ISyE 6525 – Topics on High-Dimensional Data Analytics

Georgia Tech – Spring 2027

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Office hours: By appointment.

Textbook
There is no required textbook for this course, but a reading list will be provided for complementary information.

Software: R, Python, and MATLAB

Catalog Course Description
This course focuses on analysis of high-dimensional structured data including profiles, images, and other types of functional data using statistical machine learning. A variety of topics such as functional data analysis, image processing, multilinear algebra and tensor analysis, and regularization in high-dimensional regression and its applications including low-rank and sparse learning is covered. Optimization algorithms commonly used in statistical modeling and machine learning and deep learning will also be discussed.

Course Outcomes

Students will

- Learn machine learning and statistical methods for image processing and analysis of functional data.
- Learn a variety of regularization techniques and their applications.
- Be able to use multilinear algebra and tensor analysis techniques for performing dimension-reduction on a broad range of high-dimensional data.
- Understand how to use well-known optimization methods to create efficient learning algorithms.

Grading policy

Homework	40%
Exam I - Date: TBD	30%
Exam II - Date: April 15 to April 21 11:59pm	30%

Course policy

- Homework must be submitted before *the due date*. Late submission is NOT acceptable.
- No late submission is accepted for exams.
- Requests for re-grading HW and exams should be made within a week of returning them.
- Exams are open-book and take-home style. One week from open date to close date starting whenever and submitting prior to due date.
- You are encouraged to discuss homework problems with your fellow students. But your final answers should be based on your own understanding. You are not allowed to discuss exam problems with anyone. Copying others' work is NOT acceptable and violates the **honor code**.

Academic Honor Code: It is your responsibility to get familiar with the Georgia Tech Honor Code and you are bound by its requirements.
Use of any previous semester course materials is allowed for this course; however, I remind you that while they may serve as examples for you, they are not guidelines for any tests, quizzes,

homework, projects, or any other coursework that may be assigned during the semester. For any questions involving these or any other Academic Honor Code issues, please consult with me, the teaching assistant, or visit www.honor.gatech.edu.

Tentative Lectures Schedule:
The topics covered and the dates they are to be covered are subject to change.

Topics

1. Functional data analysis
   - 1.1 Introduction to HD & Functional Data
   - 1.2 Review of Regression
   - 1.3 Splines
   - 1.4 BSplines
   - 1.5 Smoothing Splines
   - 1.6 Kernel Smoothers
   - 1.7 FPCA
   - 1.8 Gaussian Process
   - 1.9 Wavelets
2. Image processing
   - 2.1 Introduction to Image Processing
   - 2.2 Image Transformation
   - 2.3 Convolution & Image Filtering
   - 2.4 Image Segmentation
   - 2.5 Edge Detection
3. Tensor data analysis
   - 3.1 Multilinear Algebra Preliminaries
   - 3.2 Tensor Decomposition Methods
     a. Tucker
     b. CANDECOMP/PARAFAC (CP)
     c. DEDICOM
   - 3.3 Tensor Regression
   - 3.4 Tensor Time-Series
   - 3.5 Tensor Analysis Applications
4. Optimization applications in HD analysis
   - 4.1 Introduction
   - 4.2 First Order Methods
     - 4.3.1 Gradient Descent
     - 4.3.2 Accelerated Agorithms
     - 4.3.3 Stochastic Gradient Descent
   - 4.3 Second Order Methods
     - Newton method
     - Quasi-Newton method
     - Broyden–Fletcher–Goldfarb–Shanno (BFGS) algorithm
   - 4.4 Decomposable problems
   - 4.5 Coordinate descent
   - 4.6 Proximal gradient descent
   - 4.7 Augmented Langrangian Methods
   - 4.8 Alternating Direction Method of Multipliers
5. Regularization
   - 5.1 Introduction
   - 5.2 Ridge
   - 5.3 Lasso

5.4 Non-negative Garrote and Adaptive Lasso
5.5 Group Lasso
5.6 Elastic Net

6. Applications of regularization
6.1 Compressive sensing
6.2 Matrix completion
6.3 Robust PCA
6.4 Smooth-Sparse Decomposition (SSD)
6.5 Kernel Ridge Regression and Reproducing Kernel Hilbert Space (RKHS)
6.6 Anomaly detection for streaming data
6.7 Spatiotemporal SSD