Design of Experiments for Multivariable System Identification Subject to Integral Controllability

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Summary
- Problem Statement: Identify model for HIMO controller
- Existing Approaches
  - Well-conditioned systems: Use PAR inputs
  - Ill-conditioned systems: Use correlated input design based on uncorrelated inputs
- Open Issues
  - Satisfy input/output constraints
  - Achieve and maintain closed-loop stability
- This Work
  - Systematic approach to HIMO identification experiments subject to integral controllability
  - Main feature of proposed approach
    - Satisfy input/output constraints
    - Does not require system characterization as well as conditioned
    - Recover existing MIMO input designs as special cases
    - Propose new MIMO input designs
    - Generalized rotated inputs
    - Estimates upper bound for experiment duration

Integra Cal Controllability
- MIMO model identified from an identification experiment using a least-squares method
- Model-based control needs integral controllability

Ill-Conditioned Systems
- Characterized by large condition number and significant gain variation with input direction
- Use of PAR often leads to models that perform poorly in closed loop
- Example: High purity distillation in LV configuration

Main Result
Integral Controllability Bound

Implications for Input Design
- Consider following optimization problem:
- Motivated by MHC, input and output variance into a weighted sum
- Include hard output constraints
- Upper bound on integral controllability

Implications for Input Design: Selecting Analytical Solutions
- Design M or NM to satisfy bound

References:

Use of Integral Controllability Bound to Determine Experimental Time
- Using expression from earlier: $\sum \lambda_i \| \sum M \|_F^2 = \| \sum \lambda_i M \|^2$
- Simulate 100 experiments based on min variance $\lambda_i$. IC bound for $e=0$ & $e=z=1$ (same IC bound for each)

References:

Ongoing Work
- Larger systems - FCC (5x5) example
- Dynamic case - apply PRBS design to a based on estimates of open-loop dynamics
- Constrained case with min/max outputs and inputs (not just variances)

Conclusions
- Mathematical framework for designing experiments for MIN
- Method to classify systems as IR- or well-conditioned
- Algorithm in nature, allowing rigorous formulation of minimization problems
- Effective for high-dimensional cases and provide new insights
- Optimal experiments for typical situations lead to correlated related inputs

Future Work
- Application to adaptive design of experiments (do not know that plant)
- Open-loop extension to dynamic models
- Integrating IC bound into closed-loop finding schemes
- Apply to real systems
- Distribution of experimental time, probabilistic stability formulations