1. Course Introduction

- Basic course information
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Basic info

Course engr210b: advanced topics in computation (for control)

Instructor Sanjay Lall
`www.stanford.edu/~lall`
office hours: Tu 4:00 – 5:00, and other times

Time MW 8:30 – 9:45

Web-page `www.stanford.edu/class/engr210b`
all class info, lecture notes, homeworks, solutions.

Email list email `majordomo@lists.stanford.edu`
leave subject blank, message body: `subscribe engr210b`

Grading roughly: homework 50%, final project 50%.
weekly homeworks (Wednesdays)

Course objectives

- use convex optimization, real algebraic geometry, and duality to
  - find solutions to hard optimization problems
  - provide *certificates* for verification problems

- focused on the tools, not a specific set of applications

- current research
  - exciting opportunity
  - but we don't know the whole story yet
  - analogies with linear algebra; we know some of the theory, but little of the numerics

Topics

- *optimization:*

  linear programming, semidefinite programming (SDP) and their duality properties; geometric duality and certificates; quadratic programming and SDP relaxations; applications to control and combinatorial optimization

- *polynomial programming:*

  constructing dual problems via semidefinite programming; valid inequalities, and positive cones of real polynomials; introduction to algebraic geometry; formal theory of the reals, and proof systems; NP and co-NP; syntactic verifiability

- *algebra and geometry:*

  the correspondence between ideals and varieties; Nullstellensatz and its interpretation via duality and certificates; computation via linear algebra and Groebner bases

- *sum-of-squares decomposition:*

  efficient computation via semidefinite programming; duality of the SOS decomposition via Schur complements, moments, and liftings

- *semialgebraic sets:*

  cones, monoids and ideals; quantifier elimination; computation of positivstellensatz certificates using semidefinite programming; exploiting structure, sparseness, symmetry, quotient rings

Other courses

expected background

- solid linear algebra
- optimization; preferably EE364 convex programming; others possible
- some control; EE263 or Engr207a

related math courses (definitely NOT required, but may be interesting)

- Math 111: computational algebra (polynomials, Groebner bases)
- Math 120, 121, 210A, 210B: algebra; groups, rings and fields
- Math 216A, 216B, 245A, 245B: algebraic geometry

related optimization courses (also NOT required)

- MS&E 111, 211, 310–315, 318: general optimization
- MS&E 212, 217: more combinatorial
- MS&E 314: semidefinite programming

References

complete notes will be handed out, so there is no required textbook. the following books are good references:

optimization:

- Boyd and Vandenberghe, *Convex Optimization*; at `www.stanford.edu/~boyd/cvxbook.html`

algebraic geometry:

- Cox, Little and O'Shea, *Ideals, Varieties and Algorithms*

much material is only available in papers; the course website will list references

acknowledegement: these notes are based on notes originally written with Pablo Parrilo, ETH Zürich for a workshop at ECC 2003. `http://control.ee.ethz.ch/~parrilo`