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Redesigning Undergraduate Control Courseware

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Summary

- This paper reports on the courseware redesign for a senior undergraduate level control systems analysis course.
- This course includes analytic methods from both frequency and time domains with emphasis on real world problems.
- The use of dynamic animation and web experiments to enhance learning and interest constitutes the major changes.
- The use of web experiments and animation provides many advantages: better visual effects, improved communications, and higher interest levels. Student response has been very positive. A number of recommendations are made in this work based on instructor observation and course evaluations.

Introduction

- System analysis is a multidisciplinary subject encompassing all fields of engineering applications.
- Traditional treatment of this subject tends to be highly theoretical and mathematical.
- Such approach is convenient from the instructor's point of view but may not be beneficial to the students who are classified as sensing types (MBTI), or visual (ILS), or concrete experience in Kolb's model.
- It is observed that about 70% of learners are not analytic learners.
- Kolb’s experiential learning theory advocates a holistic approach to combine experience, perception, cognition and behavior.

Revising courseware

- One of the major functions of education is to shape students' attitude toward learning and to develop effective learning skills.
- The authors hope to accomplish these objectives by using dynamic animation, web experiments, and team project.
- It is not merely about including practical experiences but utilizing these experiences to induce higher levels of learning.
- Furthermore, students will be exposed to the importance of team work, working collaboratively through individual differences which is an integral part of real work scenarios.

EE482 Instrumentation and control

- Course materials are theoretical and mathematical
- Web experiments improve learning and interest

1. Introduction to Systems, Review of LaPlace Transform
2. Transfer Functions, Signal Flow Graphs, Stability
3. Frequency Response of Linear Systems: Bode and Nyquist
4. Identification of Dynamic Systems
5. Performance Characteristics and Feedback; Case study: positioners, actuators, and sensors
6. Properties and Solution of State-Space Systems
7. Modeling of Physical/Biological/Nano Processes, Linearization
8. Stability Assessment: Routh-Hurwitz
9. Root Locus Method
10. The Nyquist Stability Criterion
11. Describing Functions and Limit Cycles
12. Application of Describing Functions
13. Review and Project Presentation

Laboratory outline

1. Introduction to Matlab
2. Matlab Differential Equation Solvers
3. First and Second Order Linear Systems
4. Web experiment I: Identification of $1^{st}/2^{nd}$ order systems
5. Introduction to Simulink
6. Common Nonlinear Systems and Simulation
7. Simulating Chaotic systems
8. Web experiment II: Motor control
9. Computer Animation
10. Project Development

The projects

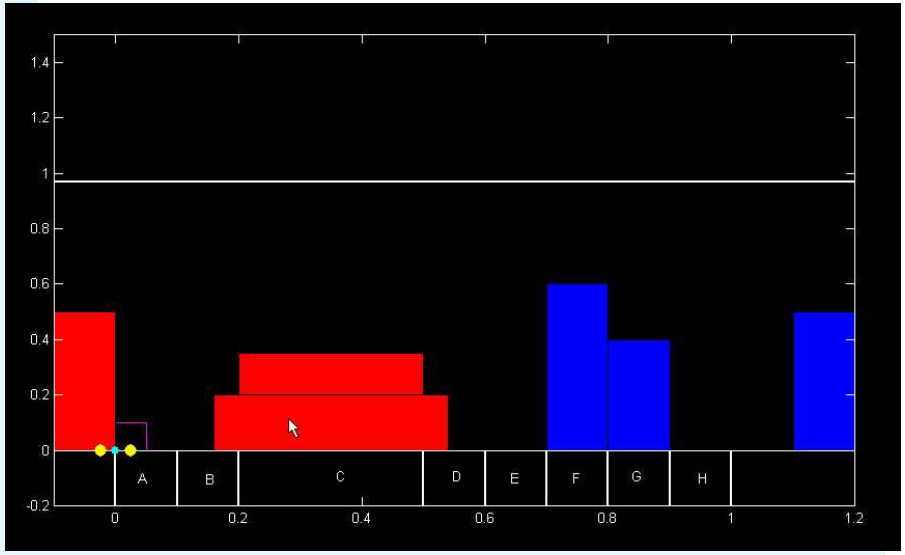
- Two students per team
- Counts for 15% for the total grade
- Lab session: simulation block build, debug, and partial animation.
- Homework: system integration, coordinate motion, analysis, parts list, and specifications for actual fabrication.
- Past projects: Crane system, 2-link robot, inverted pendulum.

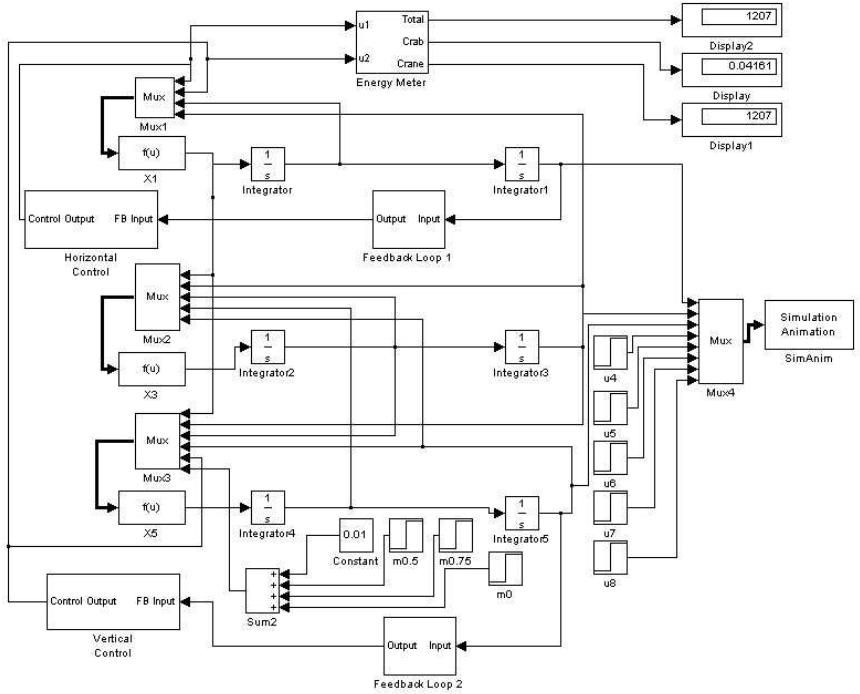
Project Example: Crane System

$$
\begin{aligned}
u_1 &= (m_L + m_c)\ddot{x}_1 + x_5\ddot{x}_3 m_L \cos x_3 + \ddot{x}_5 m_L \sin x_3 + b\dot{x}_1 + 2\dot{x}_3\dot{x}_5 m_L \cos x_3 - x_5\dot{x}_3^2 m_L \sin x_3 \\
0 &= \ddot{x}_1 x_5 \cos x_3 + x_5^2\ddot{x}_3 + g x_5 \sin x_3 + 2x_5\dot{x}_5\dot{x}_3 \\
u_2 &= m_L\ddot{x}_1 \sin x_3 + m_L\ddot{x}_5 - m_L g \cos x_3 - m_L\dot{x}_3^2 x_5
\end{aligned}
$$

where

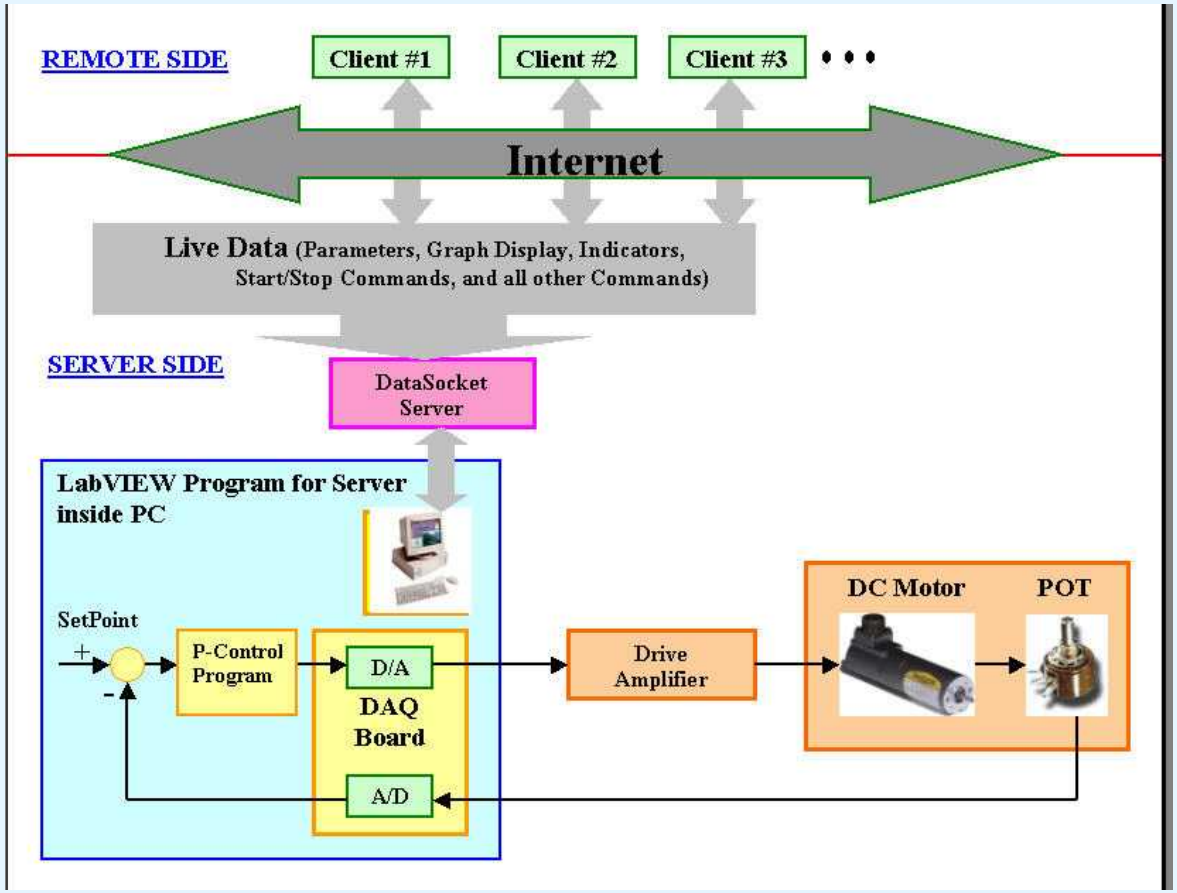
m_L	load in kg
m_c	mass of crab in kg
x_1, x_2	crab position, velocity in m and m/s
x_3, x_4	cable angle and angular speed in radians and rad/s
x_5, x_6	cable length and rate of change in m and m/s
u_1, u_2	crab and winch controls
g	$9.8 m/s^2$
b	viscous damping





Experiment on Nonlinear motor control

- To determine linearized motor transfer function based on closed loop I/O data
- Direct data acquisition and control: PC DAQ processing



Assessments and Analysis

Semester	Number of students	"Overall education value of the course" (out of 4)
2000 spring	26	3.57
2000 fall	20	3.38
2001 spring	19	3.57
2001 fall	37	3.73
2002 spring	22	3.29
2002 fall	30	3.75
2003 spring	22	3.67
2003 fall	28	3.74

1. Success rate of the project does correlate strongly with the rest of the lecture grades and work pattern. Therefore, a highly structure project schedule is recommended.
2. Most students prefer feedback approach than open loop strategies.
3. General computer skills (e.g. web surfing, games, etc.) do not necessarily translate into project success. Coordination of lecture and lab sessions is vital.
4. Team spirit is critical. It may be necessary to apply additional partnership criteria e.g. Myers-Briggs Type Indicator to improve teaming arrangements and communication among members.

Conclusions

- In this paper, courseware redesign for a senior level course on control system analysis is reported.
- Besides revising the course contents, a series of lab sessions are introduced to complement the lecture series with the review of Matlab, introduction of Simulink, Ansim, web experiment, and culminating in the project design.
- The project is a real-life system with high degree of freedoms and nonlinearities. The use of animation added an extra dimension of visual communication that brought the students closer to the physics (rather than just the mathematics) of the problem.
- Student response has been very positive despite the extra work and, at times, the difficulties in maintaining coherent team spirit.

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We are seeking collaborative partners

Email us if you are interested:

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