MULTI-OBJECTIVE OPTIMAL SENSOR DEPLOYMENT UNDER UNCERTAINTY FOR ADVANCED POWER SYSTEMS

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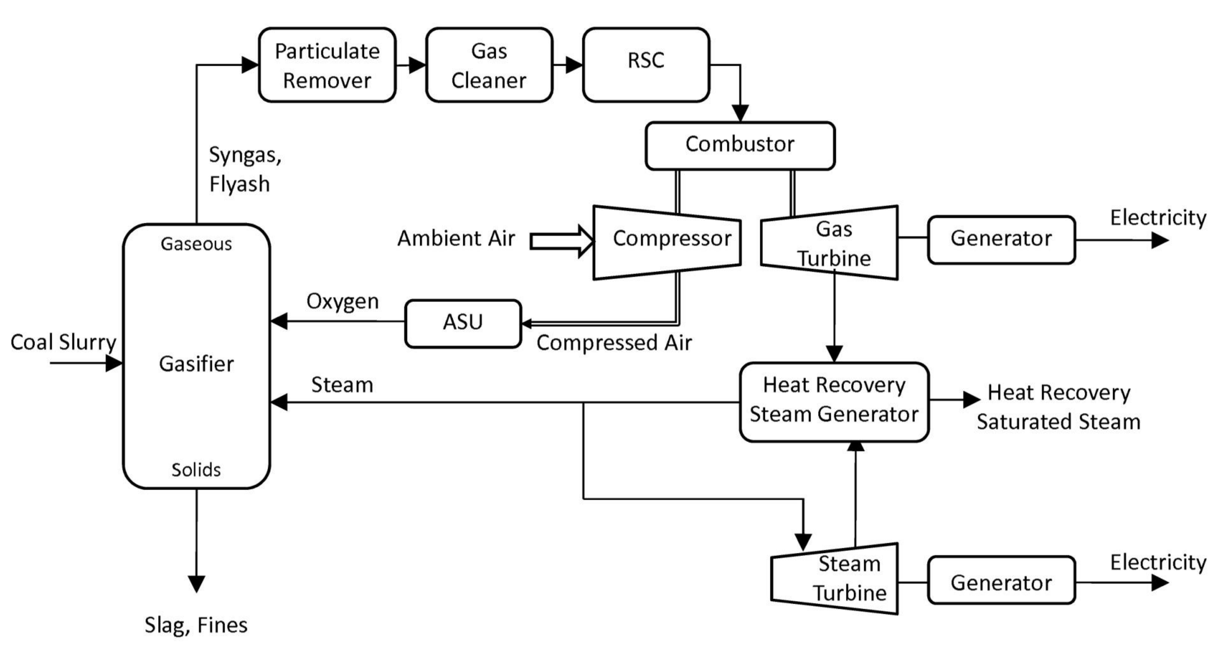
Sensor Placement Problem

Case of Advanced Power Systems
- Integrated Gasification Combined Cycle (IGCC)

Objectives
- Determine optimal location of network of sensors
- Maximize the information provided to the opertator
- Maximize efficiency of the process

- Constraints
  - Cost of sensor purchase, deployment, maintenance

IGCC System



Monitoring all process variables is expensive and technically infeasible

Objective is to determine the optimal network of on-line sensors such that

Information pertaining to the true process conditions is maximized

Budget limitations are satisfied

Use information gained from direct measurement of process variables

Estimate effect on the observability of downstream variables

Multi-objective Mixed Intenger Stochastic Programming Problem

Determine location of on-line sensors to maximize observability and efficiency of system, subject to budget constraint

$$\max_{y_{j,\tau}\in Y} \sum_{\tau=1}^{T}\sum_{j=1}^{S^{out}} f_{j,\tau}(\psi)\, y_{j,\tau}, \max_{y_{j,\tau}\in Y} \quad \eta$$

$$\text{s.t.} \quad \sum_{\tau=1}^{T}\sum_{j=1}^{S^{out}} C_{j,\tau}\, y_{j,\tau} \le B$$

$$\sum_{\tau=1}^{T} y_{j,\tau} \le 1, \qquad j = 1,2,\ldots,S^{out}$$

$$y_{j,\tau} \in \{0,1\}, \qquad j = 1,2,\ldots,S^{out}, \tau = 1,2,\ldots,T$$

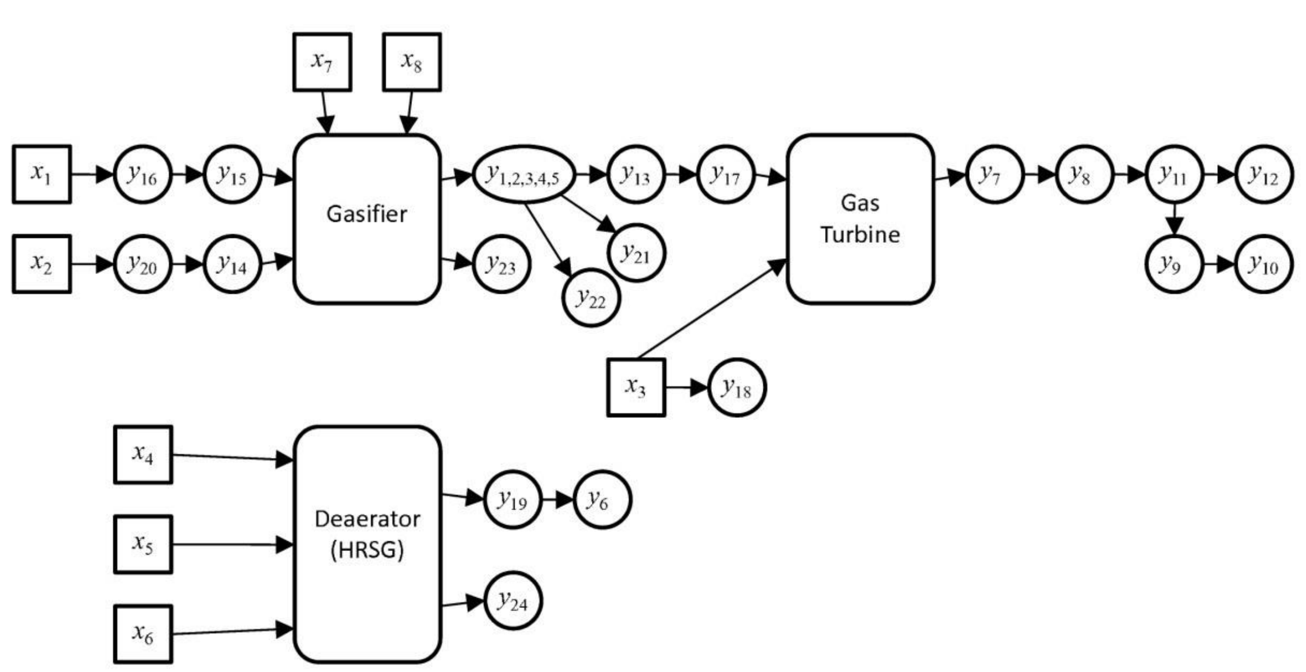
Mass and Energy Balances around the Plant

ψ = network of on-line sensors

$f_{j,\tau}(\psi)$ = level of observability resulting from the placement of sensor type τ at location j

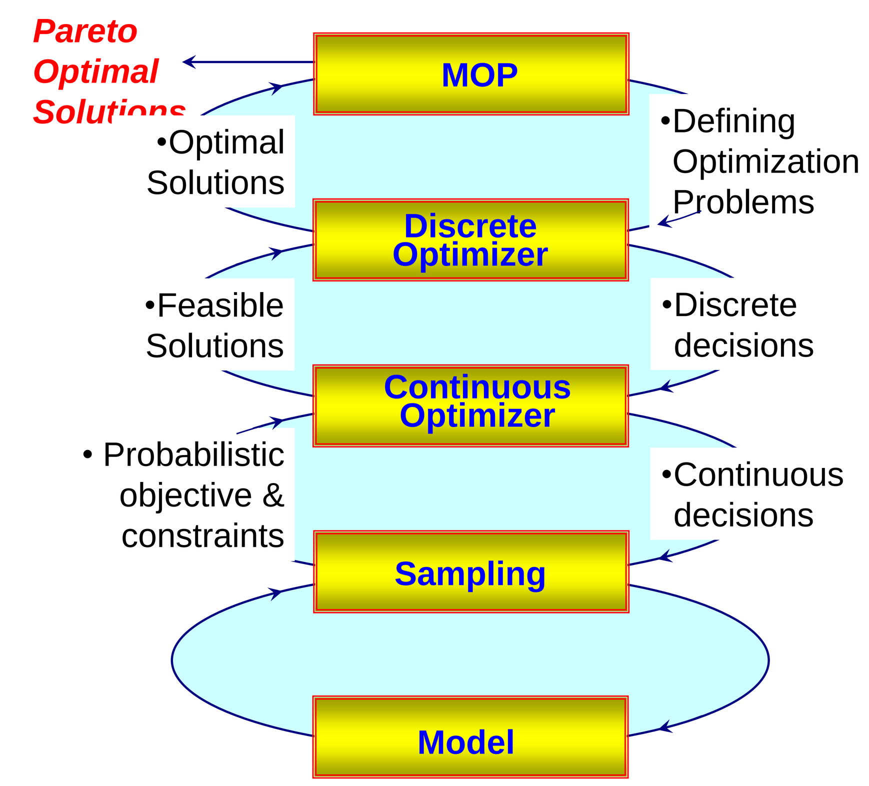
Sensor Placement in IGCC

- Generate flowchart to determine downstream variables

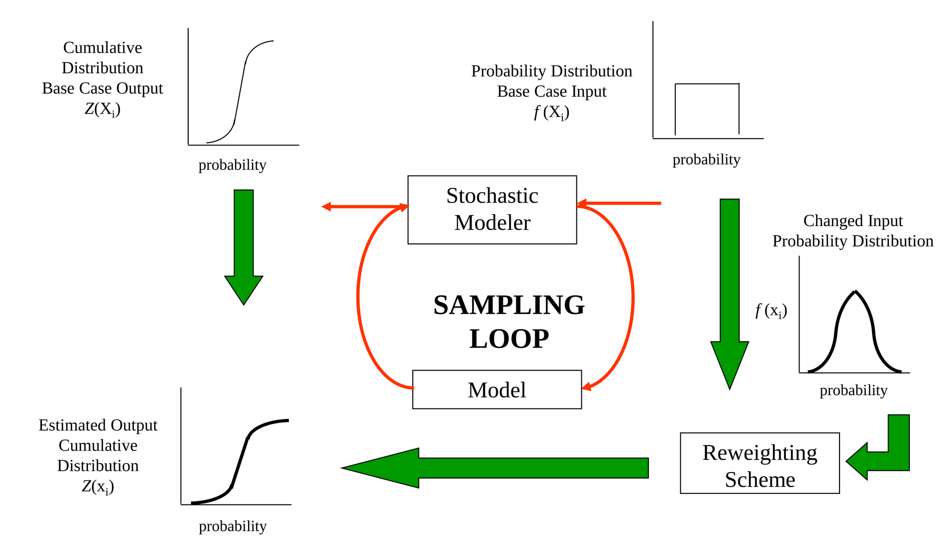


- Define $\gamma_{i,j}$ = 1 (0) if variable j is downstream of variable i
- Distribution

Algorithmic Framework



Better Optimization of Nonlinear Uncertain Systems (BONUS)

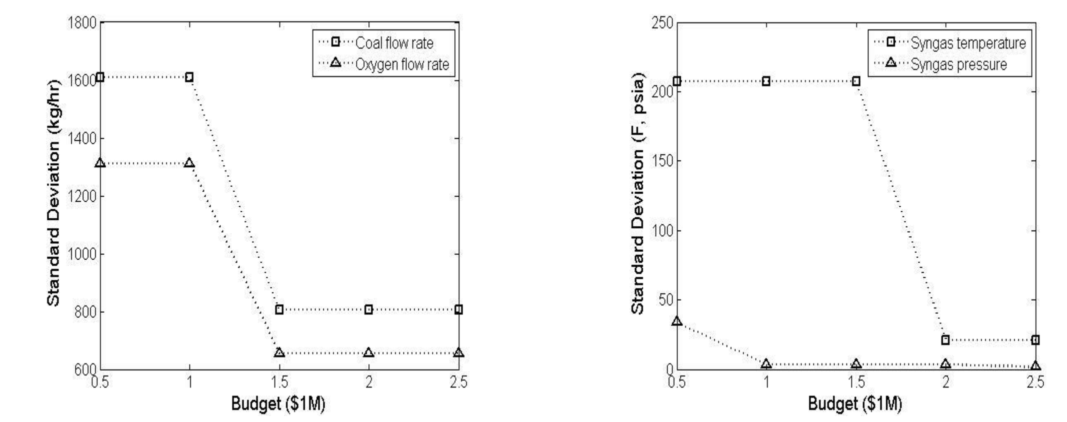


Model Uncertainties

Variations to process variables lead directly to variations in the gasification performance
- Coal slurry flow rate alters the syngas header pressure
- Ratio of oxygen to coal slurry alters the gasifier operating temperature

Harsh environments exist within the gasifier
- Knowing true gasifier temperature and pressure is difficult
- Operational performance relies on accurate temperature control
  - Refractory wear rate worsens at higher operating temperatures
  - Gasifier produces excessive amounts of flyash for lower operating temperatures

Some Results



- Sensitivity of budget on sensor deployment
- Accuracy of inferred measurements increases as number and type of sensors are deployed in network

Summary

- Sensor placement in IGCC system
- Mixed integer nonlinear programming optimization problem
  - With multiple objective
    - Observability, efficiency
  - With uncertainties
    - E.g. Measurement errors
- New algorithmic framework
  - MINSOOP for multi-objective
  - BONUS for stochastic nonlinear programming
  - L-shaped BONUS for integer programming

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