ME 231A Syllabus

Modeling

- Linear Nonlinear state space forms
  - Continuous time and discrete time
  - Linearization
  - Discretization
  - Stability

Optimization

- Basis Concept of Optimizations
  - Min/Inf, Feasible, Active Constraint, Redundant Constraint, Global and Local Optimum
  - Linear Program, Quadratic Program, nonlinear program
  - Convexity: definition, importance, convex optimization problems

- Optimality conditions
  - Necessary and sufficient optimality conditions for unconstrained optimization problems
  - Duality theory: Main concepts, what is used for, how to write a dual of an optimization problem
  - Strong duality: Definition and concept of constraints qualifications
  - KKT conditions

- LPs and QPs
  - Definitions, solution properties
  - Number of active constraints and multiple optima (LP)
  - Dual of LPs and QPs
  - Convex Piecewise-linear Optimization

- Polyhedra
  - H- and V- representation
  - Function defined on Polyhedra
  - Basic Operations on Polytopes
  - Minkowsky sum, Pontriagin difference and their application to composition with linear function.

- Multiparametric Programming
  - Main idea.
  - Main Concept of Critical Region.
  - Solutions properties of mpLP and of mpQP
Optimal Control

- General Formulation of constrained control problems
  - Finite time, Infinite time
  - Value function, Feasible sets
- Solution Finite time
  - Batch Approach (with and without substituting the dynamics)
  - Principle of Optimality and Dynamic Programming (DP)
  - Comparison Batch vs DP
- Solution of Infinite Time
  - Value Function iteration
- Solution with Receding Horizon
- Review of Unconstrained case
  - Finite time LQR (via batch and via DP)
  - Infinite time LQR
  - Lyapunov Stability
  - Solution via DP and gridding
- Constrained 2-Norm Optimal Control
  - Solution via Batch Approach and online optimization.
  - Use of Multiparametric Programming : Solution via Batch
  - Properties of the state-feedback solution
  - Infinite horizon properties
- Controllability, reachability and invariance
  - Computation of Controllable and Reachable Sets
  - Invariant Sets

Receding Horizon Control

- Definition, Notation and Basic Algorithm.
- Main Theorem of RHC (Stability and Feasibility): proof
- Tuning and Practical Rules
- Zero steady-state tracking RHC
- Online and Offline RHC implementations
Loop-Shaping

- Review of transfer functions, ode models, state-space models, frequency-response, functions, interconnections, stability, Fourier transform, Control Toolbox commands
- Nyquist stability criterion
- Bandwidths, Sensitivity (S) and Complementary Sensitivity (T) function, arithmetic for comparing open and closed-loop properties, robustness margins
- Loopshaping design theorems
- Youla parametrization for stable plants, opportunities for nonlinear optimization of performance, both in time and frequency domain.
- Youla parametrization for unstable plants
- Effect of resonances and notches on loopshape; limitations dues to open-loop right-half-plane poles and zeros
- Glover/McFarlane loopshaping procedure
- Mixed S/T synthesis for MIMO systems using \(H^\infty\) optimization