Mechatronic Design and Manufacture: A Capstone Design Experience

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Abstract

In this paper we outline the development of a new concurrent engineering capstone design sequence entitled **Mechatronic Design and Manufacture**.

Motivation

In engineering education the capstone design course is often viewed as academia's tool for introducing the student to the *real world* of engineering. Engineering in industry has undergone drastic changes in recent years. The *real world* has changed and so must academia's pedagogy. In this paper we outline the development of a new concurrent engineering capstone design sequence entitled Mechatronic Design and Manufacture, parts *I* and *II*.

As stated by Craig 1994, "The challenge to engineering educators is to develop courses that are *relevant* to the needs of the nation and its industry." We would argue that concurrent engineering and design for manufacture are very relevant in today's global economy. Widely accepted now in industry is the philosophy of concurrent engineering. As Armacost and Mullens 1995 stated,

> U.S. manufacturing has discovered that the serial, over-the-wall, approach to product development has to give way to a concurrent engineering approach.

Moreover, industry has recognized that design for manufacture and assembly is of paramount importance to its economic competitiveness. Hence, we sought to develop a new capstone sequence which would incorporate concurrent engineering and design for manufacture into the traditional capstone design experience. Mechatronics is a logical choice of design philosophy to facilitate the integration of these topics into a new capstone design course.

Below are some recently published definitions of mechatronics:
Ume and Timmerman 1994,

> Mechatronics is an application of the concept of "concurrent engineering" to the design of electromechanical systems. The design philosophy is exemplified by an interdisciplinary and integrated design approach where electrical , electronic, computer, and mechanical subsystems are simultaneously designed to function as an integrated single system.

Dinsdale and Yamazaki 1990,

> The synergistic integration of fine mechanical engineering with electronics and intelligent computer control in the design and manufacturing processes.

Acar 1994,

> Mechatronics describes a multidisciplinary engineering activity which has been practised for a number of years. It integrates the classical fields of mechanical engineering, electronic engineering and computer science/information technology at the design stage of a product or a system. Mechatronics is therefore not a new branch of engineering, but a newly developed concept that underlies the necessity for integration and intensive interaction between different branches of engineering.

From the above definitions it is clear that mechatronics is inherently a multidisciplinary field and its efficient implementation requires concurrent engineering. We believe that creating a concurrent engineering design experience is a natural reflection of current practices in industry and that such an experience will better prepare students for successful engineering careers. Hence, we have developed an alternative capstone design sequence which will bring students of all engineering disciplines into concurrent engineering groups to design and manufacture mechatronic projects.

Course Description

Mechatronic Design and Manufacture will be a year long, i.e. two semester, course which will be an optional senior design sequence open to all engineering majors at the Florida Institute of Technology. This sequence will be an alternative to the traditional capstone design sequences currently offered in each particular engineering discipline, e.g. mechanical, civil, electrical, computer, ocean, etc. Precedence for such an option to the traditional capstone design course can be found at Rensselaer Polytechnic Institute, see Craig 1994. The purpose of making the sequence available to all engineering majors is to enable the creation of multidisciplinary engineering design groups.

The goal of Mechatronic Design and Manufacture is to prepare students to be productive and successful in today's engineering workforce by (1) introducing them to concurrent engineering which will be greatly enhanced by the formation of multidisciplinary design groups, (2) introducing them to mechatronics through careful project selection, lecture material, and laboratory experiments, and (3) introducing them to design for manufacturing and assembly through lecture material, industrial visits, and by having them build, assemble, operate, and repair their designs. We believe that by creating a capstone design experience which is multidisciplinary and focused upon mechatronics that we will be preparing students to be productive engineers that are capable of addressing the needs of the nation and its industry.

Mech. Design & Manufacture *I*

In this course we introduce the student to the concept of multidisciplinary design, the overall philosophy of concurrent engineering, and we provide them the analytical and laboratory skills required to perform basic mechatronic design. Moreover, we provide the student with an in-depth discussion of the systematic approach to a mechatronic design. A proposed course syllabus is shown in Tbl. 1 and the laboratory exercises for the course are listed in Tbl. 2.

Assessment

This is a 3 semester credit course taken in conjunction with a 1 credit laboratory section. A proposed course syllabus is shown in Tbl. 1 and the laboratory exercises for the course are listed in Tbl. 2. Grading is based upon a midterm examination, a final examination, laboratory reports, and homework.

Mechatronic Design & Manufacture *II*

In Mechatronic Design and Manufacture *II* students are assigned to multidisciplinary design groups. The groups then select a project from an approved list and select a group leader. Guidelines for selecting and defining projects may be found in Carryer 1994, Craig 1994, and Armacost and Mullens 1995. Preference is placed upon industrially sponsored and initiated projects. This requires tremendous effort on the the part of the instructor however we believe the benefits to the student and to the program justify the extra work involved. Throughout the project emphasis is placed upon effective budgeting of resources, multidisciplinary cooperation, concurrent engineering, and design for manufacture and assembly.

Once manufactured the projects are operated and their performance is analyzed and compared to the design specifications. Moreover, repairs and modifications that are made to the design are noted. Special attention is given to the ease of repair and to the difficulties encountered when modifying the design. Is the design flexible? Is it easy to swap out parts? Is it easy to put back together? The project terminates with a formal design presentation and report which summarizes the design specifications, synthesis, analysis, simulation and modeling, manufacturing, assembly, performance analysis, and lessons learned.

Assessment

This is a 3 semester credit course. Grading is based upon the group's formal design presentation, the group's project report, and design group member evaluation forms which are completed by the group's leader. These forms provide the instructor with an evaluation of the performance of each individual member of the group by the group leader. We believe this additional information to be important in multidisciplinary design teams; especially in cases in which the team member's contributions were in areas outside of the realm of expertise of the faculty member responsible for assigning grades. The form used is shown in Fig. 1.

• Concurrent Engineering		
	Definition	
	Design Philosophy	
	Case Studies	
• Introduction to Mechatronics		
	Definition	
	Design Philosophy	
	Case Studies	
• Actuators		
	Electric	
		DC Motors
		Stepper Motors
		Servo Motors
		AC Motors
	Pnuematic	
		Linear Motors
		Rotary Motors
		Stepper Motors
	Hydraulic	
		Linear Motors
		Rotary Motors
	Selection and Implementation	
• Transducers		
	Position Sensors	
	Velocity Sensors	
	Force/Torque Sensors	
	Selection and Implementation	
• MicroControllers		
	Overview of Current Technology	
	Specific Hardware Case Study	
• Interfacing to Mechanical Systems		
	Analog-Digital Conversion	
	Digital-Analog Conversion	
	Sampling	
• Design for Manufacture		
	Design Philosophy	
	Case Studies	
• Design for Assembly		
	Design Philosophy	
	Case Studies	

Table 1: MDM *I*: Syllabus

Mechatronic Design and Manufacture *II*

Design Project
Group Member Evaluation Form

To be completed by the group leader.

GROUP #: ______________________________

GROUP LEADER NAME(print): ______________________________

GROUP LEADER(signature and date): ______________________________

This is an evaluation of the performance of(print name): ______________________________

1. Was this member present at all group meetings? (YES/NO)
   If NO, please comment:
2. Was this member an active participant in the group? (YES/NO)
   If NO, please comment:
3. Would the group's success have been diminished if this person had not been a member of the group? (YES/NO)
   If NO, please comment:
4. Rate the member's performance on a scale from 1 to 10; 1 = very poor, 10 = excellent.
   (a) ANALYSIS SKILLS:______
   (b) REPORT WRITING SKILLS:______
   (c) ORAL PRESENTATION SKILLS:______
   (d) DESIGN SKILLS:______
   (e) OVERALL CONTRIBUTION TO THE PROJECT:______
   (f) FLEXIBILITY AND COMFORTABILITY WHEN WORKING WITH OTHERS: ______
5. This member should receive a project grade which is(circle one):
   - higher than the average grade of a member of this group?
   - the average grade for a member of this group?
   - lower than the average grade of a member of this group.
6. This member contributed to: performing the analysis, writing the report, and preparing for the oral presentation? (YES/NO)
   If NO, please comment:

Figure 1: MDM *II*: Group Member Evaluation Form

• Industrial Site Visit
• MicroController Indexing of a Stepper Motor
• MicroController and Sensor Integration
• MicroController Position Control of a DC Motor
• MicroController Velocity Control of a DC Motor
• Reverse Engineering of a Mechatronic Product

Table 2: MDM *I*: Labs

Conclusion

In this paper we have summarized the development of a new concurrent engineering capstone design sequence in mechatronics entitled Mechatronic Design and Manufacture, parts *I* and *II*. By employing modern concurrent engineering techniques in a multidisciplinary capstone design sequence focused on mechatronics we hope we have created an environment which will foster exciting, educational, and relevant design experiences.

References

[1] Acar, M., *Mechatronics Engineering in the U.K.*, Workshop on Mechatronics Education, pp. 1-6. Stanford University, July 21-22, 1994.

[2] Armacost, R., and Mullens, M., *Teaching Concurrent Engineering at the University of Central Florida*, Journal of Engineering Education, Vol.84, No.4, Oct. 1995, pp. 389-394.

[3] Dinsdale, J., and Yamazaki, K., *Mechatronics and ASICs*, Annals of the CIRP, Vol.38, pp. 627-634.

[4] Craig, K., *Mechatronic System Design at Rensselaer*, Workshop on Mechatronics Education, pp. 24-27. Stanford University, July 21-22, 1994.

[5] Ume, C., and Timmerman, M., *Mechatronics Instruction in Mechanical Engineering Curriculum at Georgia Tech*, Workshop on Mechatronics Education, pp. 107-116. Stanford University, July 21-22, 1994.

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TEACHING MACHINES TO DREAM (IN COLOR) ---- WITHOUT BREAKING THE BANK

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Abstract
The goal of this project was to create a relatively simple but accurate optical color sensor which could be integrated with a Motorola M68HC11 processor on the mini- board v.2.0. The project takes on two main design challenges first: an optical sensor with sufficient depth of field and selectivity to be able to discern a color from a moderate range, secondly: software to make use of this information and present it to outside clients. The objectives were met with a low cost device able to directly discern 256 colors and an unlimited number of colors using a remote processor. The cost of components for the sensor system was less than $150 including the Miniboard device.

Theory of Color Sensing

The problem to be solved is a fairly simple one, most humans have it down pretty well by their first year of life: it is the ability to differentiate colors. To give a machine this ability is a more complex problem due to the basic nature of color and how the human eye perceives it.

The goal of this project is not to build a device that absolutely reproduces human color vision but one which mimics it on a fairly simple scale. The first problem is to quantify colors into numbers which correspond to the wavelengths of light. In order to quantify colors in terms of a number, one must understand the way color is perceived.

An object's color is determined by the frequency of light that is reflected when illuminated by an external source. When an object is illuminated with a white light, a broad spectrum mix of colors (typically 400nm to 900nm wavelengths), the light wavelengths reflected determine the color by which it is perceived. An object that is perceived to be red means that it absorbs all but long wavelength light, which it reflects. To complicate this further the light that is reflected from an object is never one pure frequency that can be placed on the spectrum but a mixture of reflected wavelengths.

As complex as colors are to sense they are extremely easy to create. All of the colors in the visible spectrum can be made by combining the correct proportion of red, green, and blue. Both color televisions and computer screens take advantage of this property to generate all of the colors necessary to produce lifelike images. Reversed, this property can be used to detect object color. Color can be split back into its components by prefiltering the incident source beam falling on an object.

The sensor built here was designed to return four data values, each indicating the intensity of the light in the primary colors: red, green, and blue plus a white intensity reference number. The sensing device takes advantage of a wide band photo detector, a silicon photo diode. This detector, combined with the light filtering system will isolate the colors signals and return a voltage number for each. The color detector basically illuminates a sample object with the desired color then reads the voltage intensity of the reflected light at the photo detector.

Design of Sensor device

Silicon photo diodes have extremely fast response times and are also linearily