EE 578B - Convex Optimization - Winter 2021

Syllabus

“Concrete before abstract.” - Grant Sanderson, 3blue1brown.com

Overview

Convex optimization is the theoretic core of numerical optimization techniques for modern data science, machine-learning, and control theory. In this class, we will explore convex optimization formulations of two rich application domains, network flow problems and Markov decision processes. Along with being widely used in modern data science and machine learning, these two applications provide a great concrete framework for developing general principles of convex programming and building intuition. We will become proficient with the cvx (Matlab) and/or cvxpy (Python) as well as describe the core principles of the simplex method, gradient descent, and interior point methods for optimization.

Prerequisites

- Knowledge of linear algebra and matrix analysis
- Python and/or Matlab exposure

Schedule

- PART 1: Review
  - Week 1: Linear Algebra and Lagrange Multipliers
  - Week 2: Linear constraints, polytopes, basic convexity, introduction to cvx.

- PART 2: NETWORK FLOW PROBLEMS:
  Applications: shortest path problems, traffic routing, network packet routing
  - Week 3: Primal Problem - “Routing flow along shortest path”
    * Intuition: Mass conservation of flow variables
    * Convex Principles: Stationarity, feasibility, and complementary slackness
  - Week 4: Dual Problem - “Computing minimum travel time.”
    * Intuition: Dynamic programming for optimal travel times.
    * Convex Principles: Convex duality, Lagrangians, Fenchel-duality
– **Week 5**: Algorithms:
  * Simplex Method
  * Projected gradient descent

**PART 3: MARKOV DECISION PROCESSES**

**Applications**: Robotic exploration, machine learning in dynamic scenarios, Chess, Go, Pac-man

– **Week 6**: Primal Problem - “Finding a maximum reward policy.”
  * **Intuition**: Stationary policies of stochastic flow problems,
  * **Convex Principles**: Stochastic dynamics, transition kernels, finite and infinite horizon formulations.

– **Week 7**: Dual Problem - “Computing optimal reward value.”
  * **Intuition**: Value-iteration and optimal reward-to-go
  * **Convex Principles**: Bellman equation, duality

Figure 1: Part 2 - Network Flow - Primal Problem

Figure 2: Part 2 - Network Flow - Dual Problem

Figure 3: Part 3 - Markov Decision Processes - Primal Problem
- **Week 8:** Algorithms:
  * Saddle point methods
  * Interior Point methods
  * Q-learning

- **Part 4: Special Topics**
  - **Week 9:** Overview of Selective Applications
    * Clustering/classification
    * Support vector machines
    * Optimal control
    * Online convex optimization: Multi-armed bandit problems
  - **Week 10:** Extended Convex Optimization Techniques
    * Convex Relaxations
    * Semi-definite programming (SDPs)
    * Stochastic Gradient Descent

**Grading:**

- **Homeworks (60%):** Assigned weekly. Homeworks are self graded and can be resubmitted for extra credit.
- **Midterm (20%):** One take-home midterm approximately 2/3rds of the way through the quarter.
- **Final Project (20%):** Apply techniques and algorithms to an application domain of your choosing. Grading based on completion and written report.

**Contact**

- Instructor: Dan Calderone, lecturer and post-doc in AA/EE (with Behcet Ackimese and Lillian Ratliff)
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- Lecture Time: TBD