A Perspective on Multi-disciplinary Integration of Design and Control

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Industry Report to Academia

- **Low graduate ratings in exposure to laboratories, hands-on practical experience, and inter-personal skills [2].**

- **Greater curriculum emphasis on design and controls [3].**

- **Emphasis on traits and skills and not just content, foster interdisciplinary collaboration, communication skills of all types, group dynamics [5]**

[2] Kheir, N.A., Astrom, K.J., Auslander, D., Cheok, K.C., Franklin, G.F., Masten, M., and Rabins, M., 'Control Systems Engineering Education', *Automatica*, Vol. 31, 1995, 147-166.

[3] Edgar, T. F., 'Process Control Education in the Year 2000: A Roundtable Discussion', *Chemical Engineering Education*, 1990, 72-77.

[5] Buonopane, R. A., 'Engineering Education for the 21st Century: Listen to the Industry', *Chemical Engineering Education*, Vol. 31, 1997, 166-167.

Integrated Design and Control Education

- **Need for better integrated hands-on laboratories.**
- **Application of fundamentals of engineering in practical setting.**
- **Laboratories equipped with modern hardware and computational tools.**
- **College-wide interdisciplinary controls laboratory at University of Delaware.**
- **Endorsed by industries in Delaware – Outreach courses, University interaction.**

Interdisciplinary Controls Laboratory

- **Realistic introduction to control systems design.**
- **Familiarity with computer tools and hardware in industry applications.**
- **Integrate skills from the curriculum and interdisciplinary design components.**
- **Encourage group interaction skills.**
- **Communication skills through oral and written reports.**
- **Encourage problem based learning.**
- **Facilitate university industry interaction.**
- **ABET 2000 Criteria.**

Elective Laboratory Control Course

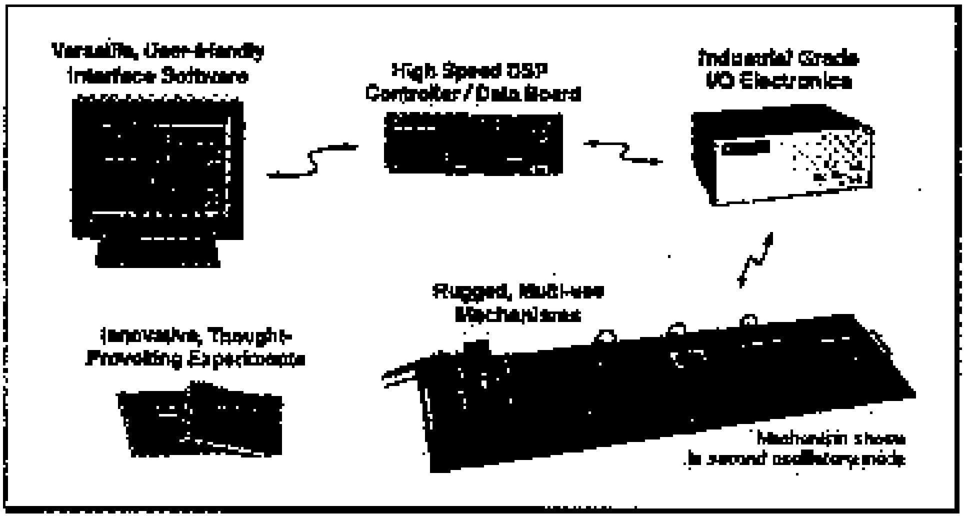
- Team taught: Civil, Electrical, Mechanical, Chemical.
- Application of fundamentals of design, fluids, thermodynamics, numerical analysis, and control theory.
- Open-ended steps in each laboratory module:
  - Development of mathematical model.
  - Numerical simulation using MATLAB.
  - Characterization of operating points.
  - Design of feedback laws for modified behavior.
  - Comparison of theoretical results with experiment data.
  - Documentation in written and oral reports.

Experiment Modules

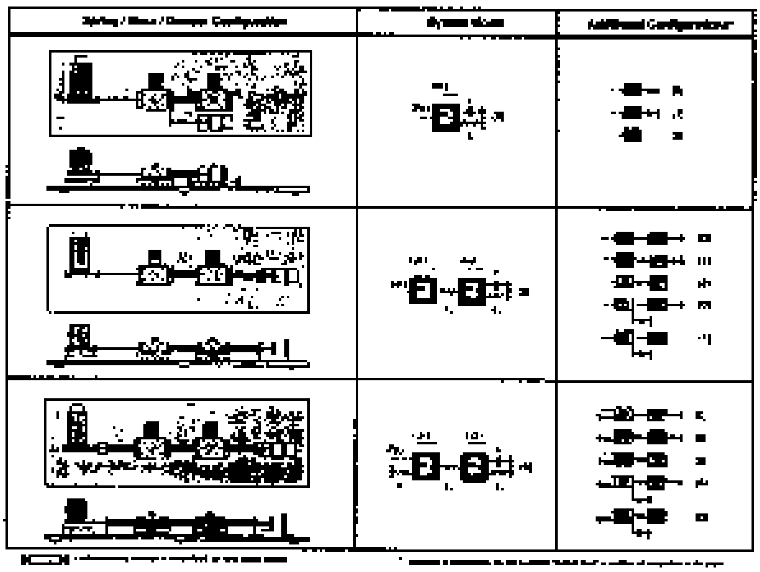
- **Rectilinear Plant.**
- **Inverted Pendulum.**
- **Servomotor.**
- **Heat Exchange Networks.**
- **Fluid flow in Series and Parallel Tanks.**
- **Distillation Column.**
- **Paper Mill Stock Preparation.**
- **Chemical Reactor.**
- **Plant wide Design (virtual experiment).**

Rectilinear Plant: Test Case

- **ECP: 3 masses, 3 springs, 3 encoders, 1 servo motor, 1 damper, DSP controller, Data acquisition board.**



- **Assemble in 27 system configurations: Students choose 2.**



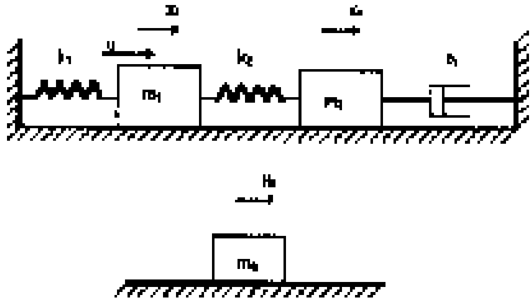
[4] *Manual for Model 210/210a: Rectilinear Dynamic System*, Educational Control Products, Woodland Hills, California, 1996.

Rectilinear Plant: Test Case (Contd.)

- Assigned Student Tasks:
  - Mathematically model forced and unforced dynamic behaviors.
  - Numerical simulation using MATLAB.
  - Assemble the physical experiment.
  - Perform parameter identification.
  - Compare theoretical and experiment data.
  - Design PID controllers using transient and controller specs.
  - Experimentally implement the controller.
- Tasks completed by students in 4 weeks with documented results.
- Course evaluations showed renewed interest of students in the subject matter.

Rectilinear Plant: Test Case (Contd.)

- **Graduate research: Real-time Motion planning with input and state saturation**



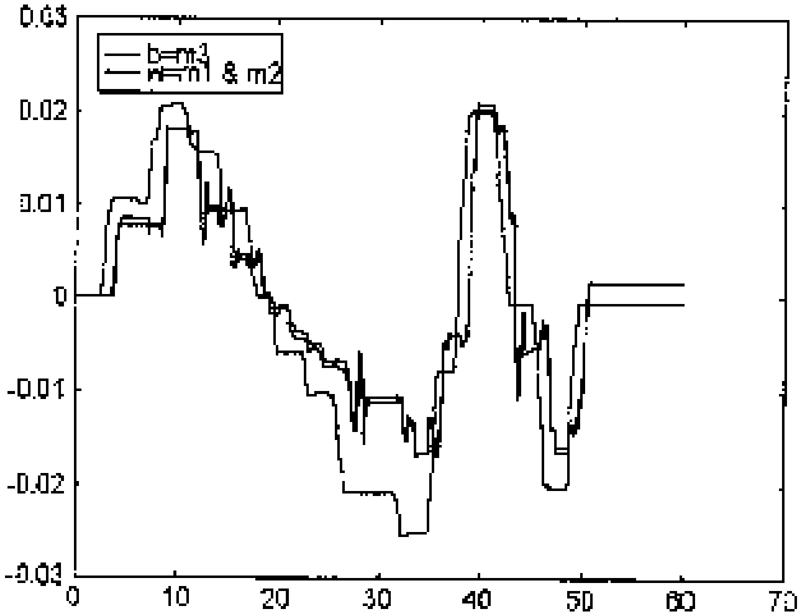


Figure 3: The data of a typical 'pursuit-evasion' experiment where mass 3 is moved around and mass 2 follows mass 3 while satisfying the constraints. The plot overlays the commanded motion of mass 3 and followed motion of mass 2

[1] Agrawal, S.K., Faiz, N., and Murray, R.M., 'Feasible Trajectories of Linear Dynamic Systems with Inequality Constraints Using Higher-Order Representations', submitted to *IFAC Conference*, Beijing, 1999.

Conclusions

- **Well integrated laboratory experiments may be a very effective way in teaching design principles applied to control of dynamic systems.**

- **'Multidisciplinary perspective' is the need of industries and academia.**

- **'Multidisciplinary Controls Laboratory' of UD will provide a front for more effective controls education and stronger ties with industry.**