Chapter 1

An Introduction to Robotics and Stiquito

Welcome to the wonderful world of robotics and embedded systems! This third book in the Stiquito series will give you an unique opportunity to learn about these fields in a way that has not been offered before. This book may also be the first affordable educational book to describe an autonomous robot and include the robot with the book! This book will provide you with the skills and parts to build a very small robot. This book also has a radical feature not seen in many books currently on the market (if any). We have designed and populated a printed circuit board for attaching to the top of the Stiquito robot. This board contains a microcontroller that drives the legs of your Stiquito robot. This circuit board is the result of several iterations of design and testing by several people.

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 hobbyist. 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 in order to produce a good 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,
- Soldering a few wires to a circuit board (just three), and
- Patiently following instructions that require two to four hours to complete.

Robotics

The field of Robotics means different things to different people. Many conjure up images of R2D2 or 3CPO-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. Therefore, a "Battle-bot" is not really a robot.

The term “robot” was created by Carl Capek, a Czechoslovakian playwright. In his 1921 play RUR (Russums Universal Robots) [Capek 1972], humans create mechanical devices to serve as workers. The robots turn on their creators, thus setting up years of human versus machine conflicts.

The term “robotics” was first coined by science fiction author Isaac Asimov in his 1942 short story “Runaround” [Asimov 1982]. 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 in order to operate without harming their human creators. The laws are:

- A robot may not injure a human being, or, through inaction, allow a human being to come to harm.
- A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
- 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 US 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 (but they do need 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 shows an example of a small robotic arm manufactured by Seiko Instruments USA, Inc.

Insert Figure 1 here. A photograph of the Seiko robotic arm (From the archives of book 2).

Figure 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 2, is the SR 3 Cyberguard by Cybermotion [Cybermotion 1999]. This device will travel through a warehouse or industrial building looking for signs of fire or intrusion.

Insert Figure 2 here: a photograph of the SR3 Cyberguard (Use the same photo as in book 1/2)

Figure 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. Still, walking robots have been popular in the "entertainment" market. Walking robots have advantages over wheeled robots when traversing uneven terrain. Two recent entertainment robots are dogs: the Tiger/Silverlit i-Cybie (retailing for $200) and the Sony Aibo (retailing for $1600). The i-Cybie was not successful in the market and was discontinued, but has a devoted following. It has a distinct feature of being the lowest-price programmable entertainment robot. Sony has now produced three generations of the Aibo. They also sell a development kit for reprogramming the robot.

Insert Figure 3 here: photographs of the Aibo and i-Cybie robots

Figure 3: The programmable Aibo and i-Cybie entertainment robots (Used by Permission of Sony and Silverlit corporations, respectively)

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. 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 have been 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™ [Dynalloy].
- For a counter-force 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 1/8” 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 two inches long, to a six-floppy-legged, four-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” long by 5” wide by 3” 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) as well as 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 [Conrad and Mills 1997]. A picture of Stiquito II is shown in Figure 4.

Insert Figure 4 here: a photograph of Stiquito II

Figure 4: The Stiquito II Robot.

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 the first Stiquito book [Conrad and Mills 1997].

The original Stiquito kit included in *Stiquito: Advanced Experiments* [Conrad and Mills 1997] and *Stiquito for Beginners* [Conrad and Mills 1999] relied on aluminum crimps for anchoring the Flexinol to the legs and body. Through experimentation and user comments, we have changed the assembly procedure to now include screws. This new Stiquito kits is named "Stiquito III".

The Stiquito III Kit

The kit that is included with this book has enough materials to make one Stiquito robot, although there are enough 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, soldering, 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 have time and patience (and after some practice), you will soon be able to tie knots like a professional.

The kit that is included with this book is a simplification of the original Stiquito described in Jonathan Mills' Technical report [Mills 1992] and offered as a kit from Indiana University. In your kit the plastic Stiquito body has been pre-molded, so now you no longer have to cut, glue, and drill the plastic rod to make the body. The addition of screws also makes it easier to build and provides the perfect interface to the printed circuit board.

Remember that Stiquito is not Lego® -- this is not a snap-together, easy to build kit. This is a hobby kit, so it takes some model building skills. Be patient! Make sure all electrical connections are clean and free of corrosion. Sand metal parts before tying, crimping, or attaching. Allow four hours to build your first robot. Jonathan swears he can build a robot in one hour, but it takes me about two (while watching sports on TV). This could be a wonderful parent-child project (in fact, my junior high school-aged daughter wants to "build bugs with dad"). Make sure to block out enough time to complete the kit.

The intent of this kit is to allow the builder to create a platform from which they can start experimenting. The instructions provided in Chapter 2 show how you can create a Stiquito that walks in a tripod gait, that is, it allows three legs to move at one time via control from the printed circuit board. What you should do is to examine your goals for building the Stiquito robot and plans for controlling how Stiquito walks. If your plans include a two-degrees of freedom robot, then you should modify the assembly of your robot such that you attach two Flexinol wires to each leg. If the design of your robot includes adding sensors to the printed circuit board on top, you should consider the function and weight of the added circuitry and programming of the robot.

This book can be used on its own for an Introduction to Robotics class or it can be used as a supplement in many different types of classes. Previous Stiquito books have been used in high schools in an Introduction to Technology class, in community colleges as an Introduction to Robotics class, and in universities in many different classes: First Year Engineering, Introduction to Electrical Engineering, Introduction to Robotics, Introduction to Bioengineering, Robotics, and Senior Capstone projects. This book, *Stiquito Controlled!,* can be used for those courses as well as for an Introduction to Embedded Systems course. How you use this book is, of course, up to you, but there are several suggestions of chapters for those who may want to use this book in classes. Since this book comes complete with assembly instructions as well as a robot kit, it can easily serve as a required textbook for a class with only a minimal amount of additional electronics required to investigate the other areas.

- Chapter 1 discusses an introduction to robotics and introduces Stiquito to those who may not be familiar with it. It should be used in all classes since it provides a good background to students.
- Chapter 2 shows how to build Stiquito for use with the microcontroller printed circuit board. These new instructions no longer have the manual controller included in the assembly process. Again, it is a central part of the book and should be used in all classes.
- Chapter 3 is an introduction to the discipline of embedded systems. It discusses microprocessors, microcontrollers, and complete computer systems. It should be used in all classes since it provides a broad assessment of technology central to the control of Stiquito and other robots.
- Chapter 4 is an introduction to the design and manufacture of printed circuit boards. This is of particular interest to Electrical Engineers and Roboticists, and should be included in these courses.
- Chapter 5 describes the Stiquito printed circuit board in more detail. It provides hardware interfacing instructions and programming steps for the Texas Instruments MSP430 microcontroller on the board. This chapter should be used in robotics and embedded systems courses.
- The Stiquito body is also designed such that all twelve large holes can be used for allowing the legs to have two degrees of freedom (just like Sticky and Stiquito II). Chapter 6 describes another type of microcontroller-based Stiquito which uses two degrees of freedom (lifting legs, as well as moving legs forward) to have Stiquito walk like a real insect. This chapter should be used in robotics and embedded systems courses.

- Chapter 7 describes how to experiment with different types of leg lengths and assembly designs, as well as gaits. This chapter should be used in robotics courses.
- In Chapter 8 we describe some additional research areas and ideas that you can explore on your own. We provide several short examples of what others have done with Stiquito. This can be used in all courses.

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

Some final comments . . .

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.

So what is next, you ask? Now that you have read the Preface and Chapter 1, you should have a good idea of the content of this book. You need to think of 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 that help you reach your goals. Remember, you can always buy more kits from the publisher (Wiley Books) if your goal is to build more than one robot.

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