2

ANATOMY OF A ROBOT

We humans are fortunate. The human body is, all things considered, a nearly perfect machine: it is (usually) intelligent, it can lift heavy loads, it can move itself around, and it has built-in protective mechanisms to feed itself when hungry or to run away when threatened. Other living creatures on this earth possess similar functions, though not always in the same form.

Robots are often modeled after humans, if not in form then at least in function. For decades, scientists and experimenters have tried to duplicate the human body, to create machines with intelligence, strength, mobility, and auto-sensory mechanisms. That goal has not yet been realized, but perhaps some day it will.

Nature provides a striking model for robot experimenters to mimic, and it is up to us to take the challenge. Some, but by no means all, of nature's mechanisms—human or otherwise—can be duplicated to some extent in the robot shop. Robots can be built with eyes to see, ears to hear, a mouth to speak, and appendages and locomotion systems of one kind or another to manipulate the environment and explore surroundings.

This is fine theory; what about real life? Exactly what constitutes a real hobby robot? What basic parts must a machine have before it can be given the title "robot"? Let's take a close look in this chapter at the anatomy of robots and the kinds of materials hobbyists use to construct them. For the sake of simplicity, not every robot subsystem in existence will be covered, just the components that are most often found in amateur and hobby robots.

Tethered versus Self-Contained

People like to debate what makes a machine a "real" robot. One side says that a robot is a completely *self-contained, autonomous* (self-governed) machine that needs only occasional instructions from its master to set it about its various tasks. A self-contained robot has its own power system, brain, wheels (or legs or tracks), and manipulating devices such as claws or hands. This robot does not depend on any other mechanism or system to perform its tasks. It's complete in and of itself.

The other side says that a robot is anything that moves under its own motor power *for the purpose of performing near-human tasks* (this is, in fact, the definition of the word *robot* in most dictionaries). The mechanism that does the actual task is the robot itself; the support electronics or components may be separate. The link between the robot and its control components might be a wire, a beam of infrared light, or a radio signal.

In the experimental robot from 1969 shown in Fig. 2.1, for example, a man sat inside the mechanism and operated it, almost as if driving a car. The purpose of the four-legged "lorry" was not to create a self-contained robot but to further the development of *cybernetic anthropomorphous machines*. These were otherwise known as *cyborgs*, a concept further popularized by writer Martin Caidin in his 1973 novel *Cyborg* (which served as the inspiration for the 1970s television series, *The Six Million Dollar Man*).

We won't argue the semantics of robot design here (this book is a *treasure map* after all, not a textbook on theory), but it's still necessary to establish some of the basic characteristics of robots. What makes a robot a robot and just not another machine? For the purposes of this book, let's consider a robot as *any device that—in one way or another—mimics human or animal functions*. The way the robot does this is of no concern; the fact that it does it at all is enough.

The functions that are of interest to the robot builder run a wide gamut: from listening to sounds and acting on them, to talking and walking or moving across the floor, to picking up objects and sensing special conditions such as heat, flames, or light. Therefore, when we talk about a robot it could very well be a self-contained automaton that takes care of itself, perhaps even programming its own brain and learning from its surroundings and environment. Or it could be a small motorized cart operated by a strict set of predetermined instructions that repeats the same task over and over again until its batteries wear out. Or it could be a radio-controlled arm that you operate manually from a control panel. Each is no less a robot than the others, though some are more useful and flexible. As you'll discover in this chapter and those that follow, how complex your robot creations are is completely up to you.

Mobile versus Stationary

Not all robots are meant to scoot around the floor. Some are designed to stay put and manipulate some object placed before them. In fact, outside of the research lab and hobbyist garage, the most common types of robots, those used in manufacturing, are *stationary*. Such robots assist in making cars, appliances, and even *other* robots!

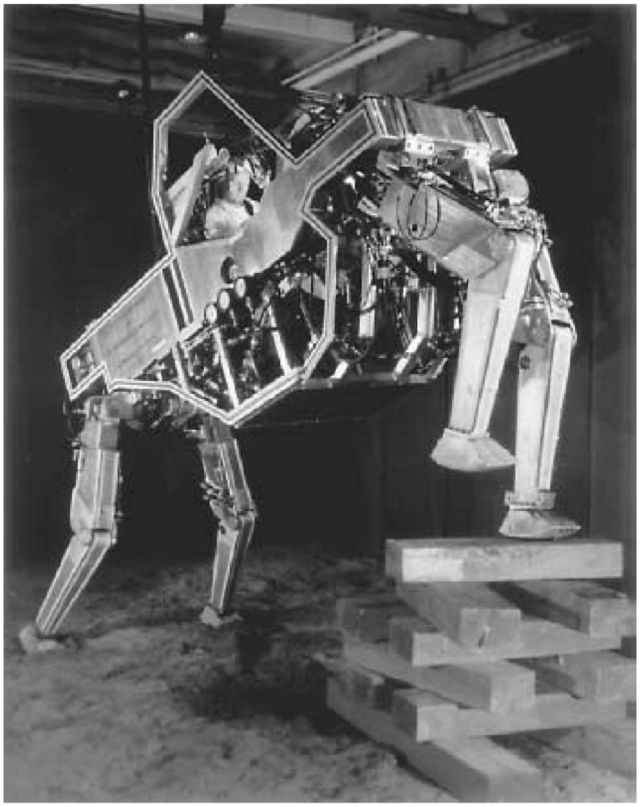

FIGURE 2.1 This quadruped from General Electric was controlled by a human operator who sat inside it. The robot was developed in the late 1960s under a contract with the U.S. government. Photo courtesy of General Electric.

Other common kinds of stationary robots act as shields between a human operator or supervisor and some dangerous material, such as radioactive isotopes or caustic chemicals. Stationary robots are armlike contraptions equipped with grippers or special tools. For example, a robot designed for welding the parts of a car is equipped with a welding torch on the end of its "arm." The arm itself moves into position for the weld, while the car slowly passes in front of the robot on a conveyor belt.

Conversely, *mobile* robots are designed to move from one place to another. Wheels, tracks, or legs allow the robot to traverse a terrain. Mobile robots may also feature an armlike appendage that allows them to manipulate objects around them. Of the two—stationary or mobile—the mobile robot is probably the more popular project for hobbyists to build. There's something endearing about a robot that scampers across the floor, either chasing or being chased by the cat.

As a serious robot experimenter, you should not overlook the challenge and education you can gain from building both types of robots. Stationary robots typically require greater precision, power, and balance, since they are designed to grasp and lift objects—hopefully not destroying the objects they handle in the process. Likewise, mobile robots present their own difficulties, such as maneuverability, adequate power supply, and avoiding collisions.

Autonomous versus Teleoperated

Among the first robots ever demonstrated for a live audience were fake "robots" that were actually machines remotely controlled by a person off stage. No matter. People thrilled at the concept of the robot, which many anticipated would be an integral part of their near futures (like flying to work in your own helicopter and colonies on Mars by 1975…yeah, right!).

These days, the classic view of the robot is a fully autonomous machine, like Robby from *Forbidden Planet*, Robot B-9 from *Lost in Space*, or that R2-D2 thingie from *Star Wars*. With these robots (or at least the make-believe fictional versions), there's no human operator, no remote control, no "man behind the curtain." While many actual robots are indeed fully autonomous, many of the most important robots of the past few decades have been *teleoperated*. A teleoperated robot is one that is commanded by a human and operated by remote control. The typical "tele-robot" uses a video camera that serves as the eyes for the human operator. From some distance—perhaps as near as a few feet to as distant as several million miles—the operator views the scene before the robot and commands it accordingly.

The teleoperated robot of today is a far cry from the radio-controlled robots of the world's fairs of the 1930s and 1940s. Many tele-robots, like the world-famous Mars Rover Sojourner, the first interplanetary dune buggy, are actually half remote controlled and half autonomous. The low-level functions of the robot are handled by a microprocessor on the machine. The human intervenes to give general-purpose commands, such as "go forward 10 feet" or "hide, here comes a Martian!" The robot is able to carry out basic instructions on its own, freeing the human operator from the need to control every small aspect of the machine's behavior.

The notion of tele-robotics is certainly not new—it goes back to at least the 1940s and the short story "Waldo" by noted science fiction author Robert Heinlein. It was a fantastic idea at the time, but today modern science makes it eminently possible. Stereo video cameras give a human operator 3-D depth perception. Sensors on motors and robotic arms provide feedback to the human operator, who can actually "feel" the motion of the machine or the strain caused by some obstacle. Virtual reality helmets, gloves, and motion platforms literally put the operator "in the driver's seat."

This book doesn't discuss tele-robotics in any extended way, but if the concept interests you, read more about it and perhaps construct a simple tele-robot using a radio or infrared link and a video camera. See Appendix A, "Further Reading," for more information.

The Body of the Robot

Like the human body, the body of a robot—at least a self-contained one—holds all its vital parts. The body is the superstructure that prevents its electronic and electromechanical "guts" from spilling out. Robot bodies go by many names, including *frame* and *chassis*, but the idea is the same.

SKELETAL STRUCTURES

In nature and in robotics, there are two general types of support frames: endoskeleton and exoskeleton. Which is better? Both: In nature, the living conditions of the animal and its eating and survival tactics determine which skeleton is best. The same is true of robots.

- *Endoskeleton* support frames are the kind found in many critters—including humans, mammals, reptiles, and most fish. The skeletal structure is on the inside; the organs, muscles, body tissues, and skin are on the outside of the bones. The endoskeleton is a characteristic of vertebrates.
- *Exoskeleton* support frames have the "bones" on the outside of the organs and muscles. Common exoskeletal creatures are spiders, all shellfish such as lobsters and crabs, and an endless variety of insects.

FRAME CONSTRUCTION

The main structure of the robot is generally a wood, plastic, or metal frame, which is constructed a little like the frame of a house—with a bottom, top, and sides. This gives the automaton a boxy or cylindrical shape, though any shape is possible. It could even emulate the human form, like the "robot" in Fig. 2.2. For a machine, however, the body shape of men and women is a terribly inefficient one.

Onto the frame of the robot are attached motors, batteries, electronic circuit boards, and other necessary components. In this design, the main support structure of the robot can be considered an exoskeleton because it is outside the "major organs." Further, this design lacks a central "spine," a characteristic of endoskeletal systems and one of the first things most of us think about when we try to model robots after humans. In many cases, a shell is sometimes placed over these robots, but the "skin" is for looks only (and sometimes the protection of the internal components), not support. Of course, some robots are designed with endoskeletal structures, but most such creatures are reserved for high-tech research and development projects and science fiction films. For the most part, the main bodies of your robots will have an exoskeleton support structure because they are cheaper to build, stronger, and less prone to problems.

SIZE AND SHAPE

The size and shape of the robot can vary greatly, and size alone does not determine the intelligence of the machine nor its capabilities. Homebrew robots are generally the size of a small dog, although some are as compact as an aquarium turtle and a few as large as

FIGURE 2.2 The *android* design of robots is the most difficult to achieve, not only because of its bipedal (two-leg) structure, but because it distributes the weight toward the mid and top sections of the body. In reality, this "android" is science fiction writer J. Steven York modeling the latest in casual robot ready-to-wear.

Arnold Schwarzenegger (if one of these asks you "Are you Sarah Conner?" answer "No!"). The overall shape of the robot is generally dictated by the internal components that make up the machine, but most designs fall into one of the following "categories":

- *Turtle*. Turtle robots are simple and compact, designed primarily for "tabletop robotics." Turtlebots get their name from the fact that their bodies somewhat resemble the shell of a turtle and also from early programming language, turtle graphics, which was adapted for robotics use in the 1970s.
- *Vehicle*. These scooter-type robots are small automatons with wheels. In hobby robotics, they are often built using odds and ends like used compact discs, extra LEGO parts, or the chassis of a radio-controlled car. The small vehicular robot is also used in science and industry: the Rover Sojourner, built by NASA, explored the surface of Mars in July 1997.
- *Rover*. Greatly resembling the famous R2-D2 of *Star Wars* fame, rovers tend to be short and stout and are typically built with at least some humanlike capabilities, such as firefighting or intruder detection. Some closely resemble a garbage can—in fact, not a few hobby robots are actually built from metal and plastic trash cans! Despite the euphemistic title, "garbage can" robots represent an extremely workable design approach.
- *Walker*. A walking robot uses legs, not wheels or tracks, to move about. Most walker 'bots have six legs, like an insect, because they provide excellent support and balance. However, robots with as few as one leg ("hoppers") and as many as 8 to 10 legs have been successfully built and demonstrated.
- *Appendage*. Appendage designs are used specifically with robotic arms, whether the arm is attached to a robot or is a stand-alone mechanism.
- *Android*. Android robots are specifically modeled after the human form and are the type most people picture when talk turns to robots. Realistically, android designs are the most restrictive and least workable, inside or outside the robot lab.

This book provides designs and construction details for at least one robot in every one of the preceding types except *Android*. I'll leave that to another book.

FLESH AND BONE

In the 1926 movie classic *Metropolis*, an evil scientist, Dr. Rotwang, transforms a cold and calculating robot into the body of a beautiful woman. This film, generally considered to be the first science fiction cinema epic, also set the psychological stage for later movies, particularly those of the 1950s and 1960s. The shallow and stereotypical character of Dr. Rotwang, shown in the movie still in Fig. 2.3, proved to be a common theme in countless movies. The shapely robotrix changed form for these other films, but not its evil character. Robots have often been depicted as metal creatures with hearts as cold as their steel bodies.

Which brings us to an interesting question: Are all "real" robots made of heavy-gauge steel, stuff so thick that bullets, disinto-ray guns, even atomic bombs can't penetrate? Indeed, while metal of one kind or another is a major component of robot bodies, the list of materials you can use is much larger and diverse. Hobby robots can be easily constructed from aluminum, steel, tin, wood, plastic, paper, foam, or a combination of them all:

FIGURE 2.3 The evil Dr. Rotwang and the robot, from the classic motion picture *Metropolis.*

- *Aluminum.* Aluminum is the best all-around robot-building material for medium and large machines because it is exceptionally strong for its weight. Aluminum is easy to cut and bend using ordinary shop tools. It is commonly available in long lengths of various shapes, but it is somewhat expensive.
- *Steel.* Although sometimes used in the structural frame of a robot because of its strength, steel is difficult to cut and shape without special tools. Stainless steel is sometimes used for precision components, like arms and hands, and also for parts that require more strength than a lightweight metal (such as aluminum) can provide. Expensive.
- *Tin, iron, and brass.* Tin and iron are common hardware metals that are often used to make angle brackets, sheet metal (various thickness from 1⁄32 inch on up), and (when galvanized) nail plates for house framing. Brass is often found in decorative trim for home construction projects and as raw construction material for hobby models. All three metals are stronger and heavier than aluminum. Cost: fairly cheap.
- *Wood.* Surprise! Wood is an excellent material for robot bodies, although you may not want to use it in all your designs. Wood is easy to work with, can be sanded and sawed to any shape, doesn't conduct electricity (avoids short circuits), and is available everywhere. Disadvantage: ordinary construction plywood is rather weak for its weight, so you need fairly large pieces to provide stability. Better yet, use the more dense (and expensive) multi-ply hardwoods for model airplane and sailboat construction. Common thicknesses are ¼- to ½-inch—perfect for most robot projects.
- *Plastic.* Everything is going plastic these days, including robots. Pound for pound, plastic has more strength than many metals, yet is easier to work with. You can cut it, shape it, drill it, and even glue it. To use plastic effectively you must have some special tools, and extruded pieces may be hard to find unless you live near a well-stocked plastic specialty store. Mail order is an alternative.
- *Foamboard.* Art supply stores stock what's known as "foamboard" (or "Foam Core"), a special construction material typically used for building models. Foamboard is a sandwich of paper or plastic glued to both sides of a layer of densely compressed foam. The material comes in sizes from ⅛ inch to over ½ inch, with ¼ to ⅓ inch being fairly common. The board can be readily cut with a small hobby saw (paper-laminated foamboard

can be cut with a sharp knife; plastic-laminated foamboard should be cut with a saw). Foamboard is especially well suited for small robots where light weight is of extreme importance.

- *Rigid expanded plastic sheet.* Expanded sheet plastics are often constructed like a sandwich, with thin outer sheets on the top and bottom and a thicker expanded (air-filled) center section. When cut, the expanded center section often has a kind of foam-like appearance, but the plastic itself is stiff. Rigid expanded plastic sheets are remarkably lightweight for their thickness, making them ideal for small robots. These sheets are known by various trade names such as *Sintra* and are available at industrial plastics supply outlets.

Power Systems

We eat food that is processed by the stomach and intestines to make fuel for our muscles, bones, skin, and the rest of our body. While you could probably design a digestive system for a robot and feed it hamburgers, french fries, and other semi-radioactive foods, an easier way to generate the power to make your robot go is to take a trip to the store and buy a set of dry-cell batteries. Connect the batteries to the robot's motors, circuits, and other parts, and you're all set.

TYPES OF BATTERIES

There are several different types of batteries, and Chapter 15, "All about Batteries and Robot Power Supplies," goes into more detail about them. Here are a few quick details to start you off.

Batteries generate DC current and come in two distinct categories: rechargeable and nonrechargeable (for now, let's forget the nondescriptive terms like *storage*, *primary*, and *secondary*). *Nonrechargeable* batteries include the standard zinc and alkaline cells you buy at the supermarket, as well as special-purpose lithium and mercury cells for calculators, smoke detectors, watches, and hearing aids. A few of these (namely, lithium) have practical uses in hobby robotics.

Rechargeable batteries include nickel-cadmium (Ni-Cad), gelled electrolyte, sealed lead-acid cells, and special alkaline. Ni-Cad batteries are a popular choice because they are relatively easy to find, come in popular household sizes ("D," "C," etc.) and can be recharged many hundreds of times using an inexpensive recharger. Gelled electrolyte ("Gel-cell") and lead-acid batteries provide longer-lasting power, but they are heavy and bulky.

ALTERNATIVE POWER SOURCES

Batteries are required in most fully self-contained mobile robots because the automaton cannot be connected by power cord to an electrical socket. That doesn't mean other power sources, including AC or even solar, can't be used in some of your robot designs. On the contrary, stationary robot arms don't have to be capable of moving around the room; they are designed to be placed about the perimeter of the workplace and perform within this predefined area. The motors and control circuits may very well run off AC power, thus freeing you from replacing batteries and worrying about operating times and recharging periods.

This doesn't mean that AC power is the preferred method. High-voltage AC poses greater shock hazards. Should you ever decide to make your robot independent, you must also exchange all the AC motors for DC ones. Electronic circuits ultimately run off DC power, even when the equipment is plugged into an AC outlet.

One alternative to batteries in an all-DC robot system is to construct an AC-operated power station that provides your robot with regulated DC juice. The power station converts the AC to DC and provides a number of different voltage levels for the various components in your robot, including the motors. This saves you from having to buy new batteries or recharge the robot's batteries all the time.

Small robots can be powered by solar energy when they are equipped with suitable solar cells. Solar-powered robots can tap their motive energy directly from the cells, or the cells can charge up a battery over time. Solar-powered 'bots are a favorite of those in the "BEAM" camp—a type of robot design that stresses simplicity, including the power supply of the machine.

PRESSURE SYSTEMS

Two other forms of robotic power, which will not be discussed in depth in this book, are hydraulic and pneumatic. *Hydraulic* power uses oil or fluid pressure to move linkages. You've seen hydraulic power at work if you've ever watched a bulldozer move dirt from pile to pile. And while you drive you use it every day when you press down on the brake pedal. Similarly, *pneumatic* power uses air pressure to move linkages. Pneumatic systems are cleaner than hydraulic systems, but all things considered they aren't as powerful.

Both hydraulic and pneumatic systems must be pressurized to work, and this pressurization is most often performed by a pump. The pump is driven by an electric motor, so in a way robots that use hydraulics or pneumatics are fundamentally electrical. The exception to this is when a pressurized tank, like a scuba tank, is used to provide air pressure in a pneumatic robot system. Eventually, the tank becomes depleted and must either be recharged using some pump on the robot or removed and filled back up using a compressor.

Hydraulic and pneumatic systems are rather difficult to implement effectively, but they provide an extra measure of power in comparison to DC and AC motors. With a few hundred dollars in surplus pneumatic cylinders, hoses, fittings, solenoid valves, and a pressure supply (battery-powered pump, air tank, regulator), you could conceivably build a hobby robot that picks up chairs, bicycles, even people!

Locomotion Systems

As mentioned earlier, some robots aren't designed to move around. These include robotic arms, which manipulate objects placed within a work area. But these are exceptions rather than the rule for hobby robots, which are typically designed to get around in this world. They do so in a variety of ways, from using wheels to legs to tank tracks. In each case, the locomotion system is driven by a motor, which turns a shaft, cam, or lever. This motive force affects forward or backward movement.

WHEELS

Wheels are the most popular method for providing robots with mobility. There may be no animals on this earth that use wheels to get around, but for us robot builders it's the simple and foolproof choice. Robot wheels can be just about any size, limited only by the dimensions of the robot and your outlandish imagination. Turtle robots usually have small wheels, less than two or three inches in diameter. Medium-sized rover-type robots use wheels with diameters up to seven or eight inches. A few unusual designs call for bicycle wheels, which despite their size are lightweight but very sturdy.

Robots can have just about any number of wheels, although two is the most common. The robot is balanced on the two wheels by one or two free-rolling casters, or perhaps even a third swivel wheel. Four- and six-wheel robots are also around. You can read more about wheel designs in Part 3.

LEGS

A small percentage of robots—particularly the hobby kind—are designed with legs, and such robots can be conversation pieces all their own. You must overcome many difficulties to design and construct a legged robot. First, there is the question of the number of legs and how the legs provide stability when the robot is in motion or when it's standing still. Then there is the question of how the legs propel the robot forward or backward—and more difficult still!—the question of how to turn the robot so it can navigate a corner.

Tough questions, yes, but not insurmountable. Legged robots are a challenge to design and build, but they provide you with an extra level of mobility that wheeled robots do not. Wheel-based robots may have a difficult time navigating through rough terrain, but leg-based robots can easily walk right over small ditches and obstacles.

A few daring robot experimenters have come out with two-legged robots, but the challenges in assuring balance and control render these designs largely impractical for most robot hobbyists. Four-legged robots (*quadrapods*) are easier to balance, but good locomotion and steering can be difficult to achieve. I've found that robots with six legs (called *hexapods*) are able to walk at brisk speeds without falling and are more than capable of turning corners, bounding over uneven terrain, and making the neighborhood dogs and cats run for cover. Leg-based robots are discussed more fully in Chapter 22, “Build a Heavy-duty, Six-legged Walking Robot,” where you can learn more about the Walkerbot, a brutish, insectlike ‘bot strong enough to carry a bag of groceries.

TRACKS

The basic design of *track-driven* robots is pretty simple. Two tracks, one on each side of the robot, act as giant wheels. The tracks turn, like wheels, and the robot lurches forward or backward. For maximum traction, each track is about as long as the robot itself.

Track drive is practical for many reasons, including the fact that it makes it possible to mow through all sorts of obstacles, like rocks, ditches, and potholes. Given the right track material, track drive provides excellent traction, even on slippery surfaces like snow, wet concrete, or a clean kitchen floor. Alas, all is not rosy when it comes to track-based robots. Unless you plan on using your robot exclusively outdoors, you should probably stay away from track drive. Making the drive work can be harder than implementing wheels or even legs.

Arms and Hands

The ability to manipulate objects is a trait that has enabled humans, as well as a few other creatures in the animal kingdom, to manipulate the environment. Without our arms and hands, we wouldn't be able to use tools, and without tools we wouldn't be able to build houses, cars, and—hmmm, robots. It makes sense, then, to provide arms and hands to our robot creations so they can manipulate objects and use tools. A commercial industrial robot "arm" is shown in Fig. 2.4. Chaps. 24 through 27 in Part 4 of this book are devoted entirely to robot arms and hands.

You can duplicate human arms in a robot with just a couple of motors, some metal rods, and a few ball bearings. Add a gripper to the end of the robot arm and you've created a complete arm-hand module. Of course, not all robot arms are modeled after the human appendage. Some look more like forklifts than arms, and a few use retractable push rods to move a hand or gripper toward or away from the robot. See Chapter 24, "An Overview of Arm Systems," for a more complete discussion of robot arm design. Chaps. 25 and 26 concentrate on how to build several popular types of robot arms using a variety of construction techniques.

STAND-ALONE OR BUILT-ON MANIPULATORS

Some arms are complete robots in themselves. Car manufacturing robots are really arms that can reach in just about every possible direction with incredible speed and accuracy. You can build a stand-alone robotic arm trainer, which can be used to manipulate objects within a defined workspace. Or you can build an arm and attach it to your robot. Some arm-robot designs concentrate on the arm part much more than the robot part. They are, in fact, little more than arms on wheels.

GRIPPERS

Robot hands are commonly referred to as *grippers* or *end effectors*. We'll stick with the simpler sounding "hands" and "grippers" in this book. Robot grippers come in a variety of styles; few are designed to emulate the human counterpart. A functional robot claw can be built that has just two fingers. The fingers close like a vise and can exert, if desired, a surprising amount of pressure. See Chapter 27, "Experimenting with Gripper Designs" for more information.

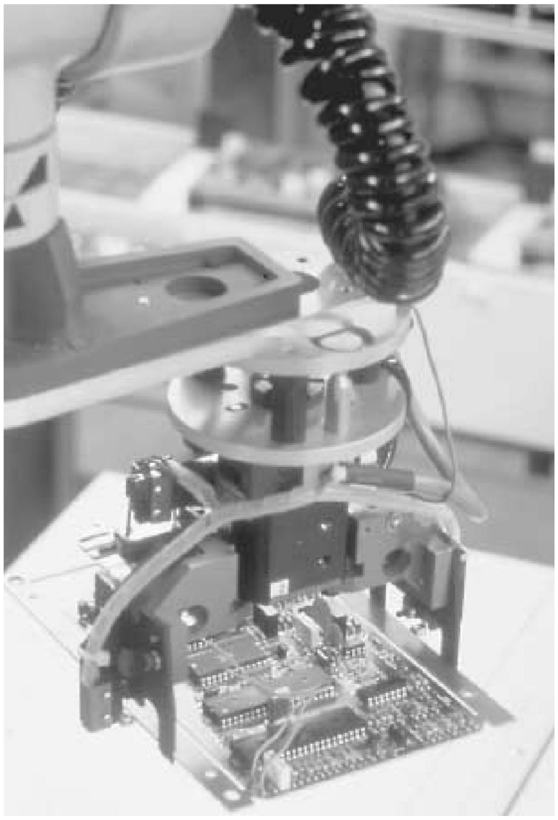

FIGURE 2.4. A robotic arm from General Electric is designed for precision manufacturing. Photo courtesy General Electric.

Sensory Devices

Imagine a world without sight, sound, touch, smell, or taste. Without these senses, we'd be nothing more than an inanimate machine, like the family car, the living room television, or that guy who hosts the Channel 5 late-night movie. Our senses are an integral part of our lives—if not life itself.

It makes good sense (pardon the pun) to build at least one of these senses into your robot designs. The more senses a robot has, the more it can interact with its environment. That capacity for interaction will make the robot better able to go about its business on its own, which makes possible more sophisticated tasks. Sensitivity to *sound* is a sensory system commonly given to robots. The reason: Sound is easy to detect, and unless you're trying to listen for a specific kind of sound, circuits for sound detection are simple and straightforward.

Sensitivity to *light* is also common, but the kind of light is usually restricted to a slender band of infrared for the purpose of sensing the heat of a fire or navigating through a room using an invisible infrared light beam.

Robot eyesight is a completely different matter. The visual scene surrounding the robot must be electronically rendered into a form the circuits on the robot can accept, and the machine must be programmed to understand and act on the shapes it sees. A great deal of experimental work is underway to allow robots to distinguish objects, but true robot vision is limited to well-funded research teams. Chapter 37, "Robotic Eyes," provides the basics on how to give crude sight to a robot.

In robotics, the sense of *touch* is most often confined to collision switches mounted around the periphery of the machine. On more sophisticated robots, pressure sensors may be attached to the tips of fingers in the robot's hand. The more the fingers of the hand close in around the object, the greater the pressure detected by the sensors. This pressure information is relayed to the robot's brain, which then decides if the correct amount of pressure is being exerted. There are a number of commercial products available that register pressure of one kind or another, but most are expensive. Simple pressure sensors can be constructed cheaply and quickly, however, and though they aren't as accurate as commercially manufactured pressure sensors, they are more than adequate for hobby robotics. See Chapter 35, "Adding the Sense of Touch," and Chapter 36, "Collision Avoidance and Detection," for details.

The senses of smell and taste aren't generally implemented in robot systems, though some security robots designed for industrial use are outfitted with a gas sensor that, in effect, smells the presence of dangerous toxic gas.

Output Devices

Output devices are components that relay information from the robot to the outside world. A common output device in computer-controlled robots (discussed in the next section) is the video screen or (liquid crystal display) panel. As with a personal computer, the robot communicates with its master by flashing messages on a screen or panel. A more common output device for hobby robots is the ordinary light-emitting diode, or a seven-segment numeric display.

Another popular robotic output device is the speech synthesizer. In the 1968 movie *2001: A Space Odyssey*, Hal the computer talks to its shipmates in a soothing but electronic voice. The idea of a talking computer was a rather novel concept at the time of the movie, but today voice synthesis is commonplace.

Many hobbyists build robots that contain sound and music generators. These generators are commonly used as warning signals, but by far the most frequent application of speech, music, and sound is for entertainment purposes. Somehow, a robot that wakes you up to an electronic rendition of Bach seems a little more human. Projects in robot sound-making circuits are provided in Chapter 40, "Sound Output and Input."

Smart versus "Dumb" Robots

There are smart robots and there are dumb robots, but the difference really has nothing to do with intelligence. Even taking into consideration the science of *artificial intelligence*, all self-contained autonomous robots are fairly unintelligent, no matter how sophisticated the electronic brain that controls it. Intelligence is not a measurement of computing capacity but the ability to reason, to figure out how to do something by examining all the variables and choosing the best course of action, perhaps even coming up with a course that is entirely new.

In this book, the difference between dumb and smart is defined as the ability to take two or more pieces of data and decide on a preprogrammed course of action. Usually, a *smart* robot is one that is controlled by a computer. However, some amazingly sophisticated actions can be built into an automaton that contains no computer; instead it relies on simple electronics to provide the robot with some known "behavior" (such is the concept of BEAM robotics). A *dumb* robot is one that blindly goes about its task, never taking the time to analyze its actions and what impact they may have.

Using a computer as the brains of a robot will provide you with a great deal of operating flexibility. Unlike a control circuit, which is wired according to a schematic plan and performs a specified task, a computer can be electronically "rewired" using software instructions—that is, programs. To be effective, the electronics must be connected to all the *control* and *feedback* components of the robot. This includes the drive motors, the motors that control the arm, the speech synthesizer, the pressure sensors, and so forth. Connecting a computer to a robot is a demanding task that requires many hours of careful work. This book presents several computer-based control projects in later chapters.

Note that this book does not tell you how to construct a computer. Rather than tell you how to build a specially designed computer for your robot, the projects in this book use readily available and inexpensive *microcontrollers* and *single-board computers* as well as ready-built personal computers based on the ubiquitous IBM PC design. You can permanently integrate some computers, particularly the portable variety, with your larger robot projects.

The Concept of Robot "Work"

The term *robota*, from which the common word *robot* is derived, was first coined by Czech novelist and playwright Karel Capek in his 1917 short story "Opilec." The word *robota* was used by Capek again in his now-classic play *R.U.R.* (which stands for "Rossum's Universal Robots"), first produced on stage in 1921. *R.U.R.* is one of many plays written by Capek that have a utopian theme. And like most fictional utopias, the basic premise of the play's "perfect society" is fatally flawed. In *R.U.R.* the robots are created by humans to take over all labor, including working on farms and in factories. When a scientist attempts to endow the robot workforce with human emotions—including pain—the automatons conspire against their flesh-and-bone masters and kill them.

In Czech, the term *robota* means "compulsory worker," a kind of machine slave. In many other Baltic languages the term simply means "work." It is the *work* aspect of robotics that is often forgotten, but it defines a "robot" more than anything else. A robot that is not meant to do something—for example, one that simply patrols the living room looking for signs of warm-blooded creatures—is not a robot at all but merely a complicated toy.

That said, designing and building lightweight "demonstrator" robots provides a perfectly valid way to learn about the robot-building craft. Still, it should not be the end-all of your robot studies. Never lose sight of the fact that *a robot is meant to do something*—the more, the better! Once you perfect the little tabletop robot you've been working on the past several months, think of ways to apply your improved robot skills to building a more substantial robot that actually performs some job. The job does not need to be labor saving. We'd all like to have a robot maid like Rosie the Robot on the *Jetsons* cartoon series, but, realistically, it's a pretty sophisticated robot that knows the difference between a clean and dirty pair of socks left on the floor.

From Here

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