Using a Mechatronics Independent Study Course to Develop New Course Materials and Train Students for Research

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Abstract

It can be very difficulty for today's young faculty members to find the time required to develop new courses and establish a research program while continuing to dedicate the time necessary for students in their regular teaching load. One way to maximize the benefit of time spent is to teach small independent study courses that evaluate course material to be used later in new course offerings. Teaching independent study courses of six to eight students does not require the course material to be completely polished, and the students can be evaluated without spending a lot of time grading written homework or exams. Furthermore, the students can be used to develop projects and handouts that will later be used as hands-on laboratory exercises or classroom demonstrations. At the same time, the students are getting the background necessary for them to be valuable to a research program.

This paper presents the results of teaching an independent study course in mechatronics to a group of six mechanical engineering students. The course included both undergraduate and graduate students working in teams of two. The first ten weeks of the course included weekly projects to teach the students the basics of microprocessors and electronics. For the last six weeks of the course, each group was given a design project that used the skills developed in the first ten weeks of the course. Student feedback is included with a commentary about the successes and failures of the project.

The course was determined to be successful for both the students and the professor. The students were able to learn a great deal about mechatronics while developing their communication skills, and they developed a great deal of pride in the fact that they had helped develop teaching tools that could be used to instruct future students. In addition, the graduate students involved in the project were given the preparation they needed to begin graduate thesis projects in mechatronics.

Introduction

After teaching a normal course load, advising students, grading papers, and writing proposals for funding there is little time left for young faculty members to develop the new courses they would like to offer. In addition, as a faculty member seeking tenure, it is difficult to devote time to developing new courses or laboratory exercises because they are often perceived as not as valuable as bringing in external funds and presenting research in refereed journals. This paper presents a way to "multi-task" and develop new course material while preparing graduate students to do research that will later turn in to publications and help with external funding efforts. Specifically, a mechatronics course was developed in an independent study course atmosphere using six students (four undergraduate and two graduate).

The objective of the mechatronics course was to give students the background and experience necessary to design and build electromechanical devices in an industrial setting or as a part of graduate research. The plan was to use simple hands-on project work and a final design project to teach students the basics needed for electromechanical design. This paper discusses the development of the hands-on project work in an independent study atmosphere and presents some of the successes and failures of the independent study course.

The first ten weeks of the course involved the students working in groups of two to complete basic projects in mechatronics. The projects included the design and construction of electric circuits, interfacing and using microprocessors, and an introduction to sensors and actuators. At the completion of each project, the students made a short oral presentation of their work. The last six weeks of the course were used construct mechatronics devices. Each group of students was presented with a different project where they applied what they had learned, did independent research into more advanced sensors and actuators, and completed the design and construction of working mechatronic devices.

Basic Projects

The microprocessor chosen for this course is manufactured by Netmedia, and is called the "BasicX". The processor is about the size of a postage stamp (shown in figure 1) and is programmed in a form of Basic making it relatively easy for students to learn how to program[1]. All of the students who were taking the course had already completed a course in C programming, so they only needed to adapt to the new programming language. A development board made by Netmedia was also used for this course (shown in figure 2). The BasicX is similar to a processor called the Basic Stamp, produced by Parallax, that is used by many universities who are teaching mechatronics courses. The BasicX was chosen over the Basic Stamp for several reasons. The BasicX is capable of floating-point arithmetic, supports interrupts, has an on-board analog to digital converter, and has more EEPROM.

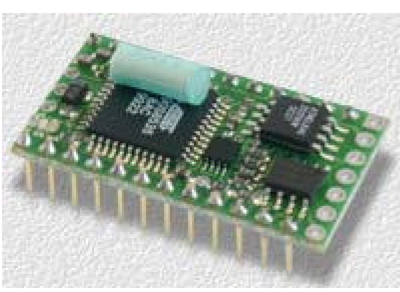

figure 1: The BasicX

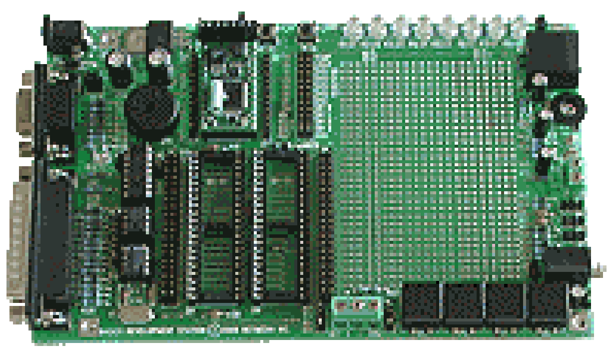

figure 2: BasicX Development Board

Because this course was taught in the Mechanical Engineering Department, the students had very little experience in building electric circuits and no experience using microprocessors. To compensate for this lack of experience, the first projects of the course included an introduction to programming the microprocessor and building basic circuits. The coursework then progressed to include projects with RC circuits, voltage dividers circuits, LEDs and switches, infrared sensors, seven-segment displays, timing functions, analog to digital conversion, H-bridges and motor control. A complete description of the projects is given in the appendix.

Final Projects

After completing the first ten weeks of simple projects, the students were feeling very comfortable using the microprocessors with different sensors and actuators and were ready to begin more substantial projects. The three groups were allowed to come up with their own project or choose from a list of example projects. One group designed their own project and two groups chose from the list.

The group that designed their own project decided to build a scale model of an elevator controlled by a microprocessor. They constructed a four-floor elevator that stood about two feet tall. The students used an H-bridge and motor in conjunction with infrared sensors to move the passenger compartment accurately from floor to floor. They used push button switches to call the elevator to each floor and diodes to display the current position of the elevator. Another motor was used to open and close the doors as the compartment reached each floor.
Of course, the microprocessor was used to control the entire system making decisions using data from the sensors to make sure each operation was executed correctly.

A second group of students decided to construct a portable weather station[4] using a microprocessor to interpret the data from the various sensors. The station included the measurement of temperature, wind direction, wind speed, and relative humidity. Temperature was measured using a thermistor in conjunction with an RC circuit. Wind direction was measured by connecting a flat panel to a ten-turn potentiometer and using the microprocessor to interpret the wind direction in relation to the resistance of the potentiometer. Wind speed was determined by counting the number of switches in a hall effect sensor that was connected to a set of rotating fins in a given time period. A specialized sensor was purchased for measuring humidity. All of the data was collected by the microprocessor and displayed on a PC monitor.

The final group chose to work on a method for locating the heads of screws counter sunk in to a flat plate. This was actually a small part of a larger project to develop an autonomous vehicle to perform eddy current analysis to find cracks around screw fasteners. The group was asked to evaluate different methods for locating the screw heads including using a laser emitting diode and light sensor or by performing pattern recognition using the signal from a camera.

Instructor Observations

Overall, the instructor was very satisfied with the outcome of this course. The time spent was minimal considering the benefit, the students understood the course material and were motivated to continue working on future projects in mechatronics, and the course projects were greatly improved for future use. The instructor also recognized a few precautions that needed to be taken concerning student learning in an independent study forum.

The total time the instructor spent on this course was about five hours per week. The preparation time was about two hours per week and consisted mainly of gathering reference materials and developing the short projects. Another two hours was spent on a scheduled weekly meeting where the students demonstrated their completed projects and were given information about the new projects. The last hour was spent working out small problems with the projects on an individual basis.

It was very clear from the students' oral presentations that they did get a good understanding of the course material. Giving them a good oral description of the project and adequate reference material worked very effectively and helped motivate them toward life-long learning. Many of the students were able to find outside sources of information that the instructor had not considered using. One group of students was even able to apply the knowledge (and the microprocessor) they used in this course to complete a final project for another course they were taking.

Another very valuable outcome of this course was the time it is currently saving in preparation for the final version of the mechatronics course. The instructor is indeed teaching a full version of the mechatronics course this semester using the same basic projects that were used in the independent study course. Because the projects are now well defined and most of the problems are worked out, time does not need to be taken each week for the instructor to build the projects and work out all the details. Instead, preparation time is used to create a self-paced manual that describes each project and lets the students complete them on their own. The manual also points out potential mistakes that the students in the independent study course made so that they can be avoided.

There are some very important precautions that should be taken with students in an independent study setting as described in this paper. First, rigid deadlines must be established. Because this course is not as structured as typical undergraduate courses, there is a tendency for students to put off completing the projects if they have a busy week with other classes. To discourage procrastination, rigid deadlines must be established with substantial penalties for not completing projects by the deadlines. Second, it must be established early on that this is indeed an independent study course and students will be expected to try to find solutions to problems on their own before turning to the instructor. This point should be made clear during the first course meeting, and reinforced when students visit the instructor's office. This not only helps develop student's problem solving abilities and motivate life-long learning, but it also saves the instructor from spending unnecessary time solving problems that the students could easily handle on their own. Finally, it is important that the instructor is very thorough in evaluating the student's projects. From the first project evaluation it must be made clear to the students that they need to not only complete the project, but that they will also be required to demonstrate their knowledge of the subject matter and be able to apply it to other situations. Because the students are not being asked to review the subject material to prepare for an exam, it is very important that they are required to thoroughly examine the material before giving the presentations. If they do not spend time reviewing and reflecting on what is important from the projects, they will not retain what they have learned.

Student Feedback

Because of the small class size, it was possible to interview all of the students to determine their opinions at the conclusion of the course. The students first interviewed each other and formed opinions about the successes and failures of this course. Then, each of the students had a one-on-one interview with the professor where their shared their opinions along with those of their classmates.

Every one of the six students was very satisfied with the material covered in the course. They also expressed appreciation for being able to take a course that was hands-on and that had direct applications in both graduate studies and in industrial positions. They liked being able to work independently on the weekly projects with a well-defined goal in mind. Two of the students also expressed pride in the fact that they were instrumental in developing a course that would be taught to future students.

The only negative feedback was that there was not enough time allowed for the final projects. In fact, none of the student finished their final projects by the end of the semester. They were given extra time and completed the projects after the semester had ended. The lack of time was partially due to a strike that completely closed the university for one and a half weeks, partially due to waiting for backordered components to arrive, and partially due to lack of foresight on the part of the instructor.

Results

The small projects that the students completed during the first ten weeks of this course were very successful. Through this work, the students were able to acquire valuable skills in mechatronics and apply them to real situations in the final projects. The students enjoyed the projects and they were able retain the knowledge because of the reinforcement through applications.

The final projects were also very beneficial for the students. They were a good way to reinforce the concepts that had been covered throughout the semester and motivate the students for future learning. The students learned how to independently find information about specific sensors and actuators that were necessary for their projects even though those sensors had not been used in the smaller projects. They also had a great feeling of accomplishment as their projects came together and were glad they had taken the course.

Conclusions

There are many important factors that helped make this course a success. First, having high quality, mature students was of the utmost importance. The six students that were chosen for this course were upper-class undergraduates and graduate students and were some of the best students in their perspective classes. The course only had one official meeting per week, so it was extremely important that each of the students was highly motivated to work independently and not afraid to approach the instructor with questions that arose during the week. The second factor that helped insure success was having students that communicated and worked well with others. Because the course material was being tested for the first time, problems often occurred during the weekly projects that were not anticipated. Communication between the groups of students and the desire to help each other was very beneficial. Finally, setting strict deadlines was extremely important to getting the course material covered. Students displayed the tendency to put off working on the weekly projects when they had exams or projects due in other courses. Maintaining rigid deadlines was the only way to keep them on track.

Some improvements could have been made to help the final projects go a little bit smoother. In order to help insure students had enough time to complete the final projects, work should have begun on the final projects while the students were completing the preliminary material. For example, students should have been required to decide on a final project and prepare a list of necessary materials after the first six weeks of class. This would have avoided delays due to parts being backordered from suppliers. Students also spend a lot of time constructing the mechanical parts of their projects. The physical construction could have easily begun while they were completing the preliminary projects. Imposing deadlines to each stage of the final project would have been another way to help insure completion of the final projects on time. Because the final projects were at the end of the semester, the students often gave precedence to coursework from other classes that did have specific deadlines. Better preliminary planning on the part of the instructor and rigid deadlines would have helped the students to complete the projects on time. All things considered, completing the projects after the semester was over did not have really have an adverse effect on the outcome of the course, but the students would have been more satisfied if the projects could have been completed on time.

Although this independent study course did have a few bumps along the way, it did turn out to be a good way to prepare material for a new course in mechatronics. In fact, the instructor is currently teaching an advanced elective course in mechatronics to fifteen students. The same material from the weekly projects, with the bugs worked out, is being organized in the form of a weekly handout for the students to read and complete independently. The final projects will again be assigned in the new course with the improvements made that have been mentioned.

In addition to the development of new course material, the graduate students received valuable training in the independent study course. The two graduate students that participated in the course are currently both working on masters thesis projects in mechatronics. The independent study course provided them with valuable skills that they did not get during their bachelors degrees. Offering the course was a great way for the instructor to teach them the necessary skills, while developing material for a new course at the same time. This time savings was beneficial to both the students and the instructor. All things considered, offering the independent study course was a very good way to prepare course material and insure the quality of the new course in mechatronics while teaching graduate students valuable skills to help them with their thesis work.

Bibliography

1. Netmedia Inc., Support Documents for BX-24 Basic Express Microprocessor version 1.46, Tucson, AZ, 2000.
2. Kiefer S., Thrower J.P., Silverberg L., Kelmer K., “Experiments in PID Control for Non-electrical Engineers”, available at www.ece.uprm.edu/~kiefer, 1998.
3. Dietz P., “A Pragmatic Introduction to the Art of Electrical Engineering”, unpublished course manuscript downloaded from the Parallax website (www.parallax.com), 1999.
4. Culbreth W., “Meeting the Needs of Industry: Development of a Micorcontroller Course for Mechanical Engineers”, Proceedings of the 2001 ASEE Annual Conference, 2001.

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Appendix – Basic Projects

The philosophy of the mechatronics course was to begin by teaching the students the basics of electromechanical design through small projects and conclude by having the students design and construct their own mechatronic device. The small projects are detailed in this appendix.

The first week was dedicated to familiarizing the student with the microprocessor. They were asked to complete a simple program that would send a message back to the computer monitor. They needed to install the software, connect the microprocessor to a PC using the serial port, and successfully write and download a program with a loop that would write the a simple phrase to the PC monitor every five seconds.

To familiarize the students with breadboards, building circuits, and calculating voltages and currents, the next project involved several simple tasks using a light emitting diode (LED), a switch, a circuit with a resistor and a capacitor (RC circuit), infrared sensors, and the microprocessor[2,3]. The students were first asked to find the resistance required to limit the current to the operational range of the LED[3]. Then, they were required to design and build a circuit using a breadboard that would use the microprocessor to make the LED turn on depending on the position of the switch. Next, the students were asked to build an RC circuit to delay the lighting of the LED[2]. Finally, to introduce students to infrared sensors, the switch was replaced with an infrared emitter and collector pair so that the LED would turn on when the path between infrared pair was broken.

By the third project, the students had gained confidence and were ready to handle more complicated tasks. They were given a seven-segment display (with a wiring diagram) and a push-button switch[3]. They were instructed to first wire the seven-segment display so that it could be used to display the numbers in order from zero through nine indexing by one each second. Then, the students were instructed to build a project that would count the number of times a button was pressed in ten seconds and output the number to the numeric display. They were given documentation about the timer that is included in the microprocessor circuitry and how to debounce a switch[1].

The students were now ready to advance past the simple control of electrical devices and learn a little more about how the processor worked and the difference between analog and digital devices. To demonstrate the difference between analog and digital, the students were asked to build a simple eight-bit digital to analog converter[3] using the resistor network shown in figure 3. They were first asked to calculate the voltage output at the point shown for each of the eight possible pin outputs (each pin zero or five volts). Then, they built the circuit and verified their calculations. After building the digital to analog converter, a class discussion was held to talk about how the microprocessor was only capable of outputting zero or five volts at each pin. However, by combining three pins and some resistors it was possible to create different output voltages at points between zero and five volts (a digital to analog converter) [3]. Another discussion took place about the difference between eight, sixteen, and thirty-two bit processors.

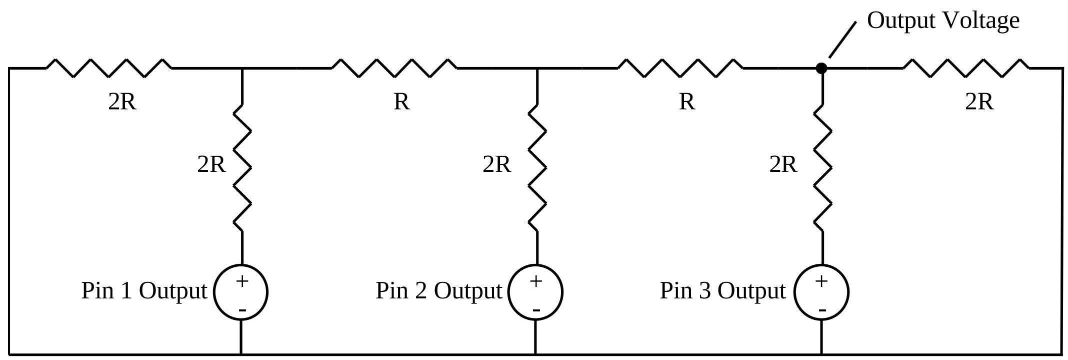

figure 3: Circuit Diagram for Digital to Analog Converter

To reinforce the understanding of the difference between analog and digital, and to give the students another practical experience, the next project included using the digital to analog converter they had constructed to determine the position of a potentiometer (converting an analog signal to a digital input)[3]. Students needed to set up the potentiometer as a simple voltage divider (to output between zero and five volts) and use an op amp to compare the output from their digital to analog converter to the voltage output from the potentiometer. They used all eight possible voltage outputs from the digital to analog converter to determine which of the eight possible voltage ranges the potentiometer output was in. They then displayed the position of the potentiometer on the PC screen on a scale of one to eight (one meaning the potentiometer was turned all the way to the left and eight meaning the potentiometer was turned all the way to the right). The students were then given another way to determine the position using a timing circuit to get better resolution.[3]

The last basic project the students were asked to perform involved microprocessor control of a motor using transistors in an H-bridge configuration. The students were given the necessary transistors and a circuit diagram for constructing an H-bridge. They were required to calculate the resistance they would need to operate a motor and construct a circuit to rotate the motor in two different directions. The H-bridge output and motor were then connected to a hanging mass and the students were asked to program the microprocessor to move the mass to three different positions (figure 4).

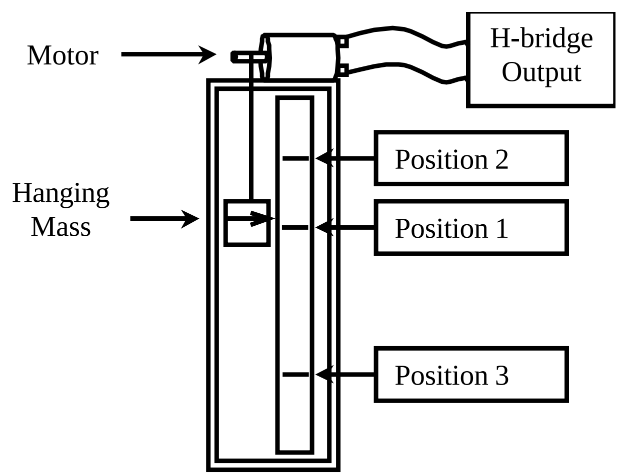

figure 4: Set-up for Motor Control Project