Process Control: Learning It and Doing It Through LabVIEW™ Based Design

Heidi B. Martin and R. Craig Virnelson

Chemical & Biomolecular Engineering Dept.
Case Western Reserve University

November 10, 2015
AIChE Fall Annual Meeting, Salt Lake City, Utah
Our Process Control Class…
Approach

Reliance on LabVIEW and data acquisition as user-friendly tools for the integration of concepts in controller modeling and implementation

Motivation

Traditional Process Control courses focus mostly on process control theory
Our Reinvented Course

- Recitation Time Switched to Lab Session
  (Overall Course is 4 Credit Hours)
- Heavy Use of LabVIEW for both Data Acquisition and Process Modeling
- Training in LabVIEW, Data Acquisition
- Design Project – Couples Modeling & Implementation
- Ongoing Emphasis - Connection Between Theory & Practice
  (Process Modeling, Transfer Functions, Linear Feedback Control Theory, Feedforward & Cascade Control)
Coupling Data Acquisition with Feedback Control

- LabVIEW software - Graphical Programming, User Friendly
- Data Acquisition Teaching Platform (*National Instruments* NI-ELVIS II)
- Custom Built Data Acquisition Platform (Uses *NI* board)
- Supply Room – Project Equipment
# Early Incorporation of LabVIEW

<table>
<thead>
<tr>
<th>WEEK OF THE SEMESTER</th>
<th>DESIGN PROJECT ACTIVITY</th>
<th>LABVIEW TRAINING/ASSIGNMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>For Data Acquisition</strong></td>
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<td><strong>For Modeling</strong></td>
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<tr>
<td>1</td>
<td></td>
<td><em>In–class Tutorials</em></td>
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<td></td>
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<td><em>Control Lab, Part 1</em></td>
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<td>2</td>
<td></td>
<td><em>Training Programs 1-3</em> Analog Inputs*</td>
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<td><em>Control Lab, Part 2</em></td>
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<td>3</td>
<td>Preliminary Project Proposal Submission</td>
<td><em>Introduction to the Simulator</em></td>
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<td>5</td>
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<td>6</td>
<td>Team Meeting with Instructor</td>
<td><em>Process Simulations</em></td>
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<td><em>Time Domain</em></td>
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<td><em>Non-Linear Systems</em></td>
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<td>7</td>
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<tr>
<td>8</td>
<td>Final Project Proposal Description</td>
<td><em>Process Simulations:</em></td>
</tr>
<tr>
<td>9</td>
<td>with Gantt Chart</td>
<td><em>Transfer Functions</em></td>
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<td>10</td>
<td>Written Status Report 1</td>
<td><em>Linearization</em></td>
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<td><em>Relating Transfer Functions to Instrumentation</em></td>
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</tbody>
</table>

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Stage 1: Predetermined Project—pH Control

- Design Program
- Tune Controller

- Non-Linear System
- Less Creativity

\[ p(t) = \bar{p} + K_c \left[ e(t) + \frac{1}{\tau_I} \int_0^t e(t^*) dt^* + \tau_D \frac{de(t)}{dt} \right] \]
Stage 2: Student-Selected Topics

- Guitar String Tuner
- Ballast Tanks – Waterline of Ships
- Dissolved CO₂ in Aquariums
- Pancake Producers
- Solar Panel-Rotation & Tilt
- Smart Umbrella
- Venetian Blinds
- Baby Rocker-for Restful Sleep

Top Project 2012

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Stage 3: Team Projects

Hydroponics (pH & T Control)

Drink Composition (Switch Valves- Integrate Flow)

Sugar Content (Auger)

Reaction Yield (Conductivity)

Public Demo Session

Violin Tuning (3-D Printing of Peg Clamp)

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Based on Example 4.4, Seborg et al., *Process Dynamics & Control*

Tank 1: \[ q_{in} - q_{out,1} = A_1 \frac{dh_1}{dt} \]

Tank 2: \[ q_{out,1} - q_{out,2} = A_2 \frac{dh_2}{dt} \]

\[ q_{in} (0) = 1 \quad q_{in} (0^+) = 2 \]

\[ q_{out,1} = \frac{1}{R_1} h_1 \quad q_{out,2} = \frac{1}{R_2} h_2 \]

\[ R = \text{valve resistance}; \quad R_1 = R_2 = 0.5 \]

\[ A = \text{tank cross sectional area}; \quad A_1 = A_2 = 1 \]

\[ h = \text{tank level} \]
Step Tests & Transfer Functions

<table>
<thead>
<tr>
<th>Step Test (Δ pH)*</th>
<th>Tau 63% of Step Response</th>
<th>Tau Fit to First Order Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 to 7</td>
<td>1.8</td>
<td>2.7</td>
</tr>
<tr>
<td>4 to 10</td>
<td>1.7</td>
<td>1.7</td>
</tr>
<tr>
<td>7 to 10</td>
<td>1.9</td>
<td>2.3</td>
</tr>
<tr>
<td>10 to 7</td>
<td>2.7</td>
<td>4.2</td>
</tr>
<tr>
<td>10 to 4</td>
<td>1.5</td>
<td>1.6</td>
</tr>
<tr>
<td>7 to 4</td>
<td>1.0</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Simulated pH

Control & Simulation Loop

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Survey – Students from Past 5 Years

Your Level of Interest in the Design Project was:

- High
- Medium
- Low

Average 42% Response Rate

All Student-Selected Projects

Level of Interest in Design Project

(Pre-built) pH control = Lower Interest

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**Project Difficulty Worth the Effort**

Most felt “Somewhat Difficult”  

(Pre-built) pH control = Somewhat or Very Easy

**Level of Difficulty of Design Project**
LabVIEW Motivated Interest in Control

As a result of your experience with LabVIEW in the Process Control course, and the LabVIEW-based Design Project...

Your Level of Interest in Process Control is:

- Blue = Higher
- Red = Unchanged
- Green = Lower

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Students Gained Confidence

As a result of your experience with LabVIEW in the Process Control course, and the LabVIEW-based Design Project...

Your Level of Confidence in Building Stuff has:

- Blue = Substantially Increased
- Red = Modestly Increased
- Green = Remains Unchanged
- Purple = Modestly Decreased
- Teal = Substantially Decreased

(Pre-built) pH control = Higher percentage felt confidence unchanged

Blue = Substantial
Red = Modest
Green = No Change

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Impact throughout Curriculum

Research, Internships and Co-ops

Chemical Process Control (Junior Year)

Measurements Lab (Junior Year)

Students Design Experiments & Systems to Solve Problems

Senior Design Projects

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Process Control is Fun & Relevant

- *Bridge Gap between Theory and Reality*
- *Provide Design Project Experience*
- *Train with a New Skill Set to Address Design Problems*

Acknowledgments

- *Chemical & Biomolecular Engineering Dept.*
- *William James (BS, Case 1964)*
- *Students of ECHE 367, Process Control*