CAN WE AFFORD THE WOW FACTOR ?
A MECHATRONICS EXAMPLE

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Abstract

A course in Mechatronics Engineering is used to provide an example of a course with the "wow factor". These are the courses that are oversubscribed and sustain their popularity from year to year through word of mouth. As with most "wow factor" examples, the course is hands-on and project based. A commonly held view is that the excitement and enthusiasm demonstrated by the students in such courses should be duplicated throughout an engineering curriculum. However, a decade of experience with the mechatronics course has left the instructors with one oft repeated question: "can we continue to afford such courses, given that they are expensive in terms of both time and money ?" This paper reviews the offering of the course in Mechatronics and discusses the underlying resource issues and future implications.

Introduction

A recent article in ASEE Prism extolled the virtues of courses with the "wow factor"[1]. These are the courses that are oversubscribed and sustain their popularity from year to year through word of mouth. It's no surprise that the majority of such courses are hands-on and project based. The ASEE Prism article wasn't the first appearance of the phrase. For example, Simcock talked about the need to reintroduce the "wow factor" to revitalize interest in electrical engineering[2]. He did so through the phased introduction of industry based projects from year 1 to year 4, with projects that involved design and build. An elective course in Mechatronics Engineering at Queen's University is put forward as an example of an elective course with the "wow factor".

The course is laboratory-based and technology-oriented course in Mechatronics Engineering, where mechatronics is the subject that combines elements of computer, electrical and mechanical engineering. The course presentation covers all the keywords that one hears in discussions on what is needed for the next generation of engineering students. The list of keywords include: active learning, integrated learning, just in time instruction, theory versus practice, written and oral communication, multidisciplinary and interdisciplinary teams, lectures, tutorials, laboratories, workshops and design projects. It is possible to find at least one course of this nature in most engineering schools. These courses are able to promote the excitement and enthusiasm among the students in a manner that should be present in all engineering courses. However, a decade of experience with the mechatronics course has left the instructors with one common question; "Can we continue to afford such a course, given that it is so expensive in terms of both time and money ?" This paper reviews the organization of the course and discusses the underlying resource issues. But a reminder will first be given of the key role that active learning plays as the underlying pedagogical concept behind all such courses.

Active Learning

Active Learning is said to be the key to truly effective education. Goff paraphrased Piaget and said "… in order for a student to understand something, she must construct it herself, she must re-invent it."[3]. He went on to observe that students who are engaged in the learning process master the material. Students who are not engaged generally do not succeed. The best way to engage students is to create an exciting active learning environment. Active learning is a key element in the conceive, design, implement and operate approach of CDIO to engineering education[4]. CDIO stands for Conceive Design Implement Operate, an international initiative supported by a leading universities that seeks to develop the framework for producing the next generation of engineers.

In engineering, it has long been recognized that a hands-on project-based or laboratory-based course lends itself naturally to the creation of an active learning environment, be it at the undergraduate[5] or graduate level[6]. Over a period of 10 years, an elective course in mechatronics engineering has been developed that is believed to to provide students with a rewarding and stimulating experience in engineering problem solving, within a process of active learning. It does so through a combination of lectures, tutorials and laboratories that culminates in a team project which requires the students to assemble and program a team of robots to perform a given cooperative task.

An Approach to Mechatronics

The Queen's approach to mechatronics is to focus on the application of electronics and microcontrollers to mechanical systems. The course is designed around a series of tasks that involve a prototyping board with a microcontroller and a mobile robot that uses the same microcontroller, as illustrated in Figure 1 and Figure 2, respectively. The "MechBOT" mobile robot has a flexible platform on which sensors, actuators and supporting electronic circuits are mounted, as illustrated in Figure 3. The chassis is a commercial R/C controlled four wheel drive ATV mobile robot. It was chosen in part due to the large deck space available to accommodate all of the sensors, actuators and supporting electronic circuits used in the course.

A series of eight laboratories is used to introduce the students to the technology, alternating between the application of the technology to the prototyping board in one week, and then the application to the mobile robot in the following week:

- Lab #1 (Introduction to the Stamp microcontroller and the protoboard) and Lab #2 (Introduction to the PBASIC language)
- Lab #3 (Introduction to Sensors, photoresistor mounted on a servomotor) and Lab #4 (Introduction to the Robot, with navigation by contact sensing or limit switches, as illustrated in Figure 2)
- Lab #5 and #6, navigation by ranging (infrared sensor), with Lab #5 as the protoboard based laboratory illustrated in Figure 1, and Lab #6 as the robot based laboratory
- Lab #7 and Lab #8, navigation by colour (CMUcam camera for colour tracking)

The laboratories are conventional in that they are structured. A handout details the procedure and every group deals with the same hardware. Variation between groups comes about due to

the software programming and differences in the placement of the sensors and actuators. The laboratories could be viewed as one part applied electronics, and one part introductory microcontrollers, with a mobile robot as the application. The majority of students are from mechanical engineering. In many cases, this is their first experience with microcontrollers.
For the laboratories, students work in pairs and this occupies the first eight weeks of the course. In the final four weeks of the course, the experience and knowledge gained in the laboratories is applied to a team design project. The current version of the project, as illustrated in Figure 4, is posed as a problem that mimics the task of autonomous vehicle navigation, with two robots per team traversing the test arena in a cooperative fashion. The test arena has a raised bridge that requires the robots to climb on to and drive off of, in a controlled fashion. Each team of 2 robots (4 students) is tasked to travel around the loop without hitting any walls (or each other). Red and green LED panels mimic traffic signals. A colour camera on each robot is used to determine whether the signal is red or green. A discussion of the past projects as they relate to their competitive aspects can be found in Surgenor, Firth and Daoust[7].

The active learning component attracts a group of students that is enthusiastic about the hands-on nature of the course. However, this enthusiasm can become a problem when the hours spent testing and troubleshooting begin to use up time required for other courses. Students have 24 hour access to the laboratory so they can work on their projects at any time. This can be a drawback for those students who get too engaged by their project, at the expense of time spent on their other courses. The assigned tasks and deliverables are structured to help limit the hours spent on the course.

Value of the Course

Student comments about the course have been universally positive, a selection of which are given below:

- "it's the best class I've ever taken, I like the practical application of things"
- "this course is awesome, I (think) everyone loves it"
- "I liked the hands-on experience, it made learning material easier and more fun"
- "good setup learning how to use components first (alone) and then on the robot"

For the past six years, the course has been consistently ranked 1st out of the 12 technical electives offered by the Department, as measured by the University Survey of Student Assessment of Teaching, a formal course evaluation that is conducted for all courses by the university. The course consistently scores 4.8 or higher on a scale of 5 in response to the question "overall, this is an excellent course", with the Department mean at 3.7 (standard deviation of 0.36), where 5 = "strongly agree".

This is not to say that students are uniformly happy with the nature of the course. The fact that assessment is based to a degree on the performance of a robot (that the students have admittedly configured and programmed) leads to inevitable “real-world” frustration, when what worked perfectly in pre-testing, fails in final testing due to unanticipated hardware failures or software bugs. “Real-world” assessment in an academic environment can be problematic.

In recent years, at the end of the course the students are asked: "*Name three positive things that you've learned in the class that you think will be of value to you in your future career as an engineer.*" The results have been positive, but rarely mechatronics specific. Students offered comments such as "Teamwork is more important than technical ability" and "You need to be methodical in the problem solving process". The fact that the feedback was positive was not surprising given course surveys from previous years. But the "non-mechatronics" feedback originally caught the attention of the instructors. On reflection, the exercise highlighted to the instructors that they had designed the course around the process of engineering problem solving, and this has become one of the dominant features of the course.

Experience has shown that problems must be presented such that the students are "forced" to be methodical. The team project problem is broken into 3 parts, roughly 1 part per week. Each part is in turn is broken into 3 manageable tasks: 1) Demo (basic elements of the overall task, 2) Basic (contains all but one of the elements of the final task, three trials) and 3) final (same as basic with one additional element, and only one trial. This approach was found necessary to "force" students to break the task into manageable parts, as well as to find a compromise between the academic nature of the exercise and the real world nature of the task, where the mark was based directly upon the performance of a machine, and only indirectly on the performance of the student.

Cost of the Course

Experience with the Queen's course in mechatronics demonstrates the well-known drawback to the laboratory or project-based approach to engineering education, that is the problem of resources, both time and money. Such courses need specialized physical resources, extra teaching assistant (TA) time and can consume excessive amounts of both student and instructor time. It's possible to cut back on the time demands (ie. reduce the number of labs), but with an obvious negative impact on the scope of what is learned. It's also possible to reduce the time required by providing a less open ended project. But this has a significant pedagogical impact, as discussed in detail in the paper appropriately titled "What did I really learn in my mechatronics class ? The challenge line problem revisited"[8], a paper that reviews the balance between the extremes of a highly constrained problem with a well defined answer versus the open ended problem with multiple, or perhaps nonexistent, solutions.

It's a given that laboratory and project based courses cost more money to deliver than lecture based courses. Ignoring the cost of contact time, the direct cost (instructor plus TA time) is estimated as 4 times that of a conventional course. Specific to mechatronics, the equipment cost is on the order of $5,000 per year, for parts replacement and the inevitable upgrades driven by changing technology. The option of charging students a course fee to cover these costs is not an option in the publically funded Canadian university system, which views such charges as hidden tuition fees. So what to do ? The only answer to be put forward at this point is to continue to lobby one's administration that the added cost is worth it, and to ensure that the students are the ones that deliver the message. A motion to drop the course in 2010 for reasons of "we can't afford it" was stopped by a petition signed by 80 students. One outcome of that result is illustrated in Figure 5.

Conclusions

A course in Mechatronics Engineering was used to provide an example of a course with the "wow factor". A commonly held view is that the excitement and enthusiasm demonstrated by the students in such courses should be duplicated throughout an engineering curriculum. However, a decade of experience with the mechatronics course has left the instructors with a common question: "can we afford such courses, given that they are expensive in terms of both time and money ?" This paper reviewed the offering of the course in Mechatronics and discussed the underlying resource issues. The only recommendation is that both students (and instructors) need to continue to lobby on behalf of such courses. The effort is worth it.

References

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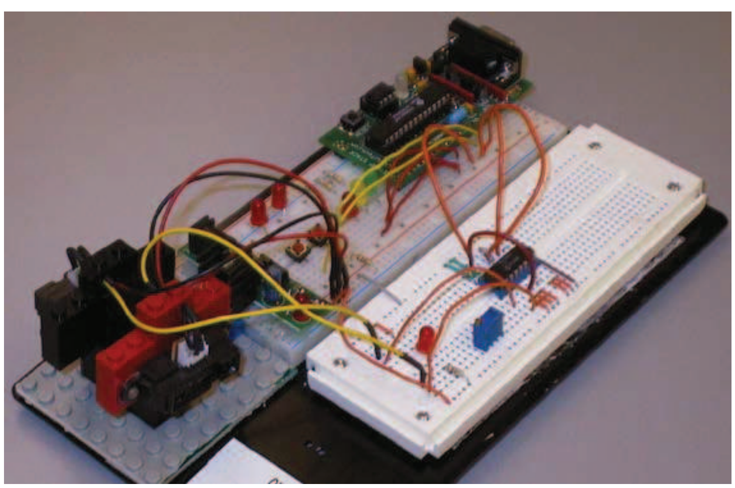

Figure 1. Navigation by range, protoboard based laboratory.

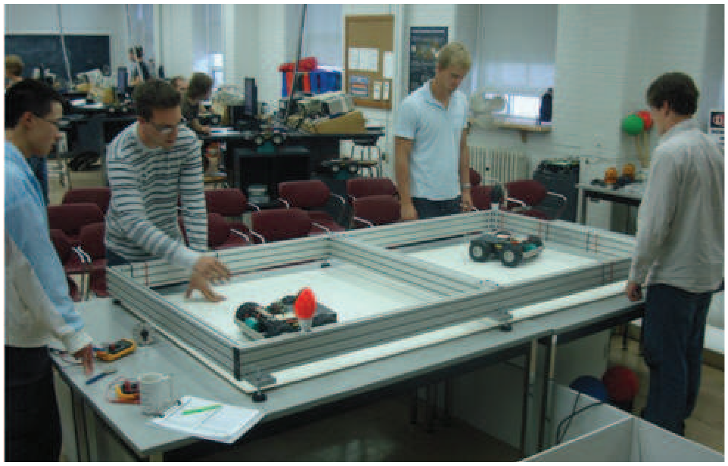

Figure 2. Navigation by range, robot based laboratory.

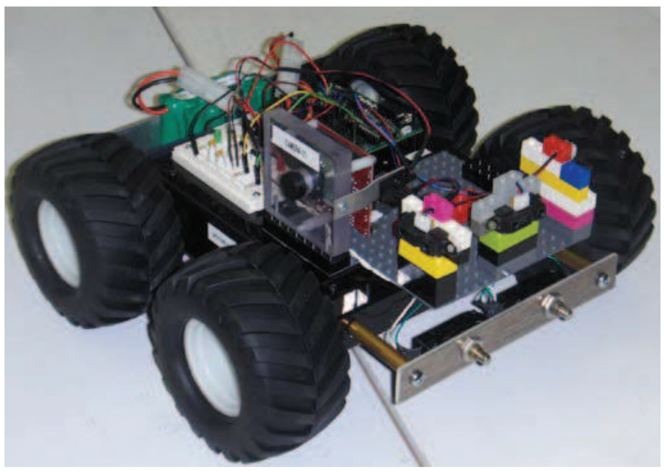

Figure 3. Typical robot configuration for the team project.

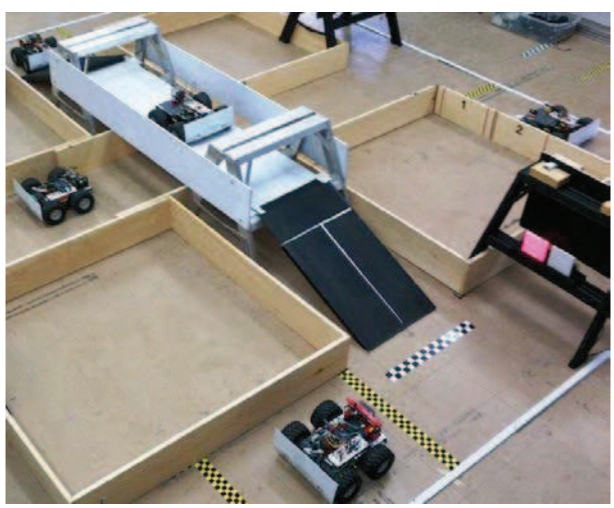

Figure 4. Test arena for the team project in 2011.

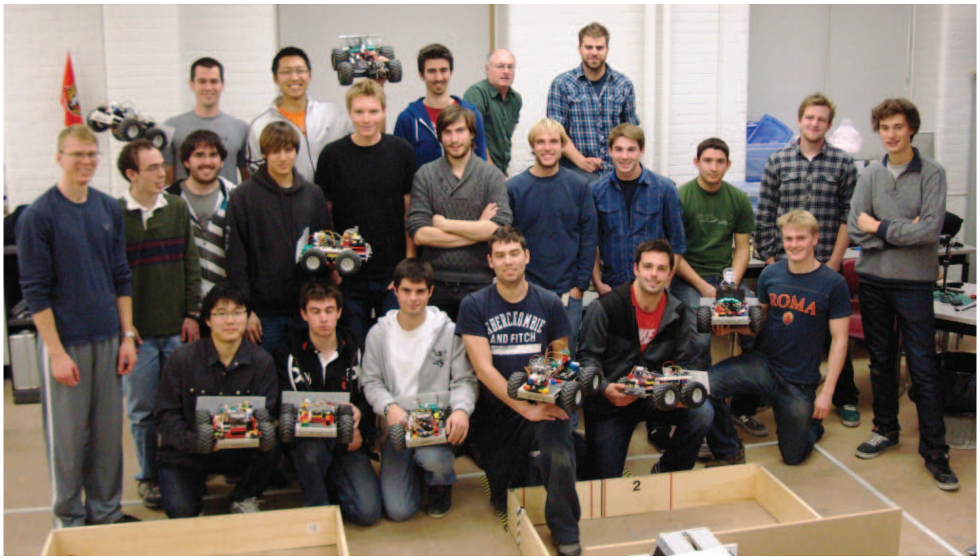

Figure 5. Outcome of the wow factor, the (partial) class photo.