Robotics

A User-Friendly Introduction

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An Introduction to Robotics

> The discovery of nature, of the ways of planets, plants and animals, required first the conquest of common sense. Science would advance, not by authenticating everyday experience, but by grasping paradox, adventuring into the unknown. . . . Nothing could be more obvious than that the earth is stable and unmoving, and that we are the center of the universe.
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> D. J. Boorstin (1983)

Robotics is the science of designing, building, and applying robots. In this chapter, we will explain what robots are and why we need to understand them. We could just assume that everyone understands what a robot is, but many of our ideas about what robots are and what they can do may owe their existence to fiction, to stories and movies. For example, the word *robot* is based on the Czeck word for slave, and was introduced into our culture in the early 1920s in a play by Karel Čapek about mechanical men that rebel against their human masters. The word *robotics* was coined by the renowned science fiction writer, Isaac Asimov, in the 1942 science fiction story, "Runabout" (Asimov, 1982). However, it has only been in the past 25 years that real robots and the serious study of them has advanced from the realms of fiction to the laboratories of universities and into the factories of industry.

Today, robotics has developed into a solid discipline of study that incorporates the background, knowledge, and creativity of mechanical, electrical, computer, industrial, and manufacturing engineering. Even without the fictional trappings of supercapabilities, robotics is an exciting, challenging field of study. Those who are students today will be the robotics experts, designers, programmers, users, and teachers of tomorrow. Today's robotics students will be very much a part of the evolution of robots toward their ultimate capabilities. Students in every discipline from engineering to sociology have the opportunity to become involved with what promises to be the greatest innovation in our means of performing work since the computer.

However, as we study robotics, it is prudent to remember that perhaps many of our assumptions about what robots are and what they can or cannot do are founded on fiction. In adventure stories, robots are able to navigate spaceships, care for children, and vie with humans for control of the galaxy. In the real world, robots do such practical work as painting and welding cars or handling radioactive elements. Although the fictitious robots may not necessarily be impossible, most experts would agree that it is far easier to imagine a mechanical marvel than it is to build one that works. Besides, we don't need or want robots that fight us. We only need robots that help us do our work faster or more efficiently so that we humans can enjoy a better life. It is important that we learn about robots and explore their capabilities so that ours never becomes a society in which the human serves the machine, but one in which the machine always serves humans.

1.1 What Is a Robot?

If you walk into the Nissan truck factory in New Smyrna, Tennessee, expecting to see shiny androids like C3PO assembling parts, you will be severely disappointed. The modern, industrial robot has far more in common with an ordinary piece of machinery than with a human. This only makes sense, since robots are machines. An example of a robot at work is shown in Figure 1–1. This industrial robot is trimming plastic dashboard components by moving them under a high-power laser. What is the difference between this robot and any other piece of automated machinery? Why is this machine called a "robot," not just an "automatic dashboard trimmer?" The robot is a special kind of automated machine. A robot can do not only this particular job of trimming, but it can be programmed and retooled to do many different jobs. This programmability and versatility is why all robots are automated machines, but all automated machines are not robots.

There is only one definition of an industrial robot that is internationally accepted. It was developed by a group of industrial scientists from the Robotics Industries Association (formerly the Robotics Institute of America) in 1979. They defined the industrial robot as ". . . a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks." Let's take a close look at this definition to see just what it implies.

The first key word is *reprogrammable*. This implies that a robot is a machine that cannot only be programmed once, but can be programmed as many times as one likes. Many electronic devices we use every day contain computer chips that are programmable. Programs are written on the chips of digital watches, for instance, that instruct them to do such things as play "Dixie" as an alarm. These programs cannot be easily changed, however. There is no allowance for input by the owner. You cannot, for example, put a song of your own into the watch when you get tired of waking up to

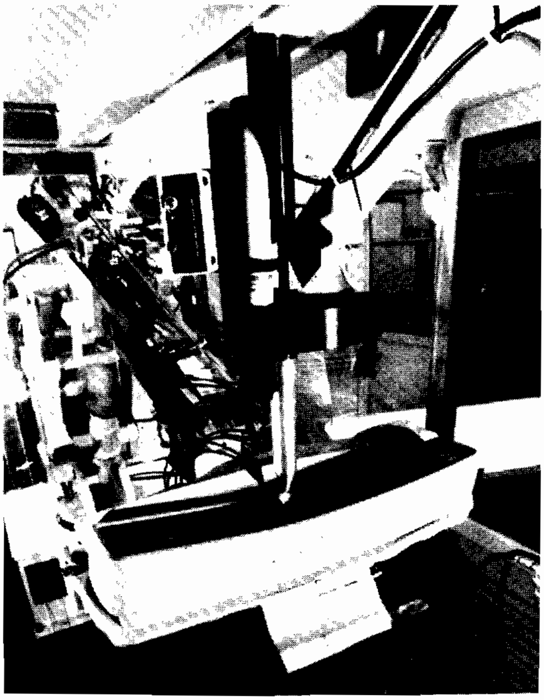

Figure 1–1. A Cincinnati Milacron T3 746 robot trims plastic dashboard components for Ford by inserting them in a shielded booth and maneuvering them under a CO_2 laser. After trimming, parts are placed on an indexing output conveyor at left. The laser is a 500-watt Versa Lase V500 made by Photon Sources, Livonia, Michigan. (Courtesy of Cincinnati Milacron.)

"Dixie." The programs are "burned in" by the manufacturer. A robot, however, contains a program that is accessible, that can be changed, added to, or deleted, as the user chooses. A robot can have many programs to do different things in any sequence whatever. And, of course, to be programmable, a robot must have a computer that can be fed new instructions and information. The computer can be either "on board," which means the computer console is mounted on the robot itself, or it can be "remote," which means the computer that controls the robot can be anywhere you like as long as it can communicate with the robot.

The next key word in the RIA definition is *multifunctional,* which implies that the robot is versatile, that is, can perform more than one task. The same industrial robot used for laser cutting in Figure 1–1 could, with a simple change of end tooling, also perform welding, painting, or assembly operations.

The third key word is *manipulator,* which implies that a robot has a mechanism of some sort for moving objects for the performance of its work. It's the manipulator that separates a robot from a computer, just as it's the reprogrammability and versatility that separate a robot from other kinds of automated machines.

Finally, let's consider the meaning of *various programmed motions*. This implies that the robot is dynamic; that is, it is characterized by continuous, productive activity.

Although this definition may seem very broad and somewhat ambiguous, it does serve to separate industrial robots from, for instance, fixed-sequence automated machinery, or from multifunctional machines, such as food processors, that are equipped with interchangeable parts to perform various tasks, from blending sauces to grinding beef. It also removes robots far from the realms of science fiction, since any anthropomorphic (humanlike) characteristics a robot may or may not possess are merely a matter of efficacy.

From this perspective, then, the robot can be considered a major advance in the logical progression in the development of automated machines. We have moved from building machines that can do one job with human control to machines that can do many different jobs without any human control. The first industrial revolution has been said to be the start of an era of general industrial use of power-driven machines. The modern industrial renaissance may be called an era in which we are building machines capable not only of building other machines, but also of repairing and "reproducing" themselves. Some of the latest research is in equipping robots with such sensory apparatus as "eyes" and artificial intelligence sufficient to allow the robot to "learn" or to adapt to variable conditions in its working environment. Good questions at this point might be, "But why do we need such sophisticated machines, or machines that can do several different jobs? Aren't the automated machines we now have sufficient?"

1.2 Why Robots Are Needed

The basic reason for using robots rather than other automated machinery to produce goods is closely related to their versatility and programmability. This versatility can be translated into increased productivity, improved product quality, and decreased production costs in several ways. In a market with periodic product changes, the cost of reprogramming and retooling a robot is much less than the cost of retooling a fixed automation machine. If product changes are brought about by inflation or competition, again, the versatility of the robot is important in permitting minor product changes quickly. Because robots assume many dangerous or annoying jobs, many employee injuries are eliminated that comprise a very costly element of production. Because robots perform their jobs the same way every time, they produce consistent quality in their goods, which provides the manufacturer with definite advantages. Predictable production rates permit better inventory control. Each savings in the cost of the value added to a product results in improved competitiveness in all markets. One other advantage that robots offer is that they can be used to make small batches of products, but hard automation is generally efficient only in mass, standardized production.

There are many other reasons for using robots. The cost of human labor has been rising at a marked rate for the past several years, but the speed at which humans can work has not increased. Human labor costs are now so high that the cost of using machine labor is usually much more attractive. Although the machine may have a high initial cost, it can increase production by working faster and for more hours per day. Machines have improved the working conditions of humans by assuming hazardous and monotonous jobs and reduced production costs because they produce fewer "rejects" that humans sometimes produce through fatigue or boredom. Robots improve productivity in a variety of applications from processing raw materials to assembling automobiles. They are especially useful for work in hostile or dangerous environments, such as in outer space or on the ocean floor. Finally, robots are fun to work with. They provide challenging opportunities to everyone from hobbyists to the most advanced robotic designers. The robot is not only going to be the servant we have always dreamed of owning, but also the ultimate machine.

1.3 Overview of Robot Applications

Industrial robots have been used in a wide variety of manufacturing applications. Hot, dirty, dangerous foundry work in which molten metal is poured into castings was one of the first jobs in which robots were successfully used. Welding operations, in which consistency of the spot or seam weld is essential but which also produces a hot, ozone atmosphere annoying or hazardous to humans, has become another widely used application. Hazardous spray painting is another application in which robots are important, because robots can safely apply extremely thin coats of paint consistently, which significantly reduces the amount of paint needed per part. Back-breaking, dangerous, and tedious machine loading and unloading is another task to which robots are often applied. An example of a machine-loading robot is shown in Figure 1–2. Such robots are often the central element of an automated work cell, which is a coordinated collection of machines designed to perform a set of tasks, such as machining parts or spray painting. Assembly of automobiles, electric motors, computers, and even robots are newly proven areas of robot application.

Most robots used in these applications are deaf, dumb, blind, and stationary. Thus, these robots are not used so differently from other kinds of automated machines. However, an entirely new phase in robotics applications has been opened with the development of "intelligent" robots. An intelligent robot is basically one that is equipped with some sort of sensory apparatus that enables it to sense and respond to variables in its environment. Much of the research in robotics has been and is still concerned with how to equip robots with seeing "eyes" and tactile "fingers." Artificial intelligence that will enable the robot to respond, adapt, reason, and make decisions in reaction to changes in the robot's environment are also inherent capabilities of the intelligent robot. For example, one of the most important considerations in using a robot in a workplace is safety. If a robot could be equipped with sensory apparatus that detect the presence of humans, it could be programmed to automatically shut down its operation if it sensed the presence of a human within its work envelope. Intelligent robots that have already found successful application can do such things as "see," "hear," and "feel." The development

Figure 1–2. The Prab Model 5800 nonservo controlled industrial robot shown loading cylinder heads in a machining application. (Courtesy of Prab Robots, Inc., Kalamazoo, Michigan.)

of sensors coupled with recent innovations in robot mobility have enabled robots to move out of factories and into such varied environments as orange groves, sheep farms, and hospitals. Robots are also used in domestic and entertainment applications. Some futurists, such as Bill Bakaleinikoff of Superior Robotics of America, see the domestic robot as a mobile entertainment or sentry machine. Others see them as personal slaves that fetch and carry for their owners. Such applications are in their earliest stages now, but offer an exciting challenge to future roboticists. We can expect many new industries to develop around the creation and applications of robots. The potential applications of these new robots seem limited only by human imagination and creativity.

Does this mean robots will take over all work? Will there be nothing left for people to do? They may take over all the hardest work, all the dangerous work, and all the boring work, because, as consistent workers, robots are vastly superior to humans. They can run 24 hours a day, 7 days a week, year after year without stopping. Robots as imitators of human beings are vastly inferior, however. No robot has ever been, and is not likely ever to be, invented that can do everything people can do. People as workers are amazingly adaptive and creative. We are capable of learning thousands of jobs in just one lifetime. Furthermore, we have a marvelous assortment of senses coupled with the most sophisticated intelligence system in existence. We cannot even begin to assess the total or potential abilities of a human being. Finally, we have feelings, emotions, and biologic responses that make us uniquely suited to helping other people. For example, contrary to some popular notions, robots would probably not be good baby-sitters, because young children need the kind human responses of which machines are incapable. The simplest answer to the question of whether robots will take over all work can be seen by considering all the ways people can help other people. Obviously, we will never run out of things for people—or robots, for that matter—to do.

1.4 Chapter Previews

In Chapter 1, we have begun with a general introduction to robotics. Some perspectives concerning robots have been reviewed, and some of the key terms have been defined. More complex terms are defined in the Glossary at the end of the book. What robots are, why we need to use them, and an overview of applications were also presented.

In Chapter 2, we present a brief history of the development of robots, showing how the confluence of automated machines, remote manipulators, and prosthetics has led to the modern, industrial robot. Some key events in the history are listed in chronological order, and early robots and their applications are also discussed.

In Chapter 3, the structure of an industrial robot is detailed to provide the reader with a basis for understanding robots in general—why they look and work the way they do. The basic components of industrial robots, such as wrists, end effectors, control units, and power sources, are also described. The operation and methods of motion control of robots are also discussed.

Chapter 4 is concerned with intelligent robot programming. Several examples of intelligent robots are described, as well as the characteristics of intelligent robots, one of which is their ability to adapt to and perhaps control their environments. Robot programming is introduced, and examples of robot programming languages are considered in detail.

The types of sensors available for use with robots are considered in Chapter 5. Vision, tactile, temperature, proximity, and other sensors used separately or integrated together are described. Sensors for mobile robots are briefly considered. The problem of control integration is also considered.

Chapter 6 presents applications of robots today in manufacturing tasks, such as welding, painting, materials handling, and assembly. The basic industries involved in manufacturing and the fundamental operations are described. Single-robot applications and manufacturing systems are also discussed, especially where the robot is the central element in these factory-of-the-future arrangements, moving parts from one location to another, loading and unloading machines, and performing production or assembly operations.

Chapter 7 centers on the economic justification for robots. Questions from both management and labor that must first be considered are discussed. From the management point of view, cost is used to justify the use of a flexible manufacturing cell and an automated factory of the future. Costs and benefits resulting from robotic installations are also discussed.

Chapter 8 deals with the social aspects of robots. The findings of sociologic impact studies are reviewed, and suggestions are given on how to deal with the social consequences and human-machine interrelations that must result from the implementation of large numbers of robots in the work force.

Chapter 9 reviews the various political implications of what many people see as an "invasion" of thousands of robots into our society. There are people who fear robots will spark massive unemployment or inflation and who want strict controls on robot development. This chapter tells why most of these fears are unnecessary and discusses the role of the United States as a manufacturing nation, international economic competition, and the cooperation required for maintaining our present way of life.

Chapter 10 tells where robotics is headed in light of ongoing research. It describes those areas where much remains to be done, what is possible, and what is probable in our immediate future. The need for standardization in the robotics community is discussed, as well as new and unusual applications of mobile and multisensory robots. The book concludes with a discussion of how technology can best be assimilated into a society.

Questions

1. Where do the words *robot* and *robotics* come from?
2. What is an industrial robot, and what makes it different from other automated machines?
3. List five advantages robots offer over other automated machines.
4. How can robots allow humans to be more productive?
5. How do you think the modern industrial renaissance differs from the industrial revolution?