1 *What Is a Robot? Defining Robotics*

Welcome to *The Robotics Primer*! Congratulations, you have chosen a very cool way to learn about a very cool topic: the art, science, and engineering of robotics. You are about to embark on a (hopefully fun) ride that will end with your being able to tell what is real and what is not real in movies and articles, impress friends with cool facts about robots and animals, and much more, most important of which is being able to better build and/or program your own robot(s). Let's get started!

What is a robot?

This is a good question to ask because, as with any interesting area of science and technology, there is a lot of misunderstanding about what robots are and are not, what they were and were not, and what they may or may not become in the future. The definition of what a robot is, has been evolving over time, as research has made strides and technology has advanced. In this chapter, we will learn what a modern robot is.

The word "robot" was popularized by the Czech playwright Karel Capek (pronounced Kha-rel Cha-pek) in his 1921 play *Rossum's Universal Robots (R.U.R.)*. Most dictionaries list Capek as the inventor of the word "robot," but more informal sources (such as the Web) say that it was actually his brother, Josef, who made up the term. In either case, the word "robot" resulted from combining the Czech words *rabota*, meaning "obligatory work" and *robotnik*, meaning "serf." Most robots today are indeed performing such obligatory work, in the form of repetitive and fixed tasks, such as automobile assembly and DNA sequencing. However, robotics is about much more than obligatory labor, as you will see.

The idea of a robot, or some type of machine that can help people, is much older than the Capek brothers. It is not possible to pin point where it orig-

inated, because it is likely that many clever engineers of the past thought of it in some form. The form changed over time, as science and technology advanced, and made many of the previously unachievable dreams of robots become a reality or at least enter the realm of possibility.

With the advancement of science and technology, the notion of a robot has become more sophisticated. In the past, a robot was defined as a machine that was, basically, a clever mechanical device. Examples of such devices, even extremely sophisticated ones, can be found throughout history, and they go way back. As long as 3000 years ago, Egyptians used human-controlled statues; and more recently, in the seventeenth and eighteenth century Europe, various clockwork-based "lifelike" creatures were constructed that could sign, play the piano, and even "breathe." But, as we will see, those were not really robots, not by our current definition and understanding of what a robot is.

While original notions of robots were really of clever mechanical automatons, as computational machinery developed (and in particular when it shrank in size sufficiently to be imaginable within a robot's body), the notions of robots started to include thought, reasoning, problem-solving, and even emotions and consciousness. In short, robots started to look more and more like biological creatures, ranging from insects to humans.

These days we have (or should have) a very broad idea of what a robot can be, and do not need to limit ourselves by what is currently possible mechanically or computationally. However, it is still hard to anticipate how our ideas of what a robot is and can be will evolve as science and technology advance.

So back to the question: what is a robot? What makes the machine in figure 1.1 a robot, but those in figure 1.2 merely robot wannabes?

ROBOT

> A *robot* is an autonomous system which exists in the physical world, can sense its environment, and can act on it to achieve some goals.

This may seem like a very broad definition, but actually each of its parts is important and necessary. Let's take it apart to see why.

> A robot is an AUTONOMOUS system

AUTONOMOUS

An *autonomous* robot acts on the basis of its own decisions, and is not controlled by a human.

TELEOPERATED

There are, of course, plenty of examples of machines that are not autonomous, but are instead externally controlled by humans. They are said to be *teleop-*

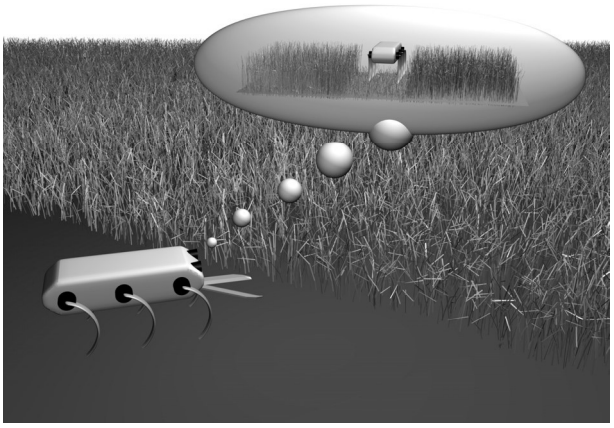

Figure 1.1 An example of a robot.

erated; *tele* means "far" in Greek, so teleoperation means operating a system from afar.

These machines, however, are not true robots. True robots act autonomously. They may be able to take input and advice from humans, but are not completely controlled by them.

> A robot is an autonomous system which exists in the PHYSICAL WORLD

Existing in the physical world, the same world that people and animals and objects and trees and and weather and many other things exist in, is a fundamental property of robots. Having to deal with that physical world, and its unbendable physical laws and challenges, is what makes robotics what it is: a real challenge. Robots that exist on the computer are simulations; they do not really have to deal with true properties of the physical world, because simulations are never as complex as the real world. Therefore, although there are a lot of simulated robots in cyberspace, a true robot exists in the physical world.

> A robot is an autonomous system which exists in the physical world, can SENSE its environment

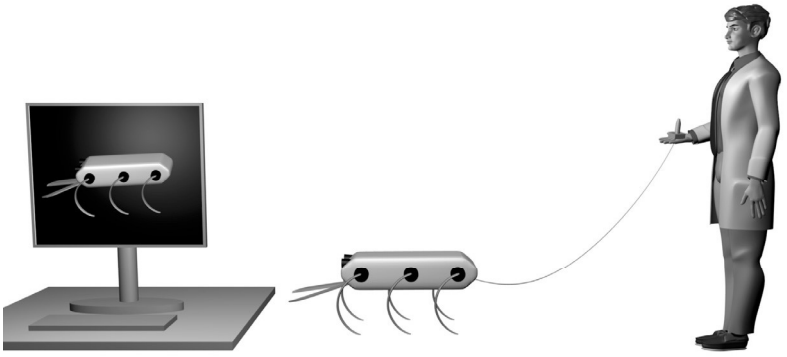

Figure 1.2 Examples of non-robots. On the left is a system that does not exist in the physical world; on the right, a system that is not autonomous. These robot wannabes are not the real thing.

SENSORS

Sensing the environment means the robot has *sensors*, some means of perceiving (e.g., hearing, touching, seeing, smelling, etc.) in order to get information from the world. A simulated robot, in contrast, can just be given the information or knowledge, as if by magic. A true robot can sense its world only through its sensors, just as people and other animals do. Thus, if a system does not sense but is magically given information, we do not consider it a true robot. Furthermore, if a system does not sense or get information, then it is not a robot, because it cannot respond to what goes on around it.

> A robot is an autonomous system which exists in the physical world, can sense its environment, and can ACT ON IT

Taking actions to respond to sensory inputs and to achieve what is desired is a necessary part of being a robot. A machine that does not act (i.e., does not move, does not affect the world by doing/changing something) is not a robot. As we will see, action in the world comes in very different forms, and that is one reason why the field of robotics is so broad.

> A *robot* is an autonomous system which exists in the physical world, can sense its environment, and can act on it to ACHIEVE SOME GOALS.

Now we finally come to the intelligence, or at least the usefulness, of a robot. A system or machine that exists in the physical world and senses it,

but acts randomly or uselessly, is not much of a robot, because it does not use the sensed information and its ability to act in order to do something useful for itself and/or others. Thus, we expect a true robot to have one or more goals and to act so as to achieve those goals. Goals can be very simple, such as "Don't get stuck" or quite complex, such as "Do whatever it takes to keep your owner safe."

Having defined what a robot is, we can now define what robotics is.

ROBOTICS *Robotics* is the study of robots, which means it is the study of their autonomous and purposeful sensing and acting in the physical world.

It is said that Isaac Asimov, the amazingly productive science fiction writer, was the first to use the term *robotics*, based on Capek's term *robot*. If so, he is the one who officially gave the name to the large and rapidly growing area of science and technology that this book aims to introduce.

To Summarize

- Robotics is a fast-growing field whose definition has been evolving over time, along with the field itself.
- Robotics involves autonomy, sensing, action, and achieving goals, all in the physical world.

Food for Thought

- What else can you do from afar, by means of teleoperation? You can talk, write, and see, as in telephone, telegraph, and television. There is more. Can you think of it?
- Is a thermostat a robot?
- Is a toaster a robot?
- Some intelligent programs, also called software agents, such as Web crawlers, are called "softbots." Are they robots?
- Is HAL, from the movie *2001, the Space Odyssey*, a robot?

Looking for More?

- This book comes with a free robot programming workbook you can download from the World Wide Web at:
  http://roboticsprimer.sourceforge.net/workbook/
  The workbook follows the structure of this textbook with exercises and solutions you can use to learn much more about robotics by trying it hands-on.
- Here is a fun, short little introductory book about robotics: *How to Build a Robot* by Clive Gifford. It's very easy, has great cartoons, and touches on a lot of concepts that you can then learn about in detail in this book.
- *Robotics, The Marriage of Computers and Machines* by Ellen Thro is another short introductory book you might enjoy.
- For a truly comprehensive review of modern robotics, complete with a great many robot photos, see *Autonomous Robots* by George Bekey.
- To learn more about various topics in this book and in general, look up things on Wikipedia, an ever-growing free encyclopedia found on the Web at http://en.wikipedia.org/wiki/.