grippers or tools at the end. Clearly, robots are very well-suited to a variety of tasks, particularly those tasks that are repetitive. However, there are many areas in which humans are superior and will probably always remain so. One of these areas consists of tasks requiring physical coordination and the ability to make many decisions based on a constantly changing environment. An example would be the ability to participate in a game of basketball, which requires the physical coordination of the entire body and the ability to make decisions about whether to pass, dribble, or shoot, based on the positions and movements of other players on the floor. While robots can react to their environment, the multitude and variety of conditions found in a basketball game call for responses that are clearly beyond the powers of robots and the computers that control them.

Robots also have difficulty with tasks that are artistic or creative. For a robot to function, it must be programmed, and for a program to work, the task must be broken down into discrete parts. All decisions to be made in each part must be capable of being reduced to equations. Therefore, humans will remain superior in art, music, medicine, and other endeavors that cannot be expressed in purely mathematical terms.

Sensory capacities of robots continue to improve as technology improves, but the human's highly developed senses of sight, smell, hearing, and touch remain difficult to duplicate. Further, the combination of these senses gives humans the capability of processing large amounts of information simultaneously. As an example, humans are able to maneuver an automobile and avoid hazards because they are constantly receiving a variety of sensory messages.

Finally, the human brain is able to make decisions based on experiences and stored information. Although the robot's computer can store large quantities of information, it cannot make decisions based on past experiences, nor can it make intuitive judgments based on stored information and past experiences.

Differences Between Hard Automation and Robotics

Throughout history, mankind has searched for ways to produce goods faster and more efficiently. The growth of factories and the use of automation moved the human race forward in its attempts to reduce human drudgery and provide more goods for more people. The robot is the latest device designed to facilitate this process. However, robots do represent a unique and extremely valuable innovation. In the case of hard automation, machines were designed specifically for one purpose. When the goods they produced were no longer needed, the machines themselves were no longer useful and had to be discarded. This made manufacturing costly and time-consuming. In contrast, the robot is flexible and reprogrammable. When the operation it is performing is no longer needed, the robot can simply be moved to another location and programmed for a new operation. The resulting savings in time and money make the robot a truly valuable innovation.

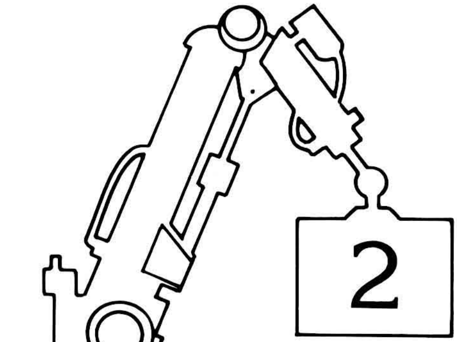
Summary

The image of the robot as portrayed in the mass media is very different from the actual robot of today, which is a reprogrammable, multifunctional manipulator that can move materials, parts, or devices through a series of programmed motions to perform a variety of tasks. Because it can be reprogrammed, the robot offers flexibility not found in hard automation. The definition of a robot and its function may vary, depending upon how the individual perceives this device. While robots have numerous capabilities, they are inferior to humans in performing tasks requiring physical coordination or in dealing with a constantly changing environment. Robots are also not suited to artistic or extremely complex tasks or problems which require the use of intuition.

QUESTIONS AND PROBLEMS

1. Write your own definition of a robot. Save this definition and add to it or change it as you read this book.
2. Explain the difference between hard automation and robotics.

3. Read the three descriptions below and decide if each device is or is not a robot. Use the definition of a robot that you wrote. Be prepared to defend your answers.
   a) Painteasy is designed to spray paint parts that are randomly placed on an assembly line. The device will speed up or slow down to keep pace with the line. Up to 200 programs can be stored. Different colors may be selected for use.
   b) A machine part is processed by a machinist, who loads the metal piece into a chuck or turning machine. After the part has been machined, the machinist unloads the part and the supervisor inspects it.
   c) The QBZX can be used to handle materials, spot weld, or inspect. It has a teach pendant which provides fast, simple programming of the operation.
4. Examine the tasks listed below and decide whether each could be done best by a robot or a human. Explain your choice for each one.
   a) Perform a routine on a set of parallel bars.
   b) Build kitchen cabinets.
   c) Collect soil samples on other planets.
   d) Babysit with an infant.



2 History of Robotics in America

OBJECTIVES:

After reading this chapter, the reader will be able to:

- Explain why robotics is not a new phenomenon.
- Trace the development of industry in America that led to the birth of robotics.
- Discuss the key events and attitudes in American history that helped foster industrial robotic development.
- Trace the development of IC chips and computers and discuss their importance in the development of robots.
- Discuss forces opposing the development of robotics.

Early Robots

In ancient times, human slaves were used to accomplish dangerous, unpleasant, and repetitive tasks. As time passed, machines began to replace human beings in carrying out these undesirable tasks. With the growth and development of industrialization, machines were able to assume more and more of the hazardous, tedious work. Today, a new era in human history is beginning to unfold. Programmable machines, such as robots, are taking the place of human beings in these degrading jobs and hence are becoming the mechanical slaves of a more enlightened mankind.

The idea of robot labor has been around for a long time. In the Middle Ages, clockmakers assembled automatons that moved about in a way that imitated human actions. Clockwork mechanisms tugged and pushed on pulley-and-gear systems to perform programmed dances to entertain people. Hence, the idea of programming is not new. Another example emerged during the Industrial Revolution in France, when automated looms were designed to replace human weavers. The program for these looms was punched into metal plates, and during operation the loom used the programs to change the patterns in fabrics.

The Growth of Technology in America

The philosophy of early America made it an ideal location for the growth of automated production. A number of the early settlers in America were criminals and peasants. The skilled craftsmen of that time preferred to stay in their homelands. This lack of skilled craftsmen created a need for more effective ways of producing goods. In addition, the philosophic foundation of America placed an emphasis on the worth and potential of the individual. It was this philosophy that supported and helped the inventors and the innovators who tried to find new and better ways to produce manufactured goods.

Partially as a result of this type of environment, by the time of the Industrial Revolution, Americans had adopted attitudes that allowed them to move easily into the area of automation. Early automation was not very sophisticated and had no feedback mechanisms, so workers were still essential in tasks such as cutting out parts. Often the craftsman would use templates to assure consistent patterns.

World War II brought rapid changes in manufacturing. Some of these developments can be directly attributed to technological advances made as part of the war effort. Prior to World War II, rockets and torpedoes had no feedback mechanisms and therefore often missed their targets. As a result, manpower and materials were often wasted. Military researchers sought to develop guidance systems which would ensure direct hits. These systems were equipped with feedback (closed-loop) devices which monitored the pathway of a rocket or torpedo and made the necessary course corrections. Such feedback systems were called servo systems. After the war was over, this servo technology was transferred to nonmilitary applications in factories and plants across the United States.

Another factor that contributed to the development of robotics systems was the space program of the United States. In 1959, the Russians launched the space probe Sputnik, and Americans became very concerned about space-based weapons. John F. Kennedy initiated the space program for two reasons: first, to allay American fears that Russians would be superior in the use of space-based weapons, and second, to promote the growth of technology in American industry to assure that America would retain its position as a world economic power.

During the years of space exploration, a new phenomenon occurred: no longer did inventions come about because of one man's tinkering in his garage or by some happy accident. Now group effort was needed to produce the devices that would place American spacecraft in orbit. Government directives were sent to scientists and researchers telling them to invent the new technology needed as quickly as possible. Many new inventions resulted from these directives. Two of the most important areas of invention were microprocessor-based systems and integrated circuit (IC) interface systems. Since both microprocessor systems and IC chips are so important in robotics, it is worthwhile to examine the evolution of each of these in detail.

The Development of Integrated Circuit Chips

The development of IC chips came about because of the need for smaller and smaller logic circuits that consumed less and less power and were more durable than those used by industry before the space race. Originally, logic circuits were hooked together with vacuum tubes, which were cumbersome, fragile, and required a great deal of electrical power. The radio consoles of the past used vacuum tubes which were too fragile to place in the nose of torpedoes. Bell Labs developed discrete transistors out of silicon (sand) that were much smaller than vacuum tubes and used much less power. The next stage of innovation came when integrated circuit chips were developed to replace transistor circuits. These chips made it possible to produce smaller and more sophisticated circuits that move at breakneck speeds. Today, Very Large Scale Integrated Circuits (VLS–ICs) are being manufactured. Microprocessor chips are an example of the VLS–IC technology.

The application of circuitry began with analog feedback systems. This type of system had intrinsic oscillation and was being replaced by digital systems even before the computer was invented. Early digital servo systems, which used mainframe computers, came into use in the early 1960s.

These systems needed the services of computer scientists who had to load lengthy programs into the computer to set up and manipulate the automated machinery.

By 1975 mass experimentation with digital circuitry was underway by both government and private industry, as well as by individual inventors who set up small labs in their basements and garages to tinker with electronic component applications. This led to such rapid progress in the application of new technology that today it is possible to produce a generic reprogrammable control unit that can be applied to a variety of tasks. This type of control unit is one of the keys to the movement from hard automation to robotic control.

The Development of Computers

The growth of the computer began with the United States census of 1950. Computers of that day were large mainframes which used vacuum tubes. These mainframes were very large, required carefully controlled temperature and humidity, and needed a great deal of electrical power. The investment required to produce and maintain this type of computer could only be shouldered by government agencies and large corporations.

When the space program began, scientists and engineers needed smaller, more durable, and more energy-efficient computers for space probes. The government funded research efforts in order to speed up the development of these smaller, more efficient computers. After these innovations, individual inventors found that they could purchase computer components and use this new technology for a variety of tasks. Growth in the microelectronic industry was phenomenal, and computer systems rapidly became better and cheaper as their capacity to store information increased and their need for electrical power decreased. By 1978, 8-bit microcomputer systems were available, but soon 16-bit systems emerged, and further increases are on the horizon.

While microcomputers were increasing in capacity, they also began to fill a need in the commercial sector of the economy as software (programs) were developed to help businesses compete with each other. All of these developments contributed to the growth of the robotics industry.

Forces Opposing the Development of Robotics

Five factors have served to slow down the growth and implementation of robotics technology:

1. lack of technology
2. need for investment in research and development