Interdisciplinary Research Experience for Undergraduates in Mechatronics and Smart Structures

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Abstract - *In recent years, mechanical systems have become increasingly dependent upon computers and electronics to achieve the degree of performance, flexibility, and reliability demanded by users. The fusion of mechanics and electronics has been called mechatronics and used for optimal design of electromechanical products and processes. In addition to mechatronics, smart structural systems with improved vibrational characteristics and structural health monitoring have been extensively investigated over the past several years. These systems have the ability to beneficially respond to internal and external stimuli through intelligent sensing, control and actuation of desired system response. In both mechatronics and smart structures, it is necessary to integrate mechanical systems, microelectronics, smart sensors, actuators and control systems. We were successful in obtaining a grant from the National Science Foundation for conducting undergraduate research in these areas. The overall goals of the project are (i) introduction of mechatronics and smart structures concepts to junior/senior undergraduate students, (ii) development of an interdisciplinary educational experience for students working in teams involving students from different disciplines, (iii) providing a unique opportunity to minority students to conduct research in state-of-the-art laboratories, and (iv) involving undergraduate students with ongoing research programs in areas and technologies. We successfully developed an eight-week summer course that was offered during the last two years. We wish to share our experience of running this multidisciplinary program.*

Introduction

Mechatronics is a methodology used for the optimal design of electromechanical systems. The mechatronic system is multidisciplinary involving electrical, mechanical, computer and information technology disciplines. The fusion of mechanics and electronics has been called mechatronics and has come to include computers as well. *"Mechatronics"* has been defined as the "synergistic integration of mechanical engineering with electronics and intelligent computer control in the design and manufacture of products and processes."

In addition to research on mechatronics, smart structural systems with improved vibrational characteristics have been extensively studied over the past several years. These systems have the ability to beneficially respond to internal and external stimuli through intelligent sensing, control and actuation of a desired system response. In both mechatronics and smart structures, it is necessary to integrate (*i*) mechanical systems, (*ii*) microelectronics, (*iii*) smart sensors and actuators, and (*iv*) computers as shown in Figure 1. There are many similarities between mechatronics and smart structures.

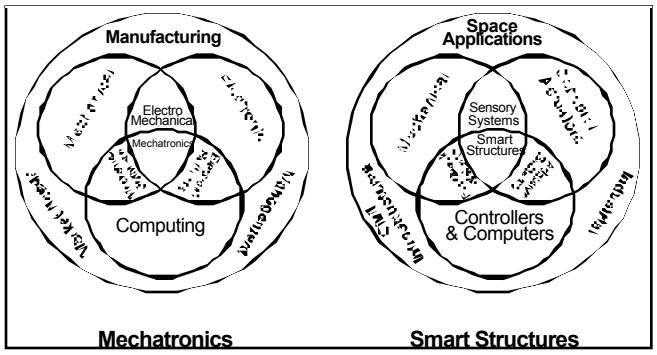

Figure 1

A key feature of the design and implementation of mechatronics and smart structures is the team work among different disciplines. These areas are relatively new and are truly interdisciplinary in nature. Our objective is to provide a cross-disciplinary research experience for the benefit of undergraduate students in electrical, mechanical and aerospace engineering and engineering mechanics.

The overall goals of the project are:

(i) The introduction of mechatronics and smart structures concepts to junior/senior undergraduate students.

(ii) The development of an interdisciplinary educational experience for students working in teams involving students from different disciplines.

(iii) Providing a unique opportunity for minority students from the University of Turabo and other schools to conduct research in state-of-the-art laboratories in mechatronics and smart structures.

(iv) Involving undergraduate students with ongoing research programs in areas and technologies of national importance.

To accomplish these objectives, we (*i*) developed an eight-week summer program on mechatronics and smart structures, containing the computer-aided design and hands-on laboratory experience, (*ii*) developed team design projects combining electrical, mechanical and mechanics of material aspects of mechatronics and smart structures, (*iii*) involved graduate students as mentors in the development of research experience for undergraduates, and (*iv*) provided hands-on experience in the laboratory to demonstrate the capabilities of mechatronics and smart structures.

Project Description

An eight-week summer program to conduct interdisciplinary research in mechatronics and smart structures was held at the University of Missouri-Rolla during the last two years. Twelve students from the departments of electrical engineering, mechanical engineering, aerospace engineering, and civil engineering from the University of Missouri-Rolla, Turabo University, Puerto Rico and six other universities conducted research at the UMR's Intelligent Systems Center. This program is designed to introduce engineering juniors and seniors to the emerging fields of mechatronics and smart structures.

The primary objective of the project is to provide hands-on experience on control of mechanical systems and smart structures. We did not expect that the students would have prior knowledge in all required topics. The philosophy of the approach to undergraduate research training is as follows: (i) introduction to the basic concepts of mechatronics and smart structures in the form of lectures and tutorials/problem solving sessions, (ii) hands-on experience in the laboratory for the interfacing of sensors/actuators with mechanical systems and computers, (iii) development of team design projects emphasizing modeling, mechanics of materials, sensors/actuators, control systems, and digital implementations. Some of the laboratory experiments include:

- usage of analog to digital (A/D) and digital to analog (D/A) converters.
- data acquisition systems.
- familiarization of testing equipment (oscilloscopes, signal generators, amplifiers, etc.).
- usage of multi-channel signal analyzers.
- tutorials on "MATLAB" control software for use in design and simulation of control systems.
- mounting of smart sensors/actuators with structural systems.
- structural identification methods.

The interdisciplinary teams of students have identified projects and successfully completed the design and implementation of controllers using digital computers. Some of the titles of the projects are:

(i) Design of control systems for vibrating fixed-fixed beams.

(ii) Design and implementation of robust controllers on cantilever beam test articles.

(iii) A first approach to active control of tail beffeting.

(iv) Analysis of flexible beams using piezoelectric sensors.

(v) Frequency analysis of cantilever beams using calibrated hammer and spectrum analyzers.

The results were presented in a seminar attended by the summer school participants and graduate students, and faculty.

Student Evaluations

At the end of the program, all participants of the summer program completed an "evaluation questionnaire" and also provided feedback comments on the effectiveness of the program.

- In general, students liked the interdisciplinary nature of the research.
- The students were exposed to a number of concepts. They said they had difficulty in comprehending new concepts in a short duration.
- The students really enjoyed the laboratory sessions and research projects.
- The students worked in teams consisting of students from different disciplines and they commented that it was very effective in completing the research projects.
- Some students commented that they enjoyed learning something other than what they learn in their own discipline.
- They suggested that the stipend paid to the participants be increased.
- They also suggested they would like to have more assistance in the laboratory for interaction with graduate students.
- The students suggested that we focus on fewer topics and concentrate on experimental work.

These suggestions were incorporated in the development of the program for the second year.

Acknowledgments

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