EE 599: Mathematics of High-dimensional Data
Fall 2016

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Lectures: Mon-Wed 4-5:20 PM.

Location: GFS 223.

Office Hours: 5:30-7:00 PM, EEB 422.

Catalog Description: modern developments in data representation/analysis, convex optimization, efficient first-order algorithms for smooth and non-smooth optimization, iterative algorithms and non-convex optimization, non-asymptotic random matrix theory, randomized numerical linear algebra, sketching, dimensionality reduction, clustering, low-rank models, inverse problems, applications in computational imaging, signal processing, machine learning, computer vision and neuroscience.

Prerequisites: EE 441 and EE 503. Familiarity with a numerical solver such as MATLAB, R, or Python is required. Familiarity with basic convex analysis and optimization is a plus but not required.

Course Overview: Modern data sets are noisy and unstructured and often contain corrupted or incomplete information. At the confluence of optimization, signal processing, statistics and computer science a new discipline is emerging to address these challenges. In this course we will explore the foundations of this area. The main goal is to expose students to modern methods that model data through vectors and matrices, efficient algorithms for representing and extracting information from such data as well as new theory explaining the success of these algorithms. A special focus will be on novel methods and mathematical tools that allow us to glean useful information from seemingly incomplete data sets.

    Course covers:

1) Fundamental theoretical and mathematical tools.

2) Efficient techniques to collect and analyze data and deal with nuances (such as noise, missing information, outliers).

3) Sample applications from computational imaging, signal processing, machine learning, computer vision and neuroscience.

Required Texts: None.

Grading (subject to change):
    - %10 Lecture scribes
    - %40 Homework
    - %50 Final Projects

Course Outline (subject to change):

- **Week 1:** Introduction to mathematics of data, sample applications, Optimization basics.

- **Week 2:** Optimization for modern data analysis I: first order methods, accelerated schemes.

- **Week 3:** Optimization for modern data analysis II: sub-gradients and non-smooth optimization, incremental and stochastic schemes.

- **Week 4:** Basics of concentration of measure and high dimensional probability.

- **Week 5:** non-asymptotic random matrix theory and matrix concentration.

- **Week 6:** Dimension reduction, sketching, and applications.

- **Week 7:** Fast and randomized methods for numerical linear algebra.

- **Week 8:** Clustering I: Matrix perturbation theory.

- **Week 9:** Clustering II: Spectral algorithms, application in community detection.

- **Week 10:** Linear inverse problems I: Compressive sensing and sparsity.

- **Week 11:** Linear inverse problems II: Recommender systems, matrix completion and low-rank modeling.

- **Week 12:** Linear inverse problems III: recovery of fine-scale data from coarse-scale measurements: applications in deblurring, fluorescence microscopy, wireless communications, medical imaging and computer vision.

- **Week 13:** Modern theory of linear inverse problems; Iterative algorithms and non-convex optimization; Phase retrieval and computational imaging.

- **Week 14:** Learning representations, sparse coding, word embeddings

- **Week 15:** "shallow" and "deep" learning.

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Statement on Academic Conduct and Support Systems

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Academic Conduct

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Support Systems

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