COM S 672: Advanced Topics in Computational Models of Learning – Optimization for Learning

Fall 2017

Course Description
This course will discuss advances in optimization theory and algorithms with rapidly growing applications in machine learning, including first-order methods, stochastic optimization, sparse/regularized optimization, compressed sensing, higher-order methods, interior-point methods, proximal methods, robust optimization, etc. The goal of this course is to prepare graduate students with a solid theoretical and mathematical foundation at the intersection of optimization and machine learning to conduct advanced research in the related fields.

Prerequisites
Working knowledge of linear algebra, probability, and real analysis. Prior exposure to optimization, Com S 572, Com S 573, Com S 472, or Com S 474 is a plus but not necessary.

Course Information
Time: Tue/Thu 5:10pm-6:25pm
Location: 3143 Pearson Hall
Instructor: Jia (Kevin) Liu (jialiu@iastate.edu)
Office: 209 Atansoff Hall
Office hours: Wed 5:00pm-6:00pm, or by appointment
Web: http://web.cs.iastate.edu/~jialiu/teaching/COMS672_F17/

Course Overview
Since its inception as a discipline, machine learning has made extensive use of optimization formulations and algorithms. Likewise, machine learning has contributed substantially to optimization theory, driving the development of new optimization approaches that address the significant challenges presented by machine learning applications. This cross-inspiration continues to deepen, producing a vast literature at the integration of the two fields, while increasingly attracting leading researchers to this effort. This course gears toward such an intersection of the two fields.

Optimization techniques have enjoyed a critical role in machine learning because of their wide applications and theoretical appeals. While classical algorithms proposed decades ago continue to be refined, the ever-increasing complexity, size, and variety of today’s machine learning applications demand a systematic reassessment of traditional assumptions and techniques. Besides describing the revival of classical algorithms in novel contexts, such as first-order methods, stochastic approximations, convex relaxations, interior-point methods, and proximal methods, the course devotes significant attention to newer themes such as regularized optimization, compressed sensing, robust optimization, a variety of gradient and subgradient methods with acceleration, and the use of splitting techniques and second-order information. We aim to provide a fresh account of optimization theory/algorithms relevant to machine learning – those that have played important roles in history as well as those that are rising in influence.

Textbooks and References
There is no required textbooks. Most of the materials covered in the class will be based on classical books and recently published monographs. A list of historically important and/or trending papers will be provided on the course website. Some useful reference books on mathematical backgrounds include:


Tentative Topics

• Fundamentals of Convex Analysis
  – Convexity
  – Duality
  – Optimality conditions

• First-Order Methods
  – Gradient descent
  – Momentum-based methods: multi-step, Nesterov, etc.
  – Conjugate gradient
  – Stochastic gradient descent

• Higher-Order Methods
  – Newton
  – Quasi-Newton family
  – Interior-point methods

• Sparse/Regularized Optimization
  – Compressed sensing
  – Matrix completion

• Augmented Lagrangian Methods
  – ADMM methods
  – Proximal methods

• If time allows:
  – Non-convex optimization
  – Robust optimization

Homework
There will be 4 homework assignments, assigned roughly biweekly. Homework must be typeset in \LaTeX. The \LaTeX homework template can be found on the course website.

Midterm
The in-class midterm exam will be closed-book and closed-notes, but you are allowed to bring a 1-page cheat sheet. The midterm will be comprehensive up to the finished lectures.
Final Project
You could choose to finish the final project individually or by a team of no more than two persons. Project proposals will be due soon after midterm. Final reports will be due by the beginning of the final exam week (Dec. 11). Final reports should follow the IEEE journal format. Each project is required to have a 15-minute in-class presentation at the end of the semester. Attendance to your fellow students’ presentations is required and will be accounted in your final grade. Potential project ideas include but are not limited to:

- Nontrivial extension of the results introduced in class.
- Novel applications in your own research area.
- New theoretical analysis of an existing algorithm.

Each project should contain something new and/or useful. It is important that you justify its novelty.

Grading Policy
Homework: 30%; Midterm: 30%; Final project: 40%.

Late Policy
Without the consent of the instructor, late homework assignments or final report will not be accepted and will result in a grade of zero. In the case of a conference deadline or something of the like, a 5-day written notice of extension is required. In the case of an emergency (sudden sickness, family problems, etc.), an after-the-fact notice is acceptable. But we emphasize that this is reserved for true emergencies.

Disabilities Statement
Any student who feels s/he may need an accommodation based on the impact of a disability should contact the instructor privately to discuss specific needs. Please contact the ISU Student Disability Resources Office (SDR) for assistance in verifying the need for accommodations and developing accommodation strategies.

Academic Misconduct Statement
Academic misconduct is any activity that tends to compromise the academic integrity of the university, or subvert the educational process, and is considered a serious offense. Any student found to have engaged in academic misconduct, as set forth in the ISU Code of Academic/Research Misconduct for Students, will be subject to disciplinary action by the university.

Student Conduct
Students are expected to abide by the provisions in the Code of Student Conduct. The Universitys Code of Student Conduct and Sexual Harassment Policy are available on the ISU Web page.