

STUFFING MORE LEARNING INTO THE COMPUTER ENGINEERING CURRICULUM BAG: CAPSTONE COURSE PREPARATION

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Abstract ^{3/4} Today's university Computer Engineering curriculum is typically of a broad range of diverse topics. Often a student's first opportunity to link their diverse topics together to a common goal occurs during their last semester in their senior capstone course. Also, the curriculum requires common engineering and liberal arts courses which further strain the typical student's ability to cover Computer Engineering topics in much depth. A short elective summer course was offered for rising juniors. This course provided an introduction to embedded computer systems and exposed students to other computer engineering topics. It also served as a "capstone project dry run."

Index Terms ^{3/4}Capstone, Computer Engineering, Hands-on, Senior Design.

INTRODUCTION

Today's university Computer Engineering curriculum rarely allows a student a chance to take a course that pulls together many diverse topics into a single project. Often their first opportunity to do this occurs during their last semester in their senior capstone course. Also, the curriculum often contains some holes that would be beneficial to address before students take advanced Computer Engineering courses. This situation was observed by a faculty member at North Carolina State University while teaching an introductory microprocessor course. Students were asking for recommendations of microprocessor courses where they could build systems, but these were not available until senior year.

To meet these two objectives, a short elective summer course was offered for rising juniors. This course provided an introduction to embedded computer systems and exposed students to other computer engineering topics. Students developed a basic understanding of embedded computer system architecture; learned to program embedded computer systems; built embedded systems, including digital and analog I/O devices; and learned how simple I/O devices are controlled by microprocessors. The class used lecture and lab to solidify concepts on embedded systems.

The culmination of the class was a project competition at the end of the semester. Students worked on the project using skills learned through the semester. They discovered the value of code reuse from earlier labs and of task scheduling and project management. All of these skills learned will help the students during their capstone project.

The class was very well received, and more students have asked for the course to be repeated this summer.

This paper describes the content, motivation, and results of the summer course. The sections include:

- Objectives and flow of the course.
- Stiquito, the small robot used as the platform for designing a microprocessor system.
- PC parallel port controller hardware and software.
- Microprocessor examples and programming.
- Lab exercises.
- The final project.
- Relevance to the capstone course.

OBJECTIVE OF THE COURSE

The objective of this class was to build a small robot and use microprocessor technology to make it walk and sense its environment. Students used the Stiquito robot, a PC parallel port controller, and a Basic Stamp 2.

This course also provided an introduction to an embedded computer systems and it exposed students to computer engineering topics. During this course, students developed a basic understanding of embedded computer system architecture; learned to program embedded computer systems; and learned how simple I/O devices are controlled by microprocessors. The course used one lecture and one lab per week to solidify concepts on embedded systems.

The typical student was a rising Junior, although the class included Sophomores and Seniors. All students had taken the introductory computer engineering course and had programmed in Assembly Language, Java, and C. All students had a background in digital logic, but many had not taken the analog electronics course yet. Their electronics skills typically did not include soldering and wire wrapping, but included bread boarding. Students were from several engineering departments.

The following material was required to be purchased by the student:

- The book *Stiquito for Beginners: An Introduction to Robotics* [1]. \$30.
- PC Parallel Port Controller Kit, \$10 (purchased by each lab pair)

Additional lab supplies and tools provided by the NCSU Electrical and Computer Engineering Department:

- Basic Stamp 2 Board of Education, Parallax, Inc. (one for each lab pair).

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- Parallax Basic Stamp User's Guide, Parallax, Inc. (in developer kit, and on web).
- Miscellaneous hardware (ULN2803, transistors, perf board, sensors, connectors)
- PC with parallel/serial port
- Soldering station
- Multi-meters, power supplies

THE STIQUITO ROBOT

Stiquito (Figure 1) is a small, inexpensive hexapod (i.e., six-legged) robot. It has been used since 1992 by universities, high schools, and hobbyists. Stiquito is unique not only because it is so inexpensive but also because its applications are almost limitless.

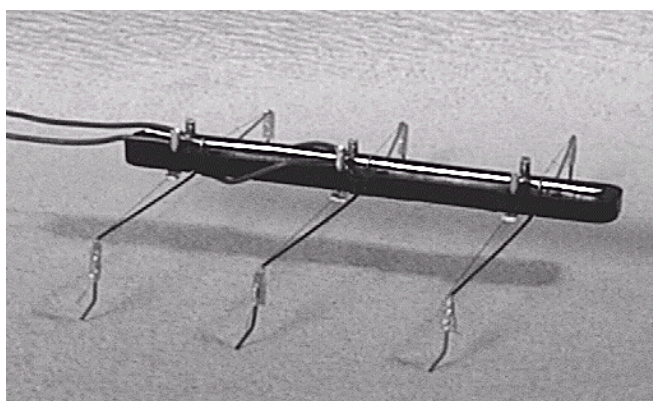


FIGURE 1
THE STIQUITO ROBOT

Stiquito was developed by Jonathan Mills of Indiana University as an inexpensive vehicle for his research. He soon found its applications extended to educational uses. It has been used to introduce students to the concepts of analog electronics, digital electronics, computer control, and robotics.

The IEEE Computer Society Press has published two books on Stiquito: *Stiquito: Advanced Experiments with a Simple and Inexpensive Robot* [2] and *Stiquito for Beginners: An Introduction to Robotics* [1]. These books contain instructions for building the Stiquito robot, instructions for designing and building control circuits, and examples of student projects that use Stiquito. Most importantly, the books contain all the supplies needed to build the robot. Only a few tools are needed to assemble a complete Stiquito. Since both books include assembly instructions as well as materials to build a robot, either can easily serve as a required textbook for a class, with only minimal electronics required to extend investigation to other areas.

The Stiquito robot also provides opportunities for examining various engineering disciplines, like Computer Science, Electrical Engineering, and Mechanical Engineering. Often, when studying a topic, students are

only provided the theory, written assignments, and basic experiments and are not given an opportunity to build an actual application or implementation -- something they can call their own and take with them. The Stiquito robot can be used to fill the gap between theory and application.

PC PARALLEL PORT CONTROLLER

During the early weeks of the class each student constructed a Stiquito robot and made it walk using a PC parallel port interface circuit (Figure 2) and software. This gave students the experience of working with small parts and some basic knowledge of how to go about programming a robot to walk. They soldered the parts on the printed circuit board and checked their work. For some, this was their first time handling a soldering iron.

Basic parallel port drivers for windows were provided to the students. Using the C programming language they programmed various LED-flashing patterns first to practice computer control, then wrote code to accept input (button pushes). Finally, they programmed various walking gaits using the Stiquito Robot they built for an earlier lab.

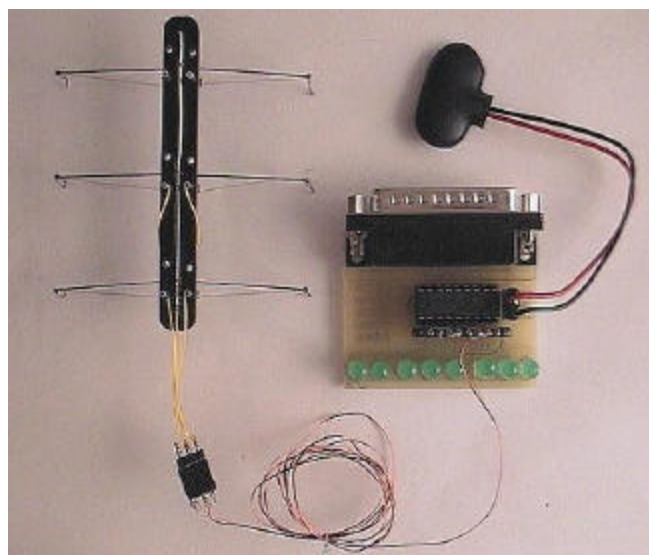


FIGURE 2
A SIMPLE PC PARALLEL PORT CONTROLLER FOR MAKING THE STIQUITO ROBOT WALK

MICROPROCESSOR EXAMPLES

The Basic Stamp 2 microcontroller (Figure 3), sold by Parallax Incorporated, was also used to realize Stiquito walking gaits. The Basic Stamp 2's dimensions are 1 3/16 inches by 5/8 inches by 3/8 inches, and weighs only 0.02 pounds. The Basic Stamp 2 contains a PIC16C57 (interpreter chip) microcontroller, runs at the speed of 20 MHz, uses 2 kilobytes of EEPROM and includes 32 bytes of RAM [3,4]. The microcontroller interprets BASIC language programs for instructions. The Basic Stamp 2 has 16

input/output pins and a total of 24 pins. It needs 7 milliamps of current to run, and 50 microamps of current to sleep. It can also provide source current of 20 milliamps and sink 25 milliamps of current. This makes it an excellent platform for examining small embedded applications, although its lack of interrupts make it less than perfect.

Labs examined control and input; students flashed LEDs and accepted push button input, similar to what was done with the PC controller board. Later, the same tethered Stiquito was used to examine walking gaits controlled by the Basic Stamp 2.

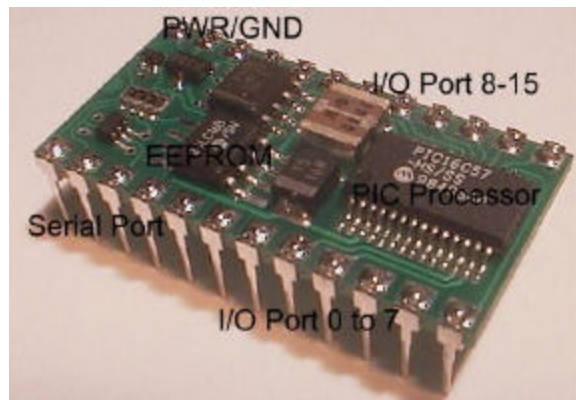


FIGURE 3
THE PARALLAX BASIC STAMP 2 MICROCONTROLLER

LAB EXERCISES

Students worked on labs in pairs. A considerable amount of time and thought was required in the labs. It was stressed that because almost all of us learn by doing, the laboratory was probably be the most effective method for learning the material. Students learned to take lab notes, and use the notes for their final paper. A lab journal was frequently examined. Lab pairs demonstrated their work at the end of their eight labs.

The Lab topics were:

- (1) Build a manual controlled Stiquito
- (2) Solder a PC Parallel Port Controller and test
- (3) Write a program (in C) to control the parallel port board (output-Stiquito gait w/LEDs)
- (4) Write a program (in C) to accept input from the parallel port controller
- (5) Build a tether and program a pulse-width modulated gait for Stiquito
- (6) Program an LED on the Basic Stamp 2 board
- (7) Develop Stiquito code on Basic Stamp - Gaits using LEDs
- (8) Program input on the Basic Stamp 2 board

THE FINAL PROJECT

The culmination of the class was a Stiquito walking contest at the end of the semester. Students worked on the project

using skills learned through the semester. They discovered the value of code reuse from earlier labs and of task scheduling and project management. These skills will be quite helpful for their future Senior Design Project. The lab pair also wrote a project report in the form of a magazine article. The objective was to submit the article to a magazine, like *Circuit Cellar Ink* or *Robot Science and Technology*, for eventual publication. The project results and final report were part of the final grade.

This race had specific design rules and restrictions that the students had to follow. The students actually helped define these rules, with guidance from the instructor. The rules for the race and the requirements for the robot were that the robot:

- must use nitinol (Flexinol) for locomotion
- must use legs in its propulsion (two or more legs required)
- must walk four times its length in the fastest amount of time on smooth Formica
- must have an on-board microprocessor
- must stop walking via sensor input
- must measure no greater than 12 inches long by 12 inches wide
- would be given multiple trials, with the best time taken for competition comparison
- would be allowed to have either external (tethered) or attached power supply

Since the robot for the race was not required to be a Stiquito some students opted to construct their own, larger versions of a walking insect. Most decided to keep the original Stiquito base design and modify it a bit (Figure 4). By adding a second degree of motion, upwards, the Stiquito no longer dragged its feet but instead lifted them into the air while moving forward to greatly reduce friction.

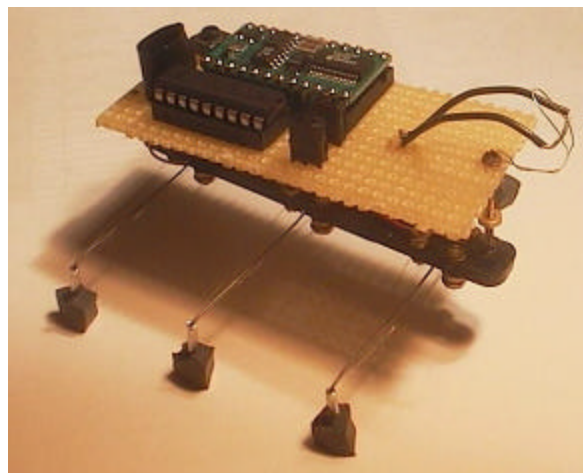


FIGURE 4
THE TYPICAL FINAL PROJECT ENTRY

Because the Stiquitos had a tripod gait and two degrees of freedom, it was necessary to design a state diagram to

create a stable and efficient walking pattern. Using the Parallax "Board of Education" during labs, students became fairly proficient in programming the Basic Stamp 2 chip and were ready to add it to their autonomous robot. After programming the BASIC Stamp 2 with code, it was removed from the Parallax "Board of Education" and placed in their circuit boards attached to the Stiquito. This was repeated many times as students began to make the final adjustments to give their Stiquito optimal performance for the race.

Race day (Figure 5) was a media extravaganza. It was held during the regular meeting of a local robotics club. A local TV station visited to tape the contest and aired footage during their evening newscast.

The first place robot won with an elapsed time of 41 seconds, the second place robot finished in 61 seconds, and the third place robot took 61.6 seconds to complete the 30 cm. "course". Some groups did not finish the race. Also, some robots did not look anything like Stiquito.

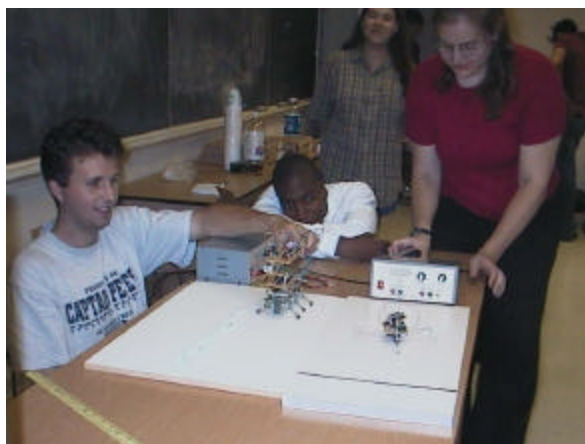


FIGURE 5
RACE DAY!

HOW THIS COURSE PREPARES STUDENTS FOR THE CAPSTONE COURSE

One of the goals of this course was to better prepare students for their Senior Design Capstone course. Throughout the semester, student assignments in this "pre-project" course included activities that they would use during the capstone course, including:

- Project identification. Students identified the project they wished to complete and submitted a one page proposal to the instructor. The project was approved or rejected. Rejected projects could be resubmitted. Several projects were rejected for being either too simple or too complex. These situations were shared with the class (with names removed) so that all students could learn project scope.
- Project design. Students wrote a detailed design document describing the technical aspects of the project. These design documents were reviewed by

the entire class. This taught students the importance of an accurate and complete design.

- Project planning. Students submitted a project schedule with specific milestones. This taught students how to identify amounts of work and create small deadlines, instead of one big one at the end.
- Lab notebook. Students were required to keep a notebook with all of their lab observations included. Their books were checked each lab session by the instructor. Project notebooks are required for their capstone project, and this class activity taught them to embrace this habit early.

CONCLUSIONS

Final evaluations for the class were excellent. Without the dynamic "teach then do" course structure, the student designs would never have been achievable. Furthermore, it was the instructor's participation in both the lecture and labs that afforded the students with necessary feedback and interaction to learn and practice the skills needed for the final project, and for future design projects. One testament for the value of the class is the long waiting list for students wishing to take it during the summer of 2002. One student article has been published as a result of the class [3], another is in process. To assess the value of this course, we will analyze the Senior Design course grades of participants in this class and compare them with the average Senior Design course grade. Our hope is that we will show that this "pre-project" project course will better prepare students for the capstone course and for employment.

There were lessons learned which will be incorporated in future classes, like making more electrical parts available to students and having students build an RS-232C interface into their robots (too many Basic Stamp 2 chips ended up with broken leads from too many removals). Overall, it was an enjoyable class that now has great interest among Computer Engineering students.

ACKNOWLEDGMENT

A special thanks to the students who participated in the NCSU course ECE 292D for their enthusiasm for the topic and efforts in the final race.

REFERENCES

- [1] Conrad, James M. and Jonathan W. Mills, *Stiquito for Beginners: An Introduction to Robotics*, IEEE Computer Society Press, Los Alamitos, CA, 1999.
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