A Rational Constraint Handling NMPC Method for Systems With Limited Degrees of Freedom

Output Constraints and Limited Actuation

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Motivation

- Real systems often have limited degrees of freedom
  - Many saturated actuators
  - Many measurements
- Real processes have product quality constraints
  - Product must meet quality specifications
  - Error norm minimization not as relevant
- Real processes have safety limitations
  - Bounds on process for safe operation
- Real systems are nonlinear

Proposed Method

- Create prioritized list of control objectives

$$|e_m(k) - c_i| \leq s_i \;\; \forall k$$

- Add soft constraint for highest priority objective and solve

$$\begin{aligned} &\min\ s_i \\ &f\left(u^T\, y^T\, e^T\right) = 0 \\ &A\left[e^T\, s_i\right] \leq \pm c_i \\ &u^{LB} \leq u \leq u^{UB} \end{aligned}$$

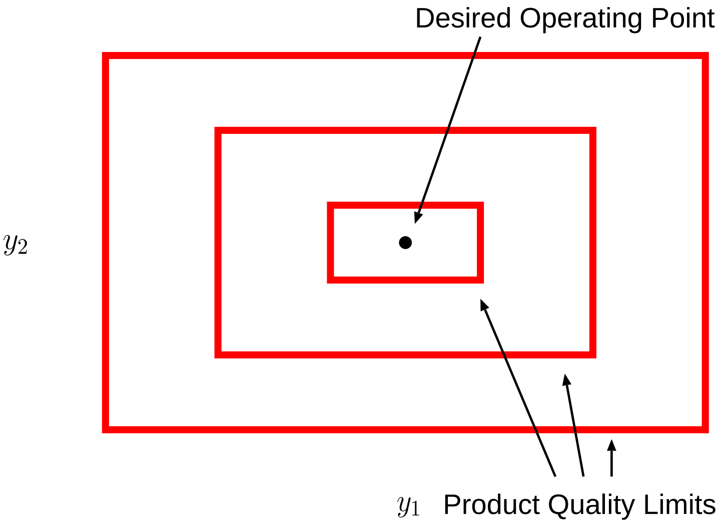
- Add hard constraint for that objective and repeat

$$\begin{gathered} \min\ s_{i+1} \\ f\left(u^T\, y^T\, e^T\right) = 0 \\ A\left[e^T\, s_{i+1}\right] \leq \pm c_{i+1} \\ u^{LB} \leq u \leq u^{UB} \;\; e^{LB} \leq e \leq e^{UB} \end{gathered}$$

- Use quadratic objective function once possible objectives are met

$$\min \sum_{k=1}^{P} e(k)^T \Gamma_y e(k) + \sum_{k=1}^{M} \Delta u(k)^T \Gamma_{\Delta u} \Delta u(k)$$

Illustration



Advantages and Disadvantages

- Accommodates qualitative control objectives rationally
- Hard constraints are always feasible
  - Feasible values provided by soft constraint problem
- For *n* objectives, must solve *n* NLP problems
  - Still better than mixed-integer optimization using branch-and-bound
  - Always have a viable (possibly sub-optimal) control move
- Not considering guaranteed stability formulation
  - Add terminal state constraint as objective
- Local NLP solves may not find the global solution
  - Global solution may actually be undesirable
  - Can use relaxation methods for bound

Application