Industrial View of Process Control

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Outline

• **Who am I? What Do I Do?**
• **Intro to Industrial Control Engineering**
  – Control centers & personnel
  – Distributed Control Systems
  – What control engineers do
• **Models**
• **An extreme industrial control perspective**
  – Why it is wrong
  – Modern uses of
    • LaPlace Transforms
    • Z-Transforms
    • Frequency Analysis
• **If we have time...**
  – An short 1960s film from IBM film “Computer Control of a Catalytic Cracking Unit”
Who am I? What do I do?

• “I’m Dave Hokanson, and I’m a process control engineer”.
  – Rice BSChE / MChE
    • Taught sections of the process control course (and before that, the design course) dating back to 1984.
    • I’ll be giving a series of 4 lectures on process control design and an intro to industrial multivariable control in November.
  – Joined Exxon Chem / ExxonMobil Chem at graduation (1978), first in process design, then with a “rotational assignment” in process control (1980).
  – Still with process control, but in much different form…
    • Had assignments at the Baytown Chem Plant (control engineer, then lead control engineer),
    • Central Engineering (first DMCs within Exxon)
    • Control supervisor / leader at Rotterdam and Singapore
    • Since 1997 back in Central engineering leading the DMC effort.
What is DMC?

• Dynamic Matrix Control (DMC) – an industrial form of model-predictive, multi-variable control.

• Originally developed by Charlie Cutler
  – Originally at Shell, formed DMC Corp in 1984
  – Sold to AspenTech in 1996
  – However, heeeeee’s back!!

Cutler Technology Corporation
We Know DMC Because We Invented It!
Industrial Control

- Refineries and most Chem plants are large and complex
- High revenue per employee (i.e., few people)
- Run 24 hours, sometimes 5-6 years between downtimes (called “Turn-Arounds”)
- Control centers are usually centralized and can be far away from the process equipment
  - Run by “Console operators” – the man / woman who sits behind the computer screens, watching trends and monitoring the unit performance.
  - There are “outside operators” who do “rounds” – checking on the equipment, moving manually operated valves, starting / stopping pumps / fans/etc.
Modern Control Centers
What does a Control Engineer do?

- **Design control strategies at process design phase**
  - We’ll be looking at this later
  - Specify measurements and final elements, along with basic regulatory control structure (i.e., control a level in a vessel)

- **Design control strategies after unit is running**
  - Basic regulatory
    - PID
    - Single-Input / Single-Output (SISO)
  - Advanced regulatory
    - Cascade & feed-forward control
    - Multiple Input / Single Output (MISO)
  - Advanced Control / multi-variable, model-based control
    - DMC
    - MIMO
  - Real-Time Optimization
    - First Principal, steady-state models reconciled with the plant

- **What are the tools:**
  - Distributed Control System (DCS) – links measurements with final control elements
  - Advanced computing platforms
  - Software packages
DCS – Engineer’s Work Station
Models

• “All models are wrong; some are useful”
• If you can model the process, you can control it!!
  – The world does not live in steady-state!!
  – Hence, many dynamic models are “useful”.
• Some industrial process control uses of models:
  – PID tuning & simple model-based control
    • 1st order plus deadtime
  – DMC and similar model-based control
    • Unit step responses (in vector arrays) – derived using various model ID packages (FIR, ARIMA, SubSpace)
  – State-Space Controllers
    • State Space Models (can be derived by “SubSpace” model ID packages)
  – Non-Linear Model-based control
    • Neural Nets or 1st principal dynamic models
  – Dynamic Simulations (for process analysis or operator training)
    • 1st principal dynamic models.
  – Real-Time Optimization
    • 1st principal, steady-state models
An Extreme Control Perspective

- Robert V. Bartman
  - ProControl, Inc.
  - Process Control Education and Technology
- A good friend / former mentor at Exxon
  - We did a lot of joint development together on Exxon’s first multi-variable, model-based control
  - Bob charges a lot of money - $12k for 96 hour course
    - Elapsed-time, not credit hours!
    - Makes Rice look very cheap!
  - “Money-back guarantee if we mention such stalwarts as LaPlace transforms, or z-transforms, or Nyquist diagrams, or Bode plots, or Ziegler-Nichols tuning, in other than critically-humorous terms.”
- While he’s an excellent teacher and a very humorous guy, he’s wrong if you want to understand the basics process control, particularly as our field continues to develop
LaPlace Transforms

- Recently had to look at the tuning on a Foxboro control system.
  - Their PID algorithm is a bit different, and I went to the book to understand what it was doing:

  ♦ Proportional and integral (PI):
    \[ m_b = \frac{100}{P} \left( \frac{1}{I_s + A} \right) r - \left( \frac{1}{I_s + 1} \right) c_f f_r + b \]
    \[ \tau = 0 \]
  
  ♦ Proportional, integral and derivative (PID):
    \[ m_b = \frac{100}{P} \left( \frac{1}{I_s + A} \right) r - \left( \frac{1}{I_s + 1} \right)(1 + Ds) c_f f_r + b \]
    \[ \frac{1}{\tau} = \left( \frac{1}{I} + \frac{1}{D} \right) K_D \]

  ♦ Non-interacting PID (NIPID):
    \[ m_b = \frac{100}{P} \left( \frac{1}{I_s + A} \right) r - \left( \frac{1}{I_s + 1 + Ds} \right) c_f f_r + b \]
    \[ \tau = \frac{D}{K_D} \]
More on LaPlace Transforms

• But there’s more...
  – This PID has a built in filter for the Derivative Term
    • Good idea
    • What type??

♦ In the above expressions of measurement filter:

\[ c_f = \frac{c}{1 + \tau s + 0.5(\tau s)^2} \]

• Bottom line: An industrial process control engineer needs to be able to speak this language.
Z-Transforms

- Used frequently in “the days of old” for coding control algorithms (filters, PID controls, etc)
  - Also used to understand “aliasing” – loss of data in a sampled data system – due mostly to slow sampling
- Now used for mostly in various forms of ARX modeling
  - Here’s a formula directly from a fundamental paper on ARX modeling by Yucai Zhu of Tai Ji Control

\[ y(t) = G(z^{-1})u(t) + H(z^{-1})e(t) \]

- Another language that needs to be understood.
Bode Plots / Frequency Analysis

• Up until about 6-8 years ago, I agreed with my old mentor Bob Bartman on the usefulness of frequency analysis

• Then the usefulness for this technique became once again useful in two areas
  – Control Performance Monitoring
  – Model quality from a model identification software
Frequency Analysis of a 3x4 Model

distlit1: Frequency Resp. (solid/blue) & Error Bounds

reflux  steam  press  feed

topcom

A  B  C  D

-0.29914  1.3973  0.075208  0.73638

bottom

B  A  B  D

0.55142  -5.2222  0.38593  1.0465

flood

B  C  B  D

0.47354  3.1024  -0.62971  0.73638

Frequency (rad/MIN): (LOG) 0.000314:3.14
Control Monitoring Tools

Stand Alone: 220-LC-1061

RPI: 3.54
Stiction: 1.19

Closed Loop Impulse Response

Analysis Reliability

Samples Requested: 144
Samples Analysed: 1394
Sample Period(s): 59.99935
Saturation (%): 0.00
Service Factor (%): 100.00
Compression Factor: 1.02
Time in Mode (%)

Closed Loop Frequency Response

Settling Time: 44.00 min (Actual)
Rise Time: 15.00 min
Time Delay: 60.00 s

PV, OP, and SP

Controller Modes

Manual
Auto
Cascade
Avg Std. Dev.

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To Summarize

- **Control Engineering can be a fun job**
  - It’s a chance to make a direct impact on the plant operation
  - In our business “No money is made until a valve is moved”
    - We move valves!

- **Technology continues to evolve**
  - What we thought was useless is now useful!

- **Bottom line:**
  - Keep an open mind as you move from the world of Process Dynamics into the world of Control
  - I’ll be back to cover process control design, feed forward, cascade, and an intro to multi-variable, model-based control (e.g., DMC)