

GRANT REPORT

2006 IPFW SUMMER GRANT FOR INSTRUCTIONAL DEVELOPMENT

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I was awarded a *Summer Grant for Instructional Development* by the *Center for the Enhancement of Learning and Teaching* (CELT) at IPFW in summer 2007. The grant was funded for the project entitled *The Development of a Multidisciplinary Control Systems Course*. The purpose of this report is to summarize my accomplishments in completing this project.

I. Rationale

The rationale for proposing this project were:

1. To widen the scope of topics currently taught in our Control Systems Course by including appropriate topics and methods which are relevant not only to our electrical but also to our mechanical engineering students, and
2. To introduce new methods of instructional delivery, through the development of experiments and emphasis on computer simulation/animation, for the purpose of simplifying difficult control systems concepts.

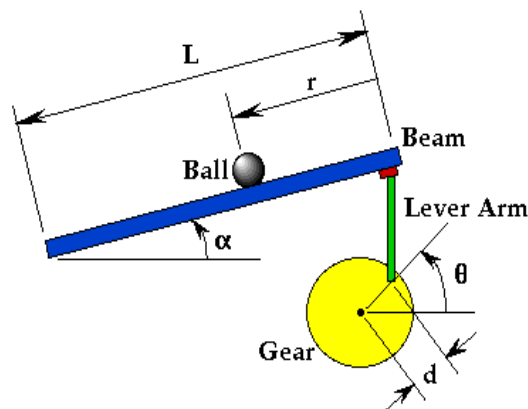
By successfully achieving these objectives, it is hoped that the revised course can provide a new learning environment in the future based on the incorporated diversity content and goals as well as experimental learning that use modern instrumentation. This should, in turn, address some of our current curriculum shortcomings in regard to the multidisciplinary skills that are required of the graduating engineering students in today's workplace.

II. Course Development

After receiving the grant, I started working on the project in early June 2007 and closely followed the schedule of the project's milestones as I had outlined in my

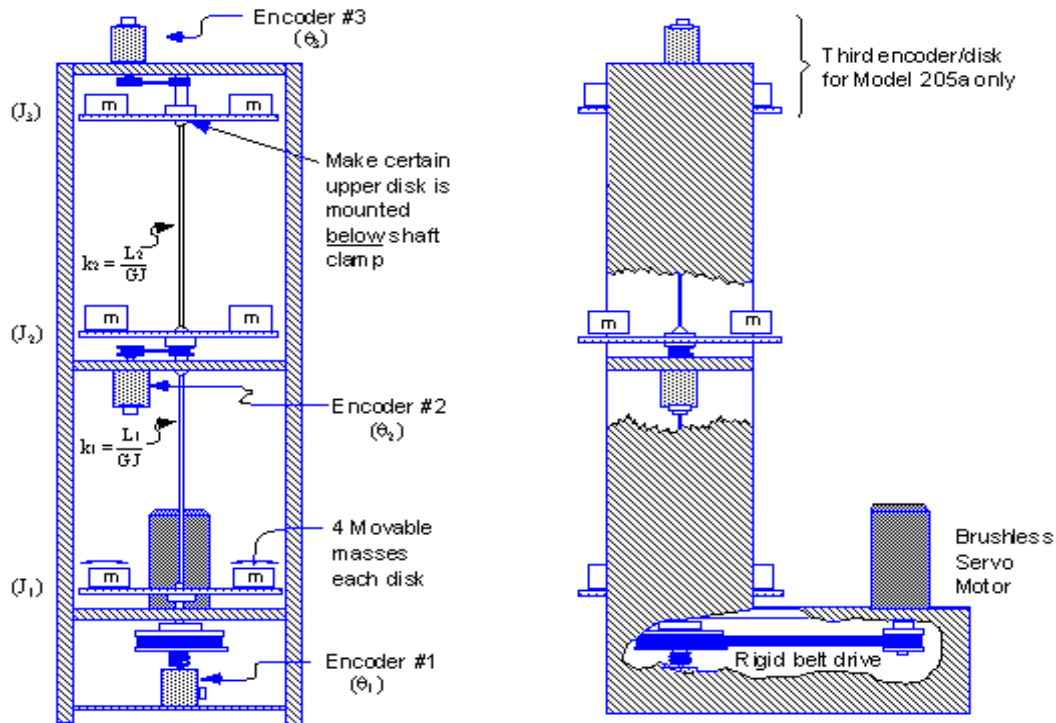
proposal. For the selection of course topics, I started by including all the core topics that I believed to be the integral part of the course. This helped me obtain an estimate of the amount of new material that I could add to the current topics in order to achieve the objectives of the project. I then searched for these new topics on the internet, as well as contacting several informed colleagues at other universities and discussed my project with them and sought their opinion and advice. By the middle of June, I was done with the selection of the new topics. Notable among the topics that I have selected for the course are the following two electromechanical control systems which I will explain below briefly.

A. Ball and Beam System. A ball is placed on a beam, where it is allowed to roll with one degree of freedom along the length of the beam. A lever arm is attached to the beam at one end and a servo gear at the other. As the servo gear turns, the lever changes the angle of the beam by a certain amount. When the angle is changed from the vertical position, gravity causes the ball to roll along the beam. A controller is then designed for this system so that the ball's position can be manipulated.



B. Torsion Plant Apparatus. The system consists of three disks supported by a torsionally flexible shaft that is suspended vertically on anti-friction ball bearings. The shaft is driven by a brushless servo motor connected via a rigid belt (negligible tensile flexibility) and pulley system with a 3:1 speed reduction ratio. An encoder located on the base of the shaft measures the angular displacement of the first disk. The second disk is

connected to its encoder by a rigid belt/pulley with a 1:1 speed ratio. This system represents a broad and important class of practical systems and will be used to study and control torsional vibration.



Both systems are currently available for the course and are stored in one of our engineering laboratories. The Ball and Beam System was designed by me a few years ago and was built by a group of engineering students while working on their senior design project under my supervision. The torsion plant apparatus, on the other hand, was purchased a few years ago for the purpose of doing research in the area of control systems. Despite the fact that both systems have rich dynamic behaviors, something that makes them very suitable for teaching control systems, neither system was ever utilized in the classroom for a number of reasons such as complexity of operation, fragility, and user unfriendliness.

Prior to receiving the grant, I was indeed very reluctant to utilize these systems in the classroom because I knew that I had to spend a great deal of time and effort before I could make these systems suitable as teaching tools. I am, therefore, very grateful for being awarded the CELT grant as this finally gave me the

opportunity to integrate these two wonderful systems in my control systems course.

Since these systems are controlled by computers, a friendly graphical interface between the user and the host computer had to be developed for each system. Therefore, I started by writing a number of graphical user interface (GUI) programs in June and completed this task by the middle of July. This new feature that I have added to these systems should allow students an easy selection of the control systems design parameters directly from the keyboard and the capability of executing the control systems program with the ease of pressing a button. The added feature should help students concentrate on the dynamic behavior of the system, which is essential to understanding of control system concepts, and alleviates other concerns such as hardware or software malfunctions, or other aspects with secondary roles.

The next thing I had to do was to provide students a means by which they could interact with these two systems in a virtual environment before experimenting with the actual hardware. The benefit of such a tool is twofold:

1. It provides students an unlimited access to the systems through which they can vary the parameters, do the simulation, and conduct experiments in a repeated manner; thus, helping them gain an intuitive feel for the system behavior through their trials and errors.
2. It provides students a working knowledge of the systems before experimenting with the actual hardware; thus, reducing the risk of damage to the system with a wrong control algorithm that can cause instability. This is a serious consideration noting that students enrolling in this course have little or no prior control systems knowledge.

Recognizing the value of virtual environment, I decided to develop a Java applet animation program for the ball and beam system. An interesting feature of my

program is that it allows the beam to be controlled through a torque applied at the center of the beam. I completed this task in early June and the outcome was very satisfactory.

Development of experiments for the systems took the full two months of my summer. I developed a number of experiments for the systems. The early experiments involve systems identification by which the parameters of the systems are determined through the curve fitting techniques. The latter experiments are concerned with the control algorithms that students usually learn in a typical control system course, but here they get a chance to actually implement their design on these physical platforms. After developing these experiments, I finally fine tuned and tested my experiments for the optimal performance.

Of course, I encountered several unexpected difficulties during the summer. In particular, I observed that the ball and beam apparatus is very sensitive to small variations in the beam angle. Consequently, control of this dynamic system had turned out to be challenging even for an experienced designer like myself. I was concerned that an incorrect design by a student could easily lead to instability and permanently damage the system. To prevent this from happening, I decided to interface a joystick to the system that allows students a manual control of the system prior to the automatic control by the computer. This attractive feature should provide students the opportunity to gain an intuitive understanding of the system behavior prior to developing their control system algorithm implementation.

I found this course development process to be beneficial to my professional growth as I made a number of new discoveries. For one thing, it clearly demonstrated to me the natural gap that exists between the theoretical and experimental results. Certain physical phenomena, such as load disturbance and sensor noise, are often overlooked in the theoretical development of control

systems in the classroom, but are quite pertinent from the practical point of view. Since these phenomena limit the level of stability and performance that could otherwise be achieved, their understanding requires a working knowledge of control systems, something that can only be demonstrated through hands-on experiments with physical systems. I believe that this will be one of the most beneficial aspects of my new course development.

II. Course Evaluation

The control system course is scheduled for spring 2008. This will be the first time that the new course will be taught and certainly, it will be of great interest to see if the new modifications have the intended effects. Therefore, to assess the course outcomes, I have developed a simple set of questions to obtain students' feedback. The assessment form which includes these questions is included in the Appendix. My plan is to distribute this form in class twice: once at the beginning of the semester, and again at the end of the semester. I will then be in a position to compare the results and make a fair assessment of the course outcomes. It is my hope that the students' feedback can provide me a tool by which I can further improve the course content in the future.

IV. Acknowledgement

I would like to thank Mrs. Gail Rathbun for her help in preparing the Initial/Final Survey form.

ECE 382 FEEDBACK SYSTEM: ANALYSIS AND DESIGN <i>Initial/Final Survey</i> <i>Semester:</i>
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Q1. Give an example of

1. an electrical control system: _____
2. a mechanical control system: _____
3. an electromechanical control system: _____

Q2. Choose *Somewhat*, *Not at all*, or *Very* to answer the following questions:

1. How important is it for an electrical engineer to have in-depth knowledge of mechanical systems? _____
2. How important is it for a mechanical engineer to have in-depth knowledge of electrical systems? _____
3. How important is it for an electrical engineer to have in-depth knowledge of electromechanical system? _____
4. How important is it for a mechanical engineer to have in-depth knowledge of electromechanical system? _____

Q3. The equation

$$\mu = K \frac{d\phi}{dt}$$

describes

1. an electrical system
2. a mechanical system
3. an electromechanical system

Q4. Using the knowledge that you already possess, please identify as many parts as you can of the system depicted below.

Parts:

- | | | | | |
|---------------|------------------|--------------------|--------------|---------------|
| (1) Plant, P | (2) Output, C | (3) Error, E | (4) Noise, N | (5) Sensor, S |
| (6) Sensor, C | (7) Reference, R | (8) Disturbance, D | | |

