Portable Wet Process Control Laboratory
for Every Student's Desk or Home

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Motivation

- If Process Control is viewed as a Mathematics class, some students lose interest
- Simulations can help, but timely hands-on experiments can be much more effective
- With large classes, it is very difficult to give a meaningful timely lab experience using centralized laboratories
- Introducing hands-on experiments in regular lecture classrooms addresses this problem
- A well-known & understood process that provides tactile output in addition to the visual output of real-time plotting is particularly attractive

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The Personal Portable Wet Process Control Lab

- Involves controlling the temperature of a water-filled can
- The can is heated using a beverage immersion heater and cooled with two computer fans
- The temperature is measured using a waterproof 12-bit digital probe
- The heater and the fans are manipulated using PWM implemented via an Arduino UNO microcontroller
- The output is real time in Excel, both tabular and graphical

- The only classroom requirement is an adequate supply of power outlets
- The components cost per student is about $80
- Successfully tested with a class of 35 students in summer 2017

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The System Hardware

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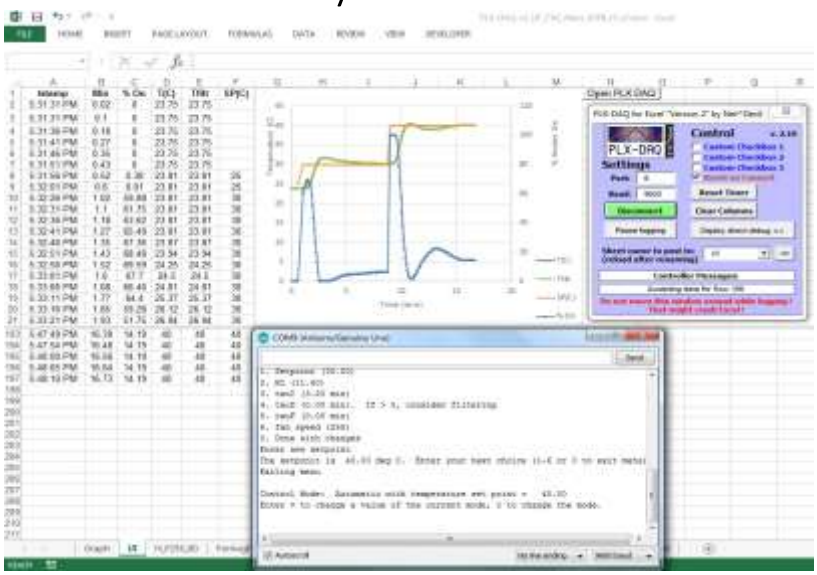
The System Software



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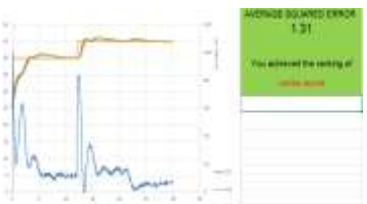
The System Software - continued

Special versions of the software:

1. Contest Version:
   - The software is locked in manual mode
   - 2 pre-programmed set-point changes and 1 disturbance change (fans turning off)
   - If the temperature exceeds a maximum the run ends.
   - Otherwise, the run ends in 30 minutes
   - At the end, depending on the sum of squared errors, the student receives a rating ranging from "PROFESSIONAL CRASH-TEST DUMMY" to "CONTROL MASTER"



2. Controller Tuning Evaluation Version:
   - Runs the same set-point and disturbance changes as the contest version in automatic mode
   - At the end, provides the SSE and a rating

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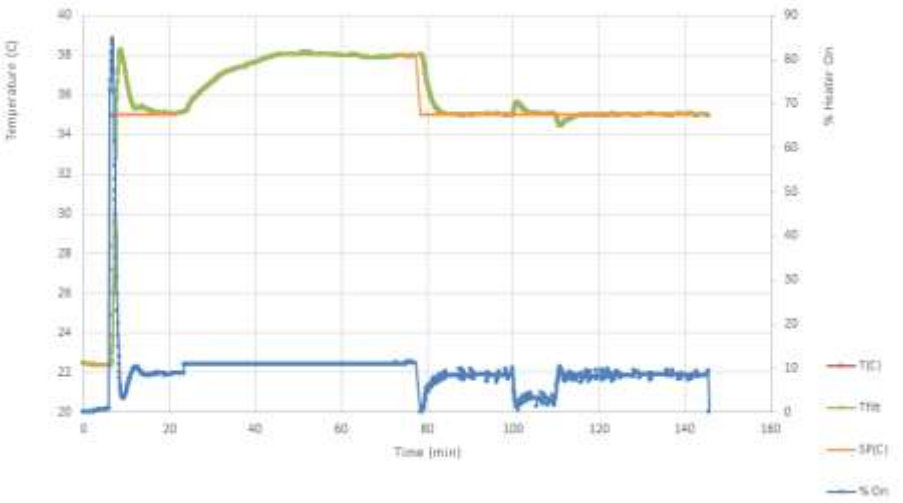
Experiments That Can Be Performed



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Summer 2017 Evaluation

33 of the 35 students filled out a 10-question survey at the end of the class

Scale: 5 = Strongly agree 1 = Strongly disagree	Average
The experiments increased my interest in the class	4.61
The experiments increased my interest in the mathematics of the class	4.24
The experiments increased my confidence that I can obtain tranfer functions for real systems	4.42
The experiments increased my confidence that I can tune controllers for real systems	4.45
I prefer the experiments over using simulations	4.09
Having an experiment running while the professor was lecturing was not distracting	3.58
The experimental set-up was reliable and performed well	3.64
The experimental set-up required no longer than 5 minutes to assemble	3.16
The experimental set-up required no longer than 5 minutes to disassemble	3.18
Overall, I was pleased with the experimental component of the class	4.55

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Summer 2017 Evaluation - continued

- The regular college end-of-class evaluations have two relevant questions
- 27 of the 35 students responded
- The same instructor taught the class with simulations the previous 5 summers with classes of similar size

Scale: 5 = Excellent or high, 1 = Poor or low	Sum 12	Sum 13	Sum 14	Sum 15	Sum 16	Sum 17
	SIMULATIONS	SIMULATIONS	SIMULATIONS	SIMULATIONS	SIMULATIONS	EXPERIMENTS
Amount learned	4.63	4.73	4.66	4.45	4.67	4.73
The educational value (relevance) of this course	4.72	4.8	4.63	4.27	4.78	4.92

- Student comments were very positive, e.g.
  - This course was very engaging and interesting, especially with the lab portion. It made the theory of the course relatable to a physical level.
  - Really liked the lab setup, and it aided my understanding of the course significantly
  - The lab is very interesting. It was cool to see a hands-on application of what was learned in the lecture portion of the class, and to get a break from lectures every now and then (haha).
  - In the past, I really have not liked my lab classes too much, but I can honestly say that I did like this one. I think that is because it was so integrated with the material we were learning

CONCLUSIONS

- Pilot test of the Control Lab was successful
- However, issues were identified

ISSUES AND IMPROVEMENTS

1. The lab had to be disassembled for transportation. Reassembling for every use led to two issues:
   - The distance between heater and probe was not always the same, affecting the time delay & controller performance.
   - Many students took longer than 5 minutes to assemble and disassemble the experimental set-up, leading to significant loss of class time

   NEW DESIGN:
   - The heater and probe are permanently attached to the can using putty, and no disassembly/reassembly is required.

ISSUES AND IMPROVEMENTS - continued

2. Some components were unreliable (breadboard, wires)

   NEW DESIGN:
   - They were replaced with high quality components
3. Spilling water on the paper can base could ruin it

   NEW DESIGN:
   - The base was changed to an aluminum tile
4. Open loop step changes could need 1 hour to reach steady state

   NEW DESIGN:
   - The 2.6” diameter soda cans were replaced by 1.75” diameter aluminum cans

THE IMPROVED EXPERIMENTAL SET UP