AIChE Annual Meeting
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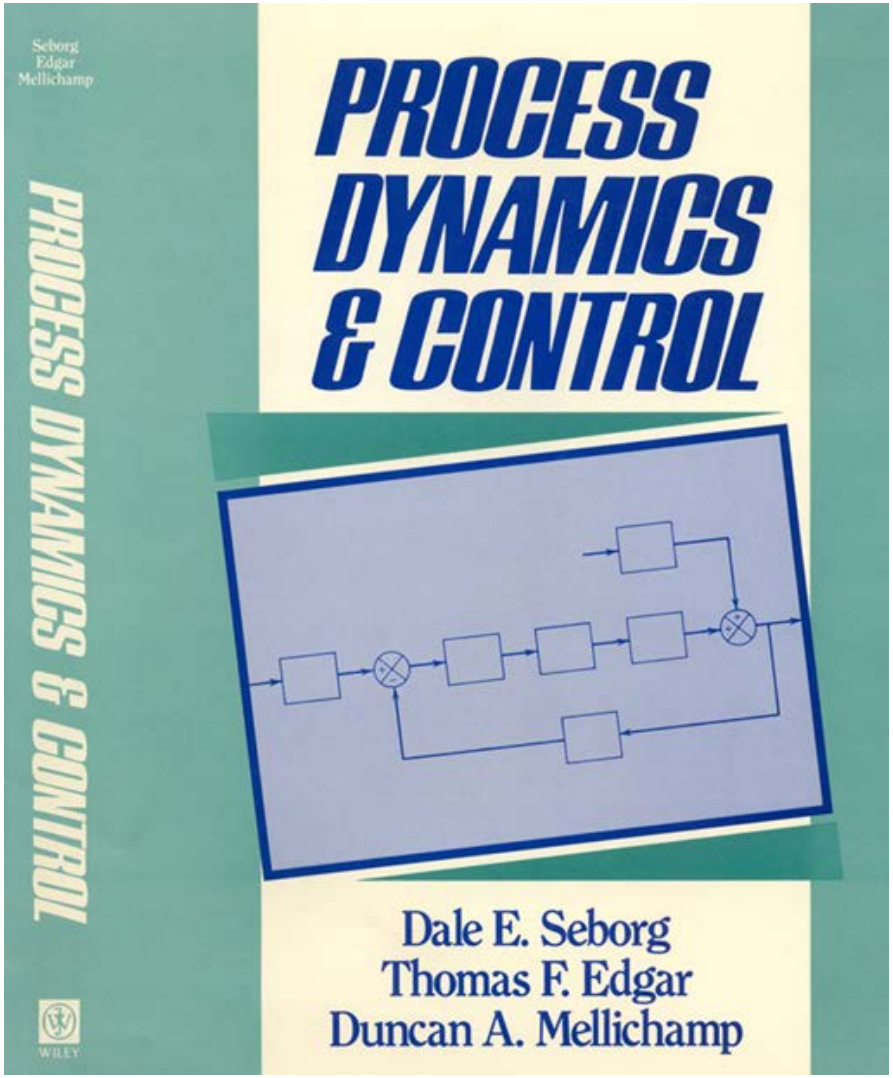
Ruminations on the Undergraduate Process Control Course

Thomas F. Edgar, University of Texas

State of Process Control Course?

What Can Be Done To This Old House?

- Repair roof
- Fix foundation
- Replace furniture
- Fix plumbing/electrical
- Add rooms
- Add windows, doors
- Repaint
- Redecorate


Seborg
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PROCESS DYNAMICS & CONTROL
PROCESS DYNAMICS & CONTROL
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Causes for Concern

- Less than 40% of ChE Departments (U.S.) have one faculty member with primary research interest in systems area
- Government funding for control research relatively hard to obtain
- Recent faculty hiring has emphasized bio, nano, enviro with few systems hires
- Some departments have eliminated a separate control course (coincides with ABET 2000 criteria change)

Current ABET Program Criteria state:

- The curriculum must provide a thorough grounding in the basic sciences including chemistry, physics, and/or biology, with some content at an advanced level, as appropriate to the objectives of the program. The curriculum must include the engineering application of these basic sciences to the design, analysis, and control of chemical, physical, and/or biological processes, including the hazards associated with these processes.

Value of Control to Industry

- Control training is valued, but emphasis may depend on industry where student is employed and nature of job responsibilities
- Job openings in manufacturing (“process engineer”) often request skills in simulation, computing, and control
- Commodity enterprises still need new engineers
- Are B.S. graduates unprepared for industrial assignments related to control?

Industrial Survey: Ranking of Key Control Concepts (10 = highest priority)

1. (8.6) Optimization of a process or operation
2. (7.2) Statistical analysis of data and design of experiments
3. (7.0) Physical dynamic process models
4. (6.9) Statistical/Empirical dynamic process models
5. (6.6) Multivariable interactions and system analysis
6. (5.3) Statistical process control and process monitoring
7. (5.1) Design and tuning of PID loops
8. (3.9) Nonlinear systems dynamics and analysis
9. (2.4) Frequency domain analysis
10. (1.9) Expert systems and artificial intelligent

Batch Processing Used in Manufacturing

- Electronic materials
- Specialty chemicals
- Metals
- Ceramics
- Polymers
- Food and agricultural materials
- Biochemicals
- Multiphase materials/blends
- Coatings
- Composites

Comments from a Batch Industry Practitioner (and ABET Visitor)

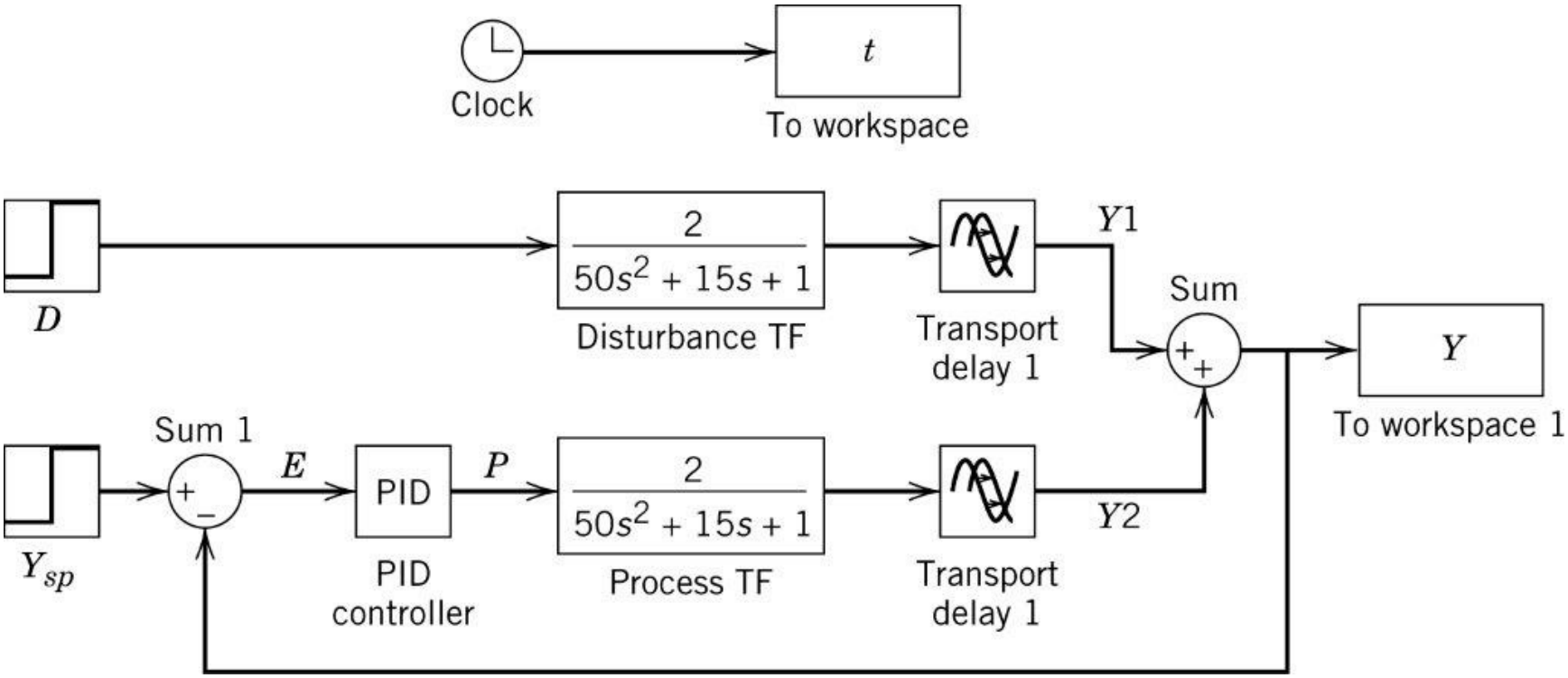
- Control course topics relatively unchanged for past 40 years
- Stability emphasis not relevant to batch processing (not steady state, nonlinear)
- Lab experiments often use manual data recording, analog controllers (no exposure to computer control)
- Not much exposure to PLC and logic programming, batch control standard (ANSI/ISA-88)

Reducing the Emphasis on Laplace Transforms and Frequency Response

- Symbolic math toolbox can alleviate math tedium
- Simulink for closed-loop control analysis aids in understanding dynamics
- Still cannot rely on Mathematics O.D.E. course to provide adequate preparation for process control
- Frequency response is being de-emphasized by more faculty

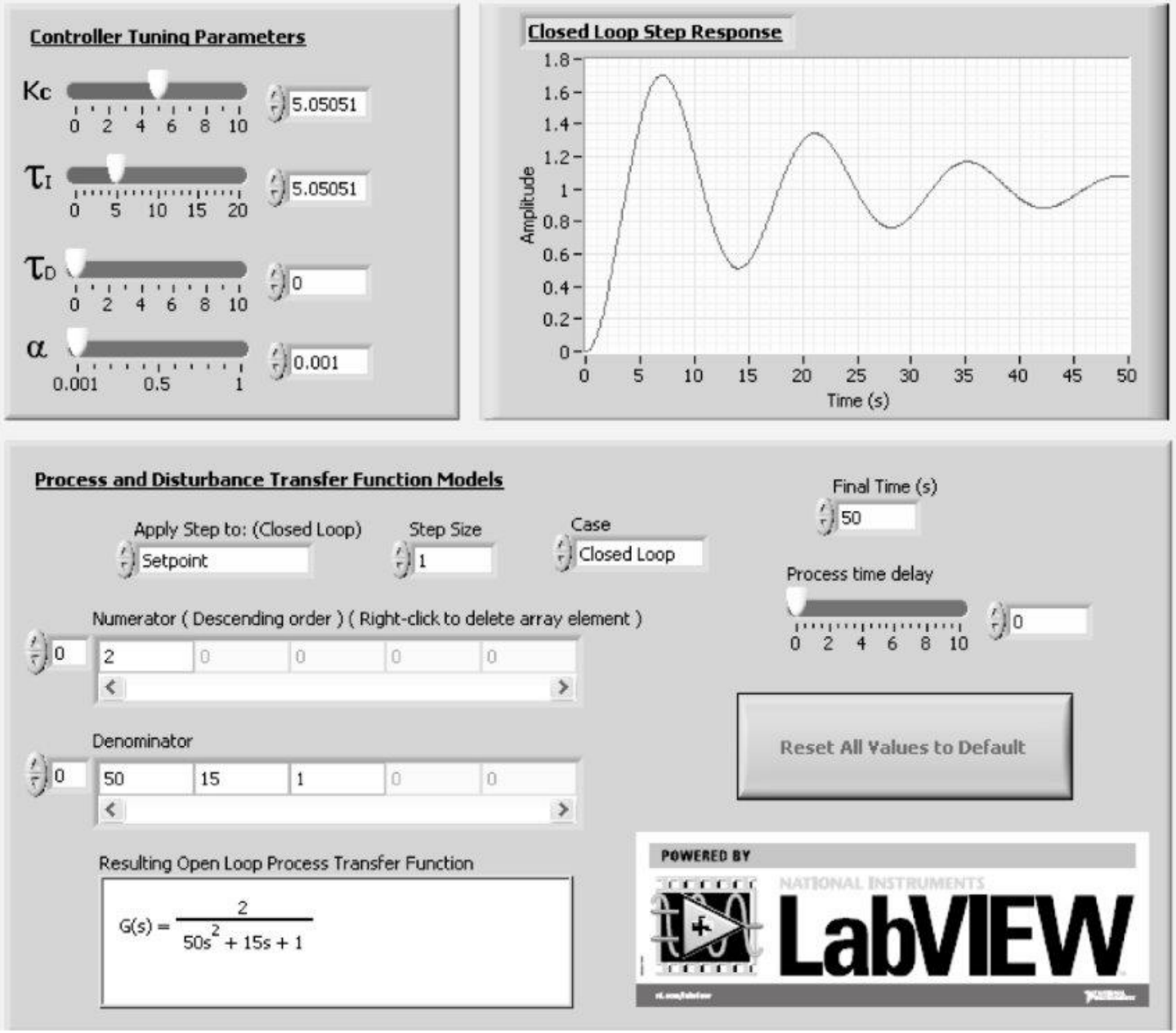
Decreased Coverage of PID Controller Tuning

- For many simple models, most methods give similar results
- Only should cover one (or two) tuning methods
- Effect of model errors (robustness) should be presented
- Optimal tuning not sustainable in industrial loops
- Coverage of PID in bio-focused control course? (Feedback control should be presented)



MATLAB Simulink

Process PID Control Tuner



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Process Control

This page is being managed by **Dr. Thomas Edgar**, The University of Texas at Austin

1. **Software/Simulation**
2. **Course Syllabi/Course Notes**
3. **Process Systems Research Consortia**
4. **Optimization websites**
5. **Process Control TextBooks**

Software/Simulation

- **Control Loop Foundation**
  The Control Loop Foundation website provides teaching, example and simulation material on process control. Based on the book "Batch and Continuous Processes—Interactive Source for Process Control", the workshops uses control studio applets that are embedded in "DeltaV InSight" developed by Emerson Process Management. The Control studio also provides a graphical diagramming tool for control modeling and visualization.
- **Model Predictive Control of an Adhesive Coater**
  A Matlab project in which students design a model predictive control system for a multivariable adhesive coating process. The project description includes a self-contained introduction to model predictive control needed for the project.
- **Interactive On-line Optimization**
  An automated system that adjusts the operation of a plant based on product scheduling and production control to maximize profit and minimize emissions.
- **Penicillin Simulation**
  PenSim© v1.0: A Web Based Program for Dynamic Simulation of Fed-Batch Penicillin Production
  Department of Chemical and Environmental Engineering, Illinois Institute of Technology, Chicago
- **GlucoSim**
  A web-based educational simulation package for glucose-insulin levels in the human body
- **Nonlinear Model Database**

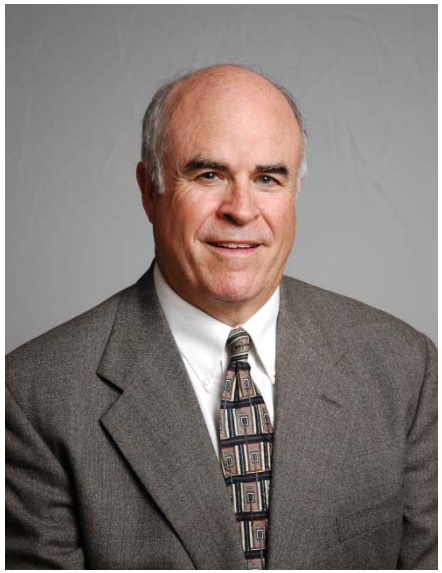
How Should Modeling be Covered in the ChE Curriculum?

- Make the entire curriculum more model-based
- Dynamics should be introduced in more than the control course
- Design course should focus more on operations than steady-state design
- This could make the process control course more efficient and allow it to focus on relevant control issues; also serve to integrate earlier core ChE courses

Future Industry Employees: The New Digital Generation

- Lives with pervasive microprocessors and telecommunications (e.g., cell phones)
- Gaming, Facebook, Instagram
- Demands computer interaction, plug and play
- Learns through experimentation, group interaction, intuition
- Focuses on future practical goals

Observations by a Faculty Curmudgeon



Today's students

- Are an impatient culture
- Prefer sound-bite answers
- Do not want to engage in a methodical analysis
- Do not enjoy deriving equations
- Say "don't tell me why, tell me how"

A harsher view:

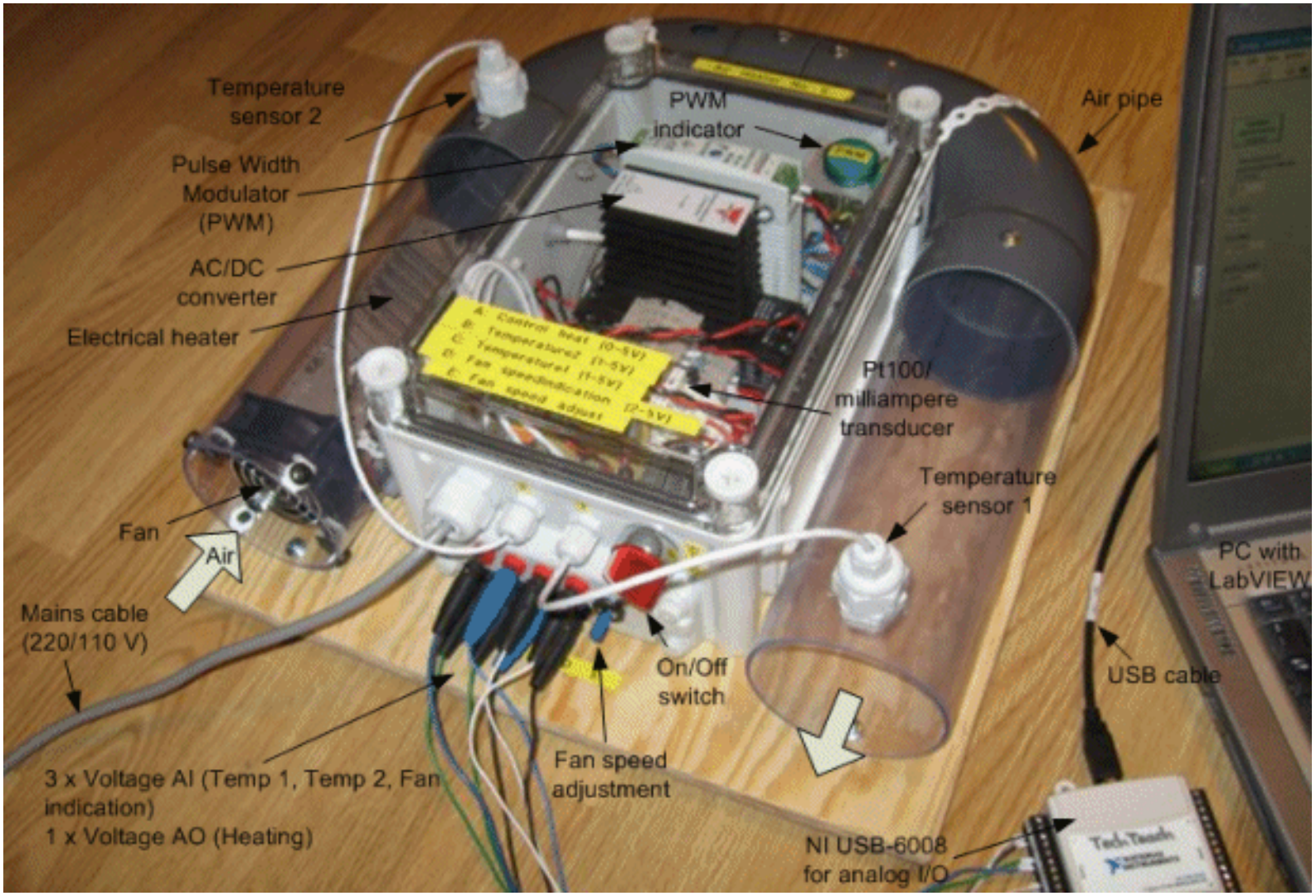
36 percent of college students showed no improvement over two years on measures of critical thinking, complex reasoning and writing. But what sort of moron thinks those skills are applicable to modern life? We don't write; we tweet. We don't think critically; that sounds mean! Reasoning? That's for people who don't want to make it on cable. And for everything else, there's Google. College students are quite justly focusing on the skills they'll need in the workplace, like staying awake and smiling vaguely but pleasantly while hung over.

-A. Petri, Washington Post, June 22, 2011

The Laboratory Experience and Process Control

- Very few dedicated control labs in existence today
- Introducing students to unsteady state operation is very important
- Simple inexpensive experiments can be pedagogically effective (table-top)
- How much is necessary (vs. simulation)?

Equipment Description



Possible Case Studies for the Process Dynamics and Control Course

Chemical Processes and Materials Processing

Fed-batch polymerization reactors; desalination of seawater; crystallization in drug manufacture; photovoltaic film processing; fuel cell

Bio Systems

Baroreceptor vagal reflex (blood pressure control system); insulin-dependent diabetic patient (glucose-insulin metabolism/control); circadian rhythm gene regulatory network; anesthesia control

Incorporation of Biological Content in Process Control

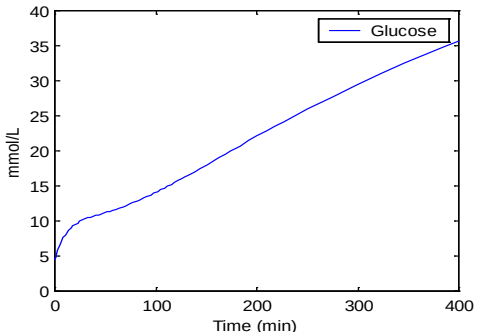
- Modest amount of biological examples in latest control textbooks
- Already occurring in control courses at U. Mass and U. Pittsburgh
- Systems biology course at UCSB
- State space emphasis (vs. Laplace transforms)
- Some topics in traditional process control course not covered
- Prototypical examples: yeast fermenter, insulin-dependent diabetic patient

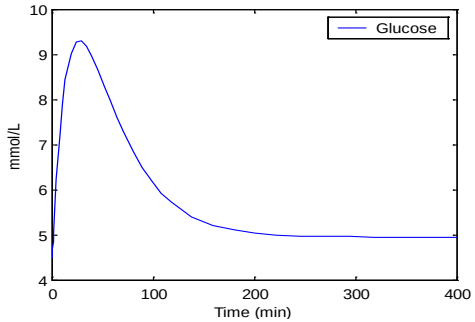
Biomedical Process Dynamics and Control Problem

- Diabetes Mellitus affects 14 million people
  - malfunctioning pancreatic response
  - hypoglycemia deprives body of fuel (dangerous)
  - long term effects of improper glucose control include nephropathy and retinopathy
- Current (and proposed) therapeutic approaches
  - injection
  - encapsulated islets
  - hydrogel devices
  - external pumps
  - implantable pumps

Problem:

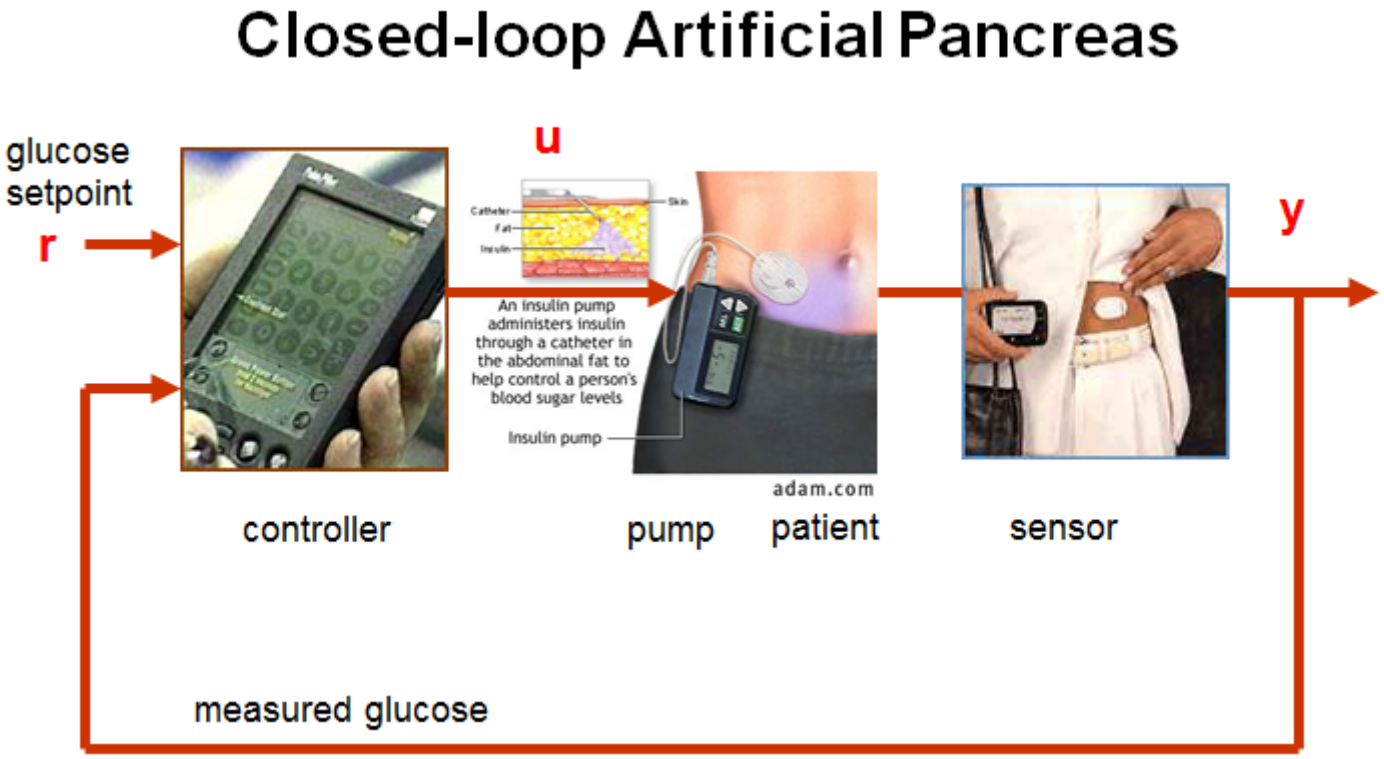
- A Type I Diabetic needs your help to maintain her blood sugar within an acceptable range (3 mmol/L < glucose < 8 mmol/L). She has just eaten a large meal (a disturbance) that you estimate will release glucose according to D(t) = 0.5 e-0.05t, where t is in minutes and D(t) is in mmol/L-min. She has a subcutaneous insulin pump that can release insulin up to 115 mU/min (mU = 10-3 Unit of Insulin). The flowrate of insulin is the manipulated variable.
- A model of her blood glucose level is given by (Bequette and Lynch, 2002)
- dG/dt = -P1 * (G - G_basal) - (X - X_basal) * G + D;
- dX/dt = -P2 * (X - X_basal) + P3 * (I - I_basal);
- dI/dt = -n * I + U / V1;
- What will happen to her blood glucose level if the pump is shut off initially?





What will happen to her blood glucose level if the pump injects at a constant rate of 15 mU/min?

Is there a constant infusion rate of insulin that will help her stay within an acceptable glucose range (3mmol/L < G < 8mmol/L) for the next 400 minutes?



Advanced Topics for Undergraduate Process Control

Alarms and safety
Model predictive control
Simulation
Distributed control software and hardware
Unit operations control applications
Batch sequence control, PLC's
Process control languages
Statistical process control and monitoring
Process control data base management
Real-time computing
Expert systems, artificial intelligence
Digital control algorithms
State space analysis
Real-time optimization
Model Identification

What's In? What's Out?

1. De-emphasize frequency response but keep some Laplace transform material (transfer function, block diagrams)
2. Reduce coverage of multiple approaches for PID controller tuning
3. Increase use of simulation in sophomore and junior chemical engineering courses, so students are well-prepared for dynamic simulation when they take the control course. Use more dynamic simulation in the capstone design and operations course

4. Introduce in-class short laboratory experiences that allow students to collect actual dynamic data, analyze the data, and use a controller to influence the behavior
5. Use case studies to show how process control can be employed to solve real engineering problems. This will help in introducing non-traditional area such as biotechnology and nanotechnology into the control course

The Joy of Writing Books
(SEMD-4, 2016)

Writing a book is an adventure. To begin with it is a toy, then amusement, then it becomes a mistress, then it becomes a master, and then it becomes a tyrant, and the last phase is that just as you are about to become reconciled to your servitude, you kill the monster and strew him about to the public.

Winston Churchill