Chapter 1

An Introduction to Robotics and Stiquito

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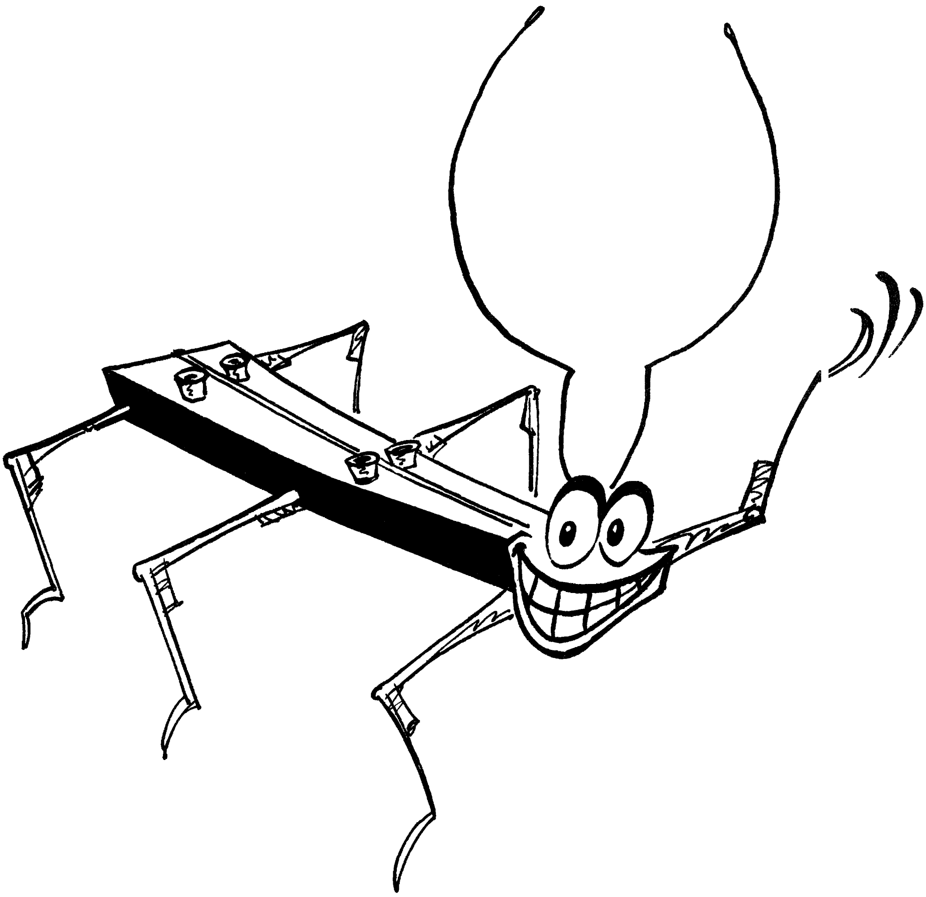

INTRODUCTION

Welcome to the wonderful world of robotics! This book will give you a unique opportunity to learn about this field in a way that has not been offered before. This book may also be the first affordable educational book to describe a robot **and** include the robot with the book! This book will provide you with the skills and equipment to build a small robot and with instructions on how to build electronic controls for your robot.

The star of this book is Stiquito, a small, inexpensive hexapod (six-legged) robot. Stiquito has been used since 1992 by universities, high schools, and hobbyists. It is unique not only because it is so inexpensive but because its applications are limitless.

This chapter will present an overview of robotics, the origin of Stiquito, and suggestions for how to proceed with reading the book and building the kit.

FIRST, SOME WORDS OF CAUTION

This warning will be given frequently, but it is one that all potential builders must heed. Building the robot in this kit requires certain skills to produce a working robot. These hobby building skills include:

- Tying thin metal wires into knots
- Cutting and sanding small lengths (4 mm) of aluminum tubing
- Threading the wire through the tubing
- Crimping the aluminum tubing with pliers
- Stripping insulation from wire
- Patiently following instructions that require 3 to 6 hours to complete

ROBOTICS

The field of robotics means different things to different people. Many conjure up images of R2-D2 or C-3PO-like devices from the *Star Wars* movies. Still others think of the character Data from the TV show *Star Trek: The Next Generation.* Few think of vehicles or even manufacturing devices, and yet robots are predominantly used in these areas. Our definition of a robotic device shall be: any electro-mechanical device that is given a set of instructions from humans and repeatedly carries out those instructions until instructed to stop. Based on this definition, building and programming a toy car to follow a strip of black tape on the floor is an example of a robotic device, but building and driving a radio-controlled toy car is not.

The term *robot* was created by Carl Capek, a Czechoslovakian playwright. In his 1921 play *RUR (Russums Universal Robots),* humans create mechanical devices to serve as workers.[1] The robots turn on their creators, thus setting up years of human versus machine conflicts.

The term *robotics* was coined by science fiction author Isaac Asimov in his 1942 short story "Runaround."[2] Asimov can be considered to be the biggest fan of robotics: he wrote more than 400 books in his lifetime, many of them about or including robots. His most famous and most often cited writing is his "Three Laws of Robotics," which he first introduced in "Runaround." These laws describe three fundamental rules that robots must follow to operate without harming their human creators. The laws are:

1. A robot may not injure a human being, or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First and Second Laws.

These laws provide an excellent framework for all current and future robotic devices. There are many different types of robots. The classical robots depicted in science fiction books, movies, and television shows are typically walking, talking humanoid devices. However, the most useful and prevalent robot in use in the United States today is the industrial arm robot used in manufacturing. These robotic devices precisely carry out repetitive and sometimes dangerous work. Unlike human workers, they do not need coffee breaks, health plans, or vacations, although they do require maintenance and the occasional sick day. You may have seen an example of these robotic arms in auto maker commercials where an automobile body is welded and painted. Figure 1.1 shows an example of a small robotic arm manufactured by Seiko Instruments USA, Inc.

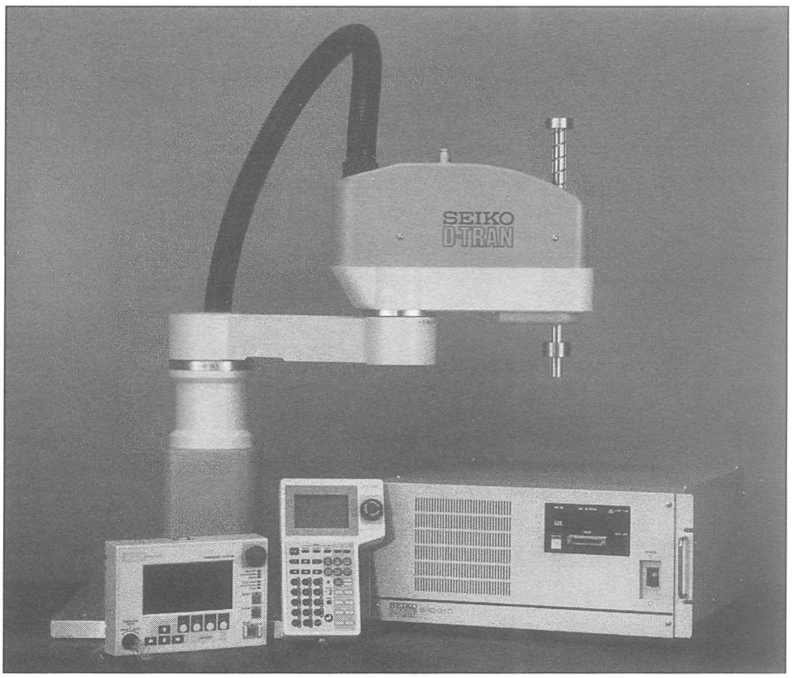

Figure 1.1. Robotic arm device. Used by permission of Seiko Instruments USA, Inc.

Another type of robot used in industry is the autonomous wheeled vehicle. These robots are used for surveillance or to deliver goods, mail, or other supplies. These robots follow a signal embedded in the floor, rely on preprogrammed moves, or guide themselves using cameras and programmed floor plans. An example of an autonomous wheeled robot, shown in Figure 1.2, is the SR 3 Cyberguard by Cybermotion.[3] This device will travel through a warehouse or industrial building looking for signs of fire or intrusion.

Figure 1.2. The SR 3 Cyberguard Autonomous Robot. Used by permission of Cybermotion, Inc.

Although interest in walking robots is increasing, their use in industry is very limited. Walking robots have advantages over wheeled robots when traversing rocky or steep terrain. One robot recently walked into the crater of a volcano and gathered data in an area too hazardous for humans to venture. Researchers at the University of Illinois have built a large walking robot, Protobot (Figure 1.3), based on the physiology of a cockroach.[4] Although humor columnist Dave Barry likens this 2-foot creature to a "FrankenRoach,"[5] the robot's designers envision such devices scurrying in hazardous environments and even adapting to the loss of a limb.

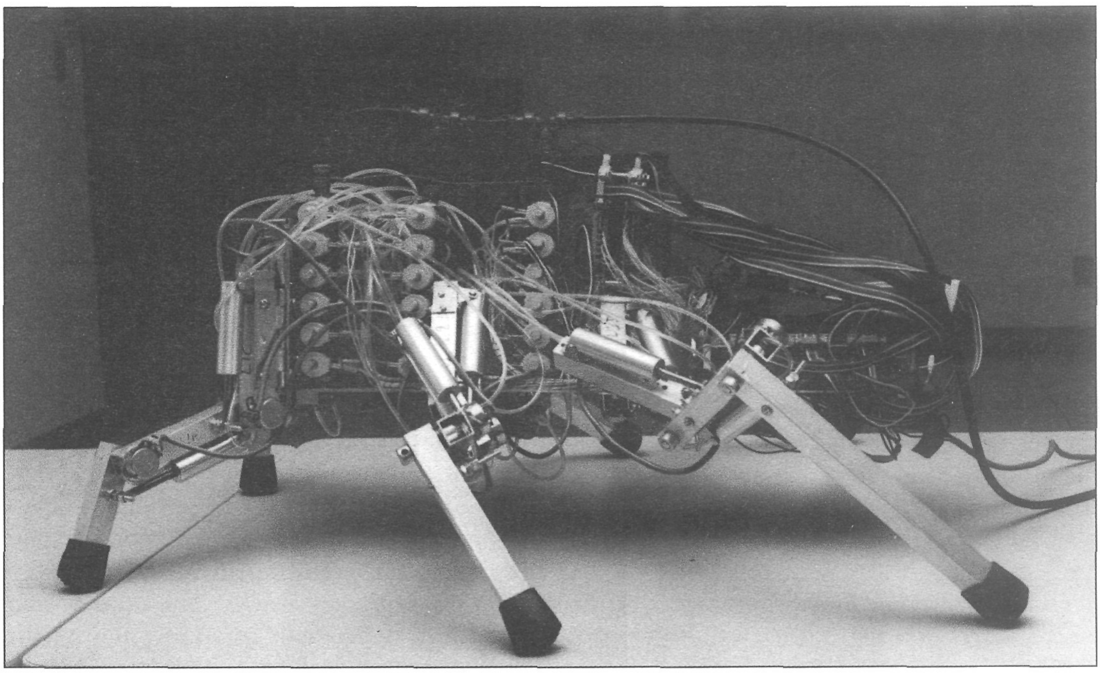

Figure 1.3. Protobot, a cockroach-inspired walking robot. Used by permission of IEEE CS Press.

Most walking robots do not take on a true biological means of propulsion, defined as the use of contracting and relaxing muscle fiber bundles. The means of propulsion for most walking robots is either pneumatic air or motors. Protobot approaches a biological construction because it walks by means of pneumatic cylinders that emulate antagonistic muscle pairs.

True muscle-like propulsion did not exist until recently. A new material, nitinol, is used to emulate the operation of a muscle. Nitinol has the properties of contracting when heated and returning to its original size when cooled. An opposable force is needed to stretch the nitinol back to its original size. This new material has spawned a plethora of new small walking robots that originally could not be built with motors. Although several of these robots were designed in the early 1990s, one of them has gained international prominence because of its low cost. This robot is called Stiquito.

STIQUITO

In the early 1990s, Dr. Jonathan Mills was looking for a robotic platform to test his research on analog logic. Most platforms were prohibitively expensive, especially for a young assistant professor with limited research money. Since necessity is the mother of invention, Dr. Mills set out to design his own inexpensive robot. He chose four basic materials from which to base his designs:

- For propulsion, he selected nitinol (specifically, Flexinol™ from Dynalloy, Inc.). This material would provide a muscle-like reaction for his circuitry and would closely mimic biological actions. More detail on nitinol is provided in Chapter 4. Other sources contain detailed specifications on Flexinol™.[6]
- For a counterforce to the nitinol, he selected music wire from K & S Engineering. The wire could serve a force to stretch the nitinol back to its original length and provide support for the robot.
- For the body of the robot, he selected ⅛-inch square plastic rod from Plastruct, Inc. The plastic is easy to cut, drill, and glue. It also has relatively good heat-resistive properties.
- For leg support, body support, and attachment of nitinol to plastic he chose aluminum tubing from K & S Engineering.

Dr. Mills experimented with various designs, from a tiny four-legged robot 2 inches long to a floppy six-legged, 4-inch long robot. Through this experimentation he found that the best movement of the robots was realized when the nitinol was parallel to the ground, and the leg part touching the ground was perpendicular to the ground.

The immediate predecessor to Stiquito was Sticky, a large hexapod robot. Sticky is 9 inches long by 5 inches wide by 3 inches high. It contains nitinol wires inside aluminum tubes. The tubes are used primarily for support. Sticky can take 1.5 cm steps, and each leg had two degrees of freedom. Two degrees of freedom means that nitinol wire is used to pull the legs back (first degree) and raise the legs (second degree).

Sticky was not cost effective, so Dr. Mills used the concepts of earlier robots with the hexapod design of Sticky to create Stiquito (which means "little Sticky"). Stiquito was originally designed for only one degree of freedom but has a very low cost. Two years later, Dr. Mills designed a larger version of Stiquito, called Stiquito II, which had two degrees of freedom.[7] A picture of Stiquito II is shown in Figure 1.4.

At about the same time that Dr. Mills was experimenting with these legged robots, Roger Gilbertson of MondoTronics and Mark Tilden of Los Alamos Labs were also experimenting with nitinol. Gilbertson and Tilden's robots are described in our first Stiquito book.

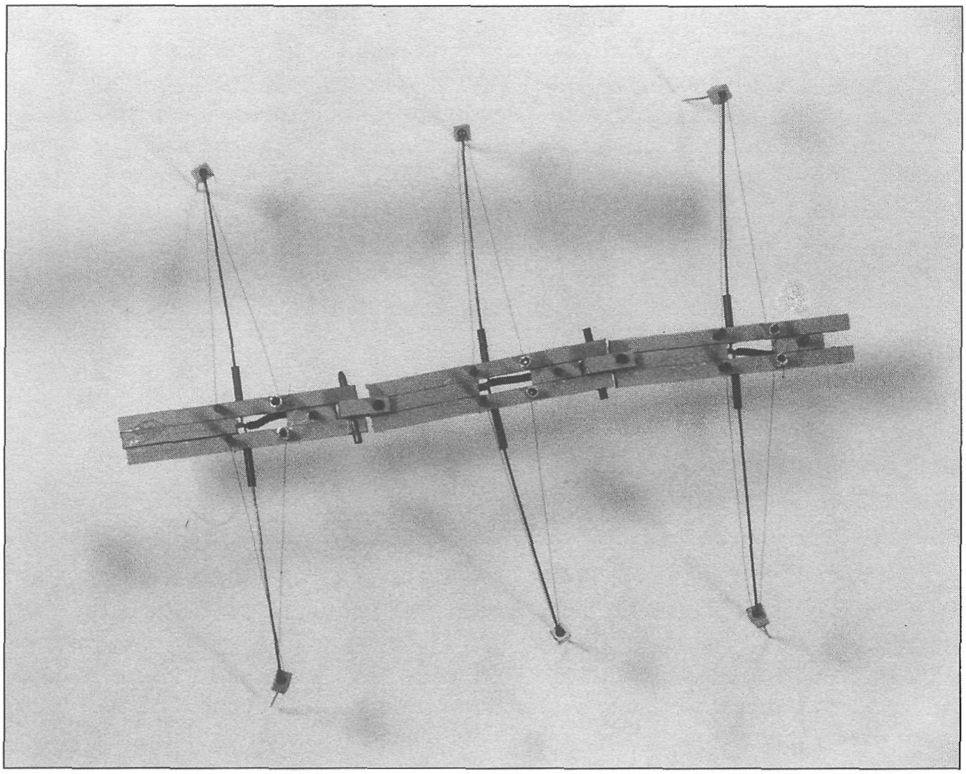

Figure 1.4. The Stiquito II robot.

THE STIQUITO KIT

The kit included with this book has enough materials to make one Stiquito robot, although there are extra components in case you make a few errors while building the robot. The most important thing to remember when building this kit is that Stiquito is a hobby kit; it requires hobby-building skills, like cutting, sanding, and working with very small parts. For example, in one of the steps, you will need to tie a knot in the nitinol wire. Nitinol is very much like thread, and it is very difficult to tie a knot in it. However, if you take time and be patient (and after some practice), you will soon be able to tie knots like a professional.

The kit included with this book is a simplification of the original Stiquito described in Dr. Mills' technical report[8] and offered as a kit from Indiana University. In your kit the plastic Stiquito body has been premolded, so now you no longer have to cut, glue, and drill the plastic rod to make the body. Because of this simplification, more than 10 pages were removed from the original instructions. This new body also allows builders to make more errors, and requires less precision when building the robot; therefore, your robot should be more robust than earlier models.

The intent of this kit is to allow builders to create a platform from which they can start experimenting. The instructions provided in Chapter 5 show how you can create a Stiquito that walks in a tripod gait; that is, it allows three legs to move at one time. What you should do is to examine your goals for building the Stiquito and plans for controlling how Stiquito walks. If your plans include allowing each of Stiquito's six legs to be controlled independently, then you should modify the assembly of your robot to attach control wires to each leg. If the design of your robot includes putting something on top, for example a circuit that will allow it to walk on its own, you should consider how you want it to walk. If you want it to walk simply (as in Chapter 6), a tripod gait may be sufficient. If you plan to put some complex circuitry like a microcontroller on top, you may want the flexibility to control all six legs.

The Stiquito robot body was also designed so you can assemble it using screws instead of aluminum crimps. If you wish to use screws instead of crimps, use the sets of holes on the body that are offset slightly. See Appendix C for an example of using screws in building Stiquito.

The Stiquito body is also designed so that all 12 large holes can be used for allowing the legs to have two degrees of freedom (just like Sticky and Stiquito II). You cannot control this robot with the manual controller, but you can control it with the PC parallel port card described in Chapter 7.

Chapter 5 has very detailed assembly instructions, but here are some additional handy hints:

- This is not Lego®. Stiquito is not a snap-together, easy-to-build kit. As a hobby kit, it takes some model building skills. Be patient! Allow 6 hours to build your first robot. Dr. Mills swears he can build a robot in 1 hour, but it takes me about 3 (while watching sports on TV). This could be a wonderful parent-child project (in fact, my elementary school-aged son wants to "build bugs with daddy"). Make sure to block out enough time to complete the kit.
- Make sure you do not introduce any shorts across the control and ground wires on the robot, tether, or manual controller. Feel free to use electrical tape to insulate areas that might cause a short.
- Make sure all electrical connections are clean and free of corrosion. Sand metal parts before tying, crimping, or attaching.
- You may need to add some weight to Stiquito when using the manual controller. You can tape pennies to the bottom of the body or tape a AA battery on top. Make sure the weight does not short the control and ground wires.

In your building activities, we cannot stress the importance of following common safety practices:

- Wear goggles when working with the kit. Many parts of the kit act as sharp springs!
- Use care when using a hobby knife. Always cut away from you.
- Use care when using a soldering iron. Watch out for burns!

This kit is intended for adults and for children over the age of 14.

EDUCATIONAL USES OF STIQUITO

One of the main functions of this book is to provide an environment for educators to introduce robotics and robotic control to students. This book can be used at the high school or university level to introduce students to the concepts of analog electronics, digital electronics, computer control, and robotics. Since this book comes complete with assembly instructions and a robot kit, it can easily serve as a required textbook for a class with only a minimal amount of electronics required to investigate the other areas.

The Stiquito robot also provides opportunities to learn about other engineering disciplines. For example, previous exercises using Stiquito have included creating Stiquito kits similar to what was found in the back of the book from raw products. Given long lengths of music wire, long lengths of aluminum tubing, spools of wire, and bags of other parts, fill a small plastic bag with the parts necessary to build Stiquito later. This requires students to contemplate Industrial Engineering concepts, including assembly lines and materials handling. A description of this exercise can be found on the IEEE Computer Society Press's Stiquito web page at: http://computer.org/books/stiquito.

As with any project conducted in a school setting, you will need additional supplies for those cases when students break their robot kit. Contact the IEEE Computer Society Press to purchase additional kits, or contact some of the suppliers listed in the back of the book for repair materials.

WHAT NEXT?

Now that you have read the Preface and Chapter 1, you should have a good idea of the contents of this book. You need to consider your goals with respect to Stiquito. If you are a student and this book is assigned by your instructor, this process may have been already determined (but you can always do more!). Use the chapters of the book

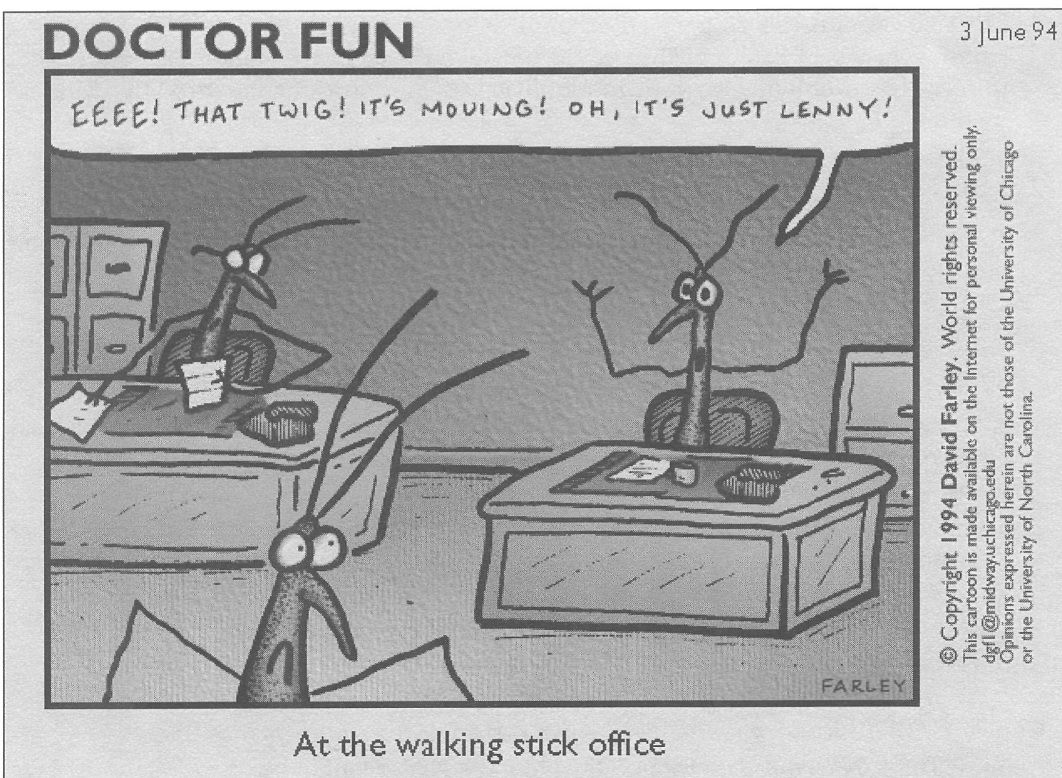

Figure 1.5. A favorite Stiquito builder cartoon.

that help you attain your goals. Remember, you can always buy more kits from the publisher (IEEE CS Press) if your goal is to build more than one robot.

EXERCISES

1. Consider the three Laws of Robotics.
   - Can you think of a situation where the three Laws of Robotics would fail in their intent?
   - Do the three Laws of Robotics take into account the competing goals of good and evil?
2. Read the Isaac Asimov short story "Runaround." This story can be found in many compilations of his short stories like *The Complete Robot* or *I, Robot.* Check your school or local library for these books. Why did the robot Speedy fail?
3. List all the robots you have seen. Identify if these are manufacturing robots or autonomous robots. Use the definition given in this chapter to categorize these machines.
4. Muscle-like contractions of wire propel the Stiquito robot. Can you think of any other machines that have muscle-like motion?
5. Search your library or the World Wide Web for information about insectoid robots. List the types of insects that engineers are trying to replicate.
6. Most successful robots perform a small range of activities very well. Identify a small, real-world problem that could be solved with a new robot. Design a robot to solve the problem. Use your imagination. Some solutions invented by students include:
   - A woodpecker-like robot to drive nails in inaccessible surfaces
   - A snake-like robot to traverse drain pipes and clear clogs
7. Today's successful mobile robots typically use wheels for movement. For example, Cyberguard and mail/food delivery robots use wheels. Of course, in nature there are no wheels.
   a. Identify the advantages and disadvantages of wheeled autonomous robots.
   b. Identify the advantages and disadvantages of legged autonomous robots.
   c. Which type of robot would work best on flat terrain? Which would work best in rough, sloped terrain? Which would work best indoors? Which would work best in a football stadium? Justify your answers.
   d. Based on your answers to parts a, b, and c, which approach holds the most promise for future applications?

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