
Joint Modeling and
Control Design
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The Big Picture

- Model-based - Advanced - Control
  - Model development
    - Deductive Physics, Inductive System Identification
      - For control/prediction/simulation
        - Model quality measures - approximation
        - Effect of experimental conditions/controller
  - Model-based controller design
    - Performance - nominal model
    - Robustness - model quality

Connections

Modeling involves approximation

A general-relativistic, quantum-mechanical model for an ore crusher

- Mostly linear tools for fitting - matlab toolbox
- There is a need for parsimony

Trade-offs need to be made in modeling

- Let's make them where they hurt control least
  - What does that mean?
  - How do experiments help us to do this?

Frequency-domain formulae really assist here

Modeling Approximation Formula

$$\lim_{N\to\infty}\frac{1}{N}\sum_{k=1}^{N}\left\{L(z)[y_k-\hat{y}_{k|k-1}]\right\}^2=\frac{1}{2\pi}\int_{-\pi}^{\pi}\left\{\left|P(e^{j\omega}-\hat{P}(e^{j\omega},\theta)\right|^2\Phi_u(\omega)+\left|H(e^{j\omega})\right|^2\right\}\frac{\left|L(e^{j\omega})\right|^2}{\left|\hat{H}(e^{j\omega},\theta)\right|^2}\,d\omega$$

- It exists
  - It is a discrete frequency domain formula
    - Connected to time domain prediction errors
- It is useful
  - Model approximation is the subject
    - Plant, noise, plant model, noise model involved
- There are some free variables - design handles
  - Input spectrum $\Phi_u(\omega)$
  - Data filter $L(e^{j\omega})$

Closed-loop Modeling Formula

$$\lim_{N\to\infty}\frac{1}{N}\sum_{k=1}^{N}\left\{L(z)[y_k-\hat{y}_{k|k-1}]\right\}^2=$$

$$\frac{1}{2\pi}\int_{-\pi}^{\pi}\left\{\frac{\left|P(e^{j\omega})-\hat{P}(e^{j\omega},\theta)\right|^2}{|1+P(e^{j\omega})C(e^{j\omega})|^2}\left|C(e^{j\omega})\right|^2\Phi_r(\omega)\right.$$

$$\left.+\frac{\left|1+\hat{P}(e^{j\omega},\theta)C(e^{j\omega})\right|^2}{|1+P(e^{j\omega})C(e^{j\omega})|^2}\left|H(e^{j\omega})\right|^2\right\}\frac{\left|L(e^{j\omega})\right|^2}{\left|\hat{H}(e^{j\omega},\theta)\right|^2}\,d\omega$$

- The same story
  - A bit more complicated
    - But not much more
      - The controller appears in the picture explicitly

Robust Control Formulae

$$\left| \frac{P(e^{j\omega}) - \hat{P}(e^{j\omega},\theta)}{\hat{P}(e^{j\omega},\theta)} \times \frac{C(e^{j\omega})\hat{P}(e^{j\omega},\theta)}{1 + C(e^{j\omega})\hat{P}(e^{j\omega},\theta)} \right| < 1$$

$$\left| H(e^{j\omega}) \times \frac{P(e^{j\omega}) - \hat{P}(e^{j\omega},\theta)}{\hat{P}(e^{j\omega},\theta)} \times \frac{C(e^{j\omega})\hat{P}(e^{j\omega},\theta)}{1 + C(e^{j\omega})\hat{P}(e^{j\omega},\theta)} \times \frac{1}{1 + C(e^{j\omega})P(e^{j\omega})} \right| < \epsilon$$

- Formulae for robust stability and performance exist
  - They are in the discrete frequency domain
    - They involve designed properties
    - They involve model errors $P(e^{j\omega}) - \hat{P}(e^{j\omega},\theta)$
      - The controller is the design variable

Outline

1. Big Pictures and introduction
2. Modeling from data and System Identification
3. Example and some Philosophy
   Combustion instability modeling
4. Modeling for control example
   Helicopter vibration control model
5. Experiment design and data preparation
   Sugar mill control problem
6. Iterative modeling and control
   Sugar mill