STA 6723: Statistical Optimization

Lecture: Tuesday and Thursday 11:35am - 12:50pm, Statistics 0327

Instructor: Yiyuan She, Statistics 209F (yshe@stat.fsu.edu)

Grader: Junge Li <jl18r@my.fsu.edu> Statistics 210C

Office hours: Tuesday 2:35pm – 3:35 pm and by appointment.

Grader: Monday, Wednesday 10:00am-11:00am

Text: None. I will make lecture notes and slides.

Some useful reference books (optional):

1. *Matrix Algebra From A Statistician's Perspective, Harville, 1997*
2. *Convex Optimization, Boyd and Vandenberghe, 2008*
3. *Matrix Differential Calculus, Magnus and Neudecker, 1999*
4. *Matrix Algebra, Gentle, 2007*
5. *Numerical Optimization, Nocedal and Wright, 1999*

Prerequisites: Linear regression (STA5167) is recommended. [Basic optimization and matrix algebra are also recommended.] **Matrix** notation will be heavily used.

Course Objectives: Matrix algebra and optimization are at the core of modern statistics. By the end of this course, students will be able to 1) evaluate matrix differentiation and do matrix algebra in multivariate and high dimensional statistics; 2) apply popular optimization techniques in statistics, biostatistics, machine learning, finance, signal processing, and related research areas; 3) implement fast and scalable algorithms in big data applications.

Course Description: The course of matrix algebra and optimization involves a wide range of real world applications in statistics, biostatistics, machine learning, finance, signal processing, and related research areas.

Some of the topics include:

1) Eigenvalues and eigenvectors, singular value decomposition, Cholesky decomposition, QR decomposition, Courant-Fischer minimax theorem, partitioned matrices, Schur complement, generalized inverse projections, canonical angles, space gap, CS decomposition; Kronecker product, vec operator, commutation matrix, Hadamard

product, Jacobian, matrix differential, Cauchy invariance, subgradients, relative interior, one-sided directional derivatives;
2) Convexity, log-concavity, conjugate functions, conjugate pairs, Fenchel-Young, generalized inequality, semi-definite programming, KKT conditions, gradient descent, steepest descent, damped Newton, proximal methods, linearization, strong convexity and strong smoothness, essential smoothness and essentially strict convexity, Bregman divergence, congjugate of Bregman, Bregman of conjugate, mirror descent, Nesterov's accelerations, primal-dual methods, Moreau decomposition, thresholding rules, Moreau envelope, MM algorithms, Lagrange duality, Dykstra projections, augmented Lagrangian, method of multipliers, ADMM, block coordinate descent and randomization, gradient boosting, random projection, stochastic approximation/optimization;
3) Entropy maximization, multivariate meta-analysis, empirical likelihood, sorted l1 for high dimensional inference, robust programming, back propagation, nuclear norm minimization, sparse principal component analysis, matrix completion, Gaussian graph learning, Izing models and pseudo likelihood, matrix completion, exponential gradient descent and online learning, nonnegative matrix factorization.

Exams: There will be no exams.

Homework (100%): There will be regular homework assignments. Each student must hand in a complete set of their own solutions. The homework must be neatly written. Illegible homework will not be evaluated by the course grader. Penalty for late homework: 10% of the maximum score per day. For problems requiring programming, both the program and the output should be turned in. All questions about scores should be directed to the TA via email or in person during the TA's office hours.

Project (100%): You may choose to apply one or multiple methods taught in class to solve a real-world multivariate optimization problem. Perform systematic computer experiments (simulations) to study the performance of your algorithm(s). Real-life data analysis is also required. You MUST discuss with me your problem and research goal.

Alternatively, you can read one theoretical paper carefully and write a report. You need to go beyond the paper in some way, say, giving a new proof of some theorem. It is recommended to stay focused on one or some parts of the paper. You MUST discuss with me which paper you want to study.

In either way, you are required to turn in a 10-15 page typed paper by 5pm on April 19.

Course Website: All pertinent information for this class will be posted on the course website at FSU's Canvas.

Grades: Your course grade is based on homework (50%) and project (50%).
90-100 A, 80-89 B, 70-79 C, 60-69 D, Below 60 F

Syllabus Change Policy: Except for changes that substantially affect implementation of the evaluation (grading) statement, this syllabus is a guide for the course and is subject to change with advance notice.

University Attendance Policy:

Excused absences include documented illness, deaths in the family and other documented crises, call to active military duty or jury duty, religious holy days, and official University activities. These absences will be accommodated in a way that does not arbitrarily penalize students who have a valid excuse. Consideration will also be given to students whose dependent children experience serious illness.

Academic Honor Policy:

The Florida State University Academic Honor Policy outlines the University's expectations for the integrity of students' academic work, the procedures for resolving alleged violations of those expectations, and the rights and responsibilities of students and faculty members throughout the process. Students are responsible for reading the Academic Honor Policy and for living up to their pledge to "… be honest and truthful and … [to] strive for personal and institutional integrity at Florida State University." (Florida State University Academic Honor Policy, found at http://fda.fsu.edu/Academics/Academic-Honor-Policy.)

Americans with Disabilities Act:

Students with disabilities needing academic accommodation should: 1. register with and provide documentation to the Student Disability Resource Center; and 2. bring a letter to the instructor indicating the need for accommodation and what type. Please note that instructors are not allowed to provide classroom accommodation to a student until appropriate verification from the Student Disability Resource Center has been provided.

This syllabus and other class materials are available in alternative format upon request. For more information about services available to FSU students with disabilities, contact the: Student Disability Resource Center, 874 Traditions Way, 108 Student Services Building, Florida State University, Tallahassee, FL 32306-4167. (850) 644-9566 (voice) (850) 644-8504 (TDD) sdrc@admin.fsu.edu http://www.disabilitycenter.fsu.edu/