MATP4820/6610 • Computational Optimization • Spring 2025

Time: 2:00pm-3:50pm Monday & Thursday   Location: TROY 2018

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Course Objective and Topics

This course is to introduce optimization methods and applications. An emphasis will be placed on understanding and implementing optimization algorithms, including gradient-type methods, Newton-type methods, derivative free methods, and primal-dual type methods. The following topics will be covered.

1. Concepts of numerical algorithm and convergence
2. Fundamentals of unconstrained optimization
3. Gradient type methods: steepest gradient descent, projected gradient, conjugate gradient, proximal gradient, Nesterov's accelerated proximal gradient methods, and stochastic gradient method
4. Newton type methods: Newton's method, quasi-Newton method, and Gauss-Newton method
5. Derivative free methods: coordinate descent method
6. Theory of functional constrained optimization: Karush-Kuhn-Tucker (KKT) conditions and Lagrangian duality
7. Interior-point methods for linear programming
8. Penalty methods and augmented Lagrangian method
9. Chambolle-Pock's primal-dual algorithm
10. Alternating direction method of multipliers and application in imaging and statistics

Learning outcomes

After taking the course, **4820 students are expected to know:**

1. how to estimate the per-iteration complexity, namely, counting the number of arithmetic operations
2. how to find stationary points of a function by formulating the first-order optimality condition
3. how to analytically check local and/global optimality of a given point for an unconstrained problem
4. how to numerically implement each optimization method that is taught and verify if a computed point is approximately a local/global optimal solution
5. how to apply optimization methods to applications such as in imaging, finance, and machine learning

In addition to the above, **6610 students are expected to also know:**

1. how to analyze the convergence and/or convergence rate of certain iterative methods
2. how to formulate the KKT systems of a functional constrained problem
3. how to choose appropriate optimization methods depending on the structure of applications

The extra learning outcomes for 6610 students will be reflected through extra/harder questions in homework assignments and the final project. For example, 4820 students can be asked to formulate the first-order optimality condition of an unconstrained problem, while 6610 students may be asked to work on the first-order optimality condition (i.e., KKT system) of a functional constrained problem. Also, 4820 students will be asked to hand-compute the solution of an unconstrained quadratic problem by two or three iterations of a gradient-type method, while 6610 students may be asked an extra question to prove the convergence of the gradient-type method applied to the specific quadratic problem.

Prerequisites

Multi-variable calculus, linear algebra, and programming experience by MATLAB/Python.

Textbooks

- *Numerical Optimization* by Jorge Nocedal and Stephen Wright, 2006
- *Lectures on Convex Optimization* by Yurii Nesterov, 2018
- *Constrained Optimization and Lagrange Multiplier Methods* by Dimitri P. Bertsekas, 1996.
- *Introduction to Mathematical Programming* by Michael Kupferschmid
- *An Introduction to Optimization* by Edwin K. P. Chong and Stanislaw H. Zak, 4th Edition, 2013

Homework, exams, and project

Note that most questions will be common to 4820 students and 6610 students. However, **extra or harder questions may be assigned to 6610 students**. For example, 4820 students can be asked to calculate a stationary point while 6610 students can be asked to prove it.

- **Homework:** roughly once every 1.5 weeks and will be posted and due in LMS.
- **Exams:** two mid-term exams (tentative time: 2:00pm-3:50pm on February 20, 2025 and on April 17, 2025)
- **Project:** one final project (to be assigned in April)

Evaluation and Grading Policy

All students will be evaluated and graded by the following policy. Note that D/D+ grades will not be given to 6610 students.

1. **Evaluation:** homework 32%, the first mid-term exam 24%, the second mid-term exam 24%, and the final project 20%.
2. **Grading of homework:**
   - For each homework, a random portion of assigned problems will be graded;
   - The score composes of two parts: completeness (25%, check if all problems are finished reasonably), and correctness (75%, check if graded problems are done correctly)
3. **Late homework:**
   - Homework that is late up to one day will be penalized by 10%;

- Homework that is late between one day and two days will be penalized by 20%;
- No homework will be accepted if it is late more than two days unless you have a special reason (like illness with doctor's note) and notified the instructor at least two days ahead of the due time.

4. **Exam:**

   - No early exam will be taken (more details on how to monitor the exam will be announced).
   - A make-up exam will be administered only at the discretion of the instructor in the event of a verifiable emergency. In the event of a verifiable emergency, the student must contact the instructor as soon as possible, and in any case, prior to the next regularly scheduled class.

Attendance

Attendance and participation in class is a vital part of the learning process. Regular class attendance is strongly encouraged. It is the students' responsibility to keep informed of any announcement, or policy changes made through LMS and/or Email.

Academic Integrity

Intellectual integrity and credibility are the foundation of all academic work. A violation of Academic Integrity policy is, by definition, considered a flagrant offense to the educational process. It is taken seriously by students, faculty, and Rensselaer and will be addressed in an effective manner.

If found responsible for committing academic dishonesty, a student may be subject to one or both types of penalties: an academic (grade) penalty administered by the professor and/or disciplinary action through the Rensselaer judicial process described in the Student Rights and Responsibilities Handbook and the Rensselaer Graduate Student Supplement.

Academic dishonesty is a violation of the Grounds for Disciplinary Action as described in the handbook. A student may be subject to any of the following types of disciplinary action should disciplinary action be pursued by the instructor: disciplinary warning; disciplinary probation; disciplinary suspension, expulsion and/or alternative actions as agreed on by the student and hearing officer. It should be noted that no student who allegedly commits academic dishonesty will be able to drop or change the grade option for the course in question and is not eligible to request an F examination for the course.

The academic integrity policy applies to all students, undergraduate and graduate, and to scholarly pursuits and research. Additionally, attempts to commit academic dishonesty or to assist in the commission or attempt of such an act are also violations of this policy.

Disability Services for Students

The Office of Disability Services for Students (DSS) assists Rensselaer students with disabilities in gaining equal access to academic programs, extracurricular activities, and physical facilities on campus. DSS is the designated office at Rensselaer that obtains and files disability-related documentation, assesses for eligibility of services, and determines reasonable accommodations in consultation with students. Call 518-276-8197 or email dss@rpi.edu for more information.