Mathematical Topics in Artificial Intelligence and Optimization 16:198:674

Place: Tillet, Room 103-A
Time: Tues., Thurs.: 5:00p - 6:30
Instructor: Dr. Wesley Cowan
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Office Hours: 3-5pm Wednesdays, Levin 257, and by appointment.

Outline of the Course: This course is meant to provide an introduction to and survey of various mathematical concepts and techniques that find extensive use in many fields of modern Artificial Intelligence and Data Science. The primary themes will be: general approaches to mathematical optimization, decisions under uncertainty, and online learning models. For optimization, the emphasis will be on non-linear programming, from both analytical and algorithmic perspectives. For decisions under uncertainty, the emphasis will be on knowledge representation and inference. For online learning models, the emphasis will be on multi-armed bandit models and decision algorithms, particularly with respect to efficiently utilizing available information.

Course Syllabus:

• Part I: Optimization Theory
  - Geometry and Convex Analysis
  - Optimality: First- and Second-order Conditions
  - Duality Theory
  - Sensitivity Analysis
  - Duality Applications

• Part II: Optimization Algorithms
  - Unconstrained Optimization:
    * Basic Descent Methods
    * Newton’s Method
  - Constrained Optimization
    * Linearly Constrained Optimization: Simplex Methods
    * Interior-point Algorithms and Barrier Methods
    * Gradient-based First-order Methods
    * Sequential Quadratic Programming Methods
    * Penalty, Cutting Plane, Trust-region, etc.
  - Stochastic Methods
    * Stochastic Gradient Descent
    * Stochastic Approximation

• Part III Uncertainty & Probabilistic Reasoning
  - Bayes’ Rule, Representing Knowledge in an Uncertain Domain,
Bayesian Networks
– Hidden Markov Models
– The Multivariate Gaussian Distribution

• Part IV Online Learning Models
  – Basic Multi-Armed Bandit Models
  – Consistent & Asymptotically Optimal Solutions
  – UCB and Thompson Sampling Algorithms
  – Contextual and Adversarial Bandits
  – Expert Pooling
  – Markov Decision Processes

Text: No text is used - each topic will be given references, links, or printouts.
Prerequisites: Graduate students who have finished basic courses in Calculus, Linear Algebra and Probability are allowed to take the course.
Grading: Midterm: 30%, Final Exam/or Project: 70%.