EECS 598: Convex Optimization Methods in Control

Instructor: Pete Seiler
Credits: 3
Pre-requisite: EECS 560 (AERO 550) (ME 564) Linear Systems Theory or instructor permission.
Meets: Tu/Th 12:00PM - 1:30PM in 1690 BEYSTER

Course Description
Convex optimization plays a central role in the numerical solution of many design and analysis problems in control theory. This course focuses on the practical aspects of using convex optimization methods to solve these problems. First, the basic properties and theory of convex optimization will be introduced. This will include techniques to formulate engineering problems as convex optimizations. Existing software and implementation issues will also be discussed. Next, we will explore the ties between convex optimization and problems in control theory. This will methods to assess robustness of systems with nonlinearities, parametric uncertainty and unmodeled dynamics. It will also include methods to solve optimal control problems, e.g. H-infinity design. The course will conclude with more recent results in nonlinear analysis, e.g. sum-of-squares programming. Example problems of industrial relevance will be used to highlight the utility of these methods.

Course Topics

Introduction
1: Course Overview

Essentials of Convex Optimization
2: Convex Sets
3: Convex Functions
4: Convex Optimization Problems
5: Numerical Tools
6: Duality
7: Unconstrained Minimization
8: Constrained Minimization

Nominal Analysis & Synthesis
9: Internal Stability
10: State Feedback Synthesis
11: Bounded Real Lemma
12: H-infinity State Feedback Synthesis
13: H-infinity Optimal Control
14: H2 Optimal Control
15: Linear Parameter Varying Systems

Robust Analysis and Synthesis
16: Modeling Uncertain Systems
17: Circle Criterion
18: Analysis with Unmodeled (Dynamic) Uncertainty
19: Analysis with Dynamic LTI Uncertainty
20: Pointwise Frequency Domain Constraints
21: Analysis with General Integral Quadratic Constraints
22: Application to analyzing convergence rates for first-order optimization methods

Nonlinear Analysis with Sum-of-Squares
22: Multivariable Polynomials
23: Multivariable Polynomials
24: Sum-of-Squares Optimization
25: Sum-of-Squares Toolbox
26: Nonlinear Analysis with SOS
27: Nonlinear Analysis with SOS

Miscellaneous Topics (Time Permitting)
Youla Parameterization and Optimization with Ritz Approximation
Model Reduction
Nonconvex QCQPs

References

1. *Convex Optimization* by Boyd and Vandenberghe (http://www.stanford.edu/~boyd/cvxbook/)

2. *Linear Matrix Inequalities in System and Control Theory* by Boyd, El Ghaoui, Feron, and Balakrishnan (http://www.stanford.edu/~boyd/lmibook/)

3. "System analysis via integral quadratic constraints," Megretski and Rantzer, IEEE Transactions on Automatic Control, Vol. 42, # 6, June 1997, pp. 819-830.

4. *Structured Semidefinite Programs and Semialgebraic Geometry Methods in Robustness and Optimization* by Parrilo (Ph.D. Thesis, California Institute of Technology May 2000). (http://www.mit.edu/~parrilo/pubs/index.html)

5. *Linear Controller Design – Limits of Performance* by Boyd and Barratt (http://www.stanford.edu/~boyd/lcdbook/)