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

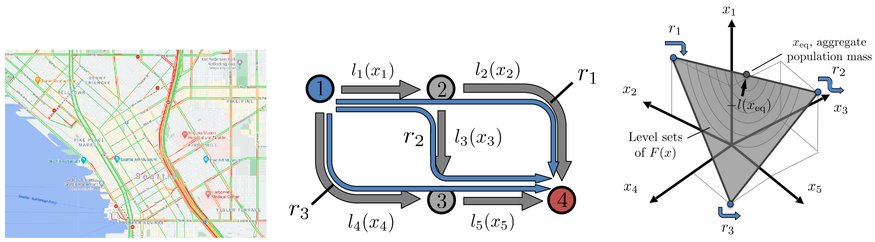

Figure 1: Part 2 - Network Flow - Primal Problem

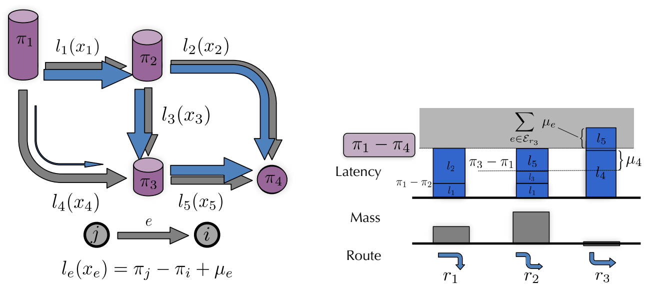

Figure 2: Part 2 - Network Flow - Dual Problem

– **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

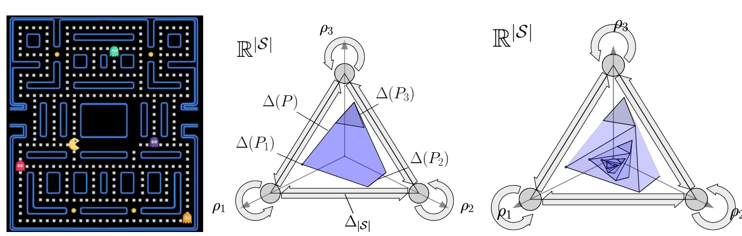

Figure 3: Part 3 - Markov Decision Processes - Primal Problem

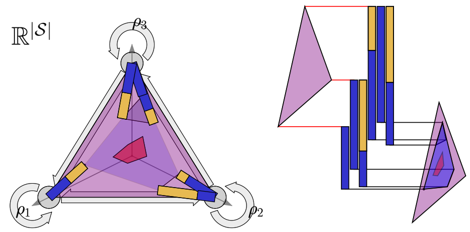

Figure 4: Part 3 - Markov Decision Processes - Dual Problem

- **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)
- Research interests: Convex programming, game theory, control theory
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- Lecture Time: TBD