INTEGRATED DESIGN AND CONTROL UNDER UNCERTAINTY - ALGORITHMS AND APPLICATIONS

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Motivation

Classical design approach

- Simultaneous data design
  - Optimal design of process
  - Optimal design for process

- Design optimization problem is separated from feasibility test.
- Main optimization problem is solved in discretized sampling space.
- Feasibility test follows the design optimization problem.

- Simultaneous design and control optimization
  - Maximizes the overall system performance in face of operational and model uncertainty.
  - Dynamic state performance & feedback are considered.
  - Quantifies the actual dynamic process and prevent dynamic constraint violation.
  - Integration renders non-polynomial (NP) hard non-convex MINLP
  - Hard to solve with existing mathematical programming methodologie.

- Problem Decomposition Algorithm (Moldovan et al. 1996)
  - Design optimization problem is separated from feasibility test.
  - Main optimization problem is solved in discretized sampling space.
  - Feasibility test follows the design optimization problem.

- Steady Uncertain Space
  - Main optimization problem is solved in discretized sampling space.

- Direct Simultaneous Approach
  - Design optimization problem is separated from feasibility test.
  - Main optimization problem is solved in discretized sampling space.
  - Feasibility test follows the design optimization problem.

- Embedded Control Optimization
  - Design optimization problem is separated from feasibility test.
  - Main optimization problem is solved in discretized sampling space.
  - Feasibility test follows the design optimization problem.

Problem Decomposition

A: Sampling scenarios for uncertain parameter space
- Convert the infinite uncertain space to a discrete space.
- Stochastically simplifies problem size.
- Sampling technique: Latin hypercube

B: Simultaneous Design and Control Optimization
- Stochastic optimization problem defined over the finite sample set
- Feasibility test follows the design optimization problem.

C: Rigorous Flexibility Test
- Ensure constraints satisfaction for ALL uncertain realizations
- Find critical scenarios

Simultaneous Design and Control

- No problem, dynamic constraints constraints.
- Existing mathematical programming solutions, usually do not work.
- Hard to solve the problems of industrial applications.

Embedded Control Optimization

Case Study: Integrated Design and Control of Isomerization Process

Overview

- The process to convert normal butane \((\alpha_C)\) into isobutane \((\alpha_I)\).
- Isobutene is more valuable as a chemical feed stock than normal butane.
- Separation is not easy because of similar volatilities of \(\alpha_C\) and \(\alpha_I\).
- MIMO highly non-linear system.
- Reaction

Process

- Exothermic irreversible reaction.
- Usable

Isomerization process (Luyben, 1999)

Conclusions

- Embedded control optimization:
  - Conceptual approaches to achieve the desired integrated design of integration and control.
  - Problem size reduction will be improved with Embedded control.
  - Simulation of integrated D&C for plantwide process is shown.

- Future work
  - Different algorithms should be considered and tested.
  - More challenging case studies must be done.

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References

- References

Sensitivity analysis

- Sensitivity analysis
  - Specifications
  - Input feed rate
  - Pressure in the reactor
  - Process variables
  - Manipulated variables
  - Design optimization
  - Capital Cost
  - Operating Cost
  - Total Annual Cost

- No other (10 uncertain scenarios)
- No other (10 uncertain scenarios)

- i* not (10 uncertain scenarios)

- No other (10 uncertain scenarios)**

- J = 0.268 (1.1, 1.950)

- No other (10 uncertain scenarios)

- No other (10 uncertain scenarios)

- No other (10 uncertain scenarios)**